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A comparison between conventional and organic farming practices 1: Soil physical properties

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Abstract

Soil samples were collected from sixteen pairs of farms, throughout England, having both arable and grass fields within each pair on similar soil type. The farms were divided into clusters which are used as replicates in this paper. Chemical (nutrients, pesticides) and physical (aggregate stability, field capacity, shear strength, soil organic matter) soil properties were measured over four main soil textures classes (clayey, coarse, medium, silty) and two land uses (arable and grassland) in organic and conventional fields. The physical soil properties varied significantly between the different texture and land use. However, there are no significant differences between organic and conventional management for any of the soil chemical and physical properties measured.

Key Words

Aggregate stability, field capacity, infiltration rates, plasticity, soil texture, SOM.

Introduction

Changing UK policy relating to farming practices, due to both consumer and governmental pressures, have fuelled the debate over the merits of organic and conventional management methods especially regarding the issues of sustainability, leaching and agricultural pollution. Conventional farming (non organic) is a more input intensive system with higher inputs such as fertilisers, pesticides and high outputs in terms of yield (Byrne, 1997). Whereas, organic farming is governed by strict legislation controlling the production of organic food within the UK; this generally reduces reliance on external inputs such as chemical fertilisers, and promotes good soil management techniques (Lampkin 1999).

Sustainable management is crucial to the maintenance of soil structure and organic matter (SOM) levels are important if the continued availability of water and nutrients and standards of soil workability are to be sustained (Pulleman *et al.* 2003). There is an abundance of recent literature comparing organic and conventional farms with respect to soil properties, microbiology and nutrient analysis (Armstrong Brown *et al.* 2000; Marinari *et al.* 2006; Mulumba and Lal, 2008; Pulleman *et al.* 2003; Parfitt *et al.* 2005). Pulleman *et al.* (2003) compared soil structure and organic matter dynamics on conventional (non-organic) and organic arable farms. It is well understood that the key to long-term success in organic farming is good soil management. There is at present a lack of comparative research into soil physical properties between organic and conventional management and Stolze *et al.* (2000) emphasised the need for new consistent collection of data on soil properties when comparing organic and conventional fields.

The aim of this paper is to provide a baseline data set; which assesses the effects on soil physical properties and leachate potential of soil management practices, under organic and conventional farming systems within England. The results will help provide a platform for future research into the impacts of organic farming on soil physical characteristics. This study forms part of an ongoing Rural Economy and Land Use (RELU) project which will explore the environmental and socio-economic impacts of 'clusters' of organic farms and to assess whether these clusters are beneficial to wildlife and soil and water quality.

Materials and methods

Site location

This study investigates sixteen pairs of organic and conventional farms, in England, with both arable (winter wheat) and grass fields (grass/clover composition) with each pair on the same or similar soil type. The paired farms were chosen in two groups (see Figure 1).

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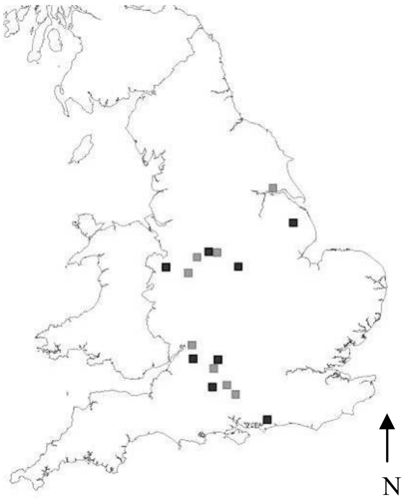

Figure 1. Site locations (RELU, 2007). The dark squares represent cold spots (less than 2% organic land use) and the lighter squares represent hotspots (more than 12% organic land use). These were used as replicates.

Field sampling and analysis

Soil sampling and within field assessment was carried out in March and April 2007, when soils were at or near to field capacity moisture content as soil structural condition is most clearly assessed at this time. The seasonal effects of variations in soil moisture content were minimised. At each site soil assessment was conducted and samples were collected to measure a suite of physical and chemical parameters. To obtain a representative sample of soil, a 'W' shaped path sampling strategy was observed, avoiding untypical areas, taking 10 samples; which were bulked (MAFF 2000). Samples were obtained from 0- 200 mm depth. One or more small pits were excavated at each site to determine the soil structure and physical conditions of the soil. A shear vane was used to measure shear strength *in situ* based on a grid sampling technique using 30 samples to cover the field.

Laboratory and statistical analysis

The soil samples were prepared through air drying and homogenisation by grinding and sieving (Allen 1989). The samples were sieved to either 2mm diameter (SOM and texture) or passed through a 5 mm sieve and retained on 3.35 mm sieve (aggregate stability). Soil texture was determined using the pipette method (BS 7755). SOM was established by dichromate digestion (BS 1377-3). Aggregate stability was determined through the wet sieving method outlined in Haynes and Swift (1990). Gravimetric moisture content was measured through oven drying at 105^{o}C. Soil water sub-samples were sent to NRM laboratory to be analysed for a suite of pesticides and nutrients using centrifugation. Data analyses were calculated using Statistica (8.0), under the assumption that data was normally distributed. Factorial analysis was used to determine whether there was a significant difference in soil properties between the two management regimes (organic and conventional); two land uses (arable and grass) and the four textural classes.

Results and discussion

Soil water nutrients and pesticides

Soil water samples were tested for a range of pesticides. Pesticides were only discovered within five of the clusters. There were only two organic fields which tested positive for pesticides, but these were only trace levels. There were fifteen conventional fields which showed traced of pesticides. The pesticides detected in the organic fields were compounds of organochlorine (DDE) and organonitrogen (pendimethaline) with concentration of 0.3 and 0.02 mg/kg respectively. The pesticides are degraded by the microbial community to form metabolites and its half life determines its persistence (Andreu and Pico 2004). Both are fairly persistent as DDE has dt50 of thirteen years whereas pendimethaline has dt50 of 90 days however it bio accumulates within the soil due subsequent applications prior to the farm converting in 2000 (Andreu and Pico 2004). The low concentrations of pesticides detected can be associated with historical application and does not pose a threat of leaching. In addition no differences in pesticide levels were found between organic and conventional management. There were no significant differences ($p<0.05$) in levels of total phosphorous and total potassium according to management, land use or soil texture. However, there was a significant difference in Total Nitrogen (ammonium and nitrate) where the conventional arable was two to three times

(32 mg/kg) greater than the other land uses and managements. This is not surprising and is due to the timings of fertiliser or manure applications on the arable land and not the grassland.

Soil organic matter (SOM)
There was no significant difference ($p<0.05$) between organic and conventional management for SOM content as was reported by Gosling and Shepherd (2005). This can be explained by the fact that to have a significant effect on SOM Bhogal *et al.* (2008) suggests that at least 65 tha/y of organic matter should be applied and currently organic farmers add 40 tha/y and in arable farming typical wheat yields are 4 and 6.75 t/ha from organic and conventional practices respectively (Nix 2007) where generally the straw yield is positively accumulated with the grain yield. There were significant differences related to land use, where grass had a significantly higher level of SOM compared to arable ($p<0.05$); and soil textural class where the clayey and silty soils had an improved level of SOM in relation to coarse and medium soils ($p<0.05$). This is due to the protective nature of the clayey soils which reduces the amount of decomposition (Loveland and Webb 2003). Schjønning *et al.* (2007) have recently shown that different land management will influence SOM level after 5-6 years; however, this research does not support this.

Aggregate stability
There was no significant difference ($p<0.05$) between organic and conventional management for aggregate stability. There were significant differences related to land use, where grass had a significantly higher proportion of stable aggregates compared to arable; and soil textural class where the clayey and silty soils were more stable in relation to coarse and medium soils. Clayey texture soil had the highest amount of SOM and the clay content helps to bind the soil improving the stability of the aggregates. The management style of grassland such as the removal of grass as silage can remove roots, SOM and binding ingredients (such as calcium ions) which reduces aggregate stability. Over all the fields, a mixture of practices were occurring which could be masking any overall effect of organic or conventional management.

Shear strength and field capacity
There was no significant difference between organic and conventional management for shear strength or field capacity. There were significant differences related to land use, where grass had a significantly higher shear strength compared to arable; and soil textural class where the clayey soils had greater shear strength in relation to the other textures. The amount of SOM present and the moisture content affect the shear strength of the soil. The soils were all sampled at field capacity and the higher amounts of SOM shown in the clayey soils mean that these have higher shear strength. It is important to note that the fields with the higher field capacity (higher moisture content) had lower shear strength as this decreases with moisture content (Smith and Mullins 1991). The grass fields generally have higher shear strength due to the formation of a strong root mat binding the soil together. The arable fields were more affected by the date of primary tillage, with a few fields having just been tilled and hence the shear strength was much lower than the untilled fields.

Atterberg Limits and workability
There was no significant difference ($p<0.05$) between organic and conventional management for plasticity index, plastic or liquid limits. Soil texture and the amount of SOM are very important for governing changes in Atterberg Limits; higher levels of SOM can cause a shift in plasticity index extending the friability zone to fairly high moisture contents (Baver *et al.* 1972). Plasticity limit can be used as a guide to determine the water content at which a soil can be handled without causing damage, if the field capacity moisture content is below the plastic limit there is a lower risk of soil damage. From the data, there is no overriding management (organic or conventional) which actually makes a positive difference on soil working conditions; it is more dependent upon the soil texture.

Conclusion

The main conclusions for this paper are as follows:

1. There are no significant differences between organic and conventional management for any of the soil physical properties measured. For the fields sampled, it can be concluded that there is little direct benefit on soil physical condition for organic farming practices but equally there is no detrimental effect.
2. There are significant differences between grass and arable land use in the following:
    - Aggregate stability, field capacity, shear strength, and SOM are all higher in grass land use.

These differences are related to the complex interactions between previous land use, current cropping cycle and tillage regime.

3. There are significant differences between the four soil textural groups for all of the soil properties measured. Soil texture plays a key role in determining physical properties which is greater than the current and past land use or management.
4. There were fewer traces of indentified pesticides and herbicides in organic fields compared to conventional fields.

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A comparison between conventional and organic farming practices 2: Soil hydraulic properties

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Abstract
This study investigates 16 pairs of farms (organic and conventional) located in England. These are over a range of soil textures: clay, silty clay loam, clay loam and sandy loam. There are also two different land uses (grass and winter wheat). The research incorporates field measurements of infiltration rates and HOST classification with modelling runoff data. This research aims to compare the effects of soil management for organic and conventional agricultural systems on soil hydraulic properties. There was no significant difference in the infiltration rates of organic and conventional arable soils. However, there was evidence to support the fact that infiltration rates were higher on organically managed grassland in comparison with conventional grassland. In the modelled landscapes, an organically dominated landscape can have a significant effect upon reducing peak runoff from a catchment by 29 % in favourable soil conditions.

Key Words
Infiltration rates, HOST, runoff, flooding, soil management.

Introduction
In the UK, the occurrence of severe flooding has greatly increased over the last few years. There are a number of factors which contribute to this. Firstly, changing climatic behaviour namely different rainfall patterns altering both duration and intensity of rain storms; and secondly, the increasing loss of soil medium as a buffer against excess runoff. In rural areas poor soil management leads to compacted soil and reduced infiltration rates of rainwater has meant that the flood hydrograph becomes ‘peaky’. Extreme flood events, such as those experienced in the UK summer 2007, maybe prevented in the future through improving soil management and attenuating the flood hydrograph.

There is a need to improve storage capacity on some of the land within UK catchments. This may not be able to be over the whole catchment as some areas could have been permanently degraded by surface sealing through urbanisation. The major area that can be improved is agricultural land which can be improved through changes in soil management practices. Holman *et al.* (2002) identified a number of UK agricultural fields as suffering from structurally damaged soils with unnaturally low infiltration capacities which significantly increased the chance of overland flow and flood potential. Schwab *et al.* (1993) suggested that there were three major ways to alleviate these problems on agricultural land:

1. Soil should not remain saturated at peak rainfall event times
2. Reduce soil surface caps and subsoil pans to increase the amount of infiltration
3. Increase the amount of surface depressional storage.

Changing land management from conventional to organic farming practices can have significant impacts on environmental factors such as wildlife and infiltration rates (RELU 2007). This study forms part of an ongoing Rural Economy and Land Use project which intends to explore the environmental and socio-economic causes of ‘clusters’ of organic farms and to assess whether these clusters are beneficial to wildlife and soil and water quality. This paper aims to compare infiltration rates and HOST classifications in two different land uses (arable and grass) and management (organic and conventional) over a range of soil textures. It also aims to model the impact of land use and management on runoff production using the USDA Soil Conservation Service Model.

Materials and methods
Site location
This study investigates four pairs of organic and conventional farms, in England, with both arable (winter wheat) and grass fields (grass/clover composition) with each pair on the same or similar soil type. The

paired farms were chosen in two groups (Figure 1). The clusters were also chosen because they cover a range of soil types: clay, clay loam, silty clay loam and sandy loam.

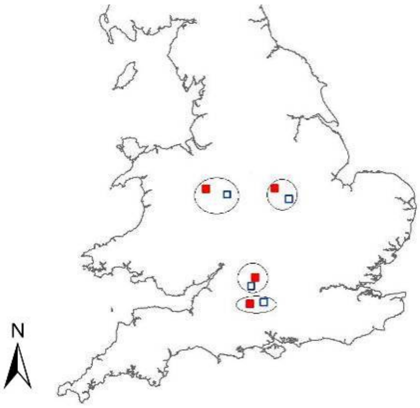

Figure 1. Map of the sites showing the clusters in organic ■ (hot - more than 12% organic land use) or conventional □ (cold - less than 2% organic land use) used during infiltration measurements (RELU 2007).

Field sampling and analysis
Fieldwork was performed during May and June 2008. At each site, infiltration (saturated hydraulic conductivity) was measured using the Decagon mini disk infiltrometer. This method was chosen in preference to the double ring infiltrometer because it requires less water (which was not always readily available in at the fields). Both methods are very time consuming and have a similar accuracy level as they need constant attention to record measurements and ensure that the apparatus is functioning correctly. The rings of the double ring infiltrometer are heavy to move and require a flat undisturbed surface (McKenzie *et al.*2002). The advantage of the tension infiltrometer is that it can provide both saturated and unsaturated hydraulic conductivity measurements as well as steady state infiltration rates. Ten replicates were made in each field along a 'w' shape avoiding atypical areas and to compensate for the level of variability in the soil surface conditions (Bodhinayake *et al.* 2004). The variation in infiltration rates experienced with the *in situ* and laboratory measurements was very similar to those obtained by Witzel (2008). Each replicate was sampled for 30 minutes at 20 mm tension and the infiltration rate was calculated using the method developed by Zhang (1997) and the van Genuchten parameters (Carsel and Parrish, 1988).

Statistical analysis
Data analyses were calculated using Statistica (8.0), under the assumption that data was normally distributed. Factorial analysis was used to determine whether there was a significant difference in soil properties between the two management regimes (organic and conventional); two land uses (arable and grass) and the variation in soil texture was accounted for through the use of covariant means based upon the percentage of silt and clay which was used to transform the data.

Results and discussion
Hydrology of soil type (HOST)
Hydrology of soil type (HOST) is the classification of the main soil types in the UK into 29 classes (Boorman *et al.*1995). These 29 classes based upon soil physical properties which are correlated with catchment scale hydrological variables the dominant pathways of water movement through the soil and substrate (base flow index, BFI and standard percentage runoff, SPR). BFI is the long-term average proportion of flow that comes from stored sources and SPR is the percentage runoff derived from event data, adjusted to standard rainfall and catchment moisture conditions (Boorman *et al.*1995). This model allows the level of degradation of soil to be input and hence modifies the HOST class. A physically degraded soil, for example compacted, can lead to a significant change in the amount of runoff for most of the HOST classes (Godwin and Dresser 2003). HOST classifications showed degradation of soil properties within 12 fields; this is indicated by an increase in the SPR by 10% and a decrease in the BFI by 0.1%. Three of the fields were organic arable fields and one was organic grass field. Overall there were less degraded organic than conventional fields and there were more degraded arable fields than grassland. This highlights the poor soil structural quality of these fields which could be due to untimely tilling of the arable land or overstocking and hence poaching of the grassland.

Infiltration rate (IR) (saturated hydraulic conductivity)
The statistical analysis of the IR data in Table 1 shows that despite a high level of in field variability which is experienced when measuring saturated hydraulic conductivity in the field the IR of the conventional management is significantly lower than the others. This difference between organic and conventional practices was also found in recent studies (Oquist *et al.*2006; Metzger and Yaron 1987; Reganold and Palmer 1995; Lettens *et al.*2004); these highlighted the issue of variability in collecting infiltration data.

For the organic land management there is no significant difference between the two land uses; this could be related to improvements in structure due to additions of FYM and other sources of SOM. It could also be related to a lower stocking density and fewer machinery passes on the arable land. There were also differences in the soil textural class where the clay and sandy loam were significantly higher than the other two soil textural classes. This could be explained by the cracking nature of clay soils and the coarse texture of the sandy loam.

Overall, it is possible to conclude infiltration is influenced by the local conditions such as the soil type and soil structural conduction which can occur regardless of the organic / conventional farming practices in place especially where the seasonal impacts of cracking, cultivation practices and crop rotation have more of an effect. It shows a well managed grass field for the conventional field where there may have been more traffic and compaction compared to the organic field above it.

Table 1. The mean Saturated Hydraulic Conductivity (mm/hr) for each of the soil textures and land uses showing significant differences with different letters where $p<0.05$.

		Land use and Management								
		Organic				Conventional				
		Arable		Grass		Arable		Grass		Mean
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Soil Textural Class	Clay	13.42	0.17	14.81	0.16	4.89	0.48	6.38	0.37	9.87a
	Silty Clay Loam	4.18	0.56	5.67	0.41	6.79	0.34	0.79	2.98	4.35b
	Clay Loam	2.36	0.99	1.57	1.49	0.77	3.04	1.16	2.01	1.47c
	Sandy Loam	3.64	0.64	8.44	0.28	16.20	0.14	1.80	1.30	7.52a
Mean		5.90a		7.62a		7.16a		2.53b		

Runoff modelling
It has been shown that both land use and management have a significant effect on the infiltration rate and HOST classification. This can have a major impact upon the amount of runoff and flood generation downstream especially with changing climatic conditions such as increasing intensity, duration and frequency of rainstorms. In order to estimate the magnitude of this effect, the USDA Soil Conservation Service Method for runoff estimation was produced according to 'typical' conditions found in the catchments monitored. The model was used for two different management and land cover scenarios with catchment size of 550 ha, total maximum rainfall (1 in 5 year rainfall 76.2 mm) and antecedent moisture contents (average value for annual floods 13-28 mm). The landscape scenarios resulted from studies by Norton *et al.* (2009) following a survey of organic and conventional landscapes where it was found that organic farms had a significantly higher proportion of grassland compared to a conventional landscape. The composition of the modelled landscapes was as follows:

1. Conventionally dominated landscape with 60% arable land, 25% grassland and 15% fallow land (bare)
2. Organically dominated landscape with 45% arable land, 40% grassland and 15% fallow land (bare)

For each scenario and soil condition both good and poor management practice effects for runoff were calculated.

Assuming these results could be replicated across a broader areas the hydrological data both infiltration rate and HOST class input into the simple SCS runoff model showed that where the landscape is organically dominated with good management practices a 37 % reduction in runoff could be achieved compared to the conventionally dominated landscape. Where the soil is degraded this would diminish to 7 % reduction. Replacing the set a side or fallow land (15% of land use) in current organically dominated landscape to organic grassland would have a very significant benefit in reducing the runoff by and from the conventionally dominated landscape and organically dominated landscape respectively. This compares to the benefit from converting fallow (set a side) in the conventionally dominated landscape to conventional grassland.

Overall, this model highlights the importance of following good soil management practices on all different soil types. There is very little difference between landscape scenarios if the land is managed poorly; however when managed according to good soil management practices there is a significant improvement when comparing organic and conventional landscapes. This is primarily linked to the increase in the amount of well managed grassland. Where both theoretically and empirically, this was shown to increase the amount of infiltration and hence reduce runoff.

Conclusion

There was no overall significant difference in the infiltration rates of organic and conventional arable soils. However, there was evidence to support the fact that infiltration rates were higher on organically managed grassland in comparison with conventional grassland. This can have a significant effect upon reducing runoff from a catchment. For example, using the USDA Soil Conservation Service model to compare a conventionally dominated landscape (60 % arable land, 25 % grassland and 15 % set-a-side) to an organically dominated landscape (45 % arable, 40 % grassland and 15 % set-a-side) there is a predicted reduction in peak runoff of 29 % from the measured soil conditions. Hence, converting land to organic or well managed conventional grassland could have the potential to reduce the likelihood of flooding through improved infiltration and lower peak runoff rates.

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Aggregate breakdown and dispersion of Brazilian soil samples amended with sugarcane vinasse by ultrasonic energy

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Abstract
Aggregate stability is very complex and related to important soil attributes. This work aimed to evaluate the aggregate stability by ultrasonic energy of Brazilian soil samples amended with sugarcane vinasse – an important byproduct from ethanol and brandy production in Brazil. Two Oxisols and one Ultisol were used in this study. Aggregates 1-2 mm size, previously treated with sugarcane vinasse under lab conditions were submitted to different levels of ultrasonic energy and the particle size distribution (53-2000 µm, 2-53 µm and <2 µm fractions) was quantified. The mass of aggregates in each of these fractions was modelled as function of applied ultrasonic energy and some parameters that describe the aggregate stability were obtained based on work of Field and Minasny (1999). The methodology was sensitive to detect differences in the aggregate stability of all three soils. The Oxisols showed more aggregate stability than Ultisol. Vinasse enhanced the aggregate stability, mainly in the Oxisols.

Key Words
Soil aggregation, ultrasonic energy, tropical soils.

Introduction
Formation and stabilization of soil aggregates are highly complex (Six *et al.* 2004). The aggregate stability is related to important soil parameters, such as: soil porosity, hydraulic conductivity, sealing, compressibility, soil erodibility and carbon stabilization (Gregorich *et al.* 1989; Raine and So 1993). The most traditional and widely used method to measure aggregate stability is the wet-sieving method, proposed by Yoder (1936) – a simple technique whose results are well reproducible and correlated with soil attributes. However, in this method, the energy which is responsible for breaking and dispersing the aggregates is unknown. North (1976) proposed the use of ultrasonic energy, so that the dispersive energy which is responsible by the aggregate breakdown could be known. Latter, Raine and So (1993, 1994) proposed a method to measure the released energy by the ultrasonic probe, based on calorimetric techniques. By this method, the results are normally expressed through soil dispersion curves. For example, the <2 µm fraction released (dispersed) at different levels of ultrasonic energy represents the soil dispersion characteristic curve (SDCC) (Raine and So 1993). From this curve the required energy to complete soil dispersion can be estimated. The rate of aggregate breakdown can also be evaluated by the aggregate disruption characteristic curve (ADCC) (Tippkötter 1994), which is represented, for example, by reduction of 53 – 2000 µm fraction aggregates. The occurrence of a soil-aggregate hierarchy results in an aggregation liberation and dispersion curve (ALDC) (Field and Minasny 1999), for example, the stepwise breakdown of 2-53µm fraction aggregates, plotted against energy. This stepwise is a consequence of linkages within and between aggregates. Field and Minasny (1999) proposed some models to describe the results and showed some parameters related to the shape of ALDC curve (k_1, k_2 and E_{crit}), where k_1 represents the rate of aggregates liberation (e.g., 2-53 µm) and k_2 represents their subsequente dispersion. The E_{crit} represents the total applied energy that is required to initiate the dispersion of particles.

The sugarcane vinasse is the main byproduct of ethanol and brandy production. It is produced in large amounts, approximately 13 liters per liter of ethanol or brandy. Considering that the 2009 ethanol production in Brazil was estimated in 27 billion liters, 354 billion liters of vinasse was produced. Disposal in soils as liquid fertilizer is an alternative use for this product, mainly as a source of K. This practice avoids dupping vinasse into the water courses and lakes, which was common in the past (Günkel *et al.* 2007).
This work aimed to assess the aggregate breakdown and dispersion by ultrasonic energy of two Oxisols and one Ultisol from Brazil amended with sugarcane vinasse, based on work of Field and Minasny (1999).

Methods

Topsoil samples (0-10 cm layer) from a Red Latosol (LV), Red Yellow Latosol (LVA), and Red Yellow Argisol (PVA), according to Brazilian System of Soil Classification, two Oxisols and Ultisol (U.S Taxonomy), respectively, were collected for this study. The samples were air-dried and carefully ground and sieved in order to obtain 1-2 mm aggregates. Soil columns made of PVC tubes (6.0 cm high and 4 cm internal diameter) containing 200 g of aggregates (density 1.00 ±0.04 g/cm^3 and total porosity 0.59 cm^3/cm^3) were used to perform the incubation with sugarcane vinasse. The vinasse (from brandy production) was applied at the following rates: 0 (control), 150 and 300 m^3 ha^{-1}; then, the samples were kept at the field capacity (~0.30 cm^3/cm^3 for all soils) for 1, 30, and 60 days. After each incubation time, the aggregates were carefully removed from columns and air-dried for 48 hours; 5g of aggregates (oven-dried basis) were placed into 250-mL beaker and pre-moisture by slow dropping of distilled water in the walls of the beaker (inclined approximately 30 degrees) using a burette. After all the aggregates were immersed in water, the volume was completed to 200 mL (soil: water ratio 1:40). The soil suspension was submitted to increasing levels of ultrasonic energy: 210, 420, 840, 1680, 3360, 6720, and 13440 J/g, based on calorimetric techniques described by Raine and So (1993, 1994) and summarized in Brazil by Sá *et al.* (2000). The equipment used was a probe-type Misonix, XL 2020 model, with an output power of 70 W and immersed 2.5 cm into soil suspension. After each level of applied ultrasonic energy, the 53-2000 µm fraction was gently separate by wet-sieving. The aggregates and soil suspension that passed through the sieve was transferred to measuring cylinders. After adequate settling-times, the <2 µm fraction was determined using the pipette method. The 53-2000 µm, 2-53 µm and <2 µm fractions was adjusted to the models proposed by Field and Minasny (1999) and calculated the energy required to aggregate breakdown and dispersion (E_{crit}) and the constants k_1 and k_2.

Results

The energy required to complete dispersion (plateau of the SDCC - Figure 1A) decrease as follows: LVA > LV > PVA. The stepwise of aggregate breakdown was observed indicating the aggregate hierarchy for all soils (Figure 1C). As mentioned by Field and Minasny (1999), the shape of the ALDC is described by constants k_1 and k_2 showed in Figure 2. The LVA showed the lowest k_1 and k_2. This indicates more resistance to aggregate liberation and subsequente dispersion. Moreover, the LVA needed more energy (> E_{crit}) to initiate the dispersion of liberated aggregates. Based on E_{crit}, constants k_1 and k_2 (Figure 2), the aggregate stability decrease as follows: LVA > LV > PVA.

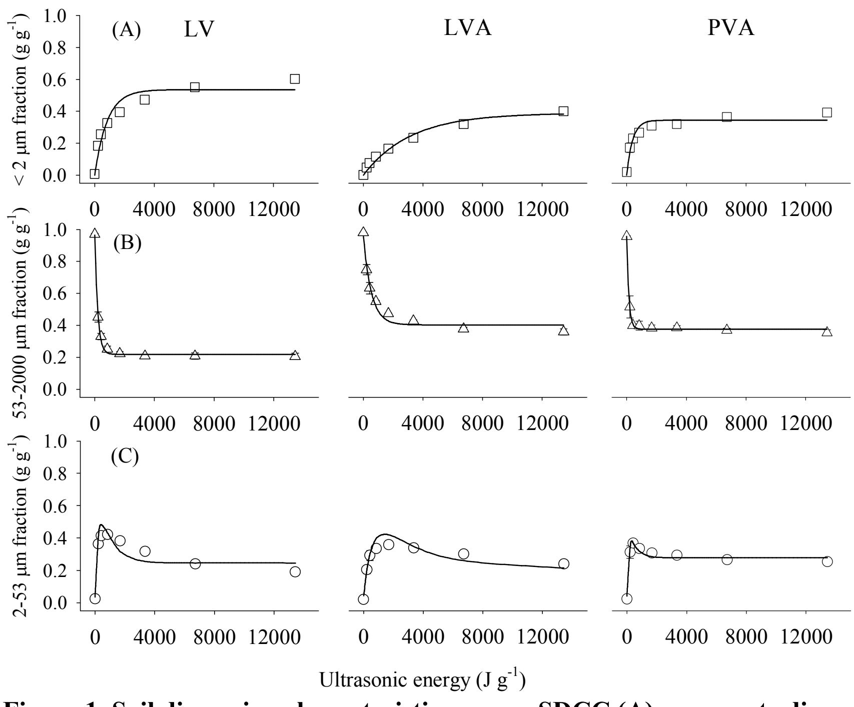

Figure 1. Soil dispersion characteristic curve – SDCC (A), aggregate disruption characteristic curve – ADCC (B) and aggregate liberation and dispersion curve – ALDC (C) to Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). The data were adjusted to models proposed by Field and Minasny (1999). Error bars indicate the average standard deviation (n = 3).

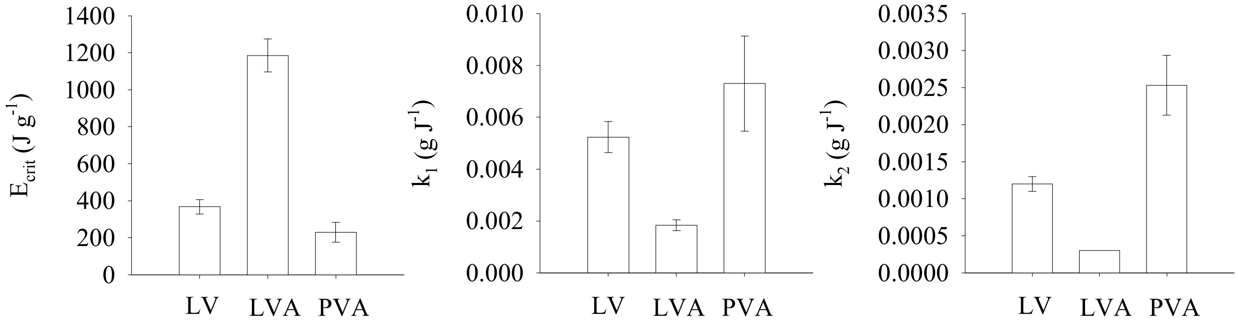

Figure 2. E_{crit} and constants k_1 (rate of aggregate liberation) and k_2 (rate of dispersion of liberated aggregates) of Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). Error bars indicate the average standard deviation (n = 3).

The vinasse enhanced the aggregate stability of soils (Figure 3). For LV and LVA the vinasse increased the E_{crit} and reduced the constants k_1 and k_2 in all incubation times. For PVA this was observed only at 60 days incubation time. In summary, the effect of vinasse on aggregate stability can be explained as follows: organic compounds presents in the vinasse and incorporated into soil protected the aggregates against the cavitation; the vinasse contributed to flocculation and binding of soil particles; the vinasse enhanced the growth and microbial activity.

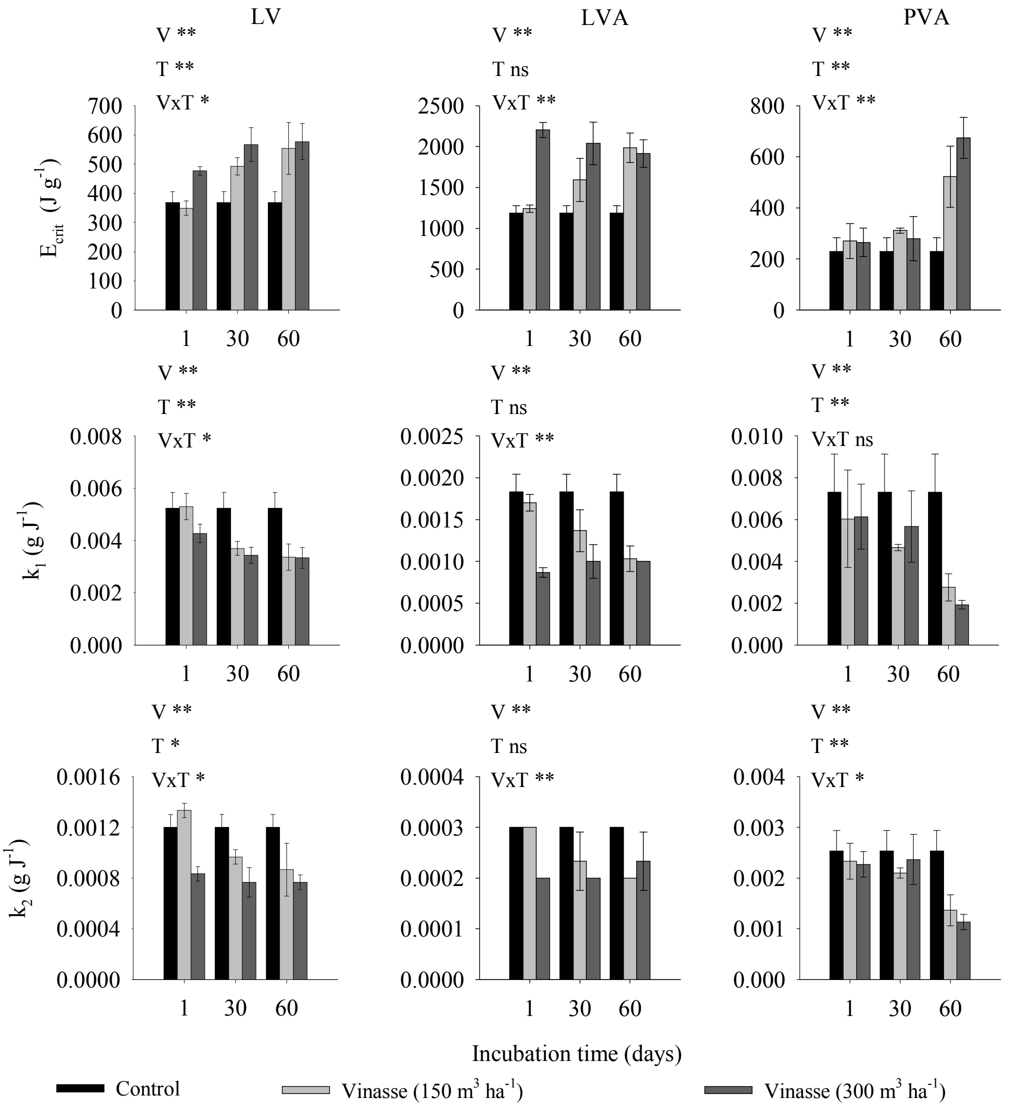

Figure 3. Effect of sugarcane vinasse and incubation time on E_{crit}, k_1 and k_2 of Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). Error bars indicate the average standard deviation (n = 3). *, ** p<0.05 and 0.01, respectively (F Test).

Conclusion

The methodology used was sensitive to detect differences in the aggregate stability of the soils. The aggregate stability of the soils decreased as follows: LVA > LV > PVA. In other words, Oxisols > Ultisol. The vinasse increased the aggregate stability of all soils, mainly in the LVA and LV (Oxisols).

Acknowledgments

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Aggregation of an Oxisol under management systems for 14 years in the Midwest of Brazil

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Abstract
The adoption of a production system after long time results in changes in soil properties that can influence the soil quality and the productivity of crops. In order to evaluate the effect of soil management systems including crop-livestock was evaluated the soil aggregation in a long-term experiment located in Dourados, MS in the Midwest region of Brazil. Four management systems were implemented and conducted since 1995 in a clayey Oxisol with soybean cultivation in conventional tillage and no-tillage, permanent pasture and soybean in rotation with pasture on no-tillage. The largest average aggregate size was found in systems with the greatest time with the presence of grazing. This trend was also found to separate the aggregate size classes and these systems with the presence of as much pasture was observed in the class greater than 2 mm. The largest amount of aggregates class lower than 0.25 mm was found in the conventional system.

Key Words
Soil quality, no-tillage, crop-livestock, Savannas, tropical agriculture.

Introduction
Crop-livestock integration system together with no-tillage can be a solution to a serious and old problem of soil conservation and seasonal forage production in Brazil. This new production system based on the integration of crops and pasture has advantages for both activities. There are many combinations of this system that can be used for different soil and climate conditions. Usually, this system has shown to be able to cause breaks in diseases and pest cycles, to increase the efficiency of fertilizer and lime, to intensify crop production and nutrient recycling and also to maintain soil cover using plants and/or straw. Together, all these benefits can improve soil and environment quality (Salton *et al.* 2001). Crop-livestock integration system must include pasture in rotation or in consortium whit crops, which usually are directly grazed. This production system can promote significantly change in chemical, physical and biological soil attributes. Moreover, this system contributes to improvement of soil quality, especially when compared to systems with only crop. One approach way of assess modifications in soil due to the use of different production systems is the use of measurements that integrate several attributes, such as macro-aggregates formation. This work had the aim to compare the use forms and soil management systems after 14 year use by evaluating the soil aggregation.

Methods
Experimental area
The experiment has been carried out since1995 in an area of 28 ha located at Embrapa Western Region Agriculture in Dourados, Mato Grosso do Sul state, Brazil (22º14'S - 54º49'W and altitude of 430 m). The experimental area had been used for grain crops between 1970 and 1994 on conventional tillage. The soil is an Oxisol (kaolinitic with 630, 215 and 155 g/kg of soil for clay, silt and sand respectively). Regional climate is classified as Cwa - mesothermal humid climate with hot summers and dry winters. The experimental area was divided into seven plots, contend the following management systems: (a) soybean monoculture in summer and oat in winter with previous tillage using disc harrows (CS), (b) crop rotation, with soybean and corn in the summer, wheat and oats for the grain production, turnip for straw in the autumn-winter, keeping the sequence: .../turnip/corn/oats/soybean /wheat/soybean/... in no-tillage (NTS), (c) alternation of crops (soybean /oats) with pasture (*Brachiaria decumbens*) in no-tillage with cycles of two years and allowing to grazing pasture (CPR) and (d) one area of *Brachiaria decumbens* implemented in November/95 for permanent pasture (PP). The pasture in PP and CPR did not receive fertilizers or lime and the intensity grazing is adjusted to maintain a constant supply of forage, around 7%. The sequence of management systems is shown in Figure 1.

Systems	1995	1995/96	1996	1996/97	1997	1997/98	1998	1998/99	1999	1999/00	2000	2000/01	2001	2001/02	2002	2002/03	2003	2003/04	2004	2004/05	2005	2005/06	2006	2006/07	2007	2007/08	2008	2008/09	2009
CS	C	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O
NTS a	C	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T
NTS b	C	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W
NTS c	C	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O	S	W	S	T	C	O
CPR a	C	S	O	S	O	*B. decumbens*				S	O	S	O	*B. decumbens*				S	O	S	O	*B. decumbens*				S	O	S	O
CPR b	C	*B. decumbens*				S	O	S	O	*B. decumbens*				S	O	S	O	*B. decumbens*				S	O	S	O	*B. decumbens*			
PP	*Brachiaria decumbens*																												

Figure 1. Sequence of crops in soil management systems on long-term experiment in Dourados, Brazil. C: corn, S: soybean, O: oat, T: turnip, W: wheat, CS: conventional system, NTS: No-till system, CPR: Crop-pasture rotation, PP: permanent pasture.

Soil sampling and methodology

Soil samples were collected in 2008 to assess the effects of management systems in soil aggregation using a grid of equidistant points with an interval of 30 m resulting in 240 sampling points (Figure 2). Monoliths with 20 x10 x 10 cm were collected and placed in sealed plastic boxes and properly identified for the determination of soil aggregation. Samples were kept in the shade and the soil was manually disaggregated observing the weak points of the monolith. Thereafter all soil samples were air dried and sieved through a 9.52 mm mesh sieve. Sample fragments retained on sieves (i.e. plants, stones and gravel) were removed from the samples. The method used for soil aggregation determination is described by Kemper and Chepil (1965) with amendments proposed by Carpenedo and Mielniczuk (1990) and Silva and Mielniczuk (1997).This method consisted of aggregate size separation in different classes by dry sieving. Two sub-samples of 50 g were sieved in a set of sieves with openings of 4.76, 2.00, 1.00, 0.50, 0.25, 0.105 and 0.053 mm by horizontal agitated vibration Solotest® during one minute with power of 30%. The content of remaining aggregate in each sieve was weighed. The values obtained in the sieving were used to calculate the mean weight diameter (MWD) through the following equation: MWD= $\Sigma(xi.wi)$, where *wi* is the proportion (%) of each class in relation to the total and *xi* is mean diameter of the classes (mm).

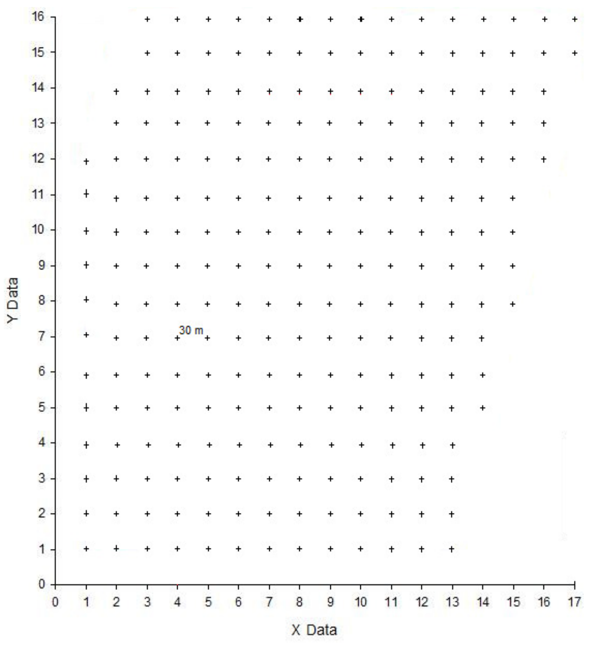

Figure 2. The grid with distribution of samples points on the long-term experiment in Dourados, Brazil.

Results

Considering only soil aggregate structures smaller than 0.25 mm, it was found predominant in conventional system (CS) with around 14% (Table 2). This lower degree of organization of soil in the CS is also evident in the analysis of the MWD (3 mm) compared to the others (Table 2). On the other hand, macro aggregates larger than 2 mm are present in systems with the presence of pasture (CPRa and PP) with values above 50%. It is evident the effect of pasture, especially root activity in the formation of macro aggregates as observed by Six *et al.* (1998), Six *et al.* (2004) and Salton *et al.* (2005).

Table 2. Relative distribution of the soil mass in class of size and mean weight diameter (MWD) of aggregates of an Oxisol submitted to management systems for 14 years in Dourados, Brazil.

Management system	Size class aggregate (mm)			MWD	n[1]
	<0.25	0.25 - 2.00	> 2.00		
	-------------------------- (%)--------------------------			(mm)	
CS	14.1±0.72	12.0±0.31	30.4±1.31	3.03±0.09	26
NTS a	5.5±0.32	11.8±0.36	45.6±1.41	4.24±0.07	26
NTS b	5.4±0.41	12.2±0.34	45.7±1.62	4.18±0.11	26
NTS c	7.3±0.87	12.8±0.36	41.3±1.62	3.91±0.10	27
CPR a	2.7±0.17	12.2±0.31	51.0±1.06	4.67±0.06	42
CPR b	3.8±0.23	13.9±0.35	46.1±1.03	4.34±0.06	45
PP	2.2±0.12	10.6±0.29	56.2±0.98	4.93±0.06	48

[1]n: number of replications considered for calculating the mean and standard error for each system, CS: conventional system, NTSa: No-till system with sequence corn-oat- soybean -wheat- soybean -turnip, NTSb: No-till system with sequence soybean-turnip-corn-oat- soybean -wheat, NTSc: No-till system with sequence soybean-wheat- soybean -turnip-corn-oat, CPRa: Crop-pasture rotation with the sequence *B. decumbens*- soybean -oat, CPRb: Crop-pasture rotation with the sequence soybean -oat- soybean - *B. decumbens*, and PP: permanent pasture with *B. decumbens*.

The spatial distribution of MWD (Figure 3) coincides with the limits of management systems in the experimental area, i.e. is distinct the CS for systems with the presence of pasture, in the case of the integrated system (CPRb) possibly the effect of the recent presence of *B. decumbens* contribute to higher MWD than others. In no-tillage system (NTSb and NTSc) can be established that the presence of turnip, with a smaller volume and number of roots resulted in a lower value for the MWD. Aggregates formation in soil is the result of energy and matter flows that occur in the soil. It represents the degree of the soil organization, which is the initial phase of micro aggregates (<0.25 mm) formation is related to the interaction of mineral matter among themselves and with organic compounds (Tisdal and Oades 1982). Subsequently, the influence of the growth of roots, fungal hyphae, along with plant material

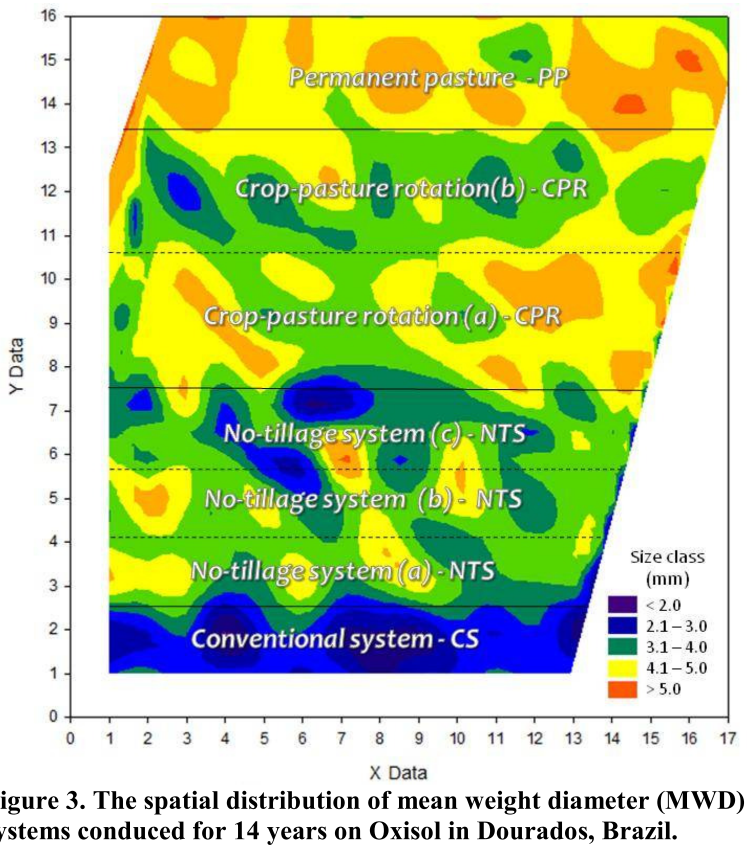

Figure 3. The spatial distribution of mean weight diameter (MWD) of aggregates and the limits of management systems conduced for 14 years on Oxisol in Dourados, Brazil.

stimulates the formation of more complexes and diverse structure as macro aggregates (> 0.25 mm). These structures are at a level of organization higher (Haynes and Beare 1996). Management systems to influence the intensity of flows of matter in soil resulting in different degrees of organization of the mass of soil aggregates.

Conclusion

The higher existence of the macro aggregates probably can be related to the presence and activity of the roots system of the plants and to the absence of revolving the soil with action of disc harrows. This sense production systems incorporating pasture and crop in no-till can be recognized as an alternative for improving soil quality.

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Agricultural potential of salmon wastes used as organic fertilizer on two Chilean degraded soils

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Abstract
The fertilizer potential of farmed salmon sludge was evaluated by a battery of tests carried out with annual ryegrass (*Lolium multiflorum* Lam. cv. Winter Star). Wastes were evaluated on two Chilean degraded soils: a Patagonian soil (Andic cryofluvent) and a granitic soil (Ultic Palexeralf). The treatments were salmon ground-farming waste (PSW) and salmon lake-farming waste (LSW) at different rates: 25, 50, 75, 100 and 150 t/ha. Tests with ryegrass were conducted for above ground biomass yield. For both soils, biomass data indicated that PSW and LSW sludge can be applied at 25 to 150 t/ha on Patagonian soil and only LSW sludge on granitic soil. However, its addition should be complemented with N and K inorganic fertilizer to increase pasture yield. MSS and PSW sludge applied at 150 t/ha was clearly detrimental for crop yield, especially when applied to granitic soil.

Key Words
Fish sludge, soil remediation, organic fertilizer, degraded soil.

Introduction
There is an enormous preoccupation that salmon sludge may contaminate pristine waterways, ruin livelihoods and damage Chile's reputation for quality produce. Besides nutrients and organic matter, sludge also contains pathogens, heavy metals and water, so soil application could be limited (Shober *et al.* 2003). There is little research published on the application of sewage sludge and salmon wastes into eroded soils in South America, and particularly on Chilean Patagonian soils. Previous studies are limited to volcanic soils (Teuber *et al.* 2005) and agricultural soils (Salazar and Saldaña 2007) of southern Chile, and of the Argentinean Patagonian region (Mazzarino *et al.* 1998; Laos *et al.* 2000). In the Chilean Patagonian region, 80% of soils are affected by wind erosion processes, whereas 39% of the soils in the Bío-Bío Region are rain-eroded (Pérez and González 2001). For that reason, there is a great potential to recover degraded soils that could be used for recycling of organic residues as fertilizer. The objectives of this research were to: (i) describe the nutrients of salmon wastes and (ii) evaluate rates of these organic wastes amended to degraded soilsin a greenhouse trial with ryegrass as an indicator plant to determine their potential use in agricultural.

Methods
The experiment was performed using two different degraded soils samples were taken from the surface (0-20 cm) of a deforested site under native pasture. In one case, soil samples of a Patagonian soil (Entisol), Andic cryofluvent, were obtained from a site located 50 km east from Coyhaique (45º30' S; 71º44' W), in the Chilean Patagonian region. Physically, this Patagonian soil is sandy loam textured, with less than 5% slope and 1 g/cm bulk density. Sampling location corresponded to a cold steppe, at the Eastern slope of the Andes Mountains, near to the borderline with Argentine. In the second case, soil samples of a granitic soil (Alfisol), Ultic Palexeralf, were obtained of a site located 10 km west from Quillón (36º40` S; 72º27` W) in the Bío-Bío Region. This granitic soil presents low water infiltration, typical of the rain-eroded coastal region of Chile, clay texture, with more than 15% slope and 1.4 g/cm bulk density (Stolpe, 2005).

Salmon sludge was collected from the settling zones at two commercial salmon farms: i) a land-based salmon pisciculture located 10 km from Puerto Octay (40º58´S; 72º52´W), Los Lagos Region, and ii) a lake-salmon farm located in Lake Tarahuín (42º42´S; 73º45´W), Chiloé. Land-based salmon pisciculture waste (PSW) was collected with shovel from the sediment in accumulation ponds, whereas lake-salmon waste (LSW) was collected with dredges from the sediment (0-20 cm) under cages at 20 m deep. Soil and sludge samples were air-dried to ambient temperature and then ground to pass a 2 mm sieve. Then, different sludge/soil ratios were prepared from mixing 1 kg of soil with sludge at different doses. These sludge/soil ratios were incubated in clean plastic bags by 15 days, using a growing chamber with controlled temperature (25±2 ºC) and humidity (60-70%). After that, chemical analysis was performed to each sludge/soil ratio with no duplicate.

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Air-dried soils and sludge ground to pass a 2 mm sieve were employed. Pots with drainage holes were filled with 1.2 kg of soil mixed thoroughly with sludge. Annual ryegrass var. Winter Star was sown at 0.4 g/pot. Soil water content in the pots was maintained at 70-80% of field capacity throughout the experiment. Mean greenhouse temperature ranged between 18 and 24ºC. Days were 17 h long, using artificial light. A completely randomized design with three replicates was used to compare sludge at 0 (control), 25, 50, 75, 100 and 150 t/ha (dry weight) and inorganic fertilizer (140 kg N, 200 kg P and 130 kg K/ha) applied as potassium nitrate and superphosphate. A no-fertilizer control (T), and an inorganic fertilizer (F) were included. Triplicate subsamples were used for chemical analyses in laboratory. The ryegrass was cut two times during the experiment period of two months (5 cm residual height). Samples were weighted fresh and oven dried at 65 ºC for 48 h to determine biomass yield (g/pot) and then transformed to dry matter (kg/ha). The samples were freeze-dried and ground to a fine powder to ensure homogeneity before analysis. Soil samples were analyzed according to Sadzawka *et al.* (2006). Municipal sludge and fish waste was analyzed for macronutrients, micronutrients and heavy metals. Samples of wastes were analyzed according to Sadzawka *et al.* (2005).

Data were subjected to analysis of variance (ANOVA) procedures for a randomized complete block design using the SAS Statistical Software Package. Differences among treatment means were compared by means of the Tukey test. Statistical comparison was made with a 5% significance level.

Results

Initial degraded soils data showed low organic matter (OM), N, P, Ca, Na and Al concentrations (Table 1). In comparison, Patagonian soil analysis indicated lower P, Al, Mn, Zn and Cu, and higher pH, OM, N, K, Ca and Na than granitic soil. Both soils presented high K concentrations. Municipal sewage sludge and salmon wastes presented high OM (values >15%) and NH_4-N (values >700 mg/kg). All three sludge showed low C/N ratios with values of <11/1. Even though it is difficult to compare these values with those from other studies because of the differences in conditions under which the wastes were produced, these values are generally similar than previously reported values for salmonid manure content (Teuber *et al.* 2005). MSS had much higher OM, N, P, K, Mg, and Na contents, and lower pH, Al, Fe, and C/N than PSW and LSW. Ca, Fe, and Mn were higher in LSW than in MSS and PSW. LSW had low N and P concentrations, in agreement with Teuber *et al.* (2005), probably because sludge came from underneath cages of lake. Higher K levels in LSW than in PSW were probably the result of lake sediment in the waste than of waste composition since soluble components from fish feces and food are leached by moving water. Calcium and Na concentrations were higher in LSW than in PSW, probably because of the decomposing lacustrine organisms. High Al, Fe and Mn concentrations could be related to silica and sand contamination (Teuber *et al.* 2005).

Table 1. Initial chemical characteristics of Granitic soil, Patagonian soil, land-based salmon pisciculture waste (PSW) and lake-salmon sludge (LSW).

Characteristic	Granitic soil	Patagonian soil	PSW	LSW
pH (water)	5.6	6.8	7.0	6.7
Organic matter, %	2.5	2.9	20.7	18.3
Total N, %	0.15	0.12	1.10	1.35
NH_4-N, mg/kg	3.3	3.8	1687.5	730.0
Olsen-P, mg/kg	5.4	3.2	480.0	19.9
K available, mg/kg	129.8	414.3	30.0	120.8
Ca, cmol/kg	3.73	6.09	0.76	17.9
Mg, cmol/kg	1.37	1.69	0.74	0.43
Na, cmol/kg	0.03	0.08	0.14	0.57
Al, cmol/kg	0.02	0.01	0.03	0.03
Fe, mg/kg	8.3	9.1	6.2	11.0
Mn, mg/kg	7.6	0.3	0.6	2.5
Ratio C/N	9.3	13.4	10.5	7.5

One of the chemical characteristics of interest when livestock manure is used as a soil fertilizer is the concentrations of toxic substances, such as heavy metals (Naylor *et al.* 1999). Salmon wastes did not exceed the heavy metal levels (Table 2), a similar trend observed by Salazar and Saldaña (2007).

Table 2. Heavy metals concentrations (mg/kg) presented in municipal sewage sludge (MSS), land-based salmon pisciculture waste (PSW) and lake-salmon sludge (LSW), used in this study.

Parameter	Sludge			EPA [1]
	MSS	PSW	LSW	
Arsenic (As)	1.33	0.73	0.94	75
Cadmium (Cd)	0.74	0.69	1.77	85
Chromium (Cr)	11.74	8.68	9.7	3,000
Copper (Cu)	239.6	29.0	24.3	4,300
Lead (Pb)	0.89	2.05	29.98	840
Mercury (Hg)	0.63	0.024	0.15	57
Molybdenum (Mo)	< 0.15	< 0.15	< 0.15	75
Nickel (Ni)	12.7	24.5	7.4	420
Selenium (Se)	0.054	0.81	1.16	100
Zinc (Zn)	684.6	390.4	364.8	7,500

[1] Ceiling concentration limits for all sludge applied to land (EPA, 1994).

Dry matter yields of annual ryegrass on Patagonian soil showed that all treatments were similar to the inorganic fertilizer treatment (Table 3), and biomass yield did not differ statistically between salmon wastes treatments. Dry matter yield, especially in the control, was small probably because of the lack of N. There were no significant differences between any other treatments, probably because of the small N inputs, as previously noted by Teuber *et al.* (2005) when using sea salmon sludge on volcanic soil. On the other hand, on a granitic soil, PSW treatment produced a significantly lower biomass yields than the control; treatment PSW at higher rates caused lower biomass yields ($P \leq 0.05$). There was no significant LSW treatment effect on biomass yield compared to control and inorganic fertilizer, even though LSW treatments produced higher yield than PSW treatment. Yield results suggest that the application in the range of 25 to 150 t/ha of salmon wastes was equivalent to the inorganic fertilizer treatment, but supplementary application of N and K would be needed to increase pasture yield.

Table 3. Dry matter yields of annual ryegrass cv. Winter Star expressed as aboveground biomass in different treatments applied in two Chilean degraded soils.

Treatment	Sludge rate						IF [¥]	CV
	0	25	50	75	100	150		(%)
Patagonian soil								
PSW	3.27a	5.37a	4.76ab	4.60ab	5.10a	5.10a	5.20a	11.6
LSW	3.27a	4.80a	5.33a	3.77a	4.40a	5.37a	5.20a	17.3
Granitic soil								
PSW	3.59a	1.98b	1.47b	0.22c	0.11c	0.07c	3.45a	19.6
LSW	3.59a	3.37a	3.59a	3.48a	3.57a	3.04a	3.45a	8.2

[¥] Inorganic fertilizer (140 kg N, 200 kg P and 130 kg K/ha); PSW: land-based salmon farm waste; LSW: lake-salmon waste; F: inorganic fertilizer. Different letters in same row indicate statistical differences ($P \leq 0.05$).

Conclusion

Salmon wasted presented high macro and micronutrient concentrations. Annual ryegrass yield indicated that either salmon ground-farming waste or lake-salmon waste can be applied successfully on Patagonian soil (Entisol) at 25, 50, 75, 100 or 150 t/ha rates. Only lake-salmon sludge on granitic soil (Alfisol) can be applied successfully at 25, 50, 75, 100 or 150 t/ha rates. High rates of salmon ground-farming waste had a detrimental effect on annual ryegrass yield when added to the degraded Alfisol.

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Are differences in soil quality between organic and conventional farming systems greater in more energy-intensive sectors?

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Abstract
The Agricultural Research Group on Sustainability (ARGOS) has undertaken a longitudinal study of primary agricultural production in New Zealand to improve economic, environmental, social and ecological performance of its farms and orchards. As part of these objectives we report on a six year investigation of soil quality between Conventional, Organic and alternative management systems for three production sectors; Sheep and Beef (SB), Dairy (DY) and Kiwifruit (KF). The relative intensity of each sector was ranked according to energy use per unit land area and was the basis of a hypothesis to test whether differences in soil quality increase between management systems with increasing sector intensity.
For each sector, ARGOS established twelve clusters of farms with each cluster consisting of a farm or orchard from each management system matched as well as possible in terms of size, climate, topography and soil type. Properties of one management system constituted a panel. A range of soil measurements were made for each property covering fertility, soil organic matter, biology and physical condition. The quantitative data was analysed using a mixed model fitted with restricted maximum likelihood (REML) whilst qualitative data was analysed using a multinomial regression model run in R. Ten of the 24 soil properties measured (pH, exch-Ca, BS%, mineralisable-N, soil bulk density, moisture content, porosity, aggregation and earthworm numbers and weights) had statistically significant interactions that supported our premise that differences in soil quality between Conventional and Organic increased with land-use intensity. These differences reached their maximums in the KF panels, our most intensively managed sector in terms of energy use per unit area. A majority, however, of soil properties had significant management effects but not all were supportive of Organic, and were often minor compared to differences between panels.
Integrated was the most sustainable and best performed system in the SB panel and had better soil quality, due to the modest amounts of fertiliser used to improve production, and lower total energy costs per weight of product. Some improvements in soil quality were found in the DY panel under Organic management but many panel members are still in a transitional stage and further effects may still follow. KF had the worst soil quality overall but a large part of this can be attributed to running a modern commercial orcharding system. Adopting Organic management practice in KF orchards, however, improved soil quality.

Key Words
Organic, earthworms, soil property, ARGOS, pasture, kiwifruit.

Introduction
The New Zealand Agriculture Research Group On Sustainability (ARGOS) is seeking to identify pathways to improve sustainability for New Zealand agriculture through improving economic, environmental, social and ecological performance. Of the 14.7 million ha of farming land in NZ, about 8 million ha is grassland, of which ~5.8 million ha is used for Sheep & Beef grazing (SB) and ~1.9 million ha is used for dairying (DY). Kiwifruit horticulture (KF), although only occupying around 14,000 ha in total, is a relatively intensive industry producing high volumes of fruit per unit area (100 million trays annually; ~20 tonnes/ha).
Our inquiry is whether differences in soil quality between Organic and Conventional management systems (and two other alternative systems) increase with the intensity of the production sector. We began with a simple null hypothesis i.e. that there are no differences in soil quality between management systems for the three sectors. We report on a number of key soil fertility, biological and physical indices.

Methods

Program structure

The ARGOS program concentrated on establishing 12 groups (clusters) of commercial farms or orchards for each sector that were under the target management systems and in close proximity. Each SB cluster consisted of an Organic farm with a matched Integrated and Conventional counterpart. Each DY cluster consists of an Organic farm matched with a Conventional counterpart. Kiwifruit clusters were selected from three groups; (i) conventionally managed 'Hayward' (Green) (*Actinidia deliciosa*), (ii) organically managed 'Hayward' (Organic), and (iii) conventionally managed 'Hort 16A' (Gold) (*Actinidia chinensis*). The sector farms or orchards that made up a management regime constituted a panel.

Structures used for comparison were:

1. between production sector (i.e. SB, DY or KF)
2. between management system (i.e. Organic, Integrated/Gold or Conventional)
3. between landform or sampling position (i.e. SB & DY- flat, slope or crest; KF- within row (vines) or between row (alleyway)).

Management system

By definition, Organic farms use accredited organic production protocols and have achieved organic accreditation status. Integrated farms follow industry protocols that although not to organic status, may require reduced pesticide and herbicide use, higher environmental performance and/or animal welfare standards and usually have higher production. Conventional farms represent the *status quo*. By virtue of the aforementioned clusters and management systems, each sector is ostensibly represented by 24-36 farms or orchards barring withdrawal of properties from the study through circumstance.

Measurements

A range of soil physical, fertility and biological measurements were made for each farm or orchard using qualitative and quantitative methods. Soil physical measurements included soil porosity and aggregation (by visual soil assessment; (Shepherd 2000), soil bulk density (SBD) and soil moisture content (SMC; at field capacity). Soil chemical analyses included pH, Olsen-P, resin-P, sulphate-S, organic-S, exchangeable cations, potentially mineralisable-N, organic-C, total-N, cation exchange capacity (CEC) and P retention capacity. Soil biology measurements included 0.5 M K_2SO_4-soluble C, soil microbial biomass (SMB) C and N and basal respiration.

Statistical analysis

The quantitative data was analysed using a mixed model fitted with restricted maximum likelihood (REML). This method allowed analysis of the entire data-set simultaneously, even though the data was not balanced and there were several areas where data was not available for many variables. Qualitative data was analysed using a multinomial regression model run in R. Principal components analysis (PCA) of all major soil properties was also conducted.

Energy usage

Comprehensive energy usage values were complied for each and used to determine a set of energy intensity indicators per hectare or per kg product and included fuel and electricity plus the embodied energy in fertiliser, agrichemicals and capital items (Barber and Lucock 2006; Barber and Benge 2006; Barber, Pellow *et al.* 2008).

Results

Energy use

Sector energy use values increased by an order of magnitude from SB<<DY<KF on a unit area basis but the order changed to KF<<SB<DY when calculated on a unit weight basis (of product leaving the farm or orchard) (Table 1). Within each sector there was a general decrease in energy use per unit area from Conventional to Organic panels but energy usage for KF-Gold and SB-Integrated panels was best in terms of efficiency for product produced for their respective sectors Table 1.

Soil fertility

Olsen-P and sulphate values were lowest for the SB sector overall but both KF Conventional and DY Gold panels had P values that were above recommended optimum ranges for NZ pastures (20-40) (Roberts, Morton *et al.* 1999). P and S values for SB Organic were below recommended critical ranges (P 20-30; S 10-

12) for NZ pastures (Morton, Roberts *et al.* 1994). Soil pH, CEC, cation and total base saturation (BS) values were highest overall for DY and KF sectors and lowest for SB. Organic panels generally had significantly higher cation values than the other panels although SB Organic showed a reverse trend for Ca and K values. Aside from soil-based sector differences, soil organic matter (SOM) values were generally higher for Organic panels but only KF specifically. C/N ratios were significantly higher for KF than either DY and SB but within all sectors, Organic panel C/N ratios were consistently greater than Conventional or Integrated/Gold. Organic-S, expressed gravimetrically (soil weight) was only significantly different at the sector level and highest for DY but expressed on a soil carbon basis only panel effects were significant whereupon Organic values were consistently lower than either Conventional and/or Integrated/Gold. Organic. Potentially (anaerobic) mineralisable-N (AMN) values were significantly greater ($P<0.001$) for the DY and SB sectors compared with KF, but values were also consistently greater for the Organic panels.

Soil biology

Earthworm numbers and weights ranged by an order of magnitude from KY<<SB=DY. A strong sector interaction ($P<0.01$) showed that differences in numbers were highly significant between the DY and KF panels but not SB. There was no significant increase in earthworm weights between DY panels.
Soil microbial biomass and basal respiration values increased significantly from KF<<DY=SB but values for Organic panels were also higher ($0.05<P<0.001$) compared with Conventional. These differences tended to decrease when related to soil-C or –N content.

Soil physical condition

VSA scores for soil porosity (Figure 2) and soil aggregation showed that generally, soil structure significantly deteriorated from SB>DY>KY. Scores for "excellent" porosity were clearly fewer for KY, with only ~15% in this category compared with more than 60% overall for SB. Porosity scores for "good" dominated the distribution for DY (~55%). Scores for soil aggregation followed similar trends.
Differences in soil porosity between panels were only significant for KY with Organic scoring almost twice as many excellent scores as Conventional and Gold, and far fewer fair and poor scores (Figure 2). KY Organic also had significantly more good scores and hence, far fewer fair and poor scores.

Table 1. Sector energy use and stocking rates for the differing panels.

Term	Sheep and Beef[1]			Dairy[2]		Kiwifruit[3]		
	Conv.	Integ.	Org.	Conv.	Org.	Conv.	Gold	Org.
MJ/ha	3416	4130	2332	37725	26311	56627	55062	40362
MJ/kg	9.2	7.5	9.5	38	38	2.2	1.7	2.0
SU[4]/ha	10.7	12.5	10.1	12.9	9.3	n/a	n/a	n/a
Fertiliser[5] kg/ha/y	60	84	13	214	113	534	517	388

[1] MJ/kg includes both meat or wool leaving farm (1Kg=~8.5 MJ); [2] 1kg MS contains ~38 MJ of energy;[3] 1 tray contains 6.0-7.0 (gold) or 6.7-7.7 (green) MJ; [4] Stocking rate- stock units/ha; [5] total annual fertiliser use (N, P, S, K).

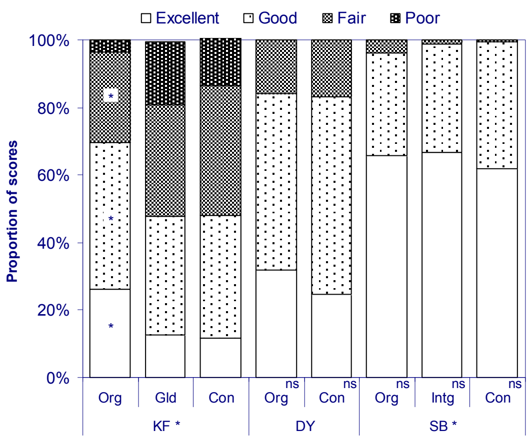

Figure 2. Soil porosity score distribution for each panel for KF, DY and SB sectors. An asterisk denotes a significant difference in scores at an individual level or cross-sector basis (ns; not significant).

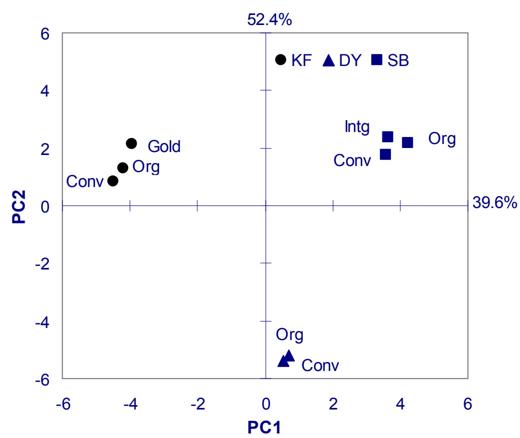

Figure 3. Principal components analysis of 27 mean soil indice values for SB, DY and KF sectors.

Principal components analysis
PCA showed distinct differences between management systems, KF in particular, but these were generally found to be minor compared to differences between the production sectors (Figure 2). The x (PC1) and y (PC2) axes accounted for 52% and 40%, respectively, of the total variation. Loadings for the PC1 component were largely predicated around those for soil fertility and physical condition (pH, CEC, Olsen-P, exch-Ca, aggregation, porosity, SBD and SMC) whilst loadings for the PC2 component were almost all predicated around soil organic matter and microbial biomass (AMN, N%, C%, C/N ratio, MC/MN ratio and SMB-N).

Conclusions
Of the 24 or so soil properties measured, ten (pH, exch-Ca, BS%, AMN, SBD, SMC, porosity, aggregation and earthworm numbers and weights) had interactions that supported our premise that differences in soil quality between Conventional and Organic increased with land-use intensity. These differences reached their maximums in KF, our most intensively managed sector in terms of energy use per unit area. Although some similar trends were also noted in the DY sector, many Organic farms in this panel are still in a formative stage and may have not reached equilibrium with their new management regime. A majority, of soil properties however, had significant management differences and many were supportive of Organic panels and higher soil quality but many were also often minor (<10%) compared to differences between production sectors related to soil geomorphology and land-use. Sparling and Schipper (2002) reported in their NZ study of land-use and soil quality that many soil properties have a basis in the soil's geomorphology and land-use and management will have a variable effect on these. Whilst we can not be entirely sure about the magnitude of the effects from differences in soil properties, they appear generally minor.
For KF, Gold was the most efficiently produced kiwifruit (MJ/kg), mainly due to its vigour, and Organic was second whilst DY Organic was also more energy efficient (MJ/kg MS) than DY Conventional. Integrated was the most sustainable and best performed system in SB and had better soil quality, due to the modest amounts of fertiliser used to improve production, and lower total energy costs per weight of product. Only a few improvements in soil quality (lower Olsen-P, higher SMB-C and earthworm numbers) were found for DY under Organic management but many Organic panel members are still in a transitional stage and further effects may still follow. Although KF had the worst soil quality of the three sectors, a large part of this could be attributed to running a modern commercial orcharding system. Adopting Organic management practice in KF orchards, however, improved soil quality.

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Assessing field sediment exports of northern Victoria farming systems using HowLeaky2008 model

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Abstract
Australian agriculture is under pressure to reduce sediment exports and improve stream water quality. However data on soil losses of different land management is lacking, thus potential benefits of adopting Best Management Practices cannot be quantified. In this study we assessed field soil losses of farming systems of North Central Victoria by using the HowLeaky2008 model. HowLeaky2008 is a one-dimensional farm system model that simulates the effect of soil and land management on daily water, sediment and nutrient exports. HowLeaky2008 was applied to current and alternative land management options in the Avon Richardson catchment, which is typical of the Wimmera-Mallee region of Victoria. Simulated long term average soil losses were similar to erosion rates previously assessed with ^{137}Cs techniques. Modelling suggests that changing from minimum to zero tillage can reduce sediment exports by 40-75% in cropping land; and switching from annual to perennial pastures or lucerne can reduce sediment exports by over 80%. Highest erosion rates and potential for reducing sediment exports were on duplex soils followed by Kandosols and Red or Grey Vertosols. The HowLeaky2008 model proved useful to quantify the relative efficacy of farming practices that improve the environmental sustainability of agricultural enterprises.

Key Words
HowLeaky2008, soil loss, land management, farming systems, Victoria, Avon Richardson catchment.

Introduction
Water quality in northern Victorian rivers is often poor, due to high turbidity and nutrient content. For public investment to reduce the impacts of agriculture on water quality effectively, a clear understanding of sources of sediments is required. In addition, quantifying the potential benefits of adopting Best Management Practices (BMP) compared with current practice is also required if on-farm investment is to be made. However, data on sediment exports of different land management and BMPs are currently lacking. Given the lack of field quantification of soil erosion in much of Victoria, in this study we pursued a modelling approach to investigate the relative impacts of current farm systems on field soil losses, and identified opportunities for reducing sediment exports. HowLeaky2008 (McClymont *et al.* 2008) proved to simulate well soil water content in crops and pastures of south-eastern Australia (Melland *et al.* submitted) and was selected for this study. The aim of this study was to assess the impact of land management on field sediment exports for the farming systems of the Avon Richardson catchment of north central Victoria, which can be considered typical of the Wimmera-Mallee region of Victoria, an area affected by severe water quality issues.

Methods
HowLeaky2008 model
HowLeaky2008 is a one-dimensional farm system model that simulates the effect of soil and land management on daily water surplus, sediment and nutrient exports. Soil losses are calculated according to:

$$E = (fCOVER\ LS\ K\ P\ Q/10)\ SDR \quad (1)$$

where E is the soil loss in t/ha, $fCOVER$ is a function of vegetation cover, LS, K and P are the topography, soil and protection factors of the Revised Universal Soil Loss Equation (RUSLE, Renard *et al.* 1996), and Q is the volume of runoff (mm). The main difference between equation (1) and the RUSLE approach is that the erosion agent is runoff instead of rainfall. SDR is the sediment delivery ratio; a value of 0.1 can be considered suitable for Australian conditions and was used throughout this study. Runoff is calculated using a modified USDA Curve Number approach and is a function of rainfall, soil water content, surface cover and surface roughness. Curve Number is maximum on bare soil (CN-bare), and declines linearly down to a minimum when vegetation cover reaches 80% or higher (CN-80).

Table 2. Howleaky2008 parameters for the hydrologic soil groups defined in the Avon Richardson catchment. GV = Grey Vertosols; GV_HS = Grey Vertosols, hard-setting; GV_hvy = heavy Grey Vertosols; RYC = Red or Yellow Chromosols, hard-setting; RS_notHS = non hard-setting Red Sodosols; RS_HS = hard-setting Red Sodosols; RedV = crusting Red Vertosols; SK = shallow Kandosols.

	GV	GV_HS	GV_hvy	RYC	RS_notHS	RS_HS	RedV	SK
Soil depth (mm)	1500	1500	1250	1500	1500	1500	1500	700
Soil PAWC (mm)	158	150	108	169	126	132	156	107
Max drainage (mm/d)								
- layer 1	24	12	24	30	240	30	24	72
- layer 3	4.8	4.8	2.4	12	12	12	4.8	48
CN-bare	75	75	75	87	85	85	75	75
CN-80	55	55	55	52	55	55	55	55
USLE K (t/ha/EI30)	0.15	0.15	0.15	0.4	0.3	0.4	0.25	0.5

Study area

The Avon-Richardson catchment is an endorheic basin that extends over 3300 km^2 of the Wimmera region of south-east Australia. Three agro-climatic zones are distinguished: grazed uplands in the south (average rainfall approximately 500 mm/y), mixed farming (i.e. combination of grazing and cropping) in the mid-catchment (average rainfall approximately 450 mm/y), and flat croplands in the north (average rainfall approximately 400 mm/y). Current grazing management consists mainly of set stocking on annual pastures (AP), whereas perennial pastures (PP) occupy approximately 10% of grazed land. In the mixed farming areas, 40% of the land is used for cropping, and 60% for pastures. In the flat croplands, 4-year rotations of canola-wheat-barley-legume (CWBL) are common. Due to recent drought, a 3-year rotation inclusive of bare fallow (wheat-barley-fallow, WBF) has re-commenced in all agro-climatic zones. Soils are mainly deep and clayey, with uniform or duplex soil profile. Published soil surveys and local knowledge were used to group soils with similar hydrological behaviour: hard-setting Red Sodosols, non hard-setting Red Sodosols, hard-setting Red or Yellow Chromosols, Grey Vertosols, heavy Grey Vertosols, hard-setting Grey Vertosols, crusting Red Vertosols, and shallow Kandosols (Melland *et al.* 2008).

Soil parameterization

Soil parameters define partitioning of water into infiltration or runoff, water losses by evapotranspiration, movement of water in the soil column, and water losses by percolation below the root zone. Most soil parameters were set according to a national databases of soil properties (Melland *et al.* 2008), with some exceptions. CN-bare and CN-80 were set as per Owens *et al.* (2003). The soil column is divided into three layers through which water moves in a cascading bucket system at maximum daily drainage rates (mm/day). These rates were based on Yee Yet and Silburn (2003) soil surface characteristics (hard-setting or not), and texture and structure of the soil profile. Table 1 indicates the most important soil parameters that affect runoff and soil loss simulation.

Model testing

The HowLeaky model has been extensively tested in Queensland, but in Victoria only its water balance has been tested (Melland *et al.* submitted). Previously published long term (about 40 years) erosion rates were assessed for several Victorian sites using the ^{137}Cs technique (Lorimer *et al.* 1996). Five of these sites were close to the Avon Richardson catchment and HowLeaky 2008 was applied to them using the soil hydrological group of Table 1 that was closest to site description, and appropriate cropping or grazing land use.

Results and discussion

Comparison of soil loss predictions with literature data

Howleaky2008 soil losses for cropping land were very close to the long-term net erosion rates assessed by the ^{137}Cs study (Table 2). However, HowLeaky2008 predictions were higher for the grazed sites. It is possible that Howleaky2008 overestimates erosion in grazed land or that Lorimer *et al.* (1996) underestimated erosion. The ^{137}Cs study used different regression equations to assess erosion under cropping or grazing conditions; the same difference in ^{137}Cs levels leads to a calculated erosion rate for cropping land that is 13 times greater than for grazed land. Higgitt (1995) found that the use of the two equations was not well justified. We therefore calculated the erosion rates for the grazing sites also using the cropping land equation. Results are shown in brackets in Table 2. Howleaky2008 soil losses are much closer to these estimates than to the original study of Lorimer *et al.* (1996) and are in reasonable agreement for the St Arnaud site. There was still poor prediction from Howleaky2008 for the Stawell site; Lorimer *et al.* (1996)

Table 2. Comparison of field soil loss estimated with HowLeaky2008 and ^{137}Cs erosion rates published for sites near the Avon Richardson catchment in Victoria. Source (Lorimer *et al.* 1996).

Location	Annual rainfall (mm)	Site description	^{137}Cs erosion rate (t/ha/y) Net†	Max	HowLeaky2008 Simulated soil group	Soil loss (t/ha/y)
Horsham	420	Cropping, fallow every 3-5 years; grey cracking clays; slope 1.5%	0.52	16	GV_HS	0.32
Charlton	400	One crop every 4 years; red duplex soil; long gentle slopes of 3-5%	0.90	5.15	RS_HS	0.71
Colbinabbin	500	Mixed cropping and grazing; red sodic soil (dr3.42); slope 2%	1.05	2.51	RS_HS	0.85
St Arnaud	584	Annual pasture; grey stony loams and red duplex soils; slopes 5-7%	0.28 (1.40)*	1.74 (6.32)*	RS_HS or SK	1.79 (RS_HS) 0.74 (SK)
Stawell	584	Annual pasture; loam/sandy loam topsoil with high rock content; slope 15%	0 (0.55)*	1.70 (7.12)*	SK	2.63

† Net erosion rates account for soil loss or gain along the transect. Max erosion rates indicate the maximum erosion rate assessed along the transect; * Values in brackets show erosion rates estimated with the equation for cropping land.

however report that they had expected higher erosion rates for this site, but outcropping bedrock and high infiltration in the upper slopes may have restricted erosion. Although Howleaky2008 model testing was limited for the number of sites, soils and land use conditions, the results increase the confidence in model capability to assess soil losses in Victorian farming systems.

Land management options to reduce soil losses

The HowLeaky2008 model was applied to assess average annual soil loss (t/ha/y) for current land management and alternative options identified as suitable for the catchment. Perennial pastures (PP) in the grazed uplands, or lucerne in the mixed systems were selected as alternatives to annual pastures, and a zero tillage 4-year rotation (CWBL_0till) was selected for the cropping land. Field soil loss depends on topographic settings; to allow comparison of different soils, slope was set to 9% and field length was set to 22.1 m, so that the *LS* factor of equation (1) was equal to 1. In annual pastures, soil loss ranged from 0.3 to 1.5 t/ha/y; it was lowest in heavy Grey Vertosols and highest from Red/Yellow Chromosols (Figure 2).

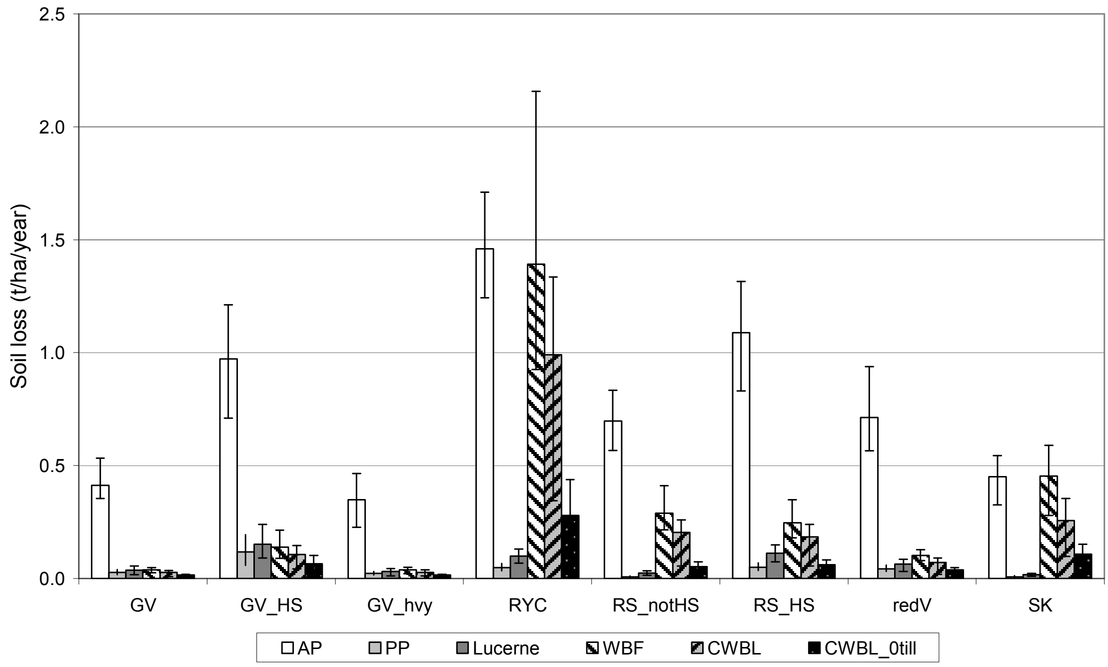

Figure 2. Soil loss (t/ha/year) under current and alternative land management systems estimated with Howleaky2008. Bars indicate min and max response across the Avon Richardson catchment climate zones.

By contrast, soil losses were always less than 0.15 t/ha/y under perennial pasture or lucerne. In cropping land, the 3-year WBF rotation generated most soil loss, at rates of 0.3 (heavy Grey Vertosols) to 3.7 t/ha/y (Red/Yellow Chromosols). Soil losses in the 4-year CWBL rotation were 25-45% lower (0.25-2.6 t/ha/y) than WBF. If zero tillage was adopted in crop land, soil losses under the 4-year rotation (CWBL_0 tillage) would reduce to 0.1-0.8 t/ha/year and would be particularly effective on red duplex soils (Red Yellow Chromosols and Red Sodosols). Estimated soil losses were similar to erosion rates measured in New South Wales under pastures (0.2-0.4 t/ha) and crops (1.5-8 t/ha) (Edwards and Zierholz 2007). Soil losses of Figure 2 do not account for topographic settings. Long fields and steep slopes multiply soil losses according to the *LS* factor. For example, in the Avon Richardson slopes are commonly as long as 100 m; at slopes of 2.7% soil losses would be halved, at 5% soil losses would be approximately equal to Figure 2, but at 10% soil losses would be 2.3 times these Figures. Vertosols occur mainly in flat areas and soil losses are of little concern, but duplex and Kandosols, which occur in the hills, may generate large soil losses.

Conclusions

HowLeaky2008 soil losses for the Avon Richardson catchment were comparable to ^{137}Cs estimates for nearby sites and observed values in NSW indicating that the model can be used to simulate Victorian farming system conditions. Model simulations showed that changing from minimum to zero tillage can reduce soil loss by 40-75% in cropping land; switching from annual to perennial pastures or lucerne could reduce soil loss by over 80% in grazing land. Highest soil losses were from duplex soils and the adoption of BMPs would have the largest impact in reducing sediment export. Further experimental work to verify the model simulations would be useful.

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Assessment of soil water balance at a distributed scale in Southern Italy

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Abstract

The purpose of this study is to analyse the components of soil water balance in an important district included in the Basilicata and Puglia regions (Southern Italy) mainly cropped with horticultural crops. The study was performed by using the spatially distributed and physically based model SIMODIS in order to individuate the best irrigation management maximizing the water use efficiency and minimizing water losses by deep percolation and soil evaporation. SIMODIS was applied taking in account the soil spatial variability and localization of cadastral units for two crops, durum wheat and water melon. Water melon cultivation was simulated adopting different water supply managements and several indicators were calculated and mapped in a GIS environment. The analysis allowed to identify the areas particularly sensitive to water losses by deep percolation because of their hydraulic functions characterized by low water retention and large values of saturated hydraulic conductivity. The irrigation scheduled on a soil basis allowed management of the irrigation in a more efficient way.

Key Words

Irrigation, distributed modelling, soil hydraulic properties, crop.

Introduction

In Mediterranean regions of Southern Italy, the efficient use of water resources in agriculture is extremely important in order to improve the economical and environmental sustainability of the agricultural activity in an environment characterized by high evaporative demand of atmosphere, water scarcity and increasing negative consequences of climate change. Different simulation models can be used for describing the soil water fluxes at spatial and temporal scales and characterizing the physical and biological processes of the soil-plant-atmosphere agrosystem. The spatially distributed and physically based model SIMODIS (SImulation and Management of On-Demand Irrigation Systems) (D'Urso 2001) is a Decision Support System (DSS) based on the integration of different tools such as agrohydrological hydraulic simulation model and GIS techniques where, for each calculation unit with homogeneous climate, crop and soil conditions, in which the total area can be divided, the SWAP model is applied in a distributed approach. The main objective of this study, carried out at a distributed scale, was to analyse the components of soil water balance through the model SIMODIS, to identify the irrigation strategies with the highest efficiency and to localize the main vulnerabilities in an important district included in the regions of Basilicata and Puglia and situated in the Ionical coastal area of Southern Italy, as regarding the cultivation of water melon (*Citrullus lanatus* Thunb).

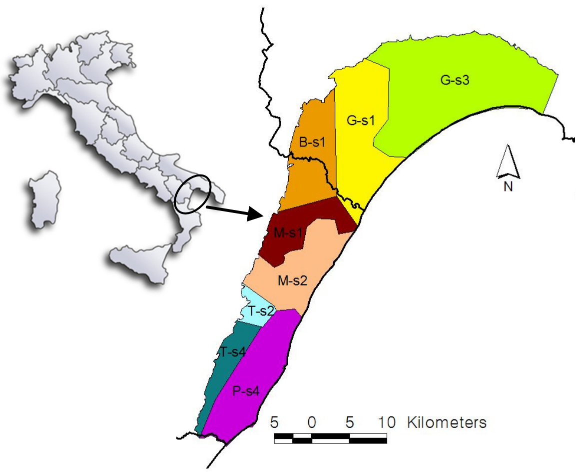

Figure 1. Map units in the Jonical coastal area.

Methods

The agricultural district of Jonical coast is located in the Puglia and Basilicata regions and has an extension of approximately 620 Km^2 (Figure 1). The area extends along the coast of Jonical Sea and toward the inside of the territory to an altitude of 60 meters including the basins of four rivers: Sinni, Agri, Cavone and Basento. With an extension of 4303 ha and 21672 ha for permanently and no- irrigated lands, respectively, the area is mainly cropped with horticultural crops, orchards and vineyards, distributed in relation to the position in the landscape: fruit and vegetable crops prevail in the alluvial deposits, cereals and olive trees predominate in the marine terraces. The data set utilized for producing the land cover maps consists of a multispectral remote sensing image used to discriminate the water melon cover class, taken by SPOT5 satellite, with the spatial resolution of 10 m and four bands in visible and near/medium infrared spectrum. To investigate the multivariate spatial structure of soil data a linear model of coregionalization (Castrignanò *et al.* 2000) was fitted to all direct and cross-variograms. All the variables were interpolated on a 500 by 500 m-grid using the geostatistical technique of cokriging. In order to divide the study area into homogeneous soil clusters or classes an algorithm based on nonparametric density estimate, was used (Scott 1992). An approximate p-value for each cluster is computed by comparing the estimated maximum density in the cluster with the estimated maximum density on the cluster boundary. The clustering approach was implemented by using the MODECLUS procedure of the SAS/STAT software package (SAS 2008; release 9.2).

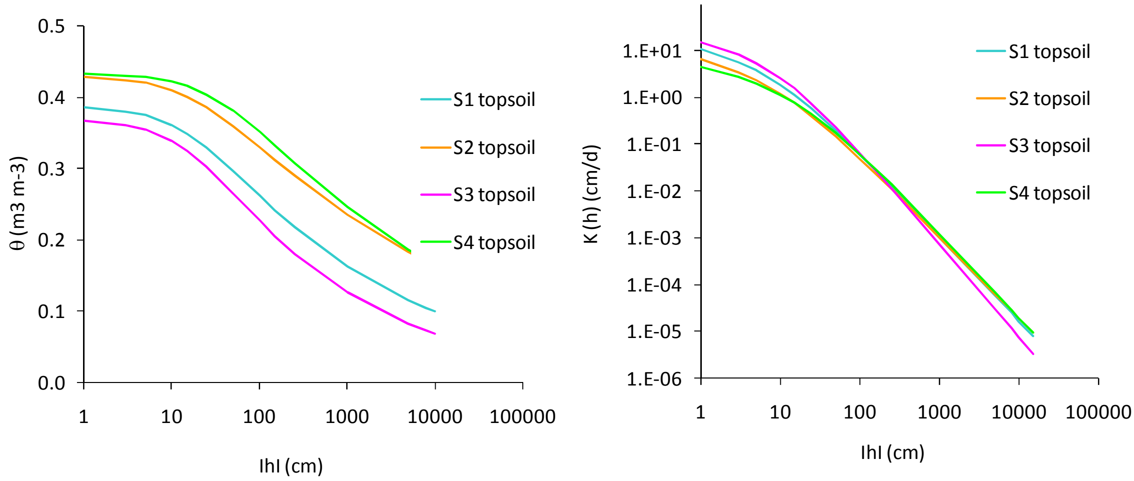

Figure 2. The estimated soil hydraulic functions.

The SIMODIS model was constituted as a Decision Support System with the main goal to simulate the irrigation requirement of a irrigation district integrating different aspects. The information about the soil concerns the depth and discretization of each horizon soil profile and the parameters of the functions of retention and hydraulic conductivity expressed in the parametric of Mualem- van Genuchten form (van Genuchten, 1980). In this work, the soil hydraulic parameters were determined through the PTF HYPRES (HYdraulic PRoperties of European Soils) (Wösten *et al.* 1998). This PTF comes from information collected in the database HYPRES containing information of 5521 soil horizons involving 20 institutions from 12 European countries. On the basis of linear regression , HYPRES estimates the hydraulic parameters of Mualem- van Genuchten equations – θs and θr, the saturated and residual soil water content, Ks, the saturated hydraulic conductivity and α, n, and l, usually considered as fitting parameters – starting from the values of sand, silt and clay, as well as organic matter and bulk density.

For water melon, five irrigation managements were simulated: (i) without irrigation (M1); (ii) allowed fraction of soil water deficit of 100% (M2), 50% (M3) and 25% (M4) with the lower limit of soil pressure head (h) equal to the value below which the crop water uptake is reduced; (iii) irrigation strategy based on monitoring of plant water status with the irrigation scheduled when the ratio “actual transpiration/potential transpiration” is equal or lower than a critical fraction defined by user (0.98 in our case) (M5). For all the M_ irrigated strategies the irrigation depth was calculated on the basis of soil water content corresponding to the field capacity. For each simulation run the following soil water balance indicators were considered at a seasonal scale: actual transpiration (Ta, mm), actual evaporation (Ea, mm), deep percolation (Perc, mm), seasonal irrigation depth (Irr, mm), watering depth (Vmed, mm) and seasonal number of irrigations (ni, -).

Results

According to the results of geostatistical analysis, the study area was subdivided into 4 distinct classes realising the best visual accordance with the prior description of the spatial variation of the soil attributes. (Figure 1). The clusters S1 and S3 (Table 1), in the Northern and Central parts of the district, respectively, are characterized by the highest percentages of sand (more than 50%) with the first one having a significant component of clay, above all in the subsoil (more than 22%). The Ks of such soils are particularly high with values for the topsoil that overcame 50 cm/d. Due to significant sandy component, the θs are not particularly high (less than 0.39) contrary to the n parameters (more than 1.2). Such findings indicate high

Table 1. Hydrological parameters according to Mualem-van Genuchten (1980).

Soil	USDA classification	θs cm^3/cm^3	Ks cm/d	α 1/cm	l -	n -
S1	Sandy clay loam	0.388	51.1	0.058	-2.95	1.21
S2	Clay loam	0.431	46.8	0.049	-3.76	1.15
S3	Sandy loam	0.370	52.8	0.058	-2.04	1.26
S4	Silty clay loam	0.434	21.8	0.027	-3.18	1.17

rate of drainage and water profile distribution after infiltration events. In the Central and Southern part of the district the finest component of texture increases in the topsoil (32 and 28% for S2 and S4, respectively) and even more in subsoil (38 and 31%), indicating higher soil water retention and high values of θs (more than 0.43) and low values of α and n parameters (less than 0.05/cm and 1.17, respectively) . The Ks, lower than 47 and 22 cm/d for S2 and S4, respectively, indicates a low infiltration rate and a sensitivity to runoff water losses (Figure 2). According the technique of Thiessen polygons, we interpolated five climatic areas (related to 2007 data) that combined with the 4 soils gave a total of seven map units (Figure 1: the unit P-s4 was not considered because no watermelon cultivation took place in 2007).

The results of SIMODIS application in the irrigated district of Southern Italy are synthetised in Figure 3 and 4. Significant variations were found as a function of irrigation management in the various map units in terms of watering depth (Vmed, the depth of water applied in a single irrigation event), actual evapotranspiration (Eta) and deep percolation (Perc). The Eta increased from about 200 mm without irrigation (M1) to over 320 mm, with irrigation, with peak values under M3 and M4. A linear increment of Eta was evident coming from M2 to M4 while M5 was characterized by values of Eta comparable to those of M2. Regarding the differences related to different pedoclimatic characteristics, the lowest average values of Eta were obtained for B-S1, regardless of the irrigation strategies adopted. The Figure 3 shows also interesting values of Vmed. In this case more evident differences can be attributed to the irrigation strategies with linearly decreasing values from M2 to M4 (from 100 to 20-30 mm) and M5 that had the second highest values (80 mm in average) with the exception of S3. The corresponding values of Vmed for S3 and S4 tended to be lower than the other soils. Obviously, low values of Vmean mean more frequent irrigation: with a Vmed of about 20-30 mm about 10-11 irrigations were simulated. Moreover, increasing the single irrigation depth, the risks of losses by deep percolation increase as reported in Figure 4 that shows the lowest water losses were obtained with M3 and M4. The graph highlights the high sensitivity, in order of magnitude, of M5 and M2 irrigation strategies that, for every map unit, showed the highest values of percolation depth: such a trend is particularly evident in G-S3 unit under M5.

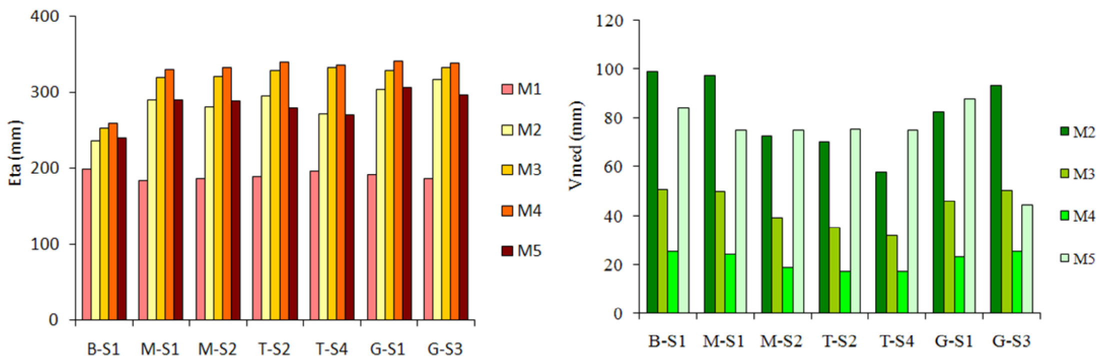

Figure 3. Actual evapotranspiration (Eta) and irrigation depth (Vmed) for watermelon simulation.

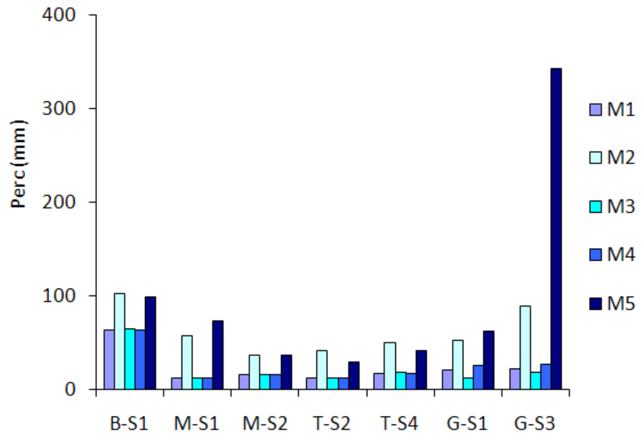

Figure 4. Deep water percolation for watermelon simulation.

Conclusion

The use of model SIMODIS allowed to estimate the principal components of soil water balance a distributed scale in an area situated in the Jonical coast of Southern Italy and cultivated mainly durum wheat and water melon. The study allowed to identify the most sensitive zones to water losses by deep percolation. For the irrigation strategies based on the concept of "allowable depletion of soil readily available water", the efficiency was higher when a depletable fraction of 0.25 was applied and the results, obtained in term of watering depth (20 mm) and number of irrigation for season (about 10), were very similar to those actually adopted by the farmers of the region. With irrigation carried out when the soil water reservoir is completely depleted (M2) the losses by deep percolation tended to increase and consequently the irrigation efficiency decreased.

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Changes in soil pH as a result of lime addition as affected by rates, time and incorporation method

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Abstract
Sandplain soils on the south coast of Western Australia are naturally acidic. Cropping systems can further reduce soil pH by as much as 0.3 pH units in seven years. A series of experiments were established to determine the effects of lime addition on soil pH within the root zone. Lime applied at rates ranging from 0.5 to 8.6 t/ha resulted in significant increases in topsoil pH. Only the highest rates of lime (> 1.5 t/ha) resulted in pH increases beyond 15 cm depth seven years after application. Only systems that incorporated lime at depth and or mixed soils to depth through slotting/trenching resulted in significant crop yields and soil pH increases within the root zone (0 - 60 cm) immediately after being applied. The resultant crop yields where subsoils pH was modified were as much as 80% higher than the control.

Key Words
Acidification, limesand, application methods, amelioration.

Introduction
The sandplain soils on the south coast of Western Australia cover some 2 M ha and are widely used for agricultural production. The soils are naturally acidic. This combined with grain removal, acidic fertilizers and nitrate leaching has resulted in a reduction in soil pH within the root zone in farmed soils when compared to native soils. The rate of acidification is exacerbated by poor chemical buffering associated with low organic carbon (<1.5%) and clay (<3 %) contents. Consequently soil pH is declining from relatively low base with most cropped sandplain soils having a pH <5 within the root zone. Limesand (crushed native limestone) is almost solely used to ameliorate acidity on the south coast of WA. However limesand, being comparatively insoluble, takes time to increase soil pH at depth within the soil profile. In order to understand how to manage soil acidification a series of experiments were conducted on the Esperance sandplain between 1999 and 2009. The aim of this research was to measure soil pH changes over time in soils treated with limesand applied at different rates and application methods.

Methods
Three experiments were established between 1999 and 2006 (Table 1). Each of the experiments was statistically designed as a randomised block with three replicates. The three experimental sites were located within 50 km of Esperance, WA on grey deep sandy duplex soils which are classified under the Australian system as hypocalcic mesonatric Sodosols (Isbell 1996). These soils form part of the Esperance sandplain and consist of a fine sand A horizon overlying a sodic B horizon light to medium clay. The sands are often > 60 deep, have low organic carbon (<1.5 %) and cation exchange (<4 me/100g) within the Ap horizon with values decreasing with depth. Soil pH_{Ca} commonly ranges from 4.3 to 5.5 with exchangeable aluminium less than 10 ppm. Two sources of liming material were used in the experiments, limesand and G Lime. The limesand was quarried at Dalyup (40 km to the west of Esperance) and had a neutralising value of 69% with 97% of particles less than 0.5 mm. The G lime, a by-product of cement manufacture, has a neutralising value of >85 % and 90% of particles less than 1 mm. For sites 1 and 2 the limesand and G lime were applied using commercial spreaders.

For site 3, limesand was either top dressed at rates of 1.6, 4.3 and 8.7 t/ha or incorporated to 60 cm depth within a slot. The slots were dug with a trenching machine with each slot 0.15 m wide and 0.6 m deep. Three slots per plot were dug along the length of the plot spaced at 0.5 m intervals. Limesand was added manually to the trenched spoil, mixed and manually incorporated back into each slot. Soil pH was measured in 0.1M $CaCl_2$ solution using the method of Rayment and Higginson (1992). Crop yields were measured at sites 1 and 2 using commercial harvesters and at site 3 using a ‘Kingaroy’ plot header with a 1.65 m wide front.

Table 1. Site location, year established, treatments, plot sizes and sampling dates.

Site	Lat	Long	Established	Treatments	Plot size	Date Sampled
1	-33.6907	122.0977	1998	Control 0.5 t/ha GL^ 1.5 t/ha GL 1.5 t/ha LS* 3 t/ha LS	20 m wide by 100m long	11/2005
2	-33.6910	121.9143	2001	Control 1 t/ha LS 2 t/ha LS	20 m wide by 100m long	2007
3	-33.6738	121.9676	2006	Control 1.6 t/ha LS 4.3 t/ha LS 8.7 t/ha LS Slots to 60 cm Slots to 60 cm + 4.3 t/ha LS	2 m wide by 20 m long	6/2007 6/2009

* LS=Limesand ^GL = G Lime

Results

Site 1 soil pH decreased by as much as 0.3 units to a depth of 25 cm when compared to the control after 7 years (Figure 1a). pH responses to G Lime and Limesand were evident at all rates applied with significant increases in soil pH recorded for the lowest application rate (0.5 t/ha) to the highest rate (3 t/ha) within the 0-10 cm layer at Site 1 (Figure 1a). Only the 3 t/ha treatment resulted in significant increase in pH below 15 cm, however, there was no significant lime effect on soil pH below 25 cm. At site 2 significant increases in soil pH were recorded for both treatments (1 and 2t limesand/ha) when compared to the control six years after the initial applications (Figure 1b). The rates required to change soil pH at a given depth were similar to Site1 in that the 1 t/ha treatment only increased soil pH to a depth of 10 cm where as the 2 t/ha significantly increased soil pH to a depth of 20 cm.

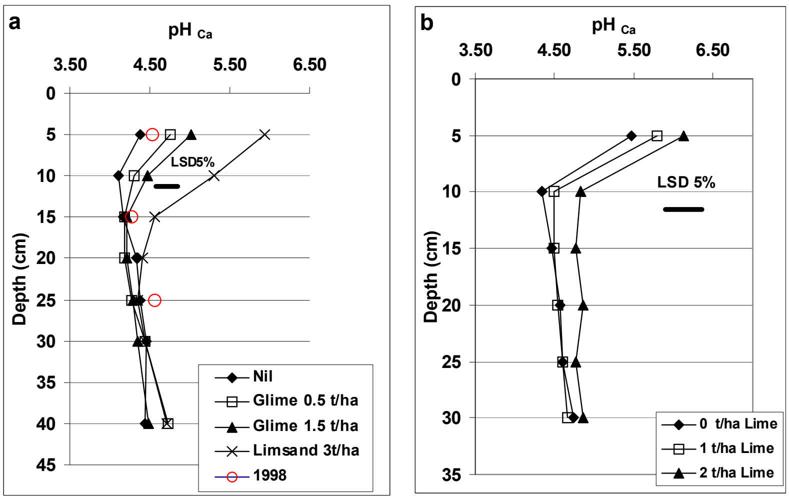

Figure 1. Effect of lime application on soil pH with depth a) Site 1 - seven years after lime application b) Site 2 - six years after lime application.

Crop yields were not affected by lime addition at either site in any of the years measured despite the changes in soil pH. Exchangeable aluminium levels were less than 8 ppm at all depth measured. The results also show that the higher the surface soil's pH the greater the depth soil pH was modified through lime addition. This data is consistent with current recommendations that maintaining soils at a pH 5.5 or more will markedly increase the depth to which the soil pH is increased with lime (Gazey pers. com). However, the results from both these sites highlight the problem of achieving significant increase in soil pH at depths greater than 25 cm in sandplain soils.

At Site 3 no differences in soil pH were found between the surface applied lime treatments in 2007. Slots with applied lime significantly increased soil pH to a depth of 60 cm (Figure 2a). In 2009, significant increases in pH were found due to surface applied lime only at a depth of 10 cm and where limes rates were greater than 1.6 t/ha (Figure 2b).

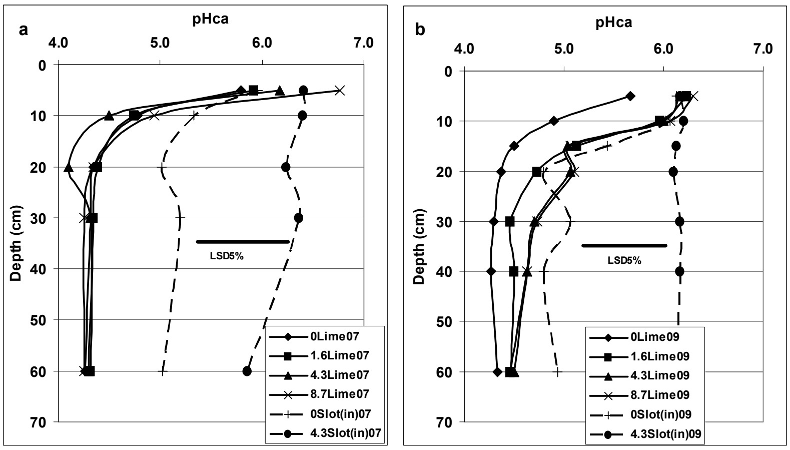

Figure 2. Changes in soil pH with depth at site 3 measured in (a) 2007 one year after application and (b) 2009 three years after the application of differing lime rates and incorporation methods. Note that changes in pH were measured within the slots.

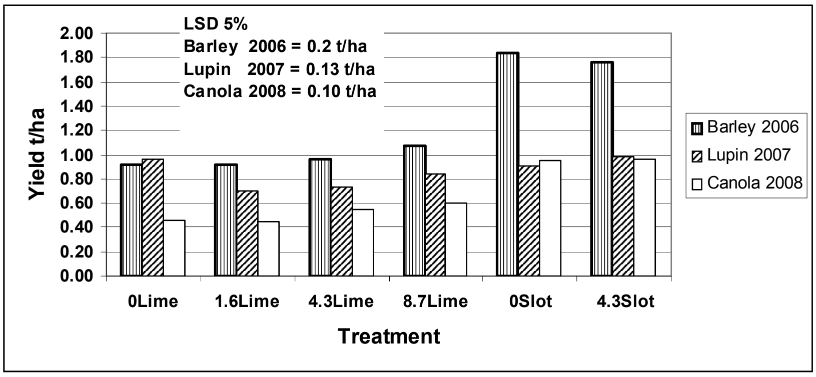

Figure 3. Effects of surface applied lime and slotting treatments on barley (2006), lupin (2007)and canola (2008) grain yields.

The slotted treatments increased soil pH to 60 cm depth both where lime had and had not been applied. Only the slotted treatments with lime resulted in significantly higher pH than the control deeper in the soil profile. Where lime had been applied in the slots then soil pH was increased by approximately 2 pH units. Significant increases in barley and canola crop yields were measured where the soil had been slotted to 60cm depth, regardless of whether lime was added or not. Canola yields were also increased ($P<0.05$) where lime was broadcast at rates greater than 1.6 t/ha. Lupins were the least responsive to the lime and slotting treatments.

Conclusions

- South coast WA sandplain soils are inherently prone to acidification due to their parent material and low chemical buffering capacity.
- Soil pH declined by up to 0.3 units over 7 years within a standard cropping system..
- Surface applied lime increased soil pH to 25 cm depth when applied at rates exceeding 1.6 t/ha.
- The depth to which soil pH changes occur is related to amount of lime applied, initial soil pH and time since application.
- Both surface and deep incorporated lime increased barley and canola yields as a result of increased soil pH and reduced soil strength.
- Techniques for rapidly increasing the subsoil pH using deep tillage with lime applications can resolve subsoil acidity issues. However separating the chemical from the physical effects was not possible in this study.

Acknowledgments

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Cropping management system influences on playa sediments in US southern high plains

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Abstract
Playa wetlands are unique, depressional geomorphic features on the Southern High Plains of the United States. These playas function as runoff catchment basins and bio-diverse wildlife habitat areas. The more than 20,000 playa wetlands in the Southern High Plains are thought to serve as major Ogallala aquifer recharge sites. Playa wetland sediment deposits are thought to impede aquifer recharge and increase evaporative water loss. This study evaluated cropping management system effects on sediment accumulation in six playa wetlands (3 cultivated, 3 rangeland). Soil cores were collected using a hydraulic probe to a depth of 1.5 m at twenty-five locations in each of the playas. Particle-size distribution and soil color proved to be adequate parameters to identify recent sediment added to the playas. Particle size distribution, however, was more useful as an interpretation and analysis tool than for distinguishing sediments. Sediment added to cropped playas was indicated by a very dark grayish brown (10YR 3/2) to very dark gray (10YR 3/1) soil-color transition. Sediment depth and land-use were directly related with greater sediment accumulation in cropped playas than in rangeland playas. Three-dimensional models will be used to depict the original playa basin with and without sediment additions.

Key Words
US southern high plains, wetlands, sediment deposition.

Introduction
Playa wetlands are unique geomorphic features on the Southern High Plains (SHP). The SHP spreads over 77,700 km^2 of West Texas and New Mexico, south of the Canadian River. Playas are natural, circular, closed-drainage watersheds with clayey basin floors (Bolen *et al.* 1989). These wetlands serve as natural catchment basins for surface runoff and deposited sediments. In the SHP, grasslands, rangelands and cultivated row crops dominate the outer-basin watershed areas that surround these playa wetlands. The typical size of playa-lake basin areas range from 57 to 104.3 ha (Gustavson *et al.* 1995). Some common playa lake uses are grazing-cattle water storage, irrigation water supplies, potential flood water collection sites, surface runoff catchments, or feedlot waste discharge catchments (Luo *et al.* 1997). Playa wetlands are important resources for both crop and livestock producers and many wildlife species (Lacewell and Masud 1994). The more than 20,000 playa wetlands also serve as major Ogallala aquifer recharge sites (Osterkamp and Wood 1987, Gustavson *et al.* 1995, Zartman *et al.* 1994, Zartman *et al.* 1996). The amount of sedimentation in playa wetlands is an important aspect of watershed management. Excessive sediment deposition adversely affects ecological services with less infiltration, more evaporation, and shorter hydroperiods.

There are many theories as to what processes were responsible for the development of playa wetlands. No single course of events, however, is responsible for playa lake genesis. Two commonly recognized processes are dissolution and subsidence (Osterkamp and Wood 1987) and deflation from wind (Reeves 1966). Hydrological events and wind also are responsible for soil erosion into and sedimentation within the SHP playa wetlands. Hydrological events, such as rainfall or irrigation, interact with cropped upland areas to produce runoff and sediment erosion (Luo *et al.* 1997). During runoff, sediments become suspended and are transported into the playa wetland. Sediment particle characteristics play an important role in suspension and ultimately, deposition. Once the sediment load has reached the playa wetland, sediment particle size determines order of deposition. Settling velocities of suspended particles increase with increased particle size. High wind gusts are another source of sediment deposition. Wind current speed is relatively low at the soil surface and dramatically increases vertically. In a cropland watershed, tractors or vehicular traffic can lift and aerosolize soil particles. Wind transport of rangeland-watershed sediments is reduced by the permanent vegetation.

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Sediment physical and chemical properties play an important role in playa development as well as ecosystem function. Sedimentation can trigger many adverse effects. Severe erosion in a watershed results in excessive sedimentation and costly maintenance. Sediment accumulation in a playa wetland decreases playa depth and the amount of water available for recharge into the Ogallala aquifer (Bolen *et al.* 1989). As more sediment is deposited in a playa, playa depth decreases and wetland surface area increases, which leads to a higher potential evaporation rate and a shorter playa-wetland hydroperiod.

Due to the functions and uses of playa wetlands, it is important to understand sediment properties and sedimentation processes. Because sediments are responsible for "clogging" natural drains through the basin floor, sedimentation is perceived as the major threat to playa ecosystem integrity (Haukos and Smith 1994). The objectives of this study were to (1) measure sediment depth with respect to the original playa basin for cropland and grassland playa watersheds, (2) develop a comprehensive three-dimensional map of the original playa basin and the sediment spatial distribution, and (3) qualitatively evaluate sediment deposition as a function of watershed management.

Methods

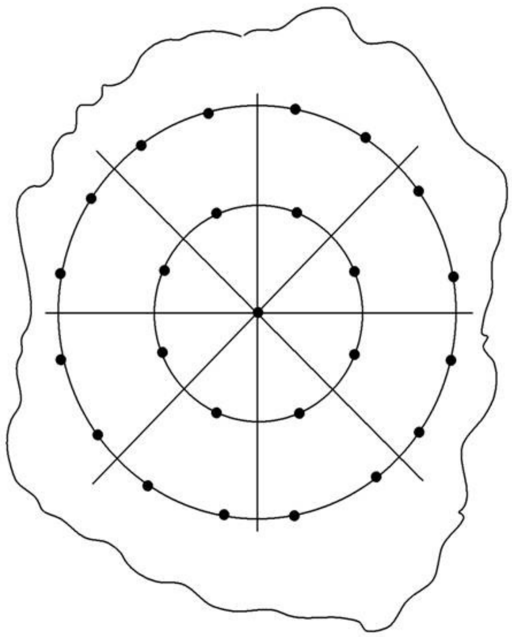
Six playas, located in Briscoe, Floyd, and Swisher counties in Texas, USA were selected for evaluation (Figure 1). One of the paired playas in each county had a grassland outer basin watershed and the other playa in the same county had a row-cropped cotton (*Gossypium hirsutum*) or grain sorghum (*Sorghum bicolor*) outer basin watershed.

Figure 1. The location of experimental playa counties in Texas and the US.

Soil core samples were collected using a 2 cm-diameter hydraulic probe to a depth of 1.5m. The cores were collected in plastic sleeves and taken to Texas Tech University for color and particle size analysis. The 25 samples from each playa were collected in a "spoke-wheel" sampling pattern (Figure 2). Soil samples were analyzed for soil color using a Munsell color chart and particle-size distribution using the Gee and Bauder method (Gee and Bauder 1986).

Results

Many conditions can affect sediment spatial distribution in SHP playa wetlands. Tillage and hydrological events create input channels into playa wetlands and are the main sediment point-sources in the SHP. Overland flow and wind are responsible for nonpoint-source sediments. The cropland watersheds produced greater sedimentation than rangeland/grassland watersheds. Although cropland and grassland playas should have different sediment volumes, the spatial distribution of the sediment should be similar. With respect to watershed size and amount of sediment, playas with large watersheds are expected to have greater amounts of sediments than playas with smaller watersheds. The playa-wetland watersheds in this study were similar and watershed size was not a factor.



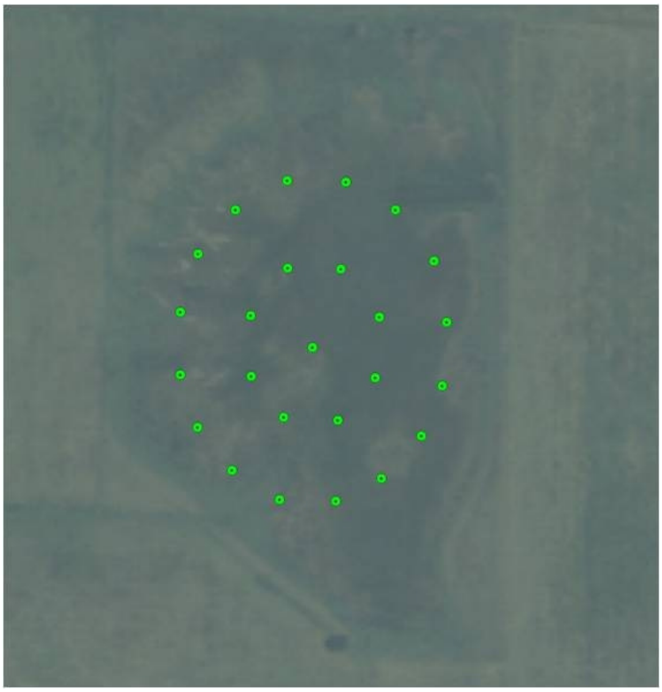


Figure 2. Wheel sampling location and playa basin (dark area) with sampling locations.

Sediments and original basin soils were distinguished by particle size analysis and soil color. Soil color proved to be most effective in distinguishing sediments from the original playa basin soil. In most cases, the sediments had a 10YR 3/2 (very-dark, grayish brown) soil color, whereas, the basin soil was darker colored with a 10YR 3/1 (very-dark, gray) soil color. The soil color change was more evident in cropland watershed playas than in the rangeland watershed playas. Sediments above the color change were more clayey in texture than sediments below the line of color change. Particle size distribution played a role in sediment distinction, but was more useful for interpretation than analysis. Sediment depths were measured and recorded and 3-D surface maps of the playa basin and associated sediment distributions will be presented.

Conclusion

Cropping systems on the outer basin watersheds that surround playa wetland basins directly influenced sediment deposition in the playas. Row-crop cultivated soils on outer basin watersheds provided more sediments to the playa wetlands than did grassland outer basin watersheds. The sediments from row-cropped watersheds were deeper and browner in color than grassland watershed sediments. An increased amount of sand-size sediments occurred below the color-change contact because the sands dropped out of suspension before the clays. The greater amounts of eroded sediments from row-cropped watersheds will probably adversely affect ecological services provided by the playa wetlands.

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Definition of biochemical parameters in composting in a Chilean Pisco industry

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Abstract
Pisco industry in Chile generates liquid and solid wastes, whose disposal and recycling constitute an environmental problem. Wastes, including grape pomace, bunch stems and other material like chipped pruning material (only produced during April- June). Composting was proposed to treat these two organic wastes and goat manure for recycling its organic matter content to the vineyard crops. In this work, the thermophilic biodegradation of organic solid wastes during 120 d using several ratios of seeds- skin, and manure were studied. Temperature and EC (electrical conductivity) were determine weekly and microbial functional groups including celulolitic, amililitic, total fungi and yeast were determined, and enzymatic activities including urease, acid and alkaline phosphodiesterase, B glucosidase three times during the process. At the same time, chemical properties were determined to characterize compost quality: %Carbon, %Nitrogen, C/N ratio, pH and some humification index like %humic and fulvic acids and E_4/E_6 ratio. Biodegraded product showed good organic matter properties (pH 6.97-8.66; %HA 3.62- 19.1; %FA 1.54-6.38 and statistical differences in ureases, phosphatase and B glucosidase activity) The results suggest that biodegraded grape marc could be used as fertilizer.

Introduction
Main factors influencing the composting process are temperature, water content, oxygen concentration in the composting matrix, porosity and free air space (FAS). Temperature is both a consequence of the composting process (microbial metabolism) and a control parameter. According to Haug, 1993 and Bernal *et al.* 2009 temperatures providing the maximum degradation velocity are in the range of 40-70 ^{o}C. The optimization of the composting process in wine and pisco industry is possible using goat manure, and stalk appears to be an ideal bulking agent for composting, providing C and physical properties such as porosity (provided by its branch- type structure) and resistance to biodgradation of the hard-wood fraction (Tuomela *et al.* 2000). Its chemical properties are also optimal. Stalk C/N ratio is high (around 39) and equilibrates the low C/N ratio of sludge (around 5). Cocomposting goal manure and pisco solid wastes as bulking agent would generate a stabilized fertilizer suitable for its application to the vineyard crops. Chemical and microbiological changes have been studied during manure composting under field conditions in windrows and heaps (Godden *et al.* 1983, 1986; N'Dayegamiye and Isfan, 1991; Martins and Dewes, 1992; Atallah *et al.* 1995) and there are different criteria for compost quality and maturity (Bernal *et al.* 2009). The aim of this study was to investigate the evolution of some physical, chemical and microbiological parameters in solid pisco industry wastes and goat manure in a composting system.

Material and methods
Description of the experiment
The compost is based on the raw materials available within Empresas Bauzá, located in the Coquimbo Region of Chile; these are pruning material, residues from the pisco industry, fruit remains, and goat manure. The total amount of each material is currently being surveyed. Compost will be manufactural and controlled using wireless temperature and moisture sensors. Before composting, raw materials will be analyzed for total C, N, lignin, and some other evaluations that can be of interest. After composting, some compost-derived products will be obtained. Each product will be analyzed in terms of its chemical composition, physical characteristics as well as microbial activity. Stalk, wheat straw and goat manure (in ratio 10:1; a practical ratio for the farm system used in the experiment), mixed at different ratios (Table 1). Automated thermocouple-sensors were placed along the length of between the windrows to determine the temperature daily. Weekly temperature was also defined using a thermometer inserted 50 cm and pH and electrical conductivity defined. Aeration was provided by mechanical turning weekly and the process was carried out for 14 weeks.

Table 1. Treatments evaluated- Proportion of different materials.

Treatment	horse manure	goat manure	grape residues	cane, oat residues	Total %
1	1		89	10	100
2	9	7	82	2	100
3	4		91	5	100
4		50	50		100
5		63	33	4	100
6	22	25	25	28	100
7	22	24	48	6	100
8	42	20	33	5	100
9		66	34		100

Samples for microbiological and chemical analysis were collected during composting from the infeed and from the material in the middle of the pile. The samples from the heaps were collected when the compost was turned and at the end of the experiment, after the whole heap was mixed thoroughly by hand.

Analytical determinations

Immediately after sampling, the samples (101) were transported to the laboratory and homogenized by hand. Subsamples were taken for immediate analysis of microbiological parameters, moisture, pH, conductivity and water-soluble nutrients, and for drying at 40°C. The rest of the sample was frozen and stored for later use. Total carbon was determined by Walkley & Black (1934). Ammonium was determined pH (in water and in 0.01 M $CaCl_2$, 1:3 fresh compost/liquid ratio, w/w), dry matter content (% fw, 105°C) were all measured in triplicate.

Microbiological analysis

The heterotrophic microbial populations were determined using the micro drop method. Fresh compost samples (4 g) and sterile saline solution 0,85 % (36 ml) were homogenized with a vortex, after which additional dilutions were made up to 10^{-6}. A 20µL aliquot of the dilutions 10^{-6}, 10^{-5} and 10^{-4} were cultivated in nutritive agar (Merck); when the drop was dry, the plates were incubated at 30°C for 48 hours to count the number of colonies in each drop and establish the UFC/g. From the same dilutions, count was made of cullulolytic, amilolytic, proteolytic, phosphate solubilizer microorganisms and total fungi and yeast by surface plate count method in specific media: cellulose agar, starch agar, milk agar, SMRS1 agar and potato dextrose agar (PDA Merck media) respectively. The plates were incubated at 30°C for 8 days except the fungi and yeast cultures which were incubated at 25° for the same time. For the count of the functional of enzymatic and solubilizer activity groups, it only the colonies who presented halo were counted; for the cases of the amilolytic and cellulolytic count, it was necessary reveal the activity by the addition of lugol (Merck) and congo red 1% (m/v) respectively.

Enzymatic activity

Urease activity

5 g of compost were moistened with 2.5 mL of urea 0.08 M and incubated for 2 hours at 37°C and 100 rpm; then 50 mL of KCl 1 N acidified in HCL 0.01 N was added and re incubated for 30 minutes at 100 rpm and room temperature. The suspension was filler with Whatman filter paper number 2 and 1 mL of the extract was used to determine the NH_4 produced with the colorimetrical method using indophenol blue (Mulvaney, 1996). The urease activity was expressed as µmol of NH_4 /g*h.

Phosphatase activity

This activity was determined by the methodology established by Dick *et al.* (1996), using 4 mL of Buffer MUB (pH 6,5 for acid phosphatase or pH 11 for alkaline phosphatase) and 1 mL of p-nitrophenil phosphate 0,05 M. The product p-nitrophenol was determined spectrophotometrically at 410 nm using a calibration curve with standar solutions of p-nitrophenol (0, 2, 4, 6, 8 and 10 µg/mL). The phosphatase units (UP) were expressed as µmol of p-nitrophenol /g*h.

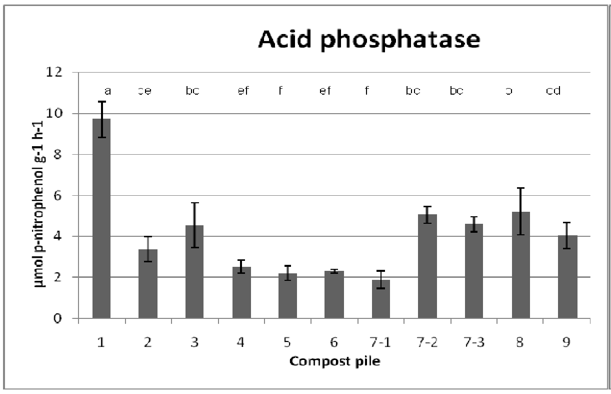
β Glucosidase activity

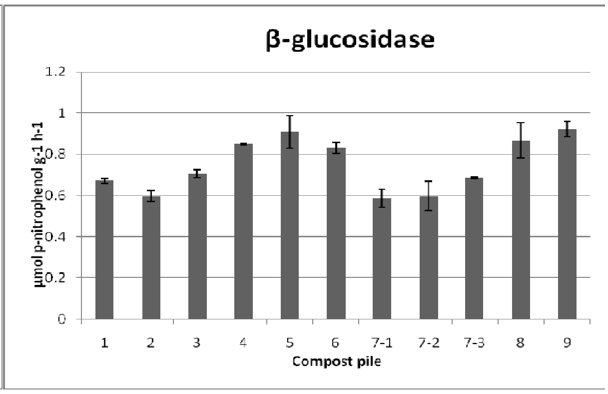
For the determination of this enzyme, the method established by Dick *et al.* (1996) was used, where 1 g of the compost was mixed with 0.2 mL of toluene, 4 mL of Buffer MUB (pH 6,0) 1 mL of p-nitrophenil β-D-glucopiranoside 0.05 M. The product p-nitrophenol was determined spectrophotometrically at 410 nm using a calibration curve with standard solutions of p-nitrophenol (0, 2, 4, 6, 8 and 10 µg/mL). The β glucosidase units (UBG) were expressed as µmol of p-nitrophenol /g*h.

Results

Compost piles showed a normal increase in temperature in week 1, reaching temperatures approaching 50 ° C (data not shown), which was maintained for 8 weeks. After this time the temperature dropped to reach environment temperature. The process was carried out in winter (12-4°C). Regarding the biochemical data obtained, there is a behavior associated with maturation of the material in the mixture for the treatments 4, 5 6 and 7 without statistical differences between them. Treatment No. 5 presents a lower concentration of B-glucosidase enzymes, and phosphatases, as well as a C / N of 12, meeting all the parameters in relation to food safety (absence of Salmonella sp., - Data not shown) and concentration heavy metals, as defined in rule NCh. 2880

Treatment	C/N	C	Cr	Cu	Ni	Pb	Cd	Zn
		%	(-----------------			mg/kg		-----------------)
1	16	27	14.5	33	7.2	4.5	<0.01	36
2	13.5	29.8	7.3	31	6.4	4	<0.01	40
3	15.1	29.4	13.3	30	6.5	4.3	<0.01	35
4	13	26.4	6.2	31	8.5	5.8	<0.01	55
5	12.2	24.5	10.3	32	8.8	4.6	<0.01	57
6	15.1	31.1	12.5	33	7.2	5	<0.01	44.5
7	12.5	28.2	12	33	8.3	4.7	<0.01	43.5
8	11	24.1	9.3	36	9.1	5.5	<0.01	50
9	12	27.5	13	31	9.7	5.7	<0.01	58





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Determining minimum data set for soil quality assessment of organic farming system in Korea

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Abstract
Soil quality is the most important factor for crop production and consequently soil quality assessment is necessary for organic farming systems because of limited usage of fertilizer. For this reason, a minimum data set (MDS) was determined with principle component analysis (PCA) for soil quality assessment in organic farming and soil quality was evaluated based on normalized scoring function. Among other soil properties, NH_4-N, NO_3-N, pH, EC, and water contents were chosen as a MDS for soil quality assessment in organic farming system. In addition, the result of soil quality evaluation with normalized scoring function in examined organic farming revealed that 85% of organic farming soil was within the optimum range for soil pH while only 30% for EC and 15% for orthophosphorus were within the optimum range. Therefore, adequate management for EC and orthophosphate are necessary to enhance the soil quality in study area. The result of this study could provide general guideline to manage organic farming systems.

Key Words
Organic farming system, soil, minimum data set, scoring function, management.

Introduction

Organic farming systems have been mainly initiated since 1990s due to environmental and health concerns for conventional farming system (Monokrousos *et al.* 2006). In organic farming systems, plant production mainly depends on nutrient transformation in soil because only a limited amount of fertilizer is used. Therefore, evaluation of soil quality including physicochemical and biological properties is necessary for organic farming systems. However, the evaluation of soil quality is a quite complex and also time and labour intensive (Wander and Bollero 1999). For this reason, the main objectives of this research were i) determining minimum data set (MDS) for evaluating soil quality of organic farming system using multivariate analysis and ii) developing scoring function for soil quality assessment of organic farming system in Korea.

Methods

Soil sampling

Soil samples were collected from 8 locations where organic farming systems have been adopted for crop cultivation. Surface (0-15cm) and subsurface (15-30cm) soils were collected at each sampling event and a total of 3 sampling events (May, July, October) were conducted in 2009. Collected soil samples were completely air dried at 25℃ and ground to pass through a 2 mm sieve for chemical and biological analysis.

Soil analysis

Soil density, soil temperature, and infiltration rate were measured in field and soil texture was determined using the hydrometer method. For soil chemical analysis, soil organic carbon (SOC) was determined following Walkley-Black method and total nitrogen and available phosphorus were measured using the Kjeldahl method and ascorbic acid methods respectively. In case of soil biological analysis, soil microbial biomass C (MBC) was measured by the fumigation incubation method of Jenkinson and Powlson (1976). Soil microbial biomass N (MBN) was determined by the fumigation extraction method using a factor of 0.54 (Brooks *et al.* 1985). Methods of soil analysis are summarized in Table 1.

Multivariate analysis

Multivariate analysis was performed to determine the minimum data set (MDS) for soil quality assessment in organic farming system. All measured soil properties were compared with principle component analysis (PCA) and only factors with eigenvalues > 1 were used. Statistical analysis was conducted using SAS version 9.1 software (SAS institute 2002-2003).

Table 1. Physicochemical and biological analysis methods for soil.

Parameters	Method	Instrument
Soil texture	Hydrometer method	
pH	1:5 (solid:water)	pH meter
EC	1:5 (solid:water)	EC meter
Soil organic matter	Walkley-Black method	UV/Vis Spectrophotometer
Total nitrogen	Kjeldahl method	Automated Kjeldahl distillater
Available phosphorus	Ascobic acid method	UV/Vis Spectrophotometer
Cation exchange capacity	1M NH4OAc (pH 7.0)	Atomic Adsorption Spetrometer
Soil microbial biomass C	Fumigation incubation method	
Soil microbial biomass N	Fumigation incubation method	

Scoring function

General scoring function was adapted from previous study (Karen and Stott, 1994). In this study, normalized scoring curves were developed based on normalized indicator parameters. Normalized score equation is shown in Eq. 1. Using the normalized scoring curve, three types of standardized scoring function was generated: i) more is better, ii) less is better, iii) optimum depending on soil properties (Table 2). In order to develop normalized scoring curve, total of 1,650 upland soil properties were used.

$$\frac{1}{[1+((B-L)/(x-L))^{2S(B+x-2L)}]} \quad (1)$$

Where B: the baseline value of the soil property, L: lower threshold, S: slope of the tangent to the curve at the baseline, x: soil property value

Table 2. Scoring system of soil properties.

More is better	Optimum	Less is better
Infiltration rate, Soil organic Matter, Cation exchange capacity, etc.	pH, EC, Avail.-P_2O_5, etc.	Bulk density, Erosion, etc.

Results

Soil analysis

Average values of soil physicochemical and biological properties are summarized in Table 3 and 4. Soil texture was generally sandy clay loam for all sampling sites and soil density ranged 0.87-1.72 Mg/m^3. Soil pH at all sampling sites was weak acidic condition except for sampling site E and the highest EC, TN and CEC were measured at sampling site C.

Table 3. Physical properties of soil at sampling sites.

Sites	Particle size distribution (%)			Soil density	Water contents	Temperature	Infiltration rate
	Sand	Silt	Clay	Mg/m^3	%	□	cm/sec
A	53.04	25.09	21.87	1.34	20.32	25.30	7.1 x 10^{-5}
B	62.92	19.42	17.66	1.00	23.56	24.30	7.3 x 10^{-3}
C	63.80	15.51	20.69	1.63	22.04	18.40	4.5 x 10^{-5}
D	82.32	5.89	11.79	1.72	12.08	23.30	2.9 x 10^{-3}
E	58.47	38.09	3.44	0.87	21.66	22.20	3.8 x 10^{-2}
F	57.07	36.37	6.56	0.91	18.36	23.20	9.2 x 10^{-3}
G	68.87	24.57	6.56	1.19	16.12	25.50	3.5 x 10^{-3}
H	18.97	62.32	18.72	1.20	12.17	24.30	7.0 x 10^{-3}

Table 4. Chemical and biological properties of soil in sampling sites.

Sites	pH	EC	TN	SOM	CEC	P_2O_5	MBN	MBC
		dS/m	mg/kg	%	cmol$_c$/kg	mg/kg	mg/kg	
A	6.70	0.43	1,731.9	3.90	11.86	137.48	37.85	22.47
B	5.78	1.09	1,968.5	4.29	13.69	169.24	23.28	7.05
C	5.24	5.15	4,277.5	6.81	28.25	215.44	49.00	6.09
D	6.11	1.74	1,938.9	3.00	12.92	94.76	31.15	5.79
E	7.43	0.32	866.5	6.88	14.89	68.16	25.43	15.09
F	6.03	0.72	2,989.0	6.55	19.07	78.95	27.78	28.29
G	5.02	0.90	2,630.5	6.16	16.58	306.54	16.65	29.35
H	6.74	0.25	3,825.5	7.42	14.66	173.64	17.38	28.25

Minimum data set determination

The result of principle component analysis (PCA) is shown in Table 5. Considering factors with eigenvalue > 1, factor 1, 2 and 3 were selected for soil quality indicator and cumulative percentage for the first 3 accounts 84% of the total variance. In factor 1, NH_4-N (0.78) and NO_3-N (0.85) showed high positive loading indicating that nitrogen measurement might be necessary for soil quality assessment. In factor 2 and 3, pH (0.83), EC (0.67), and water contents (0.79) showed high positive loading indicating that those soil properties should be considered for soil quality assessment in organic farming systems.

Table 5. Result of PCA with physicochemical properties of soil.

	Factor 1	Factor 2	Factor 3	Factor 4
Eigenvalue (%)	3.62	1.87	1.23	0.65
Proportion (%)	0.45	0.23	0.15	0.08
Cumulative (%)	0.45	0.68	0.84	0.92
pH	-0.34	0.83	-0.01	-0.29
SOM	-0.95	0.13	0.09	0.09
EC	-0.60	0.67	0.02	0.01
Water contents	0.16	-0.38	0.79	-0.42
NH_4-N	0.78	0.51	0.11	-0.11
NO_3-N	0.85	0.46	0.06	-0.12
P_2O_5	-0.51	-0.29	-0.54	-0.58
CEC	-0.80	0.07	0.54	0.05

Normalized scoring function for soil quality assessment

In order to assess soil quality in organic farming system, the normalized scoring function was calculated using Eq. 1 and scoring function parameters were estimated with measured soil properties of upland soils (Table 6). Considering optimum score is 0.5 in normalized scoring function, the result of soil quality assessment in organic farming system showed that 85% of soil was within the optimum range for pH while only 30% of soil satisfied the optimum range for EC. In case of P_2O_5, only 15% of examined soil was within the optimum range and lower scoring of P_2O_5 was observed for the rest of 85% soils (Figure 1). This result indicated that management for EC and P_2O_5 in organic farming systems is necessary for better crop production.

Table 6. Estimated scoring function parameters for normalized scoring function calculation.

Parameters	LT	UT	LB	UB	Slope
pH	3.30	8.40	5.3	6.5	1.30
EC	0.01	9.50	0.3	0.8	2.23
P_2O_5	4.50	2,275.0	310.0	750.0	0.05
CEC	0.02	90.50	20.0	45.0	0.12
OM	0.50	234.50	16.0	30.0	0.01

LT: Lower threshold, UT: Upper threshold, LB: Lower baseline, UB: Upper baseline

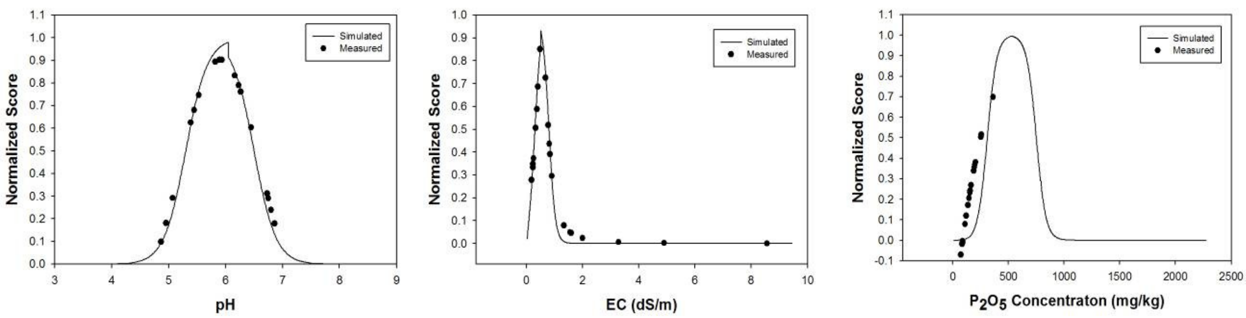

Figure 1. Result of soil quality assessment with normalized scoring function in organic farming systems.

Conclusion

Minimum data set (MDS) was determined with principle component analysis (PCA) for soil quality assessment in organic farming. The result of PCA showed that among other soil properties, NH_4-N, NO_3-N, pH, EC, and water contents are need to be considered for soil quality assessment. Furthermore, soil quality was evaluated with the calculated scoring function and the result revealed that 85% of organic farming soil was within the optimum range for soil pH. However, only 30% for EC and 15% for phosphorus were within the optimum range. This result indicated that management of EC and phosphorus are necessary for better crop production. Overall, the result of this study could provide general guideline to manage organic farming system.

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Developing a multi-factor crop production environmental risk index

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Abstract
The production of crops is not always done without soil degradation or damage to the environment. Many indexes have been developed to define the productivity of soils but fewer are designed to integrate many soil and landscape factors to describe the potential hazards of crop production. The objective of this work is to report on a method of quantifying the environmental risk that may occur to the soil resource and the environment as a result of crop production. The risk of erosion by water and wind, compaction, acidification, salinization, denitrification, surface and subsurface water contamination, and organic matter loss are examined using the soil interpretations module of the National Soil Information System. This system allows the magnitude of soil properties to be evaluated in terms of their degree contribution to a risk factor and also permits weighting of the importance of each risk factor. Productivity index and the environmental risk ratings are mapped for Mason County, Illinois, USA. The result of combining the risk and productivity indices has clear implications for biofuels and other land uses.

Key Words
Soil productivity, soil degradation, dynamic soil properties, sustainable land use.

Introduction
Many models have been developed to quantify the relative inherent productivity of soils. These include the Storie Index (Storie 1978), and the National Commodity Crop Productivity Index (Dobos *et al.* 2008), among many others. Similarly, many models have been developed to quantify or index the degree of environmental hazard inherent in land use due to one factor, such as soil erodibility, pesticide leaching, or phosphorus indexes. Lal *et al.* (2004) list several ways in which soil can be degraded during use. Soil erosion by water and wind are major types of degradation. Soil can also be degraded due to salinization and mining (Lal *et al.* 2004). In the Soil Atlas of Europe (2005), several key threats to soil are recognized in addition to erosion and salinization. These include loss of organic matter, compaction, soil sealing, decline in biodiversity, and hydrogeological risks (European Commission 2005). Long-term application of anhydrous ammonia can cause soils to acidify (Bouman *et al.* 1995), which has implications for micronutrient bioavailability and pesticide efficacy. Crop production can have effects that are not necessarily manifested in the soil, but rather are shown to be detrimental to surface or subsurface waters. The materials added to the soil during pesticide or fertilizer application can have one of several fates. They can remain immobilized in the soil, they can contaminate surface water due to runoff, or they can move through the soil and contaminate ground water. A method of integrating the level of risk associated with many different hazards to the environment or impacts on the soil resource is needed. Having both a risk index and a productivity index will allow a degree of quantification of the potential harm that can be done to the soil or environment associated with the agricultural use of a state, county, landscape, or parcel of ground. This paper describes such a system.

Methods
The "Environmental Risk Index" is being developed using the National Soil Information System (NASIS) database. This database contains soil property, climate, and landscape data for nearly 3000 soil survey areas in the United States. The geographic extent includes the continental United States, Alaska, Hawaii, Puerto Rico, and the U.S. territories of the Pacific Basin. Data can be readily retrieved and manipulated using the NASIS-based Calculation/Validation, Interpretation and Reporting (CVIR) scripting language (Soil Survey Staff 2002). The interpretations module of the soil survey database system uses fuzzy logic to allow soils to be considered in terms of their degree of membership in the set of soils that are limited for a particular land use. A statement can be made such as: "A soil that has a given set of characteristics is a non-member, partial member, or a full member of the set of soils that are prone to environmental risk". The degree of truthfulness ranges from zero (absolutely false) to one (absolutely true). The actual linkage between a soil characteristic and the degree of membership in the set of soils that may pose an environmental risk is based on a graphed

function that describes the fuzzy set. The shape of the relationship can be specified to reflect the effect of an independent variable on a dependent variable, whether it is linear, sigmoidal, bell-shaped, or any other shape based on empirical evidence. One of the challenges in fuzzy systems modeling is determining the relationship between the variables being modeled (Cox 1994). In the Environmental Risk Index (ERI), this task was handled by assuming a linear relationship between the critical values, since there is not much hard data on the impact of the variables studied on the nationwide scale of the model.

The ERI model is a system that calculates an index of the degree of hazard of environmental or soil degradation due to crop production. The model has three parts (subrules): Surface Water Contamination (SWC), Groundwater Contamination (GC), and Soil Degradation (SD). SWC examines the relationships between the soil and site properties that contribute to rapid runoff (saturated hydraulic conductivity, slope, and landform shape) and the availability of enough precipitation to create runoff under normal circumstances. Also considered is if the soil is artificially drained, since nutrients can move quickly into surface water through the drainage network. Finally, the possibility of removal of nutrients or crop residue by floodwaters is considered. The GC section of the model examines the permeability of the soil profile, the availability of water for leaching, and the adsorptive capacity of the soil. Soils having moderate permeability and adequate adsorptive capacity can attenuate nutrients or pesticides to prevent or at least slow their deposition into the aquifer. SD considers dynamic soil properties that can be degraded by some crop and soil management systems (Tugel *et al.* 2005). A risk of denitrification losses is indicated when saturation is at or near the soil surface during the growing season. Organic matter loss sensitivity is indexed by observing the current organic matter level and estimating a loss rate from the mean annual soil temperature with modification due to seasonal wetness. Water erosion risk is indexed using the water erodibility factor and slope of the soil. Soil compaction hazard is rated from the difference between the observed bulk density and a maximum bulk density dampened using the structure grade and organic carbon content of the surface layer. Wind erosion hazard is indexed using a calculation used in the interpretations generator. Salinization risk is indicated for soils that are in groundwater discharge areas that already have some salts and a non-leaching moisture regime. Acidification risk is based on the cation exchange capacity and the existing pH of the surface layer. Balancing or weighting the various risk factors in terms of their degree of limitation on the use of the soil is an ongoing process. Factors that are irreversible or only slowly reversible, such as erosion and groundwater contamination are weighted more heavily than those factors, such as pH, which can be changed in a short term time scale. Illustrating the actual mechanisms involved in the derivation of the index, while of great interest, is unfortunately beyond the scope of this paper.

The productivity aspect of the paper is provided by the NCCPI, which is described by Dobos *et al.* (2008). The NCCPI, briefly, is a fuzzy system model that ranks the impact of soil, landscape, and climatic properties on relative commodity crop yield. Being fuzzy systems models, both the ERI and NCCPI return values from 0 to1.

Soil attribute data contained in the Soil Survey Geographic (SSURGO) Database were used to develop thematic maps showing the National Commodity Crop Productivity Index and the Environmental Risk Index as unitless index values. The NCCPI and ERI values were originally prepared in NASIS for soil survey areas in Illinois. The NASIS text output was converted to Dbase IV format and then joined to SSURGO feature classes for mapping using ArcGIS version 9.3 (Soil Data Mart source dated 8/2009). The study area for this paper is Mason County, Illinois USA. This area is chosen because it is highly agricultural and has a diversity of soil parent materials, ranging from deep loess to outwash sands (USDA-NRCS 2009)

Results and discussion

Figures 1 and 2 are plots of NCCPI and ERI, respectively, for Mason County, Illinois. Figure 1 shows that much of Mason County is comprised of soils that are highly productive, having the NCCPI greater than 0.6 (dark green and blue). The Environmental Risk Index, mapped in Figure 2, on the other hand, indicates a significant proportion of soils that are potentially risky to farm, in terms of the potential for environmental degradation, having the ERI greater than 0.6 (orange and red). Figure 3 illustrates some selected combinations of NCCPI and ERI. The dark blue areas in Figure 3 are soil map units that are both highly

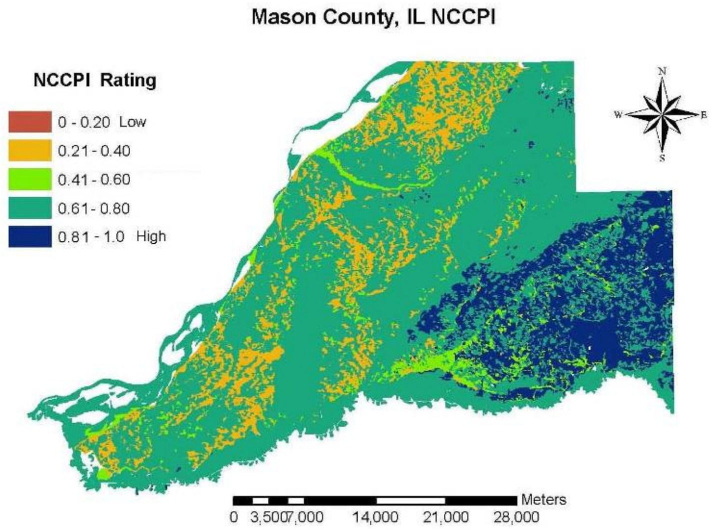

Figure 1. Mason County, IL National Commodity Crop Productivity ratings

productive and not typically an environmental hazard to farm. These areas are composed mostly of Tama and similar soils (Fine-silty, mixed, superactive, mesic Typic Argiudolls) that formed in deep loess. The red areas in Figure 3 denote highly productive soils that are predicted by the model to be prone to increasing environmental degradation when farmed. Thorp (Fine-silty, mixed, superactive, mesic Argiaquic Argialbolls) and

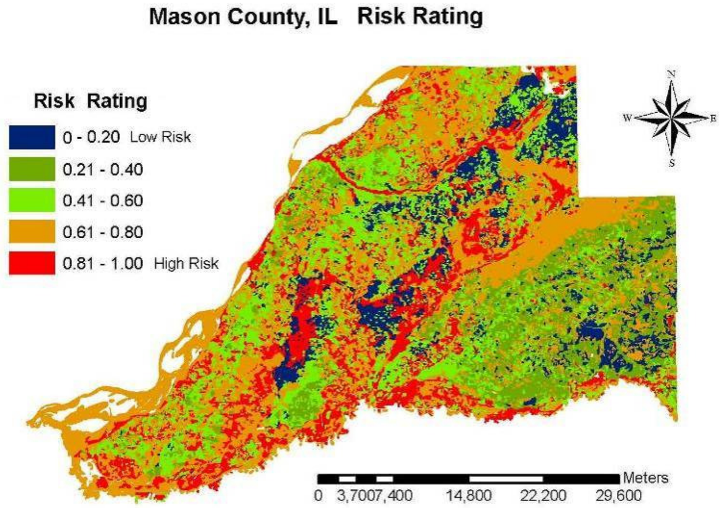

Figure 2. Environmental Risk Index map for Mason County, IL.

Edgington (Fine-silty, mixed, superactive, mesic Argiaquic Argialbolls) and similar soils are found in the red areas of Figure 3. These soils have been drained in order to produce crops and the drain tiles and ditches can provide a ready conduit for transmitting nutrients and agricultural chemicals to streams. The gold areas in Figure 3 are soils that are of low to moderate productivity and are somewhat risky to farm. The soil found in this area is almost exclusively Plainfield (Mixed, mesic Typic Udipsamments). These very permeable soils having low cation exchange capacity formed in sandy parent materials.

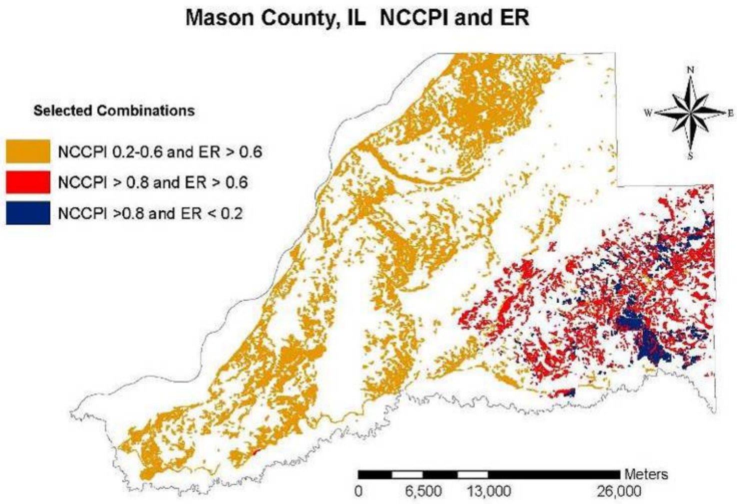

Figure 3. Selected combinations of NCCPI and ERI for Mason County, IL.

Groundwater contamination is a serious concern when these soils are farmed. Moderate to low productivity soils may be targeted for production of biofuels, but producers must be cognizant of the potential for environmental damage that exists when these soils are cropped.

The ERI can provide information for better land use decisions. A future experiment with the ERI will be to intersect the risk level with the spatial distribution of lands in the Conservation Reserve Program (CRP). This would allow a way to judge the benefits and risks of returning parcels of this land into crop production. This process may be especially valuable in terms of locating and selecting soils for biofuels production. This index is relatively new and thus is subject to improvement and enhancement. The authors welcome suggestions for improvement.

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Distribution of organic carbon and total nitrogen in aggregate size fractions in a southern Nigeria Ultisol under different agricultural land use

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Abstract
We studied the effect of different land uses on organic carbon and total nitrogen content in soil and soil size fractions. A range of land uses was selected, that included tree plantings, pasture and soil tilled at different intensity. Soil organic carbon and total N were significantly higher under forest and tree crops in comparison to pasture, no tilled and tilled plots. Converting conventional tillage to no tillage lead to significant increase of the soil organic matter content. Organic carbon and total nitrogen contents generally decreased with increasing size of soil aggregates, whilst the C:N ratio was directly related to the aggregate size. The presence of higher amounts of organic C associated with lower C:N ratio in the finer fractions suggests that these aggregate size classes protect the soil organic matter and make it inaccessible to degrading agents.

Key Words
Soil organic matter, C:N ratio, organic matter protection.

Introduction
The contribution of soil organic matter to aggregate stability is well known. To describe soil aggregate stabilization Oades (1993) proposed the hierarchical model, based on the hypothesis that macro-aggregates are collections of micro-aggregates and that different binding agents are active at different hierarchies of soil aggregation. However this model has not been clearly confirmed by studies on aggregate fractionation (de Sa *et al.* 2000), maybe due to variations in methods employed for soil fractionation (Ashman *et al.* 2003). Soils with different clay mineralogy were observed to respond differently to fractionation, and aggregate hierarchy exists only in soils where aggregate stability is controlled by organic materials (Oades and Water 1991). This paper examines the effect of land use on organic carbon distribution in soil aggregate fractions and implications to carbon protection in soil.

Materials and methods
The experimental area was in the Teaching and Research Farm of Obafemi Awolowo University, Ile Ife (7°25'N, 4°39'E), Nigeria. The soil (Oxic Haplustult according to USDA Soil Taxonomy) derived from coarse gneiss and granite and varied from sandy loam to sandy clay loam (table 1). Seven land use type were selected: forest, cocoa, teak, oil palm, pasture, no tillage and conventional tillage. Forest was a control secondary forest site left undisturbed for 30 years, while the ages of cocoa, teak and oil palm ranged between 24 and 27 years. The conventionally cultivated plot had been tilled for 15 years using disk plough and harrows, while the no tillage plot was converted from conventional cultivation 3 years prior to this study. The pasture was established 15 years prior to this study and it had been under cattle grazing since then. Composite soil samples (40 subsamples) were taken in the different land use types at depths of 0-15 cm (topsoil) and 15-30 cm (subsoil). They were air dried, gently crushed by hand, and carefully sieved into size fractions of 1-2, 0.5-1, 0.25-0.5, 0.125-0.25, 0.05-0.125, and <0.05 mm. Organic C and total N were determined in each size class using the Multiphase LECO RC-412 C analyzer and the FP-528 N analyzer respectively.

Results and discussion
Soil organic carbon (SOC) was significantly higher under forest and tree crops in comparison to pasture, no tilled and tilled plots (Figure 1). There is a noteworthy difference between tilled and no

tilled plots, showing a significant increase of SOC three years after the soil management was changed. Soil N also followed a similar pattern of distribution with slight variations among the crops. The mean C:N ratio in the topsoil was 10.9, considering the all the land use types, except oil palm, whose ratio was 19.5. This may be attributed to the low N content of the fibrous roots of the oil palm tree. The C:N ratio in subsoil was not significantly

Table 1. The soil physical properties for different land use types.

Land use	0-15 cm pH	Sand (0.02-2 mm)	Silt (0.002-0.02 mm)	Clay (<0.002 mm)	Texture	15-30 cm pH	Sand (0.02-2 mm)	Silt (0.002-0.2 mm)	Clay (<0.002 mm)	Texture
No tillage	6.36	69.54	20.15	10.31	LS	6.20	76.68	13.74	9.58	LS
Conv. Tillage	5.88	77.88	14.27	7.85	LS	5.82	86.88	10.74	2.38	LS
Forest	6.76	65.54	21.06	13.4	L	6.76	63.65	22.57	13.78	L
Oil palm	5.95	62.63	22.02	15.35	L	6.00	63.98	22.71	13.31	L
Teak	6.12	68.45	20.81	10.74	LS	6.26	66.71	18.78	14.51	L
Cocoa	6.98	63.97	21.92	14.11	L	6.95	67.03	19.74	13.23	L
Pasture	5.65	64.13	22.48	13.39	LS	5.71	66.53	23.65	9.82	LS

LS = Loamy sand, L = Loam.

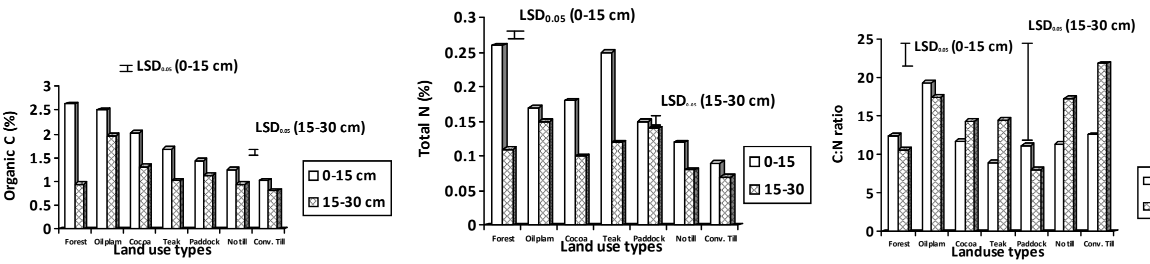

Figure 1. Topsoil (0-15 cm) and subsoil (15-30 cm) distribution of (a) organic C, (b) total N and (c) C:N ratio under different land use types.

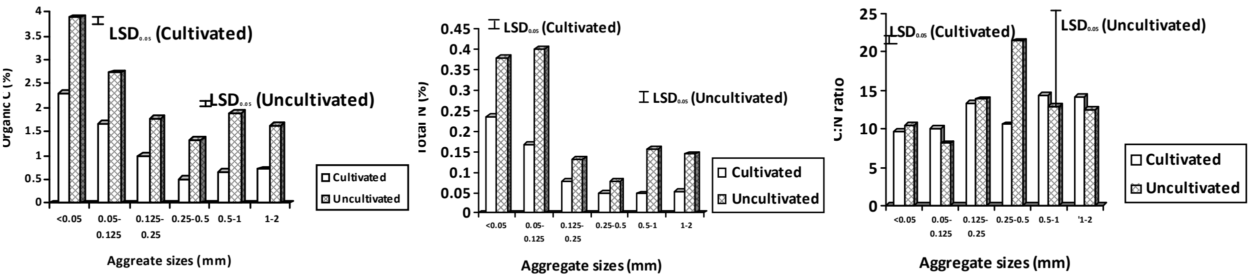

Figure 2. Topsoil (0-15 cm) distribution of (a) organic C, (b) total N and (c) C:N in aggregate size fractions as influenced by cultivation

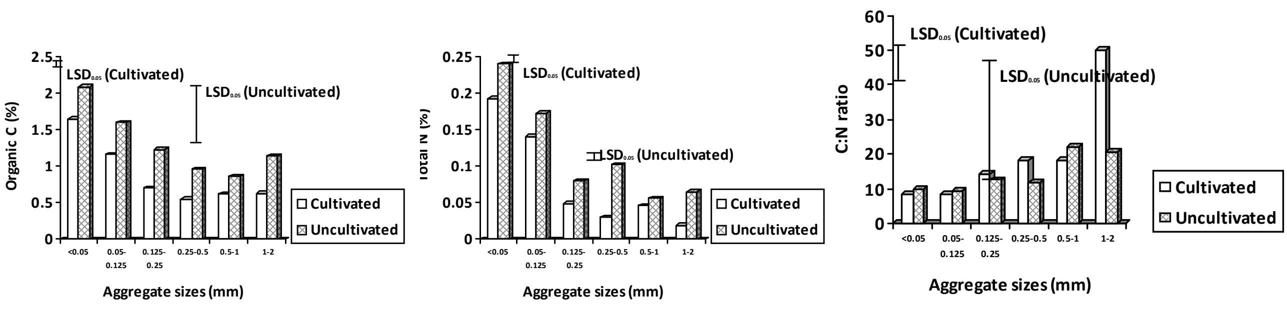

Figure 3. Subsoil (15-30 cm) distribution of (a) organic C, (b) total N and (c) C:N in aggregate size fractions as influenced by cultivation

different among land use types, with the exception of the pasture. This result and the high amount of N in the pasture soil can be related to the presence of fresh animal manure left during the grazing. Data of SOC and N in different size fractions are reported in Figure 2, where values from forest, cocoa, teak and oil palm are grouped as “uncultivated” and tilled and no tilled plots are grouped as “cultivated”. SOC and N contents generally decreased with increase in the size of soil aggregates, with the highest values in the <0.05 mm class and the lowest in the 0.25-0.5 mm class. This trend is consistent across land use types and the two soil depths investigated. The C:N ratio in the cultivated topsoil was directly related to the aggregate size; no clear trend was shown by the uncultivated soil, even though the lowest values were those of the smallest size classes. In the subsoil only the largest classes showed significant higher C.N ratio, namely 1-2 mm in cultivated soil and 0.5-1 and 1-2 mm in uncultivated soil.

Conclusions

As expected, tillage and cultivation reduce the organic carbon in the soil. The trend can be inverted with proper soil management using no tillage. The consistently higher C and N in the fine particle size fractions may indicate lower decomposition rates of the organic matter associated with clay and fine silt size particles and aggregates. This suggests a measure of protection of soil organic matter by the fine sized soil particles. The lower C:N ratio of the fine sized particles could suggest that this soil fraction offers protection to soil organic matter, while the coarse fractions were readily accessible to microbial degradation thus leaving the recalcitrant organic materials with high C:N ratio.

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Earthworm population response to tillage and residue management in central Iran

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Abstract
Tillage can affect earthworms directly by the mechanical action of the tillage operations as well as indirectly as a result of the consequent changes in soil environment. The objective of this study was to investigate the effect of tillage practices on earthworm populations used as an indicator of soil biological status using different tillage practice. Earthworm populations, cocoons and live earthworm masses were significantly different for the treatments within three years reflecting practices and residue management. Results showed that a majority of the earthworms were found 5-15 cm deep in the plots and the large-bodied anecic species were more abundant in the minimal-tilled soils, whereas the endogeic species, which were smaller in size, were more abundant in the conventionally-tilled soils.

Key Words
Anecic, earthworms, tillage, residue.

Introduction
For millions of years earthworms were Nature's plough and were responsible for maintaining the soil in suitable physical condition. Until recently, modern agriculture has been often accompanied by intensive tillage with heavy machinery. Many farmers, organic gardeners and researchers have recognized earthworms as important organisms contributing to healthy soils. Tillage can change the abundance as well as the composition of earthworm populations. The actual impact is dependent on soil factors, climatic condition, the tillage operation and residue management; but this information is still not well documented. Low (1972) reported that earthworm populations in fields in England, which had been tilled for 3 and 25 years, were respectively, 50 and 15% of those found in old grassland. Increases in earthworm populations after tillage were usually observed after ploughing of pasture and the associated burying of large quantities of plant material. Earthworms, whose primary source of food is partially decomposed plant tissue, are expected to flourish in the short-term (Lee 1985). Edwards and Lofty (1969) reported that after an initial increase in the first two seasons, a progressive decline in earthworm populations under repeated tillage occurred over the following seasons. According to Lee (1985), the gradual decline in earthworm abundance with successive tillage after the initial increase was due to subsequent adverse changes in soil environmental conditions as a result of loss in soil aggregate structure and reduction of soil organic matter content. Tillage is often defined as the mechanical manipulation of soil physical conditions. Therefore, tillage can affect earthworms directly by the mechanical action of the tillage operations as well as indirectly as a result of the consequent changes in soil environment. The objective of this study was to investigate the effect of tillage practices on earthworm populations used as indicator of soil biological status using different tillage practices and residue management.

Materials and methods
Conservation and conventional tillage systems in the presence of barley stubble on forage corn biomass were established to assess the impact of management practices on earthworm populations. The soil was a silty clay loam at Kabootar Abad research station, 40 km southeast of Isfahan, central Iran. The six treatments were: 1- burning barley stubble + moldboard plowing to a depth of 25cm + disking (MPB) 2- shredding the stubble + moldboard plowing to a depth of 25cm + disking (MPC) 3- incorporation of the stubble by plowing to a depth of 25cm + disking (MPS) 4- chisel plowing to a depth of 10cm + mixing the stubble with the soil surface with a rotary tiller (CPC) 5- shredding barley stubble + direct drilling with Amazon (NT250) no-till drill (NCM) 6- shredding the stubble + irrigation + hand planting (NCH). Each treatment was established with three replicates in a randomized block design. Earthworm populations were measured annually in situ from four random positions in each plot by removing replicate samples of soil (25cm x 25cm x 25cm) from each treatment plot. Earthworms contained in the soil samples were carefully removed by hand-sorting

(Edwards and Bohlen 1996) and were subsequently identified (using the key of Edwards and Lofty 1977), age-classified and weighed to ascertain the earthworm population size, composition and biomass for each treatment**.**

Results and Discussion

Earthworm populations, cocoons and live earthworm masses were significantly different in the treatments within three years (Table 1). The amount of crop residues on the soil surface, and low soil disturbance under the (NCH) and (NCM) treatments, were most likely factors, which encouraged the proliferation of the earthworm population. These results are similar to those reported by other researchers (Francis and Knight 1993; Karlen *et al.* 1994). No-tilled plots had a greater population density and biomass of earthworms and cocoons than the tilled plots. The size (mean weight) of adult earthworms and the numbers of cocoons per adults were also greater in the no-tilled plots. However, no differences in earthworm populations were detected between minimum tillage (CPC) and stubble incorporation (MPS). Burning stubble (MPB) resulted in significantly smaller adult earthworms, a lower density of cocoons and a lower mean number cocoons per adult than in unburnt plots, but the differences in numerical abundance and in biomass were not statistically significant. Results also showed that a majority of the earthworms were found 5-15 cm deep in the plots and the large-bodied anecic species were more abundant in the minimal-tilled soil (CPC) whereas the endogeic species, which were smaller in size, were more abundant in the conventionally-tilled soil (MPC and MPS).

†Table 1. Effect of tillage practices on earthworm population, cocoon and earthworm live mass.

‡Treatments	Earthworm (no.m^{-2})	Cocoon (no.m^{-2})	Earthworm live mass (g m^{-2})
NCH	219a	120a	82a
NCM	228a	116a	78a
CPC	130b	115a	37b
MPS	118b	77b	37b
MPC	65bc	68b	16c
MPB	33c	29c	13c

Values followed by the same letter in columns show no significant differences ($p<0.05$).
†Values are for the plots after 3 years of the treatments and for the top 25 cm of soil.
‡See text for definitions.

Conclusions

Our findings show that rotation with reduced tillage increased earthworm numbers. These results also confirm that continuous tillage plays a major role in declining earthworm populations. Previous studies found that the greater the intensity and frequency of tillage, the lower the population density of earthworms (Gerard and Hay 1979; Mackey and Kladivko 1985). Different species of earthworm respond differently to tillage. While the abundance of the deep burrowing species (anecic) tends to decline under tillage, particularly under deep ploughing, endogeic species can actually increase in number especially when there is increased food supply. Under conservation tillage systems, earthworms can potentially play a more important role than under conventional tillage in the functioning of the farming systems because of their abilities to modify the soil physical environment and nutrient cycling. More research is needed to fully understand the ecology of different earthworm species, their interactions and their potential roles in promoting more sustainable farming systems.

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Effect of agricultural practices on soil acidification in acid precipitation area

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Abstract
Both acid precipitation and unreasonable agricultural practice are notorious artificial factors resulting in soil acidification. To sort out reasonable agricultural practices favorable to abating soil acidification, the task of this study was directed to a long-term field trial from 1991 to 2007 in Chongqing, China during which chemical fertilizer were applied to the rice-wheat-rotated field and the soil pH value was measured. The result indicated that all treatments decreased pH in the 0 to 20 cm soil layer after ten years, especially when chlorine-containing fertilizer, excessive chemical fertilizer and mixed fertilizer were applied. It is demonstrated that balance rates of N, P and K fertilizers and application of muck in field are advantageous to abating soil acidification.

Key Words
Soil acidification, agricultural practices, acid precipitation.

Introduction

Soil acidification is one of the major causes of soil degeneration, which leads to decrease in the pH value, loss of base and nutrient content, consequently results in deforestations and decrease of crop yield. Once acidified leaching water enters into water bodies like lakes, rivers, etc, it causes water acidification and death of fish. Therefore, soil acidification is one of the serious environment problems in the world. Soil acidification is originally a slow natural process. However, human activities have dramatically accelerated the process in recent decades. Two artificial factors, including acid precipitation caused by air pollution and unreasonable agricultural measures such as abusing chemical fertilizer, considerably aggravate soil acidification. Therefore, these two factors were a hot topic and were studied by many researchers through field or simulated experiments in recent years. Their results indicated that acid precipitation could acidify the soil in a short time and the soil pH decrease caused by unreasonable agricultural measures presented in a few years, especially when N-fertilizer was applied to the field. However, the effects of agricultural measures on soil acidification in China have been less studied. The object of this work was to find reasonable agricultural measures to buffer and inhibit soil acidification in acid precipitation areas.

Materials and methods

Site and experimental design

A long-term fix fertilizer application experiment was carried out from 1991 at the National Monitoring Station of Soil Fertility and Fertilizer Efficiency on Purple Soils, located at Beibei(29°39′N, 106°18′E, 1208.3 mm annual precipitation), Chongqing, China. The soil was classified as Typic Purpli-Udic Cambosols wherein purple sandy and silt rocks of the Shaximiao formed in Jurassic period. Soil properties such as pH (7.45), exchangeable acidity (0 g/kg), oganic matter (16.61 g/kg) and cation exchange capacity (20.05 cmol /kg) were measured at the beginning of the experiment in 1990.

The experiment was conducted in rice-wheat-rotated field with nitrogenous ($CO(NH_2)_2$), potash (K_2SO_4), phosphorus (CaH_2PO_3) fertilizers and organic manure. Different chemical fertilizer and organic manure were applied to rice-wheat-rotated field to compare their effect on soil acidification. The chemical fertilizers were converted into N, P_2O_5 and K_2O respectively. No N, P_2O_5, K_2O or organic manure were applied to the CK. In the chemical fertilizer treatments, N (15.0 g/m^2/yr) for N, N (15.0 g/m^2/yr) and P_2O_5 (7.5 g/m^2/yr) for NP, N (15.0 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for NK, P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for PK, N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for NPK treatments respectively were applied to the rice-wheat-rotated field. In the organic manure and chemical fertilizers treatments, pig dung (150.0 g/m^2/yr) but no chemical fertilizer for M_1, pig dung (150.0 g/m^2/yr), N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for M_1+NPK, pig dung (150.0 g/m^2/yr), N (22.5 g/m^2/yr), P_2O_5 (10.3 g/m^2/yr) and K_2O (10.3

g/m^2/yr) for M_1+NPKadd, straw (50.0 g/m^2/yr), N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for M_2+NPK, were applied to the rice-wheat-rotated field. In the M_1+P(NK)Cl treatment, $CO(NH_2)_2$ and K_2SO_4 were replaced by NH_4Cl and KCl.

Soil analyses

Soil samples from each plot in the experiment were colleted at the depth of 20 cm and homogenized in 1991, 1996, 2001 and 2007. The pH value was measured in slurry of soil and water at the ratio of 1:2.5 by a glass electrode pH meter.

Results and discussion

Effect of chemical fertilizer on soil acidification

A significant effect of the application of chemistry fertilizer on soil acidification was observed at the long-term fertility trial (Figure 1). In 1996, 2001 and 2007, the soil pH was obviously decreased more by all fertilizer treatments than that in control treatment (CK). It showed that chemical fertilizer accelerated soil acidification. The soil pH value of NP, NP and PK treatments decreased more than that of N and NPK treatments in 1997 and 2001. From 1991 to 2007, the soil pH values of NP, NK and PK treatments decreased by 0.66, 0.64 and 0.61, respectively. During the same time, the soil pH values of N and NPK treatments decreased by 0.08 and 0.23, respectively. The soil pH value changed discontinuously in the time from 1991 to 2001. In 1996, the soil pH values of all treatments increased together but those applied chemistry fertilizer increased less than that of the comparisons. In 2001, the soil pH values of all treatment decreased together and those applied chemistry fertilizer dropped more than that of the comparisons. In 2007, the soil pH values of NP, NK and PK treatments went down further and those of all kinds of chemistry fertilizer kept below that of comparisons.

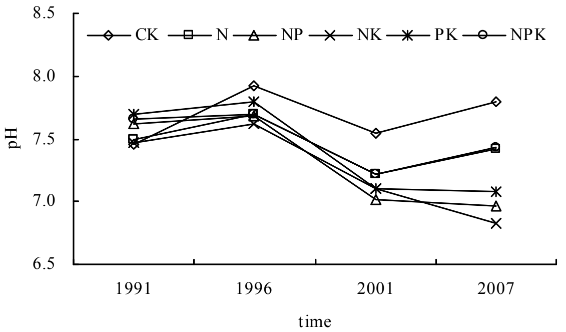

Figure 1. Soil pH value influenced by application of chemical fertilizer.

The results suggested that application of chemistry fertilizer accelerated soil acidification and balance rates of N, P and K fertilizer had less effect on soil acidification.

Effect of organic fertilizer in soil acidification

The application of organic manure affected the soil acidification process differently, as can be seen in Figure 2. The soil pH values of adopting organic manure decreased after ten years. The order of soil pH value decrease was: M_2+NPK>M_1+NPK>NPK or M_1. From 1991 to 2001, the soil pH values of M_2+NPK and M_1+NPK treatments decreased by 0.55 and 0.46, respectively; and those of NPK and M_1 treatments by 0.23 and 0.07. M1 treatment decreased the soil pH value less than M_1+NPK and M_2+NPK did. It indicated that muck had less effect on soil acidification. But mixed manure and fertilizer in field could accelerate soil acidification. N input was greater than that need by biota in M_1+NPK treatments and the excessive was oxidized into more nitric acid by microorganisms in soil. M_2+NPK decreased the soil pH value from 7.58 to 7.03 during ten years. Though part of negative ion returned to soil increased the soil pH values, the putrefaction of straw increased organic nitrogen that would take into reaction and result in soil pH values decrease. The soil pH value depended upon the balance of the two effects. In this experiment, the straw returned to the soil accelerated soil acidification.

Effect of different element and quantity of fertilizer on soil acidification

To study the effect of chlorine-containing fertilizer on soil acidification, NH_4Cl and KCl was used in treatment $M_1+P(NK)_{Cl}$ to replace urea and K_2SO_4. The soil pH values of $M_1+P(NK)_{Cl}$ and M_1+NPK_{add} treatments were lower than of M_1+NPK treatment. From 1991 to 2001, the soil pH values of M_1+NPK_{add}

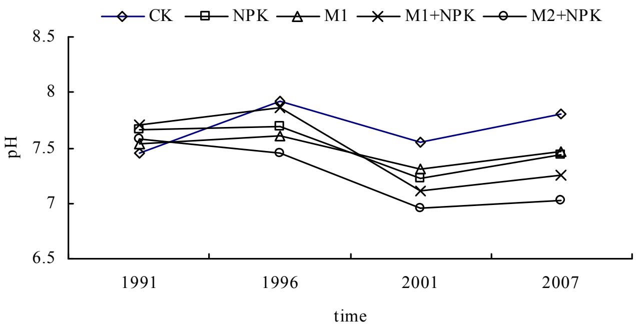

Figure 2. Soil pH value influenced by application of organic manure.

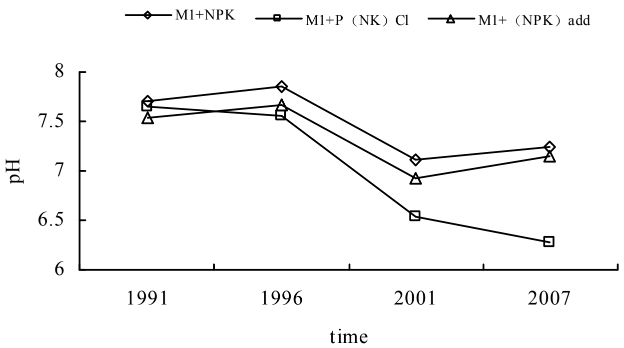

Figure 3. Soil pH value influenced by application of chlorine-containing fertilizer.

treatment dropped from 7.64 to 6.27, decreased by 1.37, the most in all treatments (Figure 3). It indicated that application of chlorine-containing fertilizer or excessive chemical fertilizer accelerated soil acidification. There have been some reports about chlorine-containing fertilizer resulting in soil acidification. When chlorine-containing fertilizer is applied, crop absorbs more ammonia nitrogen than nitrified nitrate. In the process, roots of crop release H^+ that directly causes soil acidification. It is not wisdom to apply excessive chemical fertilizer to farming for yield growth. Replacing chemical fertilizer with organic fertilizer of appropriate amount according to the need of the crop is a good measure to buffer soil acidification. Chlorine-containing fertilizer should be avoided. However, some study indicated that addition of chlorine-containing fertilizer at intervals could buffer soil pH values decrease rapidly.

Conclusion

Soil pH value decreases in the 0 to 20 cm soil layer with application of chemical fertilizer and organic fertilizer, and is influenced by crop rotations after 15 years in acid precipitation areas. Problems are more serious when chlorine-containing fertilizer and excessive chemical fertilizer are applied. But the balance rates of N, P and K fertilizer in field can abate soil acidification. It is shown that soil pH value decreases significantly with application of mixed fertilizer and organic manure. So, application of a reasonable amount of organic manure is a necessary measure in farming.

Acknowledgements

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Effect of elevated carbon dioxide on straw decomposition and soil respiration under wheat in Australia

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Abstract
This research investigates the effect of elevated [CO_2] and irrigation on straw decomposition and soil respiration in wheat field under ambient (380 µmol/mol) and elevated (550 µmol/mol) [CO_2] at the Free-Air Carbon dioxide Enrichment (FACE) experiment in a wheat field in Victoria, Australia. Pure cotton cloth, wheat straw and pea straw were decomposed using litter-bag method for 140 days. The percentage mass remaining was the highest for cotton cloth (90%), followed by wheat (73%) and pea (50%). Total C content of wheat and pea straw and total N content of pea straw were reduced only under elevated [CO_2] and irrigated conditions. Increase in C/N ratio was observed for wheat only under elevated [CO_2] and rainfed conditions. Soil CO_2 emissions were increased by elevated [CO_2] only under irrigation.

Key Words
Free air carbon dioxide enrichment, decomposition, straw C/N ratio, irrigation, soil respiration.

Introduction
The atmospheric carbon dioxide concentration ([CO_2]) has been increasing from 280 ppm in 1800 to the current value of around 380 ppm, and is expected to reach 700 ppm by the end of 21st century (Houghton *et al.* 2001). Elevated [CO_2] alters not only crop growth, but also crop tissue quality. In particular, change in tissue carbon (C)/nitrogen (N) ratio was well documented and C/N ratio was generally enhanced under high [CO_2] (Kimball *et al.* 2002). As a result, straw decomposition was reduced (Gorissen 1996; Torbert *et al.* 2000). However, a higher straw decomposition was observed under elevated [CO_2] (Hagedorn and Machwitz 2007) which is possibly related to enhanced fungal population (Jones *et al.* 1998) and microbial activity (Lipson *et al.* 2005) under high [CO_2]. While many decomposition experiments included the straw of same species but treated with different [CO_2], using straw of same quality gives a fair comparison of soil microbial activity with respect to straw decomposition. For instance, the rates of C loss from ^{13}C-labelled wheat roots per unit root dry weight were not significantly different under ambient and elevated [CO_2]. This was associated with a similar root C/N ratio of wheat grown under the two CO_2 treatments (Van Vuuren *et al.* 2000). Soil CO_2 flux reflects is another indicator of soil microbial activity. CO_2 emissions were mostly stimulated under elevated [CO_2], which was attributed to enhanced microbial and root respiration (Zak *et al.* 2000; Kou *et al.* 2007). However, the interaction between elevated [CO_2] and irrigation on straw decomposition and soil respiration needs further research. The present study was conducted on a wheat field in Victoria, Australia using Free-Air Carbon dioxide Enrichment (FACE) facility. The objectives are to investigate (i) the interaction of elevated [CO_2], irrigation and straw type on decomposition rate and straw C/N ratio; and (ii) the interaction between elevated [CO_2] and irrigation on soil respiration.

Methods
Experimental site
The study site is located in an experimental wheat farm on vertosol in Horsham, Victoria, Australia (36°45'S, 142°07'E), with an average rainfall and maximum temperature of 316 mm and 17.5°C during wheat growing season. The present experiment was conducted from late July to December in 2008.

Carbon dioxide elevation
The elevation of atmospheric [CO_2] was achieved from FACE system, consisting of 16 12 m diameter experimental areas, eight elevated and eight ambient. The two target CO_2 concentrations were 380 (ambient) and 550 µmol/mol (elevated). The design and performance of this FACE system was detailed in Mollah *et al.* (2009). Carbon dioxide exposure commenced at sowing time and terminated at the physiological maturity of wheat crop.

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Irrigation
Each experimental area was split into two halves receiving different irrigation regimes. Rainfed (I0) and irrigated (I+) treatments were achieved using irrigation to give decile 5 and decile 7 rainfall conditions, respectively.

Litter-bag experiment
Three straw types were included, *viz*. pure cotton cloth, wheat straw and pea straw, representing respectively straw type of high, medium and low C/N ratios. Pure cotton cloth (100% C) was used as to indicate the presence of N in residue is the prerequisite of microbial decomposition. Wheat straw and pea straw grown under ambient [CO_2] were collected from a farm near the study site. Cotton cloth and the two straw were washed, oven-dried at 60°C and cut into pieces of around 0.3-0.5 m long. Three grams of each straw type were put into polyester bag of 0.1 m by 0.15 m, with 1 mm mesh size. Five bags of each straw type were buried to 0.5 m depth, and one of these five bags was collected at 30, 60, 90, 120 and 140 days. The straw remaining in the bag was washed with tap water to remove the dirt adhered, dried at 60°C for 48 h and weighed to give the percentage mass remaining.

Gas sampling and flux determination
The location of microplots of this experiment was different from the litter-bag experiment, but within the corresponding experimental area. Gas samples for CO_2 analysis were taken from microplots from closed flux chamber (0.15 m height by 0.16 m diameter) on 24 September, 7 & 30 October, 18 November and 10 December between 1300 and 1500 h of the day. One chamber was inserted a day before the first measurement to a soil depth of 70 mm, and remained *in situ* throughout the experimental period. Neither wheat crop nor straw was included inside the chamber. Fluxes measured from this experiment reflected soil respiration (including root and microbial activities). On each sampling day, the chamber was closed for 0.5 h prior to the first gas sampling. Five gas samples were then collected from the chambers at 7 minute intervals (chambers remained closed) using a gas tight syringe through a rubber bung. Gas of 15 mL was transferred into evacuated glass vials and transported to the laboratory for analysis by gas chromatography equipped with TCD. Flux rate of CO_2 was calculated from the linear change in gas concentrations in the chamber.

Chemical analysis
The dried straw was ground into very fine powder for the analysis of total C and total N by CHN Analyzer.

Statistical analysis
All data were analysed using the MINITAB 14 statistical package using a factorial model analysis of variance with main effects as [CO_2], irrigation, straw type and sampling time for litter-bag experiment, and [CO_2], irrigation and sampling time for CO_2 flux experiment.

Results
Percentage mass remaining
The percentage mass remaining decreased with time for cotton cloth, wheat straw and pea straw for all treatments (Figure 1), and averaged 90 ± 9, 73 ± 8 and 50 ± 5%, respectively, after 140 days of decomposition. Cotton cloth was hardly decomposed throughout the course of the experiment, indicating the presence of N is crucial to microbial decomposition. Decomposition rate was highest within the first three months of the study period, and levelled off thereafter (Figure 1). The higher percentage mass remaining for straw of wheat than pea was associated with the higher C/N ratio wheat straw (59.4 ± 4.2) than pea straw (27.1 ± 3.1) for microbial decomposition. There was no significant effect of elevated [CO_2] on the percentage mass remaining, regardless of straw type. Irrigation decreased the percentage mass remaining by 5% ($p < 0.001$), regardless of [CO_2] and straw type.

Total C, total N and C/N ratio
Chemical analysis of nutrient contents was not performed for cotton cloth (100% C). Total C was reduced by 5% ($p < 0.05$) by irrigation for both wheat and pea straw only under elevated [CO_2]. Total N was decreased by 19% ($p < 0.05$) under elevated [CO_2] only for pea straw under irrigated condition. The interaction among [CO_2], irrigation and straw type on C/N ratio was marginally significant ($p = 0.091$). Elevated [CO_2] increased (47%) the C/N ratio of only wheat straw under rainfed condition. This was probably attributed to the 3% increase ($p > 0.05$) in total C and 15% decrease ($p > 0.05$) in total N under the same condition.

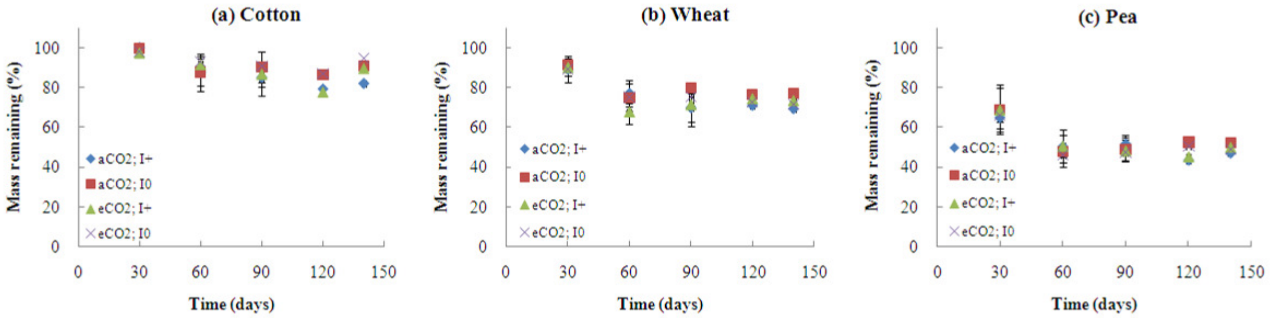

Figure 1. Percentage mass remaining at different time after decomposition of (a) cotton cloth, (b) wheat straw and (c) pea straw. Bars indicate standard deviations. aCO_2 (ambient [CO_2]); eCO_2 (elevated [CO_2]); I+ (irrigated); I0 (rainfed).

CO_2 flux

CO_2 fluxes during the experimental period were always positive. The interaction between elevated [CO_2] and irrigation was marginally significant ($p = 0.095$). Elevated [CO_2] increased CO_2 emission by 78% under irrigation (Figure 2), but not under rainfed condition.

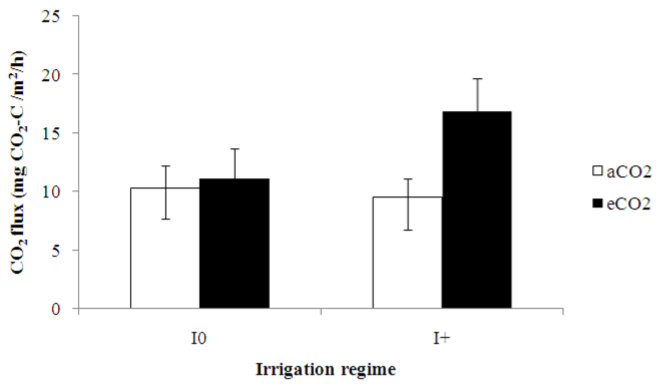

Figure 2. Effects of [CO_2] and irrigation on CO_2 flux. Bars indicate standard errors. ns, not significant; * $p < 0.05$. aCO_2 (ambient [CO_2]); eCO_2 (elevated [CO_2]); I0 (rainfed); I+ (irrigated).

Discussion

Effect of [CO_2] and straw type on straw decomposition and straw C/N ratio

Elevated [CO_2] did not significantly affect straw decomposition for cotton cloth, wheat and pea straw. Since the straw placed under ambient and elevated [CO_2] was of the same quality, the non-significant effect indicates that microbial activity of surface soil was unlikely affected by elevated [CO_2] in short term (140 days). When considering the difference in decomposition rate of the three straw types, cotton cloth was always the lowest, followed by wheat straw and then pea straw. This reflects C/N ratio is a key factor to decomposition rate under both ambient and elevated [CO_2]. For example, the higher C/N ratio of wheat straw produced under elevated [CO_2] resulted in reduced decomposition rate in a wheat field and a fallow field (both under ambient [CO_2]) (Frederiksen *et al.* 2001), in a soil incubation experiment (Marhan *et al.* 2008) under ambient [CO_2], and in a pot experiment in open-top chambers under both ambient (370 µmol /mol) and elevated [CO_2] (700 µmol /mol) (Liao *et al.* 2002). In contrast, when the root C/N ratio of wheat grown under the two CO_2 treatments was similar, there was no significant difference in the rates of C loss from ^{13}C-labelled wheat roots per unit root dry weight under ambient and elevated [CO_2] (Van Vuuren *et al.* 2000). The above findings together suggest that CO_2-induced change in tissue quality (C/N ratio), rather than microbial activity, plays a contributory role in altering decomposition rate in short term elevation of [CO_2]. Indeed, Søe *et al.* (2004) observed no significant change in soil microbial biomass under elevated [CO_2].

Irrigation reduced the percentage mass remaining (or increased decomposition), regardless of [CO_2] and straw type, which indicates water or soil moisture is critical to microbial activity. In particular, it stimulated the C mineralization of wheat straw and C and N mineralization of pea straw under elevated [CO_2]. This highlights the importance of water in C and N cycling. Moreover, the C/N ratio of wheat straw was increased under elevated [CO_2] and rainfed conditions, which has major implication on soil N immobilization as well as progressive N limitation in semi-arid regions, if there is no additional N input (Luo *et al.* 2004).

Effect of [CO_2] and irrigation on soil CO_2 emissions

Since the stimulation of efflux was associated with increased biomass under elevated [CO_2] (Jablonski *et al.* 2002; Kimball *et al.* 2002), the marginally increased soil CO_2 efflux only under elevated [CO_2] and irrigation implies that irrigation is crucial to biomass increment under elevated [CO_2] in the study site, as well as the subsequent increase in C substrates for soil microbes (Zak *et al.* 2000; Kou *et al.* 2007). Nonetheless, the decomposition experiment indicates that there was no significant effect of elevated [CO_2] on decomposition, regardless of irrigation, and the stimulation of microbial activity in surface soil was unlikely. Therefore, the stimulation of CO_2 efflux was possibly resulted from an increase in microbial activity in subsurface soil and/or root respiration, as soil respiration comprises respiration by autotrophs and heterotrophs (Kuzyakou *et al.* 2006). This is possible as root respiration was observed to increase under high [CO_2] as a result of increased root biomass and concomitant root activity (Søe *et al.* 2004). However, sufficient amount of water is a prerequisite.

Conclusions

Straw decomposition was not significantly affected by elevated [CO_2], regardless of straw type, but irrigation increased decomposition. Change in straw quality induced by elevated [CO_2], rather than microbial activity, was proposed to result in a change in decomposition rate under elevated [CO_2]. Parallel to this, the increase in CO_2 emission under elevated [CO_2] and irrigation was possibly attributed to the stimulation of root biomass and activity. Water plays an important role in regulating decomposition and soil respiration, which are important processes of soil C cycle altering the global climate.

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Effect of household land management in constraining soil organic carbon storage at plot scale in a red earth soil area of South China

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Abstract
An inventory of topsoil organic carbon content in household farms was performed in a village from a typical rural area with poor soil fertility in a red earth region in Jiangxi Province, South China in 2003. A statistical analysis of SOC variation with land use and household management types, and with crop management practices was conducted. The size of plots surveyed ranged from 0.03 ha to 0.63 ha, with a mean of 0.1 ha, showing consider cropland fragmentation. Topsoil SOC content ranged from 1.72 g/kg to 25.2g/kg, with a mean of 12.7g/kg, varying widely with a variety of household land management and agricultural practices arising from individual household behaviours. Land fragmentation played a minor role in SOC variation with the mean SOC content in plot size <0.1 ha being 20% lower than plot size ≥0.1ha. Nevertheless, the land use (rice fields or dry croplands) and the land contractual system (direct contract or subcontracted land) had greater impacts; SOC content in the plots of dry croplands was 70% lower than that in rice paddies, and the SOC in contracted plots was almost double that found in subcontracted plots. In contrast, agricultural management practices had smaller effects; a 30% increase in SOC with green manure cultivation, and a 55% increase with changing cropping intensity. The difference in SOC levels between the least and most favourable cases of household land management and agricultural practice was up to 150%. Our results suggest that policies targeted at agricultural management alone may not deliver the expected SOC benefits if household land management is not also improved. This case study provides rare quantitative information linking limits in the efficacy in soil carbon storage with potential barriers to implementation and may serve as a template for investigating barriers to implementation of climate mitigation practices in agriculture elsewhere in the developing world.

Key Words
Agricultural management; C storage and sequestration; household land management; land fragmentation, soil organic carbon, plot scale.

Introduction

Soil organic matter contents in farmlands may be influenced by changes in land use intensity and land management effects (Grandy and Robertson 2007). In developing countries land resource availability constraints, with fragmented croplands and small-scale farm management systems, impact upon sustainable agriculture and food security (Niroula and Thapa 2005). C sequestration in croplands in developing countries will depend on the existing performance of these management practices as implemented by household farmers.

China has experienced profound changes in land use, land use cover and land management systems over the last 50 years. Since the late 1970s, farmland management had been shifted to household responsibility (collectively owned, individual use right) systems, which has resulted in small scale household farms with intense land fragmentation (Tan *et al.* 2006). However, there has been little information on how, and to what extent, household farm management behaviors impact SOC storage and C sequestration capacity of China's croplands.

The purpose of this paper is to quantify the variation of SOC storage in household farms under different land management settings, with respect to the land contractual structure, household farm size, and land use, using a dataset of a farm inventory conducted in 2003. From this analysis, we aim to provide information for policy making to improve household farming for enhancing C sequestration and GHG mitigation in China's agriculture.

Materials and methods

Household farm inventory

An inventory at household farm scale was conducted in a village in Honghu Township, Yujiang County, Jiangxi Province, China in February, 2003. The village is located in a red soil terrace from a Quaternary deposit at an elevation of 45-50 m above sea level. The local climate is governed by a subtropical monsoon, with the mean annual temperature of 17.2 -18.1°C and annual precipitation of 1700 - 1800mm, with 70% in late April to early July for the last 2 decades.

The village surveyed was among those with the least developed economy and poor agricultural productivity during 1970-1990s, and most of the farmers lived on agricultural output before 2003 (Tan 2005). The village had 220 households with a population of 900 in 2002, dividing into 4 hamlets with a total of 133.3 ha of farmland, giving a density of 0.15 ha per capita. Of the total farmland area, irrigated rice paddies accounted for 82.3 ha with mostly double rice cropping, and a further 31.1 ha farmland in dry croplands, mainly with peanuts and vegetables plus citrus trees. The rice yield per year was, on average, 5.1 t/ha in 2002. Chemical fertilizers were commonly applied with very limited use of farmyard manure. The land tenure system shifted to household responsibility in 1982, and the farmlands were allocated to households according to family size and labour force, and by considering soil quality and distance from the village.

For this survey, 15 households from a single Hamlet without land transfer between 1985 and 2002 were randomly selected. Farm scale, plot size, land property rights, and management practices were surveyed with questionnaire visits. The area, history of cultivation, yield and management (including land property rights, crop rotation system; fertilization, straw return, soil fertility condition and agrochemical application, etc.), were recorded for 105 fields in total.

Soil sample collection

Topsoil samples of all the plots associated with the surveyed 15 households were collected at depth of 0-15cm using a soil core sampler (Eijkelkamp 2000) in Late February, 2003 when no crop growth was present. A composite sample was formed with 3 randomly selected subsamples for each plot, surveyed after sampling in the field.

Soil property determination

Soil total organic carbon and nitrogen were measured with an Elementar Vario MAX CNS Analyzer. The determinations of soil pH (H_2O), available phosphorus and potassium, and clay content were conducted. All the extraction and determinations were performed in duplicate. The cropland topsoil SOC values surveyed and measured during the 2nd National Soil Survey completed in 1985 of the surveyed village were retrieved from the records available in the local soil survey service of Yujiang Couty.

Statistical analysis

Data processing was conducted with MS-EXCEL in MS-WINDOWS 2003. Statistical differences in SOC between the land use types and land tenure systems were tested with the analysis of variance procedure (ANOVA) using the SPSS11.0 statistical package. Statistical significance was defined at $p<0.05$.

Results and discussions

Land management status of the households surveyed

The size of the households surveyed was 4.5 persons owning a total area of farmland of 0.67 ha on average. The farmland occupation of 0.15 ha per capita is larger than the mean for China as a whole, which was 0.09 ha per capita in 2004, reported by the Ministry of Land and Resources through a national land use change survey (Anonymous 2006). Of the total 105 plots surveyed, 84 were used for rice paddies and 21 were for dry croplands, reflecting the common rice-dominated agriculture in South China. Rice cultivation occupied 90% of the total cultivated area in Jiangxi in the late 1980s (JBLM 1991) and 85 % of the total of the local county of Yujiang (SSOYC 1986). With reform of the land tenure system finalized in 1985, most of the plots surveyed were under use of households by direct contracting from village collective. However, 21 plots of the total surveyed had been leased to secondary land managers for 5 to 10 years.

The plot size of the household farmlands followed a skewed distribution and ranged from 0.007 ha to 0.600 ha, with the majority of plots being small. The mean plot size of 0.11 ha for the household farmland plots was close to that of China as a whole of 0.09 ha. A great degree of land fragmentation occurred in these household farmlands; 47 plots had a mean size of 0.05 ha compared to a mean size of 0.22 ha of the 58 plots with a single plot area more than 0.1 ha. Furthermore, a significantly higher degree of land fragmentation was associated with subcontracted plots, and with dry croplands.

Variation of SOC content with land management

Following a quasi-normal distribution pattern, the SOC contents of the total 105 plots ranged from 1.72 g/kg to 25.2 g/kg with a mean of 12.7±6.06 g/kg. Thus, the variability in plot SOC is smaller than the variability in plot area. The variation of topsoil SOC content with land management type is presented in Figure 1. The land use type also had profound impacts on SOC contents. The majority of the 105 plots were rice paddies with a mean SOC of 13.95 g/kg, being higher than the dry croplands by 70% on average. However, the contracted plots had much higher SOC contents than the subtracted ones, with the mean value of the former almost double the latter.

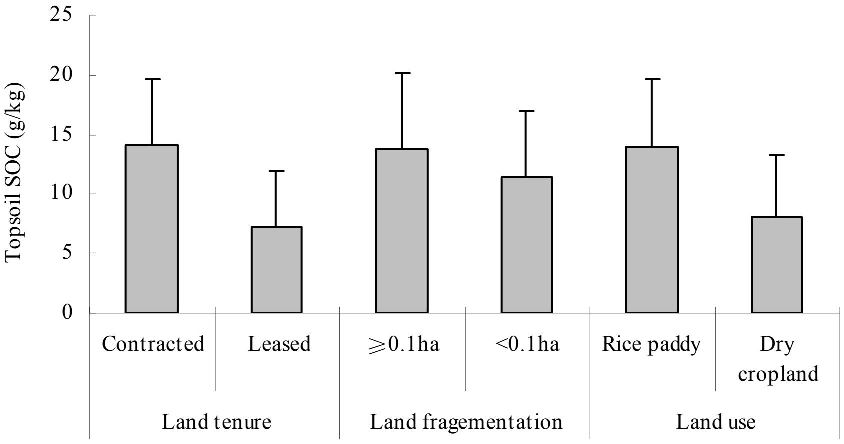

Figure 1. Variation of topsoil organic carbon content with land management, land use and fragmentation of the 105 plots surveyed.

A smaller effect of land fragmentation on SOC content was observed as the plots smaller than 0.1 ha in area per piece had significantly lower SOC levels (by up to 20% on average) than those larger than 0.1 ha in area per parcel of land. Land fragmentation associated with household farm size had an impact on SOC. The farmlands of the households with large total area in a smaller number of plots showed higher SOC contents by 3.4 g/kg on average, and even much higher SOC enhancement compared to the original SOC level. Accumulation of SOC by 6.2 g/kg was found in the household farmlands with total farm size over 0.7 ha in less than 7 plots, compared to that of 1 g/kg in small sized household farmlands. SOC in the farmlands of the 15 households surveyed varied both in the present SOC content, and in the SOC dynamics compared to their background in 1985, before the household land tenure system was implemented. The samples from the farmlands of the households occupying a larger farmland area with less degree of land fragmentation were richer in SOC than those having a smaller area and greater fragmentation. After 20 years since implementation of the land tenure system, SOC had increased in larger sized household farmlands, by over 6 g/kg on average, compared to an insignificant increase in those with smaller size.

Variation of topsoil SOC contents with agricultural management practices

The area had been characterized as low productivity for rice due to the poor soil quality and low nutrient pools, as the soils on the red soil terrace have suffered from acidity and severe soil erosion (Li 1992). Traditionally, double or triple rice cropping had been performed to meet demand for cereal production, and in the absence of conservation practices, soil fertility has largely been exhausted. Improved agricultural management in the area would entail a cropping system with straw return and green manure cultivation (Tan 2005). Most of the plots had been cultivated with double or triple cropping of rice, with very little green manure cultivation or straw return. For dry croplands there was a single cropping of peanuts and fruit trees with poor soil conditions, with double and triple cropping predominantly used for rice-rice and rice-rice-vegetable in winter, respectively (Tan 2005). While the topsoil SOC under single cropping of dry crops tended to be much lower than the double and triple cropping with rice, there was small difference in SOC contents between the double and triple cropped plots. Cultivation of green manure crops, mainly as alfalfa in this region, yielded significantly higher SOC contents than the non-green manure cultivated plots, by 3.3g/kg on average. However, straw return resulted in an increase in topsoil SOC by 5 g/kg compared to plots without straw return. Comparatively, the effect of management practices on topsoil SOC was greatest with straw return, followed by green manure cultivation and least with rice cropping intensity.

Conclusion

The findings suggest a large intercative impact of land property rights and land use on both SOC storage and SOC dynamics of household farmlands. Aspects of household land management, such as land tenure management may have strong impacts on SOC levels in China's croplands superimposing the agricultural management effects at farm scale.

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Effect of long-term irrigation with dairy factory wastewater on soil properties

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Abstract

The effects of irrigation with dairy factory wastewater on soil properties were investigated at two sites that had received irrigation for > 60 years. In comparison with paired sites that had not received effluent, long-term wastewater irrigation resulted in an increase in pH, EC, extractable P, exchangeable Na and K and ESP. These changes were related to the use of phosphoric acid, NaOH and KOH as cleaning agents in the factory. Despite these clear changes in soil chemical properties, there were no increases in soil organic matter content (organic C and total N) and the size (microbial biomass C and N) and activity (basal respiration) of the soil microbial community were, in fact, increased by wastewater irrigation. These increases were attributed to regular inputs of soluble C (e.g. lactose) present as milk residues in the wastewater.

Key Words

Dairy factory; wastewater; effluent; irrigation; soil quality.

Introduction

The dairy industry is a major source of food processing wastewater (Britz *et al.* 2006). Dairy factory wastewater (DFW) generally contains a high organic load, due to the presence of diluted milk/milk products, and contains significant quantities of cleaning and sanitizing compounds (e.g. NaOH, H_3PO_4/HNO_3, NaOCl). There are three methods of disposal of such wastewater: (i) point source discharge to surface waters, (ii) discharge to the municipal sewer system and (iii) irrigation onto land surrounding the factory (land disposal). In Australasia, and other parts of the world, dairy factories in rural areas (often those manufacturing longer self-life products such as butter, cheese, long-life milk and milk powders) commonly irrigate effluent onto surrounding pastoral land. This is not only a waste disposal strategy for the factory but also it increases productivity of surrounding land since it is a supply of irrigation water (often a scarce resource) and nutrients (e.g. N and P) to farmers without cost.

Environmental concerns surrounding DFW irrigation include the possibilities of leaching of nutrients to groundwater and accumulation of Na in the soil (Britz *et al.* 2006). Nevertheless, a limited amount of research has shown that effluent irrigation has positive effects on soil properties including a liming effect, sometimes modest increases in soil organic matter status and substantial increases in the size and activity of the soil microbial community (Degens *et al.* 2000; Sparling *et al.* 2001). Such research has been carried out on a very small number of sites in New Zealand on soils mainly derived from volcanic ash and the wider applicability of the findings is, as yet, unknown. The purpose of this study is to investigate how irrigation of grazed dairy pastures with dairy factory effluent influences soil chemical and microbial properties.

Materials and methods

The experimental site is in the Bega Valley (NSW). Soils in the study area are light textured, alluvial soils and are classified as granitic Chromasols and Tenosols (Isbell 2002). Experimental monitoring transects were laid down by the Victoria Department of Agriculture in 32 fields surrounding the factory in 2001 (Gourley *et al.* 2007). Typical factory effluent content is BOD_5 = 3438, P = 46, N = 161, Ca = 71, Mg = 16, K = 536, Na = 340 mg/L. For this study, initially two sites close to the factory were chosen that had a known history of long-term (i.e. > 60 years) DFE irrigation [long-term DFE (1) and (2)]. Two fields close-by, which had not received

DFE, were chosen as control sites (one irrigated and one dryland) [control (1) and irrigated control]. The transect lines were split into three equal lengths. Twenty soil samples (0-10 cm) were taken from the three areas (within a distance of 3 m out either side of the line within each of the three lengths). Samples from each area were bulked to give three replicate samples per field. Bulked samples were thoroughly mixed and sieved (< 2 mm). A portion of each sample was stored at 4ºC for microbial analysis and the rest was air-dried and stored for chemical analysis.

Table 1. Some chemical properties of soils under long-term irrigation with dairy factory effluent (DFE) compared to control sites.

Treatment	pH	EC	Extractable P	Exchangeable Cations Ca	Mg	K	Na	ESP
	($CaCl_2$)	(dS/m)	mg P/ g soil	$mmol_c$/kg				(%)
Control (1)	4.2a	0.04a	61.8b	58a	22b	2.7a	2.7a	1.7a
Irrigated control	5.5b	0.06a	7.8a	54a	23b	2.3a	1.3a	3.2a
Long-term DFE (1)	6.5c	0.31c	629d	64a	13a	11.2b	11.5b	11.2b
Long-term DFE (2)	6.3c	0.20b	439c	95b	16ab	13.9b	12.2b	8.9b

Means followed by the same letter are not significantly different $P<0.05$.

Electrical conductivity and pH were analysed in a 1:5 (v/v) water extract using glass electrodes. Exchangeable bases were extracted with 1 M ammonium acetate (pH 7) and Ca, Mg, K, and Na in the extracts were analysed by ICP-AES (Rayment and Higginson 1992). Available P was extracted with 0.5 M $NaHCO_3$ (pH 8.5) (1:100 w/v for 16 h) (Rayment and Higginson 1992) and measured colorimetrically by the molybdenum blue method. Organic C and total N content were measured by automated dry combustion using a Carlo Erba C, H, N analyser.

Microbial biomass C and N were estimated based on the difference between organic C and N extracted with 0.5 M K_2SO_4 from chloroform-fumigated and unfumigated soil samples using a K_C factor of 0.38 and a K_N factor of 0.54. Basal respiration was determined by placing 30 g oven dry equivalent of moist soil in a 50-ml beaker and incubating the sample in the dark for 10 days at 25ºC in a 1-l air-tight jar along with 10 ml 1M NaOH. The CO_2 evolved was determined by titration. The metabolic quotient was calculated as basal respiration (µg CO_2-C/h) expressed per mg of microbial biomass C.

The statistical significance of experimental treatments was determined by Analysis of Variance Analysis using the Minitab Statistical Software Package and differences were calculated at the 5% level using Tukey's test.

Results and discussion

Long-term irrigation of effluent with a high Na content will, as shown in Table 1, inevitably result in accumulation of exchangeable Na in the soil. Although, in general, monovalent cations are held less strongly on cation exchange sites than divalent ones, by mass action the added Na displaces other cations (e.g. Ca and Mg) into soil solution and they can then be leached down the soil profile. A decrease in exchangeable Ca and Mg is therefore commonly reported where Na-enriched effluents have been repeatedly applied. At these sites, a decrease in exchangeable Mg was evident (Table 1) but exchangeable Ca levels were not greatly changed. This is presumably attributable to the application of about 3 t/ha of gypsum ($CaSO_4.2H_20$) in early 2007 which was applied to counteract previous accumulation of exchangeable Na that had occurred at the long-term irrigated sites (Gourley *et al.* 2007). The elevated exchangeable Na noted here will be the result of residual Na remaining after the gypsum application plus that which has accumulated since the application. Effluent irrigation also, as expected, increased soluble salt levels and, because of its significant K content, exchangeable K levels were also elevated (Table 1). The increase in pH is attributable to the high pH of DFW (7-8). This increase in pH will need to be monitored since values are 6.3-6.5 in 0.01 M $CaCl_2$ (about 7 in water) and further increases could induce micronutrient cation deficiencies (e.g. Fe, Mn, Zn and Cu).

Table 2. Microbial biomass C and N, basal respiration and metabolic quotient in soils under long-term irrigation with dairy factory effluent (DFE) compared to control sites.

Treatment	Microbial biomass C	Microbial biomass N	Basal respiration	Metabolic quotient
	mg/kg	mg/kg	µg C/g/day	µg C/g/day
Control (1)	164b	30.3a	25.8a	0.16ns
Irrigated control	126a	50.7b	22.3a	0.12
Long-term DFE (1)	261c	70.4c	36.5b	0.14
Long-term DFE (2)	282c	72.8c	34.8b	0.12

Means followed by the same letter are not significantly different $P<0.05$.

Although EC values were moderate in long-term DFW-irrigated irrigated soils, ESP values of 9-11% reflect sodic conditions (Isbell 1995). Nonetheless, dispersive behaviour has not been noted in these soils in the field and subsequent aggregate stability measurements (by wet sieving) have revealed stable aggregation under both control and DFW irrigation. The reason for the stable structure is probably related to the fact that these soils are under permanent pasture. Under pasture, the extremely ramified root system of grasses explores a large proportion of the surface soil and carbohydrate exudates from the roots themselves, and from the extensive rhizosphere microflora have an aggregating and stabilizing effect on soil aggregates (Haynes and Beare 1996). In addition, organic materials in the DFW (e.g. lactose) may also have a stabilizing effect (Cameron *et al.* 2003).

Extractable P levels are very high under long-term irrigated sites (i.e. 439 and 629 mg/kg) (Table 1) reflecting the high P content of dairy factory effluent (due principally to the use of H_3PO_4 as a cleaning agent). Degens *et al.* (2000) also noted a large accumulation of extractable and total P in soils under long-term DFW irrigation. Accumulation of P in the surface soil could result in increased losses of P via runoff. Nonetheless, under permanent pasture, where the surface soil is protected by vegetation, such losses are likely to be small. Due to strong adsorption onto inorganic soil colloids, it is usually considered there is a low risk of P leaching down the soil profile. Some studies have, however, suggested that at high soil test P levels measureable movement of P down the profile can occur (Hesketh and Brookes 2000). It will, therefore, be important to monitor for any possible downward movement of P in these long-term DFW-irrigated soils.

Long-term DFW irrigation did not result in significant increases in organic C or total N in the soil profile (data not shown). The lack of any increase in organic C following long-term effluent irrigation suggests that the additional inputs of organic C in effluent are balanced by losses of C of the same magnitude. Similar results were recorded by Degens *et al.* (2000) and Sparling *et al.* (2001) on long-term DFE-irrigated soils in New Zealand. Under any particular management system, soil organic matter characteristically equilibrates to a level where inputs and losses balance (Haynes and Beare 1996). Losses of C are likely to be principally as CO_2 evolution due to the increased microbial activity (Table 2) but leaching of soluble organic matter could also play a part (Menneer *et al.* 2001). The lack of any accumulation of total N in the soil under DFE irrigation may well be at least partially related to similar N loads being applied to the "control" and DFE-irrigated fields. That is, control sites typically received substantial inorganic fertilizer N inputs (i.e. 100-200 kg/ha/yr) while fertilizer rates were much reduced on effluent-irrigated fields (to take account of N inputs from the effluent).

The increase in the size (microbial biomass C and N) and activity (basal respiration) of the soil microbial community under DFW irrigation (Table 2) is likely to be the result of regular inputs of soluble C (e.g. lactose), along with additional N and P, in the effluent. This occurred despite there being no increase in total soil organic C content. Such an increase in microbial biomass, despite no increase or even a decrease in organic C, was also noted by Sparling *et al.* (2001) in long-term DFE irrigated pastures. There was no increase in metabolic quotient due to DFE irrigation (Table 2) indicating that the increase in basal respiration was proportional to the increase in microbial biomass C. An increase in metabolic quotient is considered a response of the microbial community to adverse conditions (either stress or disturbance) (Wardle and Ghani 1995). Thus, the accumulation of soluble salts, P and Na in the effluent-treated soil did not appear to cause undue stress to the soil microbial community.

Conclusions

Under DFW irrigation there is a characteristic increase in EC, ESP, extractable soil Na, K and particularly P, and an increase in the size and activity of the soil microbial community. Further work will investigate the effects of DFW irrigation on the catabolic diversity and structural composition and diversity of the microbial community.

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Effects of long-term different fertilization on yield stability of maize

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Abstract
A long-term experiment was started in early 1990s and continued until 2008 to study the effects of crop rotation and chemical fertilization on the yield and yield stability of maize (*Zea mays L.*). The results indicated that the yield of maize was higher in the cropping system of soybean-maize rotation than that in maize monoculture. Under P combined with K fertilizer (PK) treatment and no fertilizer control (CK), the yield of maize increased in the crop rotation system up to 38.30% and 36.11%, respectively. This observation can be explained by residual nutrients after legumes, especially N nutrient. However, the rotation effect would be diminished by balanced nutrient supply. Maize yield increased significantly under N fertilization treatments and was even higher under the treatments of N combined with P (NP) and NP plus K (NPK). The stability analysis showed that stability of maize yield of soybean-maize rotation was significantly improved compared to maize monoculture, and higher stability could be obtained in NP and NPK treatments regardless of crop sequences, which can be attributed mainly to balanced macronutrients supply.

Key Words
Long-term trail, yield stability, crop rotation, drylang maize yield.

Introduction
The worldwide agricultural structure has been undergoing profound changes in recent decades, and one of the major changes is the utilization of chemical fertilizers to achieve high crop yield. The yield as well as the yield stability are the most important targets to evaluate a cropping system (Piepho 1998). The researches showed that the yield stability was significantly influenced by agricultural practices and the environment, especially fertilization, seed genotype, tillage, precipitation, accumulated temperatures, pests, and diseases (Berzsenyi and Dang 2008). The common approaches to stability analysis were environmental variance parameters, regression (Crossa 1990) and the fluctuation of production about a long-term average or the fluctuation of production about a long-term trend can be assessed by the long-term experiments. To some extent, long-term experiments are indispensable in investigations on the stability of crop production, predicting soil carrying capacity and assessing system sustainability (Regmi *et al.* 2002).
The objectives of this work were (i) to evaluate the long-term effects of different fertilization treatments and crop rotations on maize yield based on about 20 yr of data and (ii) to study the effects of fertilization treatments and rotations on yield stability by conventional variance parameter analysis, regression analysis, and AMMI analysis.

Methods
Experimental site, design and treatments
A long-term field experiment has been conducted since 1990 in the Institute of Applied Ecology, Chinese Academy of Sciences (41° 32′ N latitude, 123° 23′ E longitude). The mean annual temperature of 7.0-8.0 °C. Its annual precipitation is about 700 mm. The soil of the experimental field is Luvisols soil. The initial properties of the surface soil (0-20 cm depth) were as follows: pH 6.5, soil organic matter of 20.9 g/kg, total nitrogen of 1.13 g/kg, total P of 0.44 g/kg, total K of 16.4 g/kg, soil available P of 10.6 mg/kg, and available K of 88.0 mg/kg. The experiment had 8 treatments: no fertilizer (CK), N, P, K, NP, NK, PK, and NPK treatments. N, P, and K fertilizers were applied at the rates of 150, 25, and 60 kg/ha/year in the form of urea, double superphosphate, and potassium chloride, respectively. Each plot area was 162 m^2, with a buffer zone of 1.0 m. Initially, in 1990, the experiment was started with a soybean-maize-maize 3-year rotation. Then there were two crop sequences for maize per year that the forecrop was maize or soybean, respectively, namely maize monoculture and soybean-maize rotation. Each treatment consisted of 3 replications.

Data analysis
Maize grain yield data was subjected to analysis of variance (ANOVA) followed by Duncan's multiple range test for multiple comparisons of paired means of treatments.

Stability analysis

Stability analysis on the experimental treatments and effect of rotation was carried out using univariate (variance and regression parameters). Among the variance parameters, the ecovalence (W^2), the stability variance (σ^2) were calculated using the STABLE proposed by Kang and Magari (1995). The regression method of stability analysis was applied as described by Finlay and Wilkinson (1963). The regression model can be written as

$$y_{ij} = \mu_i + \beta_i u_j + d_{ij} \quad (1)$$

where μ_i is the mean (expected value), i.e. the systematic effect of the ith treatment; β_i is a regression coefficient corresponding to the ith treatment; u_j is an effect of the jth environment and dij is a random deviation from the regression line. Finlay and Wilkinson (1963) suggested that slopes with $b_i < 1.0$, where b_i is an estimate of β_i obtained by regression onto the environmental mean, indicated better adaptation to poor environments, whereas slopes with $b_i > 1.0$ were best used in superior environments. A cropping system with an estimate of $b_i = 1$ showed an average response to environmental conditions.

Results

Yield response

The effects of crop rotation and fertilization on the grain yield of maize over the years 1991-2008 are summarized in Table 1. Application of N fertilizer significantly increase maize yield over the other treatments, and comparison of treatments revealed that the average yields of maize under combined application of N with P or K were significantly higher than those in control and N, P or K alone. It can be also seen that the yield of maize in monoculture was always lower than in soybean-maize dicultrue except NPK treatment, especially without N fertilizer. The yield-increasing effect of crop rotation was greatest in the PK treatment, followed by the CK and P, with the poorest effect for the NPK.

Table 1. Effect of fertilization and rotation on grain maize yield (1991-2008).

Treatments	Yield response (t/ha)		Increase yield(t/ha)		Yield-increase rate (%)	
	Monoculture	Soybean-maize	Monoculture	Soybean-maize	Monoculture	Soybean-maize
CK	3.302Aa	4.494Ba	-	-	-	-
N	5.641Ab	5.866Abc	2.339	1.372	70.85	30.53
P	3.688Aa	4.849Bab	0.386	0.355	11.70	7.89
K	3.438Aa	4.493Ba	0.136	-0.001	4.12	-0.03
NP	6.569Abc	6.698Acd	3.268	2.203	98.96	49.02
NK	6.205Ab	6.529Acd	2.903	2.034	87.91	45.26
PK	3.678Aa	5.087Bab	0.377	0.593	11.40	13.19
NPK	7.482Ac	7.477Ad	4.180	2.983	126.60	66.36

Data followed by the same letter (lowercase for different treatment and uppercase for different rotation) do not differ significantly at the $P \leq 0.05$ level.

Stability analysis

On the whole, the treatments without N fertilizer differed markedly from the remaining treatments. In soybean-maize diculture the better adaptation to poor environments of CK compared to monoculture can be interpreted as the rotation effect. Since both slopes of control treatment was less than 1.0 (Table 2), yield was not responsive to a superior environment. The slopes of P, NP and NPK in soybean-maize rotation were greater than in monoculture. The highest yield in all environments was achieved in NPK treatment.

Table 2. Linear regression parameters of grain yield on the environmental mean in a long-term experiment.

Treatments	Intercept		Slope		R^2	
	Monoculture	Soybean-maize	Monoculture	Soybean-maize	Monoculture	Soybean-maize
CK	-1.456	-0.235	0.951	0.832	0.746***	0.767***
N	-0.320	-0.375	1.192	1.098	0.731***	0.794***
P	-0.529	-0.713	0.843	0.978	0.668***	0.816***
K	-1.095	-0.649	0.907	0.904	0.721***	0.837***
NP	2.348	0.701	0.844	1.055	0.598***	0.874***
NK	-0.389	-0.230	1.319	1.188	0.723***	0.852***
PK	-0.772	0.277	0.890	0.846	0.434**	0.790***
NPK	2.214	1.224	1.053	1.099	0.603***	0.800***

**Significant at $P \leq 0.01$; ***Significant at $P \leq 0.001$.

In the maize monoculture there was no difference in stability between CK and K, and the difference between CK and P under high-yield smaller than under low-yield conditions. In the soybean-maize diculture comparable with the monoculture the stability of treatments CK, P and K were similar and they also showed better adaptation to poor environment. Only the treatment N indicated a good adaptation in superior environments and its yield level was higher up to an environment mean of 5.0 t/ha and 5.7 t/ha, respectively in the monoculture and soybean-maize diculture. Yields with NP, NK and NPK treatments have improved markedly in all environments and their yield levels were higher than environment mean yield. The stability and yield of NPK was greatest in maize monoculture. However, NP and P treatments were more stable in soybean-maize rotation.

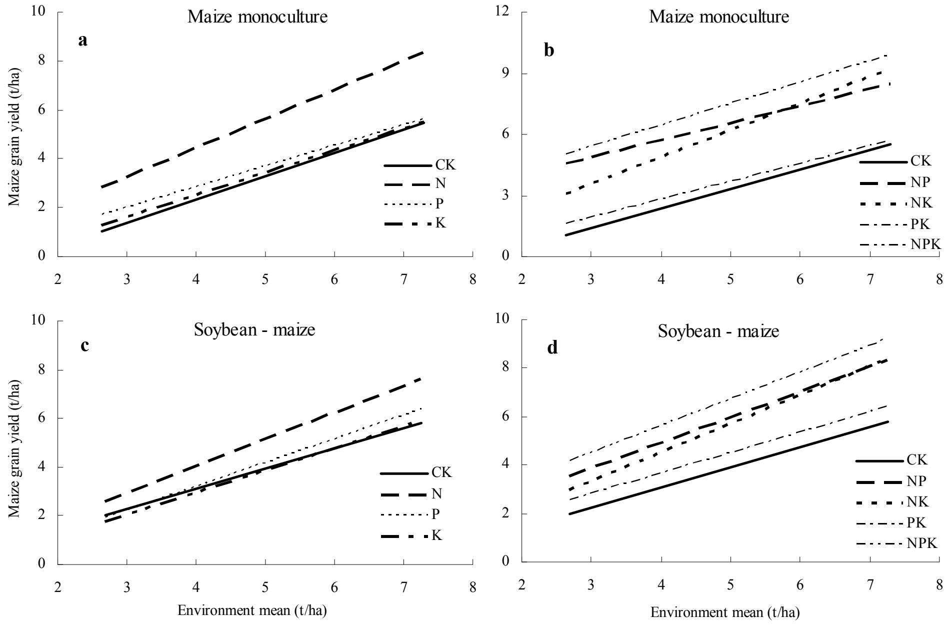

Figure 1. Stability of grain yield for different fertilization treatments according rotations vs. monoculture.

The CV % values, which evaluate the yield deviation, were the highest under PK treatment in monoculture system and under P treatment in crop rotation system. Because of the slight yield-increasing effect of P in superior environment, the yields fluctuation under P and PK were higher than in CK over the period of the experiment. The lowest CV % values were obtained under NP and NPK treatments. The CV values were practically higher in the maize monoculture than those in crop rotation. It suggested that the rotation effect can improve the stability of maize yield regardless of nutrients management. The stability variance index (σ^2) is the extent to which different treatments are responsible for the interaction. The values of stability variance index (σ^2) and ecovalence (W^2) were obtained under PK and P treatments and the smallest in NP and NPK treatments.

Table 3. Variance parameters of grain yield stability of maize (1991-2008).

Treatments	CV (%)		W^2		σ^2	
	Monoculture	Soybean-maize	Monoculture	Soybean-maize	Monoculture	Soybean-maize
CK	39.25	29.05	18.10	9.02	1.27	0.62
N	29.08	28.87	13.18	6.87	0.88	0.45
P	32.91	30.70	11.86	10.03	0.78	0.70
K	36.54	30.25	17.27	10.35	1.20	0.73
NP	19.56	23.16	7.31	5.42	0.42	0.34
NK	29.42	27.12	8.88	6.94	0.54	0.46
PK	43.21	25.72	24.60	7.66	1.78	0.51
NPK	21.33	22.61	7.70	5.24	0.45	0.32

Conclusions

Fertilizer N, P and K were used more efficiently in fully balanced than in imbalanced fertilizer treatments. The yield-stabilizing effect of crop rotation was mainly due to the residual soil fertility after soybean. Then the N-fixing effect of legume was also important for maize production. Under CK, PK, and single mineral fertilizer treatments, maize yield decreased and yield stability was poor. Balanced nutrient supply and appropriate cropping management practices were essential for the achievement of high yield and yield stability.

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Effects of rice species, germanium application method and soil texture on germanium uptake and growth of rice plants with germanium

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Abstract
The growth characteristics, Ge absorption and grain quality of rice plants were investigated for different rice cultivars, Ge application method and soil textures in order to select the optimum rice cultivars, germanium (Ge) application method and soil texture for production of functional rice with Ge. The rice yield for soil application was higher in the order of Hopyungbyeo = Junambyeo > Ilmeebyeo >> Dongjinbyeo. On the other hand, the rice yield for foliar spray was higher in the order of Junambyeo > Ilmeebyeo= Hopyungbyeo >> Dongjinbyeo. The rice yield for soil application was higher than that for foliar spray regardless of rice cultivars. For soil application, the Ge absorption in various parts of the rice was higher in the order of rice bran > brown rice > polished rice regardless of rice cultivars. The Ge absorption of brown rice in Hopyungbyeo, Ilmeebyeo, Dongjinbyeo and Junambyeo by soil application was 14.5, 8.0, 11.6 and 10.4 mg/kg, respectively. In leaf, stem and root, Ge absorption for foliar spray was higher than that for soil application, whereas, in rice bran, brown rice and polished rice, the Ge absorption for soil application was higher than that for foliar spray. The growth status of rice plant was similar in all soil textures, and rice yield was higher in the order of silt loam > clay loam > loam > sandy loam. In rice bran, the Ge uptake for silt loam, clay loam, loam and sandy loam were 980, 868, 754 and 803 μg/pot, respectively. The Ge uptake of brown rice and polish rice were greater in the order of silt loam > sandy loam > clay loam > loam. In silt loam, the Ge uptake rates of leaf, stem, root, rice bran and brown rice were 19.7, 2.3, 0.03, 3.1 and 0.44%, respectively. Therefore, the optimum rice cultivars, Ge application method and soil texture were Hopyungbyeo, soil application and silt loam, respectively, provide suitable conditions for production of functional rice with Ge.

Key Words
Germanium, rice cultivars, germanium application method, soil texture, functional rice with Ge.

Introduction
Germanium, a metal element with an atomic number of 32, is well known to be a constituent of semiconductors such as diodes. On the other hand, it is said that organic germanium shows therapeutic efficacy. Organic germanium is used mainly as a therapeutic agent and additive for health food. Organic germanium was reported as antitumor, which induces interferon, antivirus, antiathritic activity and an immunological modifier. Recently, effective organic germanium is produced by the use of microbes or algae. Objectives of this study were to investigate the effects of rice cultivars, germanium application method and soil texture on germanium uptake and growth in rice plant with germanium.

Methods
In order to obtain the optimum rice cultivars and germanium (Ge) application method for production of functional rice with Ge, the growth characteristics, Ge absorption and grain quality of rice plant were investigated under different rice cultivars (Hopyungbyeo, Junambyeo, Ilmeebyeo and Dongjinbyeo), Ge application method (soil application and foliar spray) and soil textures (clay loam, silt loam, loam and sandy loam). This study was carried out in Wagner pots. Ge concentration in soils (clay loam, silt loam, loam and sandy loam) for rice plant cultivation was at 8 mg/kg.

Results
The Ge absorption of brown rice in Hopyungbyeo, Ilmeebyeo, Dongjinbyeo and Junambyeo for soil application was 14.5, 8.0, 11.6 and 10.4 mg/kg, respectively (Table 1). In leaf, stem and root, the Ge

Table 1. Rice yield and Ge contents of brown rice for different rice cultivars.

Rice cultivars	Yield (g/pot)			Ge content (mg/kg)		
	Control	Soil Application	Foliar spray	Control	Soil Application	Foliar spray
Hopyung	11.7±0.4	9.7±0.4	6.3±0.4	0.8±0.2	14.5±1.4	14.5±1.2
Junam	11.9±0.7	9.4±1.1	8.4±0.7	0.6±0.3	8.0±1.2	11.8±2.6
Ilmee	10.3±1.5	7.9±1.0	6.6±0.7	1.1±0.3	11.6±3.2	11.8±3.6
Dongjin	11.5±0.6	8.3±1.1	8.0±1.1	0.6±0.3	10.4±2.6	12.9±2.8

Data represent mean ± SD (n = 6).

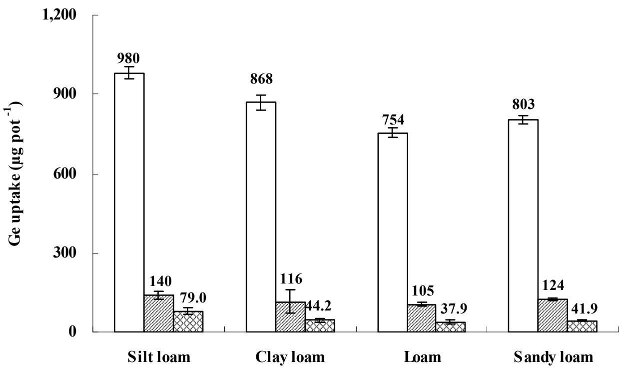

Figure 1. Ge uptake of rice grain under different soil texture. (□: Rice bran, ▩: Brown rice, ⊠: Polished rice).

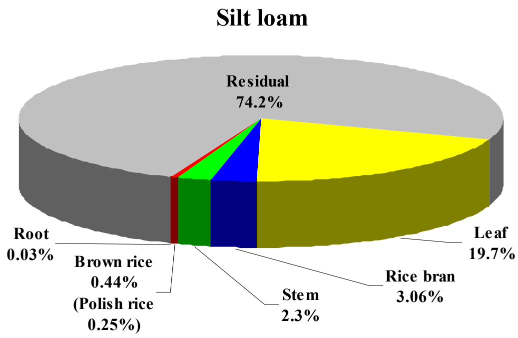

Figure 2. Ge absorption rate of rice plant in silt loam.

absorption for foliar spray was higher than that for soil application, whereas, in rice bran, brown rice and polished rice, the Ge absorption for soil application was higher than that for foliar spray. In rice bran, the Ge uptakes for silt loam, clay loam, loam and sandy loam was 980, 868, 754 and 803 μg/pot, respectively (Figure 1). The Ge uptakes of brown rice and polish rice was greater in the order of silt loam > sandy loam > clay loam > loam. In silt loam, the Ge uptake rates of leaf, stem, root, rice bran and brown rice were 19.7, 2.3, 0.03, 3.1 and 0.44%, respectively (Figure 2).

Conclusion

The optimum rice cultivars and Ge application method were demonstrated to be Hopyungbyeo and soil application, respectively, which provided suitable conditions for production of functional rice with Ge. In addition, under the given experimental condition the optimum soil texture for production of functional rice with Ge was a silt loam.

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Effects of rolling operations on cover crops termination, soil moisture, and soil strength in a Southeastern US no-till system

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Abstract
In the Southeastern US, three weeks are typically required after rolling/crimping cover crops before planting cash crops in no-till systems. To enhance cover crop termination, a supplemental application of herbicide is usually needed. However, herbicides cannot be used in organic production, thus requiring additional rolling operations, but multiple rolling operations might contribute to soil compaction, which could be detrimental for cash crop development. Our objectives were to determine the effectiveness of two roller designs in terminating rye and a mixture of rye, crimson clover, and hairy vetch in multiple rolling operations, and the effects on volumetric moisture content (VMC) and soil strength. In 2007, 2008, and 2009, two weeks after rolling, both roller designs terminated rye above 90%, which was the recommended rye termination to plant a cash crop. Rolling two or three times did not cause additional soil compaction, and rolled residue kept soil strength significantly lower compared to standing cover crops due to soil moisture conservation. Results indicated that VMC after three rolling operations was significantly higher compared with standing rye and untreated mixture. Multiple rolling can be beneficial for faster mechanical termination of cover crops but may not be adequate for mixtures that include hairy vetch.

Key Words
Cover crops, roller crimper, cone index, conservation agriculture.

Introduction
Cover crops are a key component of conservation agriculture, but they must be managed appropriately to optimize their benefits which include increased water infiltration, reduced soil erosion, runoff, and soil compaction (Revees 1994). Mechanical rollers/crimpers have been used to successfully terminate cover crops without herbicides (Derpsch *et al.* 1991) but should be used at least three weeks before planting a cash crop into rolled residue since this period is needed to prevent the cover crop from competing for soil moisture and nutrients (Hargrove and Frye 1987). Ashford and Reeves (2003) indicated that due to accelerated rye senescence rye termination rates above 90% were sufficient to plant a cash crop. To speed up cover crops termination, producers utilize herbicides to supplement rolling/crimping. However, in organic vegetable production, commercial herbicides cannot be used. Because of this restriction, several rolling applications may be required to increase termination. However, there is a concern that additional soil compaction may occur which could be detrimental to water infiltration and cash crop root development. A three year (2007-2009) field study was conducted in northern Alabama, USA, to evaluate the effects of multiple rolling/crimping events on termination of two cover crops, soil strength, and soil moisture using two rollers in a replicated field experiment. Cover crop termination rates were evaluated one, two, and three weeks after rolling. The objectives of this study were: (1) Determine the effectiveness of a roller with straight bars, and a two-stage roller in terminating a single cover crop (rye, *Secale cereale* L.) and a mixture of rye, crimson clover (*Trifolium incarnatum* L.), and hairy vetch (*Vicia villosa* L.) in one, two, and three rolling applications, (2) Determine the effect of multiple rolling on volumetric moisture content (VMC) during the cover crop termination period, and (3) Determine soil strength (Cone Index; CI) before and after application of rolling treatments.

Methods
In the spring of 2007, 2008 and 2009, replicated field experiments were conducted in Cullman, Alabama, USA, with two cover crops: rye and a mixture (rye, hairy vetch, and crimson clover) using two different rollers for termination. Rye and the mixture were drill seeded with 17 cm row spacing in October 2006, 2007 and 2008. The rolling treatments were applied 23 April 2007, 30 April 2008, when rye was in the early milk growth stage, and 13 May 2009 in the soft dough stage. These stages are desirable for rye termination (Nelson *et al.* 1995). The rye was rolled parallel to the rows of the drilled winter rye cover crop using a 1.8 m

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Figure 1. (a) Straight-bar roller; (b) Two-stage roller/crimper; (c) Tractor-mounted penetrometer.

wide straight bar roller (Figure 1a) and the two stage roller (Figure 1b). Before and after rolling application, cone index data were obtained from non-trafficked areas (two per plot) using a mobile soil cone index (CI) penetrometer (Raper *et al.* 1999; Figure 1c) with stainless steel cone tips (ASAE 2004).

Soil strength measurements were repeated after three rolling/crimping operations, to determine the effect of multiple rolling on soil strength. The experiment was a randomized complete block design (RCBD) with four blocks (replications). Randomly assigned cover crops were rolled once, twice, and three times at 6.4 km/h and scheduled every other day from the previous rolling application. Injury (visual desiccation) of the rye and mixture were estimated on a scale of 0 (no injury symptoms) to 100 (complete death) (Frans *et al.* 1986) and was evaluated at one, two, and three weeks after rolling. Volumetric moisture content was measured after the first, second, and third week using a portable TDR moisture meter with 12-cm long rods (Spectrum Technologies, Plainfield, Illinois). Rolling treatments were considered fixed effects and years were considered random effects. Analysis of variance (ANOVA) was performed on termination rates, VMC, and soil strength using SAS (2001). Treatment means were separated by the Fisher's protected LSD test at the 0.10 probability level. Where interactions between treatments and years occurred, data were presented separately; otherwise, data were combined. Also, a preplanned single degree of freedom contrast procedure was performed to detect differences (α=0.10) between two specific means (SAS 2001).

Results

a. Cover crop termination rates

Since interactions between years and treatments (with respect to cover crops termination rates) were significant ($p<0.0001$), analyses of variance were done separately for each year. Termination rates for rye and the mixture from 2007-2009 are shown in Table 1.

Table 1. Rye and mixture termination rates (%) for roller types and number of rolling operations. *Same letters indicate no significant differences within each column.

Rolling Treatment	Cover Crop	Roller type	2007, weeks after rolling			2008, weeks after rolling			2009, weeks after rolling		
			One	Two	Three	One	Two	Three	One	Two	Three
No rolled	Rye	No Roller	0.0f	39g	63cd	24e	44e	86b	75d	96ab	100a
	Mixture	No Roller	0.0f	21h	56d	21e	31e	49d	57e	81d	88c
Rolled 1 time	Rye	Straight	66e	80cd	91a	88a	90a	99a	96ab	100a	100a
		Two-Stage	68cde	83bc	91a	82a	89a	99a	97ab	99a	100a
	Mixture	Straight	68de	46fg	71bc	57cd	57d	60c	76d	87cd	92bc
		Two-Stage	69cde	46fg	71bc	54d	57d	61c	84c	86cd	91bc
Rolled 2 times	Rye	Straight	79ab	88abc	90a	82a	94a	100a	96ab	99a	100a
		Two-Stage	74bcd	86abc	93a	89a	95a	100a	98a	100a	100a
	Mixture	Straight	68de	53f	77b	62bcd	69b	67c	87c	89bc	96ab
		Two-Stage	75abc	64e	71bc	65b	66bc	67c	90c	89bc	94bc
Rolled 3 times	Rye	Straight	81a	90ab	94a	88a	95a	100a	98a	100a	100a
		Two-Stage	81a	91a	93a	85a	94a	100a	97ab	100a	100a
	Mixture	Straight	78ab	64e	71bc	64cd	69b	69c	95ab	96ab	96ab
		Two-Stage	78ab	73d	71bc	63bcd	66bc	67c	96ab	96ab	97ab
LSD at **α** = 0.1			6.8	8.6	8.4	8.4	9.2	10.2	7.1	7.7	6.2

In 2007, one week after rolling, significantly higher termination rates were reported for cover crops (rye and mixture) rolled three times compared to plots that were rolled once or non-rolled. Two weeks after rolling, lower termination rates were reported for the mixture compared to rye. The main reason for lower rates was a recovery and new active growth of hairy vetch that altered termination rates for the mixture. Three weeks after rolling, no significant differences in termination rates (90% and above) were reported among roller types and number of rolling events. Compared to rolled residue, non-rolled covers showed significantly lower termination rates (51% to 63%). It should be noted that, two weeks after rolling rye three times by each roller type, rye termination rates were high enough (90% and above) to successfully establish a cash crop into the rye residue (Ashford and Reeves 2003). One, two, and three weeks after rolling, significantly higher termination rates were reported in 2008 for rolled residue both for rye and the mixture compared with untreated checks (Table 1). During the same period, no difference was found between the two roller designs. Two weeks after rolling, the mixture showed significant differences in termination rates between one rolling application (57%) and three applications (69%). No differences were found between these treatments at one and three weeks after rolling. In contrast to the 2007 growing season, termination rates three weeks after rolling for the mixture were lower. The reason for lower mixture termination rates were most likely that the hairy vetch in the mixture was able to recover and actively grow during the intervening weeks. In the spring of 2008, volumetric moisture content was significantly higher than in 2007. This growth was also triggered by the fact that rye and crimson clover in the mixture were effectively killed by the third week after rolling and did not compete for nutrients and moisture, allowing the hairy vetch to recover. In 2009, because of substantial rainfall in the spring, rolling was done two weeks later than in 2008 which accelerated rye growth to soft dough stage. Since rye is more susceptible to termination at this stage, termination rates were higher one week after rolling compared to 2007 and 2008. One week after rolling all rolled treatments had higher termination rates compared to untreated checks. One and two weeks after rolling, higher termination for the mixture was found for rolling three times versus rolling once.

b. Volumetric Moisture Content (VMC)

VMC was measured on the day of rolling operation, one, two and three weeks after rolling. Comparing the three years of study, there was a significant difference in VMC among three growing seasons ($p<0.0001$).

Table 2. Mean VMC (%) for untreated rye and mixture and rolled residue during three growing seasons.

Year	2007			2008			2009		
Time after rolling	Week 1	Week 2	Week 3	Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
Untreated Rye	13.8	4.8	2.1	22.6	16.7	20.9	17.6	22.8	17
Untreated mixture	13.8	4	2.3	22.7	18.4	19.9	18.1	23.2	17.5
Rolled Residue	14.4 ÷18.3	5.3 ÷8.1	2.8 ÷4.0	23.0 ÷24.8	19.1 ÷21.7	19.6 ÷ 22	21.4 ÷24.6	23.5 ÷ 25.9	20.8 ÷ 23.5

In 2007, a severe drought caused a major deficit of soil water. During the three weeks of evaluation after rolling in 2007, rainfall at the Cullman, AL, location was only 40 mm compared to 181 mm in 2008 and 214 mm in 2009. Average VMC measured over the three week period was 9.8% in 2007 compared to 22.7% in 2008 and 24.4% in 2009. In 2007 and 2008, no differences in VMC were found among treatments except for two weeks after rolling (Table 2). For untreated checks, VMC was lower (4.8% for rye and 4% for the mixture) compared to the rolled treatments (between 5.3 and 8.1%). This probably because of two factors: the untreated checks were actively growing, and the standing vegetation allowed more evaporation than the rolled plots. The lower VMC for the mixture compared to rye was most likely because the hairy vetch recovered from rolling and used available soil moisture (data not presented). Reeves (1994) reported that in several studies in the U.S., hairy vetch cover depleted soil moisture and delayed planting of cash crops. Due to drought in 2007, three weeks after rolling VMC decreased further (2.1% to 4%) and there were no differences in VMC among all treatments. In spring of 2008, one week after rolling, VMC was higher than in 2007 due to preceding rainfall (22.6% and 24.8%), and there were no differences in VMC among all treatments. Two weeks after rolling, VMC was higher for rolled residue (19.1 to 21.7%) compared to untreated checks (16.7% for rye and 18.4% for the mixture). Three weeks after rolling no differences in VMC were found among treatments (19.6 to 22%). In 2009, substantial rainfall during the evaluation period kept VMC high: after the first week VMC for checks was 17.6% for rye and 18.1% for mixture and 21.4 to 24.6% for rolled treatments. Similar VMC was measured in the second and the third week after rolling. Overall, the rolled residue protected the soil from moisture loss by creating a mulch effect; standing residue actively used moisture due to rye and mixture growth and allowed higher evaporation from exposed soil. The rolling helped to preserve VMC which is critical in drought periods such as in 2007 for successful cash crop establishment.

c. Soil Cone Index (CI)

In 2007, average CI value for the top layer (0-15 cm) for the untreated rye and mixture was 7.1 MPa and was significantly higher than for CI observed for rolled covers (4.15 MPa). CI for untreated checks were significantly higher compared to covers rolled once, twice and three times (P=0.0008 to 0.0002, probability table not presented). The higher CI found with untreated checks is most likely associated with decreased soil water content due to reduced surface cover of standing cover crops and evapotranspiration during the drought in spring of 2007. The CI for untreated checks exceeded (3 times) the 2.0 MPa recommendation for unrestricted root growth in cotton (Taylor and Gardner 1963).

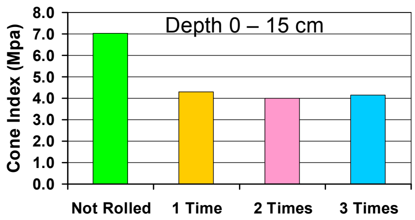

Figure 2a. 2007 CI after rolling

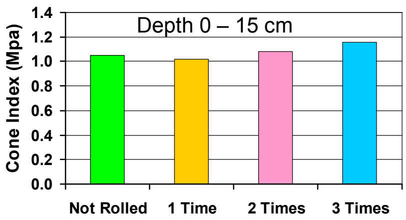

Figure 2b. 2008 CI after rolling

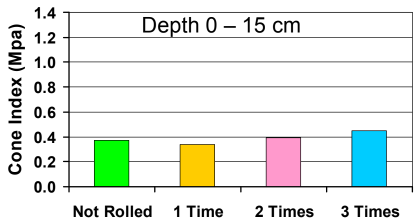

Figure 2c. 2009 CI after rolling

In 2008, after rolling treatment applications, no differences in CI (from 1.02MPa to 1.15MPa) existed at the top layer across all treatments including checks (Figure 2b). Corresponding probabilities were from 0.145 to 0.798. In 2009, the Cullman location received unusually high rainfall (214 mm) which caused delays in cover crop termination. During wet soil conditions, significantly higher CI were obtained from rolling 3 times versus untreated covers (P=0.016), rolling once (P=0.0002), and twice (P=0.0452), although these differences were very small. Despite these differences, CI was very low (0.34 to 0.42 MPa) and was related to the soil high moisture content.

Conclusion

During three growing seasons, rolling two or three times did not cause additional soil compaction, and rolled residue kept soil strength (Cone Index) significantly lower compared to standing cover crops due to cover crop termination and moisture conservation. VMC after three rolling operations was significantly higher compared with standing rye and mixture. Multiple rolling can be beneficial for faster mechanical termination of cover crops but may not be adequate for mixtures that include hairy vetch.

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Effects of soil management on changes of soil carbon content in alluvial paddy soil in Niigata

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Abstract
Effects of soil management on carbon content in alluvial paddy were investigated using past soil survey data of Niigata prefecture, Japan. The changes of soil management were as follows; (1) slight decrease in nitrogen and phosphate fertilizer application rates, (2) decrease to half in the application of soil amendments, like calcium silicate, (3) decrease in compost application and increase in rice straw application, (4) increase in pipe drainage. In spite of these changes, negligible change of carbon content in the plow-layer of alluvial paddy soils had been observed for past twenty-five years. However, without rice straw application and paddy-upland rotations, the soil carbon content had been decreased. Carbon content of alluvial paddy soils classified into Gley Lowland soil (Fluvisol or Gleysol) at the depth of 0-30 cm was calculated about 49-103 g/kg and gross carbon sequestration was calculated 7.68 Mt in the paddy field soils in Niigata prefecture.

Key Words
Carbon sequestration, soil survey, alluvial paddy, soil management.

Introduction
Pedscape stocks a large amount of soil carbon. The amount of global carbon stock is estimated at 1,200-1,600Gt, which is more than that of vegetation biomass (Paustian *et al.* 1997). Therefore, changes of soil carbon contents may affect global climate change, through the changes in CO_2 concentrations in the air. Improvement of agronomic practices for carbon sequestration in the agricultural soils is very important for the mitigation of climate change (IPCC 2007). It is well known that soil carbon content in agricultural land was affected by soil managements such as the application of organic matter and plowing, etc. For example, application of fermented compost, no-tilled cropping, cover crop and multiple cropping, etc. add carbon to soils (Paustian *et al.*1997; Franzluebbers 2005; Reicosky *et al.*1997). The purpose of this study is to clarify the effects of soil management on changes of carbon content in the alluvial paddy soils, which had been used for paddy rice production a major grain in monsoon-Asia, or paddy rice-upland crop rotations, using the past soil survey data in Niigata Prefecture.

Methods
In Japan, the national soil information database was developed with the obtained data from Soil Survey for Maintenance of Farmland Fertility, and Fundamental conducted by the Ministry of Agriculture, Forestry and Fisheries (MAFF). We used the data of Soil-Environment Monitoring Project (Stationary Monitoring) in Niigata prefecture carried out in every 5 years for 25 years (1979-2004). Niigata prefecture is a major rice production area located in the middle of Japan. About 90 % of arable land is paddy field and 70% of paddy fields is the alluvial paddy, which is classified Gray Lowland soil and Gley Lowland soil, mainly (Figures 1, 2). The both soils were classified into Fluvisol or Gleysol by FAO *et al.* (1998). To clarify the effect of soil management on changes of soil carbon content, data of alluvial paddy soils (total number of data was 1,418 and classified as following, Gley Lowland soil: 1,122, Gray lowland soil: 259, Brown Lowland soil: 37) were selected from above survey. Many paddies have pipe-drainage and drain canal, thus a good drainage paddy has been rotated upland and was used for upland crop like soybean and some vegetables frequently. The effects of soil management, such as the application of fertilizer, soil amendments and organic matter in several soil types, on changes of soil psycho-chemical properties (mainly in top soil) were examined with interviewing farmers.

Results
Changes of soil management
The changes of paddy soil management in twenty years were shown in Table 1. The amount of nitrogen and phosphate fertilizer applied had been decreased slightly, for a production of good-taste rice grain. The

amount of soil amendments, such as calcium silicate, was decreased to half, for cutting production cost and reducing labor, while phosphate materials were increased for enhancing soil fertility. In contrast, the ratio of compost application was reduced and the ratio of rice straw application was increased markedly. Thus, it was considered that the measures for enhancing soil fertility had been changed from compost, which is getting hardly and need much cost, to rice straw. The ratio of pipe drainage was increased markedly for efficient machinery work and avoiding wet injury.

Actual conditions of soil carbon content

Figure 3 showed that the changes of soil carbon content of plow-layer in alluvial paddy fields for twenty five years (1979-2004). There was a dispersion widely in Brown Lowland soils due to a little sample number. The rough carbon content of several soil types was as follows: 30 g/kg for Gley Lowland soils, 20 g/kg for Gray Lowland soils, a little less than 20 g/kg for Brown Lowland soils. Although the soil management, such as manure and compost applications and pipe drainage, in this survey period had been changed, no changes of soil carbon content had been observed statically. Generally, pipe drainage forced to lower of groundwater level in paddy field. Therefore, especially Gley Lowland soil changes into Gray Lowland soil with the reduce of soil carbon gradually. It is considered that one of the reasons for no-change of soil carbon content in the past survey is the effect of the rice straw application, which avoids the soil carbon decrease in well-drained paddy fields. The soil carbon content in several layers in Gray Lowland soils and Gley Lowland soils had been shown in Figure 4. The carbon content in Gray Lowland soil was lower than that of Gley Lowland soil, and was lower toward subsoil, while a little decrease of carbon content of subsoil had been observed in Gley Lowland soils. It is recognized that the carbon content of surface horizon in arable land is high, because of accumulation of organic matter and root residues. Some Gley Lowland fields, however, had been included the peat in subsoil; therefore, a large amount of carbon is sequestered in subsoil than Gray Lowland field. Thus, the carbon content of subsoil should be more decreased than the surface horizon by the convert from poor-drained to well-drained in Gley Lowland soils using pipe drain.

Effect of soil managements on changes of soil carbon content

Table 2 showed the effect of paddy-upland rotation on changes of soil carbon content in several soil types. The history of paddy-upland rotation was classified as follows: rotation which had experienced irrigated paddy rice and upland crop rotation in past five years, no-rotation, which had not been converted into upland at all in past five years. Carbon content in Brown Lowland soils and Gley Lowland soils were lower than that of no rotational cropping significantly. The decrease in carbon content was observed in Gray Lowland soils. Therefore, the paddy-upland rotations might provoke decreasing carbon content in paddy soil.

The effect of rice straw application had been examined by comparison of carbon content recorded in first survey (1979-1982) and in forth one (1994-1997) (Table 3). The carbon content in Gray Lowland soils and Gley Lowland soils were observed to decrease without application of rice straw. While, carbon content of plow layer was the same or increased by rice straw application.

Sumida *et al.* (2005) had reported that the total carbon content in soils was on the same level or increasing by continuous irrigated paddy rice without application of rice straw and were increasing conspicuously with application of rice straw, while the carbon content in soils rotated paddy and upland were markedly lower than that in the continuous paddy field in field experience. The same phenomenon was observed in this study using the data of Soil-Environment Monitoring Project (Stationary Monitoring). Thus, it was suggested that rice straw application and continuous irrigated paddy rice in alluvial paddy fields was the important management for mitigation of the depletion of soil carbon content.

Trial's calculation of carbon content in Gley Lowland soils

Carbon sequestration of Gley Lowland soils, which was 70 % of paddy fields in Niigata prefecture, had been calculated using area classified several soil types of Soil Survey for Maintenance of Farmland Fertility. Carbon content was calculated using carbon concentration in several layers, bulk density and layer depth, which contained in the data of Soil-Environment Monitoring Project (Stationary Monitoring). These soil surveys had been conducted by the Ministry of Agriculture, Forestry and Fisheries (MAFF). As a result, carbon content of Gley Lowland soils to a depth of 30 cm was calculated about 49-103 t/ha and gross carbon sequestration was calculated 7.68 Mt in Niigata prefecture (Table 4). Moreover, it was recognized that fine texture and poorly drained soil such as Strong Gley Lowland had much carbon.

Batjes (1996) had reported that the carbon content at a depth of 0-30 cm was as follows; 42 t/ha for Eutric Fluvisol, 58 t/ha for Eutric Gleysol. The same results had been recognized in this study generally.

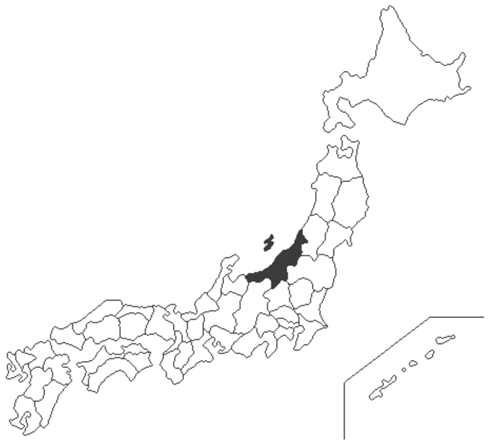

Figure 1. Place of Niggata pref.

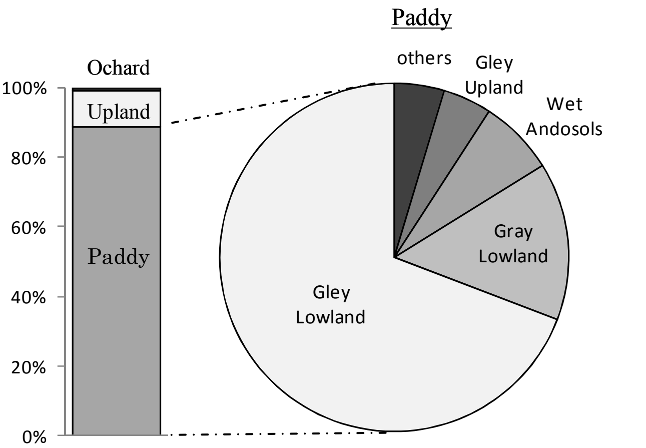

Figure 2. Ratio of arable land area in Niigata pref. *
*Fundamental Soil Survey for Soil Fertility Conservation
Total arable land area :171288 ha

Table 1. Change of Soil management in paddy field.

Item	1st survey (a)※2	4th survey (b)※2	b/a
(Fertilizer application)	(kg ha^{-1})		
N	74	70	0.95
P_2O_5	85	80	0.94
K_2O	88	89	1.01
(Soil amendments)	(kg ha^{-1})		
P_2O_5	37	45	1.21
CaO	448	221	0.49
SiO_2	256	120	0.47
(Ratio of area)	(%)		
Rice straw application	34.4	91.9	2.67
Compost application	20.6	4.5	0.22
Pipe drainage	11.3	33.6	2.97

※1 Quotation from " Agriculture in Niigata prefecture"
※2 Basic Soil - Environment Monitoring Project、1st(1980)，4th(2000)

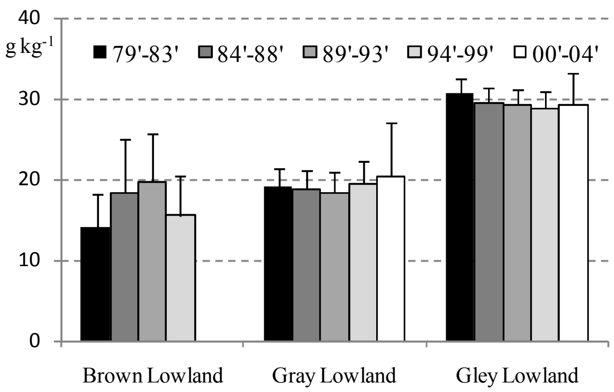

Figure 3. Changes of carbon content of several soil type.

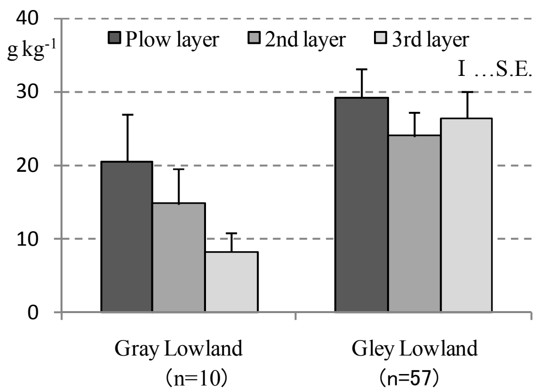

Figure 4. Carbon content of several layers.

Table 2. Effect of paddy-upland rotation in past 5 years on carbon content of plow layer in several soil types.

Histroy	Soil type		
	Brown Lowland	Gray Lowland	Gley Lowland
		(g kg^{-1})	
No-rotation	24.2 (22)***	19.5 (219)	29.9 (1013)
Rotation	11.5 (17)	18.1 (40)	26.7 (109)
t-test**	**	n.s.	**

*Basic Soil - Environment Monitoring Project

**Significantly different at p <0.01

***Number of survey sites

Table 3. Effect of rice straw application on changes of carbon content of plow layer.

	Gray Lowland		Gley Lowland	
	no-application	application	no-application	application
		(g kg^{-1})		
1st survey (1979-1982)	18.4	18.8	31.0	30.4
4th survey (1994-1997)	17.4	21.0	28.1	30.3
4th / 1st	0.95	1.12	0.91	1.00

Table 4. Carbon content within 30 com depth of Gley lowland soils in Niigata pref.

Soil type* / Texture	Strong gleyed soil			Gleyed soil			Total
	Fine(25)	Medium(3)	Skeletal(3)	Fine(13)	Medium(2)	Thapto-humic(3)	
Carbon content** (t ha^{-1})	73.5	72.5	62.3	54.8	49.3	103.2	
Area*** (×1000ha)	60.1	17.1	5.1	9.8	3.6	9.6	105
Carbon sequestration (Mt)	4.42	1.24	0.32	0.53	0.18	0.99	7.68

* Classification of Cultivated Soil in Japan Second Approximation (1977)

* Carbon content calculated in 30 cm depth using the data of Soil-Environment Monitoring Project (Stationary Monitoring)

** Quotation from results of "Soil Survey for Maintenance of Farmland Fertility"

Conclusion

Changes of soil carbon content were not observed in the alluvial paddy soils in Niigata using past soil survey data. However, decrease of carbon was observed with no-rice straw application and paddy-upland crop rotation. Additionally, it is not to be denied that carbon content might be decreased by a pipe drainage and repeated paddy-upland rotation. To increase of soil carbon sequestration, rice straw application is necessary and suitable times of paddy-upland rotation should be required for keeping soil carbon sequestration in several soil types.

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Effects of soil sodicity on the germination, growth and productivity of Soybean (*Glycine max*)

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Abstract

Considering soybean potential for the inland irrigation and coastal areas where occurrence of surface and/or sub-surface soil sodicity impairs agricultural productivity, investigations were conducted on the two commercial paddocks in 1995/96 and 1996/97. Fifty plots of 3 m^2 size were marked at random locations based on their pre-determined surface (0-15 cm) soil exchangeable sodium percentage (ESP) variations (1.2-27.8). Composite samples were collected from each plot before sowing and after harvest of soybean for soil analysis. Experimental data showed significant reduction and delay in emergence of soybean seedlings due to increasing surface soil ESP. Soybean germination was comparatively less sensitive to soil ESP than its growth and yield. Surface soil ESP of 12.1 and 13.3 were found effective in reducing soybean yield to half whereas 50 per cent reduction in emergence of soybean seedlings occurred at ESP of 18 or more. Sub-soil ESP did not show high correlation with soybean growth and yield. Soybean grain yields had shown highly significant negative relationship with the surface soil ESP, with r^2 values of 0.979 and 0.989 in 1995/96 and 1996/97 respectively. Surface and sub-surface soil ESP were observed to reduce water infiltration rates and saturated hydraulic conductivity whereas clay dispersion and mechanical impedance of soil were found to increase with increasing ESP of the soils.

Key Words

Crop establishment, growth, crop yield, exchangeable sodium percentage, clay dispersion, infiltration.

Introduction

Prevalence of surface and sub-surface soil sodicity in irrigation areas of NSW is reported (Loveday 1974; McKenzie *et al.* 1993) to be an important constraint that reduces crop productivity as well as the productive performance of agricultural inputs and resources. Intensity of sodicity problems is generally quantified by measuring exchangeable sodium percentage (ESP) and relevant soil properties (Sumner 1993). Adverse effects of sodicity on crop growth mainly results in from the breakdown of soil structure through dispersion of aggregated particles (Loveday 1984; Rengasamy *et al.* 1991). Dispersive behavior of soils results in poor water use efficiency, reduced plant emergence and crop yields by promoting surface sealing, crusting and increasing mechanical impedance to plant roots (Abrol and Painuli 1986; Abrol *et al.* 1988; So and Aylmore 1993). Movement of air and water into the root zone is also reduced significantly. Plants, sometimes, face aeration stress due to prolonged water logging or impeded infiltration of irrigation and/or rain water.

Soybean crop holds considerable promise and potential for diversification of Australian farming systems of the inland irrigation areas and rain-fed coastal regions where surface and/or subsoil sodicity do occur commonly. Available information on response of soybean to sodicity in Australian soils under different climatic conditions is limited. Therefore, field investigations were carried out on the two commercial paddocks with spatial variations in surface and sub-surface soil sodicity.

Methods

Effects of the surface and sub-surface soil sodicity on establishment, growth and productivity of soybean were evaluated by investigations on the two commercial paddocks in 1995/96 and 1996/97. Irrigated lucerne (for hay) was grown on these paddocks during 1992-1995. High levels of variations in its patchy growth and establishment accompanied by morphological differences (crusting, water logging, seals, and poor water infiltration) in the surface soil were typical of sodicity effects. An intensive soil study was conducted on these paddocks previously. Experimental results from that study on important soil properties and apparent electrical conductivities (E_a) measured with EM-38 were used to utilize natural heterogeneity in surface and sub-surface sodicity rather than creating plots of variable sodicity by treating a sodic soil with variable amounts of gypsum.

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To accomplish this study, 50 observation plots of 3 m^2 in size were marked in each of the two commercial grey soil (Grey Vertisol) paddocks at locations determined previously based on ESP variations. Composite soil samples were collected from each plot before the sowing and after the harvest of soybean (variety *Benjalong*). After their processing, these were analyzed for important soil properties and their variation range for different soil depths is shown in Table 1. Variation in each of these soil properties was more in the surface (0-15 cm) layer and it decreased with the depth.

Table 1. Variation ranges of important soil properties for different soil layers of the two paddocks.

Soil depth (cm)	$pH_{1:5}$ (H_2O)	$pH_{1:5}$ (0.01 M $CaCl_2$)	$EC_{1:5}$ (dS/m)	SOC (g/kg)	ESP	$CEC_{(+)}$ (cmol/kg)	Textural class
0-15	6.52-7.62	6.06-7.12	0.15-0.30	1.12-1.26	1.2-27.8	22.3-29.3	Clay loam
15-30	7.15-7.82	6.65-7.45	0.16-0.34	0.82-0.94	5.4-28.3	24.4-30.2	Silty clay
30-45	7.72-8.18	7.35-7.69	0.25-0.32	0.62-0.72	10.8-29.2	24.6-30.8	Clay
45-60	8.02-8.54	7.82-8.32	0.32-0.45	0.48-0.57	14.8-28.4	28.4-31.2	Clay
60-90	8.40-8.62	8.02-8.35	0.38-0.56	0.46-0.54	17.9-28.9	30.4-31.8	Clay
90-120	8.48-8.65	8.16-8.38	0.36-0.58	0.48-0.58	21.8-30.2	29.7-33.2	Clay

Establishment (germination) of soybean was assessed by recording emergence of plants on a 3 m^2 area of each plot daily for 20 days after sowing. Relative growth was evaluated by measuring dry biomass and leaf area index (LAI) at three growth stages (after 40, 70, and 100 days of sowing). At maturity, 2 m^2 area of each plot was harvested for determining grain and stubble yields. Plant and grain samples were also analyzed for their chemical composition. Selected agronomic parameters such as mass/100 seeds and pods/plant were also recorded for each plot during both the years. Soybean crop was commercially grown on flat (unlike the most preferred bed) layout under uniform agronomic management including the flood irrigation practices.

Infiltration rate of soil in each plot was measured after harvest of soybean crop for both the years. Bulk samples of surface (0-15 cm) soil were collected from all the plots before sowing soybean crop. After their air drying, these were grinded and sieved through a 2 mm sieve before using for laboratory measurements on hydraulic conductivity, clay dispersion, texture, EC, pH, exchangeable cations, CEC and SOC following standard methods (Rayment and Higginson 1992, Anderson and Ingram 1993). Statistical significance of data was tested following analysis of variance.

Results

Field observations showed significant effects of soil sodicity on germination (Figure 1). Per cent emergence of soybean was not only reduced but also delayed significantly with an increasing ESP of the soil. The soil ESP of 6 or less showed an average maximum 92 per cent emergence after 10 days of sowing. But it took 14, 16, 17, and 18 days for the mean maximum emergence of 82, 70, 50, and 30 in plots with ESP of 6-12, 12-18, 18-24, and ≥ 24, respectively. Soil sodicity was observed to inhibit early growth and vigor of seedlings. Data on biomass accumulation at 40, 70 and 100 days of sowing did indicate consistent effects of sodicity with almost linear decrease in growth. Irrigation was noticed to exacerbate impact of soil sodicity through surface crusting and prolonged flooding of surface soil.

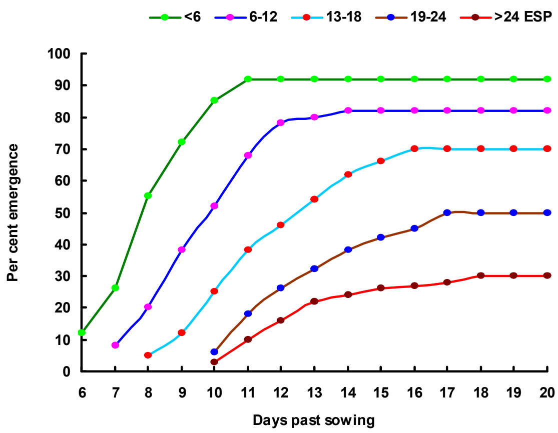

Figure 1. Effect of different soil ESP categories on the changes in average emergence of soybean seedlings during the 20 days past its sowing

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Data on grain yield of soybean (Figure 2) illustrated adverse effects of surface soil ESP in both the years. In both years, surface soil (0-15 cm) ESP of 12.1 and 13.3 was found to cause grain yield reduction by 50 per cent. Highly significant relationships of grain yield with the dry biomass produced at 40, 70 and 100 days of sowing illustrated similarity in sodicity effects during growth periods of soybean in 1995/96 and 1996/97.

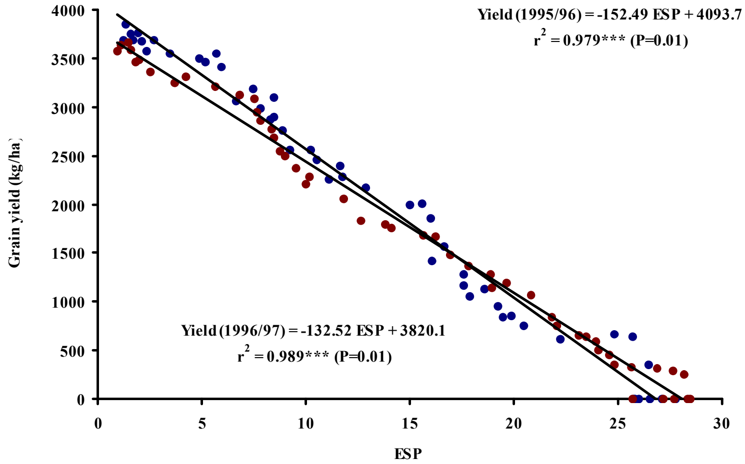

Figure 2. Relationships of ESP with grain yield of soybean crop grown in 1995/96 (blue) and 1996/97 (brown) on the two different paddocks

Soybean grain yield and ESP of 15-30 and 30- 45cm soil layers were also statistically highly significant. The ESP of soil layers beyond 45 cm depth did not show significant relationships with grain yield, indicating greater significance of surface than sub-surface soil sodicity for its adverse effects.

Experimental results of additional investigations in glasshouse indicate that germination of soybean is comparatively less sensitive to soil sodicity (ESP ~12) provided the maintenance of optimum moisture in the soil. Some plots with fairly high ESP (16-18) showed 75-90 per cent emergence. But growth of seedlings in those plots showed decline and significant mortality after post sowing irrigations and rain. This was mainly due to the dispersion induced sealing, crusting and water logging on sodic areas (Sumner 1993).

Field measurements of infiltration rates and penetration resistances of the surface (0-15 cm) soil (Table 2) provided sound support for explaining agronomic data on germination, growth and yield of soybean. Despite high variability, average penetration resistance (0.78 MPa) of non-sodic (ESP<6) was measured to increase by more than five times (4.26 MPa) in plots with ESP of ≥ 24. Average resistance values for plots with ESP of 6-12, 13-18 and 19-24 were 1.48, 2.95 and 3.84 MPa respectively. This was found associated with the impact of sodicity on reducing the amount of moisture in the soil, probably due to more evaporative losses from sodic surface soils.

Influence of surface soil sodicity did also show universally recognized adverse effect on water infiltration rate, a sharp decrease in average water intake rate of 16.26 mm/hr in non-sodic (ESP<6) plots to 6.84, 2.56, 1.65, and 0.84 mm/hr in plots of 6-12, 13-18, 19-24, and ≥ 24 respectively. Effects of rain and very low EC (0.115 dS/m) of available water for irrigation may have accelerated leaching of the surface soil. The irrigation water itself used to be highly turbid most times. Reduction in electrolytic concentration of irrigation water and/or soil solution is reported (Abrol *et al.* 1988, Rengasamy *et al.* 1991, Sumner 1993) to enhance adverse effects (surface sealing, crusting, oxygen diffusion rates, mechanical impedance, and infiltration rate) of sodicity or ESP by inducing clay dispersion.

Table 2. Averages of important soil physical properties in plots of different ESP categories. (Means with different letters are significantly different at P=0.05).

Soil property	Surface soil (0-15 cm) ESP				
	< 6	6-12	13-18	19-24	>24
Hydraulic conductivity[A] (cm/h)	1.56a	0.65b	0.28c	0.08d	0.06d
Dispersible clay[A] (per cent)	12.85a	34.85b	65.86c	74.62d	86.97e
Penetration resistance[B] (MPa)	0.78a	1.48b	2.95c	3.84d	4.26e
Infiltration rate[B] (mm/h)	16.26a	6.84b	2.56c	1.65d	0.84e

[A] and [B] denote measurements made on disturbed samples in the laboratory and *in situ* on undisturbed soil respectively.

The differences in saturated hydraulic conductivity and dispersible clay as measured in laboratory indicated the trends and their magnitudes similar to field measurements on penetration resistance and infiltration rate (Table 2) of water. A strong interaction between surface soil ESP and total electrolyte concentration, as measured by EC of the soil samples, was highly significant. This relationship was observed to weaken with soil depth. This may be due to the role of soil cementing agents other than electrolytic concentration.

Conclusion

Based on experimental results of these investigations, following conclusions can be made;

1. Variation in surface (0-15 cm) soil ESP affects establishment of soybean significantly. An increase in soil ESP was found effective in reducing and delaying the emergence of soybean seedlings.
2. Germination of soybean appeared relatively less sensitive to an increase in ESP than its adverse effect on the growth and productivity of soybean.
3. The surface soil (0-15 cm) ESP of 12.1 and 13.3 were found to reduce soybean yield by 50 per cent. Relationship between sub-surface soil ESP to soybean growth and productivity was not prominent.
4. Grain yields of soybean showed highly significant (P=0.01) negative relationships with the surface soil ESP in 1995/96 (r^2 = 0.979) and 1996/97 (r^2 = 0.989).
5. Surface and sub-surface soil ESP were observed to reduce water infiltration rates and saturated hydraulic conductivity and increase clay dispersion as well as mechanical dispersion of surface soil.

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Effects of stock type on soil physical properties and losses of phosphorus and suspended sediment in surface runoff

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Abstract
By altering soil physical properties and dung deposition, livestock grazing can enhance the loss of phosphorus (P) and suspended sediment (SS) in surface runoff which can impair the quality of receiving water bodies. The impact of cattle, deer, and sheep on surface (0-5 cm) soil physical properties and P and SS losses in surface runoff was investigated. No significant difference was found between stock type and P and SS losses. However, significant differences were evident for the interaction of stock type with soil physical properties (bulk density, macroporosity, and saturated hydraulic conductivity-K_{sat}). Furthermore, a gamma log generalised linear model detected a significant relationship between macroporosity, K_{sat} or time (days) since grazing and certain concentrations and loads of P fractions and SS losses, whereby more pore space, a greater infiltration rate or time since the paddock was last grazed decreased losses. This suggests that soil physical measurements may have the potential to aid management to decrease P and SS losses in surface runoff.

Key Words
Treading, rainfall, dissolved phosphorus, particulate phosphorus, concentrations and loads.

Introduction
Livestock treading can have detrimental impacts on soil physical properties and promote the loss of non-point source pollutants such as phosphorus (P) and suspended sediment (SS) in surface runoff (McDowell *et al.* 2003a). Although cattle have been reported to have greater influence on soil surfaces than that of sheep from a soil physical condition and pasture production (Drewry 2006), little work has examined the impacts of livestock other than cattle on contaminant losses in surface runoff (McDowell *et al.* 2003a; McDowell *et al.* 2003b; Nguyen *et al.* 1998). McDowell and Wilcock (2008) reported that mean loads of P were similar from catchments grazed by deer or mixed stock (sheep and beef) to those grazed by dairy cattle, whereas loads of sediment were greatest for deer followed by mixed stock and dairy cattle. The current study looks at the impact beef cattle, sheep and deer grazing on soil physical properties and losses of P and SS in surface runoff from a soil known to be structurally vulnerable to treading damage, a Pallic silt loam.

Materials and methods
The trial was located at the AgResearch Invermay sheep, beef, and deer farm, near Mosgiel, New Zealand. The soil at the site was a Pallic silt loam (Fragic Pallic according to the NZ soil classification, or a Fragiochrept in US soil taxonomy; (Hewitt 1998). Two paddocks grazed by sheep and beef cattle and one adjacent paddock, grazed by deer, were chosen for study. Within each sheep and beef paddock areas 20 x 20 m were fenced off for one of the following three treatments: cattle, sheep, and control (nil grazing). Each treatment was replicated twice. Within each 20 x 20 m grazing zone a pair of sub plots were installed. Sub plots, 4 m long and 1 m wide, were bounded by wooden boards 150 mm wide by 25 mm thick. At the downslope end an open ended metal gutter was fitted which directed all surface runoff into a 50 L container placed below the height of the gutter and connected via an underground hose. Within the deer paddock, the control area was fenced off which contained a pair of subplots. However, due to the problem of containing deer within small enclosures, 2 sets of paired subplots were further installed in the remainder of the paddock and deer allowed to roam freely. Pasture was cut and carried off each control area when necessary.

Each stock class was rotationally grazed in accordance with feed supply and generally on the same day or within a few days of one another. After grazing, soil cores (3) were taken for macroporosity, bulk density and saturated hydraulic conductivity (K_{sat}) analysis. After each rainfall event, any surface runoff was collected, the volume noted, and analysed for dissolved reactive P (DRP), dissolved unreactive P (DURP), total dissolved P (TDP), particulate P (PP), total P (TP) and SS.

Results

Paddocks were grazed seven times between August 2008 and July 2009. Surface runoff was produced within a few days of these grazing events, and there were forty three runoff events in total, mostly in winter (Figure 1). No significant differences were found between mean concentrations and loads of P and SS lost according to stock type (data not shown). However, the effect of stock type was significant (P <0.001) for bulk density, K_{sat}, and macroporosity (Figure 2). Overall mean macroporosity was least for the cattle treatment and greatest for the cattle/sheep control. Saturated hydraulic conductivity followed a similar pattern with the slowest rates occurring in the cattle treatment and fastest rates in the cattle/sheep control (data not shown).

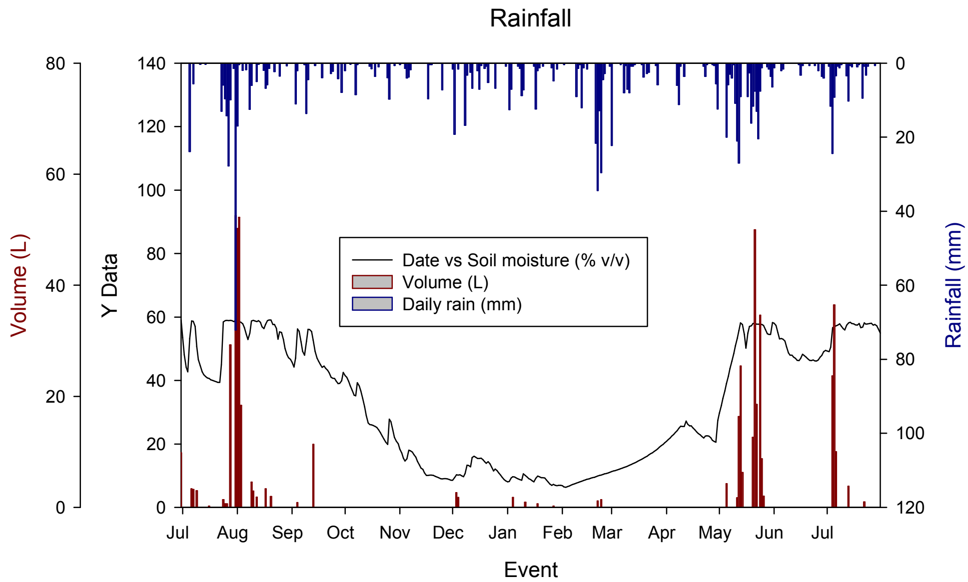

Figure 1. Interaction of rainfall and soil moisture on the mean volume (L) of surface runoff produced for all plots

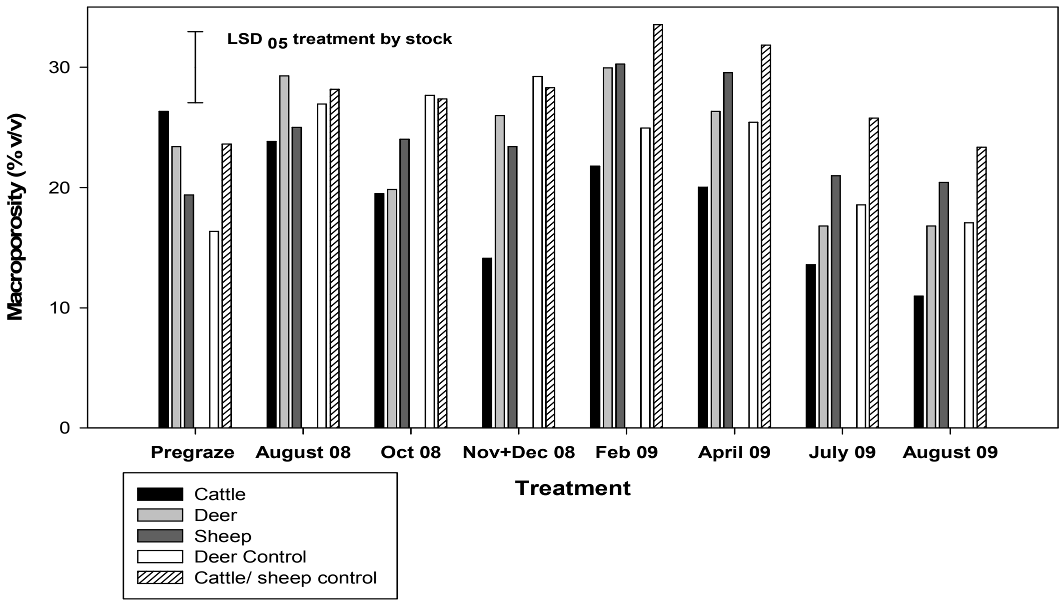

Figure 2. Effect of stock type on soil macroporosity % (v/v) after each grazing event (month given). The least significant difference (LSD) (P < 0.05) is given for the interaction of stock type with treatment.

A gamma log generalised linear model was used to analyse factors affecting concentrations and loads of DRP, TDP, and TP lost and showed, after adjusting for grazing treatment, stock, and time since grazing, that a decrease in macroporosity was associated (P<0.05) with an increase in losses (Figure 3a),. Likewise, concentrations and loads of DRP, DUP, TDP, TP, and SS showed significant decreases in losses with time since grazing (Figure 3b).

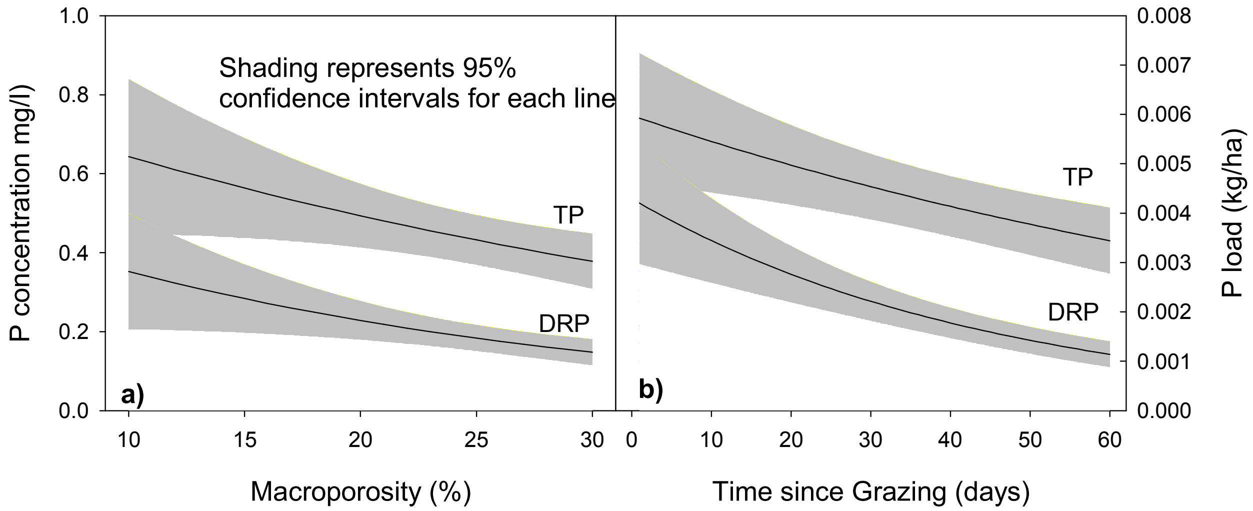

Figure 3. Regression of concentrations of DRP and TP in surface runoff against macroporosity (0-5 cm depth) (a) and days since grazing (b).

An association (P<0.05) was also observed between K_{sat} and the concentrations and loads of PP and SS losses, whereby losses decreased with an increase in infiltration rates (Figure 4).

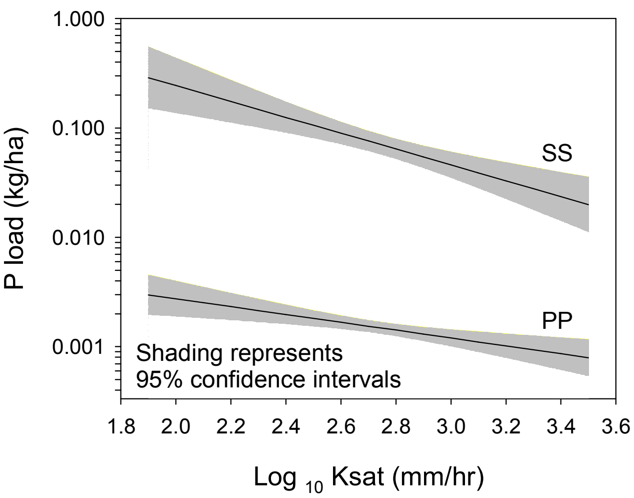

Figure 4. Regression relationship between saturated hydraulic conductivity (K_{sat}, mm/hr; 0-5 cm depth; log-transformed data) and the load of PP and SS lost during surface runoff.

Discussion

Results showed that macroporosity and K_{sat} may have an important role on SS and certain fractions of P losses in surface runoff. Macroporosity has been reported to be a useful tool to predict impacts on pasture production and P losses in surface runoff (Drewry *et al.* 2008; Mc Dowell *et al.* 2003b). Drewry *et al.* (2008) recommended a macroporosity range between 6 to 17% (v/v) for optimal pasture yield and McDowell *et al.* (2003b) reported a significant negative relationship between macroporosity and the time to ponding. Although soil physical properties never reached critical values whereby pasture was sacrificed or visual destruction was evident the relationships between soil physical values and P and SS losses confirms that environmental impacts may pose a threat well before agronomic effects are noticed.

The decrease in concentrations and loads of DRP, DUP, TDP, TP, and SS with time since grazing could be due to the recovery of soil physical properties (i.e. K_{sat} or macroporosity increased) or pasture after stock were removed (Drewry 2006; Nash and Haliwell 1999) or a decrease in P from dung with time as the threat posed by dung is greatest in the first few days of deposition (Mc Dowell 2006). However, dung counts on the plots were low throughout the study and the return of dung in runoff samples collected was unlikely and so was attributed to the former effect.

Conclusion

No differences in the concentrations and loads of P and SS losses in surface runoff from plots grazed by different stock types were detectable, but the effects of stock type were evident for soil physical properties with cattle being most detrimental. An significant relationship was found between macroporosity and K_{sat} on loads and concentrations of certain P fractions and SS losses, and was also evident with days since grazing. Therefore, soil physical measurements may have the potential to be used as a tool for environmental assessment which should be considered in future studies.

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Effects on soil chemical properties in Swedish arable soils of different lime products

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Abstract

In field experiments the effects on soil pH and base saturation of different lime products were investigated. Product property hardness depending on geological origin of the raw material was compared in two groups, soft and hard. Crystalline dolomites *e.g.* were regarded as hard products and sedimentary lime-stones as soft ones. Also particle size and particle size distribution in the products were compared. Two classes were used, fine graded (<1 mm) and coarse graded (<3 mm), respectively. All material used was ordinary commercial products. Twelve experiments were run for 8 years. Tested factors *i.e.* hard/soft and fine/coarse increased pH and base saturation (BS) significantly. Soft products resulted in 4% higher BS than hard products. Fine graded products increased BS with 5% relative coarse grades ones. The lime effect on BS was the highest the 2nd after lime application. After that the effect declined. Eight years after lime application treatments with minor rates the first 4 years were superior concerning BS to treatments with full rate the first year and then nothing. On average for the last 4 years over the 8-year period the split application treatment gave 6% higher BS than the single rate treatment.

Key Words

Geological origin, particle size, soil pH, base saturation, single application, split application.

Introduction

Liming is a well recognized method to control and correct soil acidification in arable soils (Johnston 2004). Total consumption of liming material for Swedish arable soils is approximately 260 Mkg/yr (SCB 2009). It is well known that particle size and geological origin are important factors for the reactivity of the products (Ohlsson and Torstensson 1956; Persson 1985; Erstad 1992). There are many products for liming available on the Swedish market. They differ in properties and effects, which makes it difficult to evaluate products with respect to their soil chemical effectiveness. Rules and advice for liming have been elaborated (Albertsson 2008). These rules take into account the raw material for the lime products on the one hand and particle size distribution for the final product on the other. The scope for the present investigation was to evaluate these rules under field conditions.

Material and methods

Twelve Swedish experimental sites, both sandy soils and clay soils were chosen. The chosen sites were located between 55 and 64 °N in agricultural areas with organic matter contents from 1 to 10%. pH-values varied from 5.5 to 6.3 and CEC from 7 to 39 cmol/kg with exchangeable bases from 3 to 25 cmol/kg. It gave base saturation (BS) values from 22 to 68% (Table 1).

Lime calculated to give 70% BS was applied once. Target BS was 85% in some experiments due to regional adaptations. A specific comparison was made between lime applied in a single rate calculated to give 100% BS or eventually 120% and the same amount split on 4 consecutive applications during the first 4 years. All lime rates were based on CaO equivalents and ranged from 0.3 to 6.2 tonnes /ha to target the lower BS and 4.3 to 11.5 tonnes /ha to target the higher level. Lime was autumn applied and incorporated in the top soil (0-20 cm) before the experiments started. The split applications the following years were always spring applied. Randomised block experiments with four replicates and plot size 6 x 12 m were used.

The experiments were run and harvested at least four years. In nine instances they were run for eight years. Top soils (0-20 cm) were sampled the 1st, 2nd , 4th , 6th and the 8th year. All samples were pooled treatment wise. Error variance estimation was calculated from the interaction between sites and treatments. Used lime products were characterized and grouped as hard or soft depending on the geological origin of the raw material. Crystalline lime stones and dolomites were considered as hard, while sedimentary lime stones were considered as soft ones. Products with a particle size distribution falling below <1 mm were characterized as fine graded products, while products with fractions in the 0-3 mm interval were considered coarse.

Table 1. Relevant soil parameters for the experimental sites. Targets for the base saturation (BS %) and rates of CaO equivalents to achieve the target.

Site	pH	Exch. bases	CEC	Base saturation	Organic matter	Clay content <0.002 mm	BS target	CaO
		(------cmol/kg------)		(------------------------%------------------------)				(tonnes /ha)
AC-87-1999	5.5	2.7	12.4	21.8	5.3	4	70/100	4.2/6.8
L-106-1999	5.6	1.6	6.5	24.6	1.4	2	85/120	2.7/4.3
W-1-2000	5.6	7.0	19.3	36.3	5.0	22	70/100	4.6/8.6
O-12-1999	5.8	8.9	25.3	35.2	8.7	34	70/100	6.2/11.5
P-35-1999	5.8	7.4	21	35.2	6.2	36	70/100	5.1/9.5
C-21-1999	5.9	24.6	38.5	63.9	10.4	6	70/100	1.6/9.7
D-117-1999	6.0	16.1	30.2	53.3	6.0	6	70/100	3.5/9.9
N-321-1999	6.0	4.1	11.6	35.3	4.2	10	70/100	2.8/5.3
M-417-2000	6.1	6.6	11.4	57.9	3.6	10	85/120	2.1/5.0
Y-86-1999	6.1	12.7	21.3	59.6	4.8	21	70/100	1.5/6.0
L-303-1999	6.3	4.2	8.8	47.7	2.2	6	85/120	2.3/4.5
U-111-1999	6.3	13.6	20.0	68.0	2.1	40	70/100	0.3/4.5

Soil analyses results

Both soft and hard lime products affected pH values clearly and significantly compared to the control (Table 2). Similar effects were obtained also for exchangeable bases and BS. A small but statistically significant pH difference was also measured between the products. Base saturation increased from 50 to more than 60% when limed. There was a relative difference, although not at a statistically significant level, in BS of 4% in favour for the soft products

Table 2. Effects on pH, exchangeable bases and base saturation (BS) after liming with products with varying hardness. Means of year 1, 2 and 4 from start. One, two or three asterisks denotes significant levels p<0.05, <0.01 and <0.001, respectively.

Treatment, type of product	pH	Exch. bases (cmol/kg)	BS %
No lime	6.0	9.3	50.3
Hard	6.3	11.0	60.6
Soft	6.4	11.2	63.1
Effect			
H-N	0.3***	1.7***	10.3***
S -N	0.4***	1.8***	12.0***
H-S	-0.1**	-0.2	-2.5

The comparison of coarse and fine graded products showed that fine graded products gave 0.1 pH-units higher pH-values than the coarse ones (Table 3). Exchangeable bases were 0.7 cmol/kg higher in the fine graded group and base saturation was 63% compared with 60% in the coarse graded treatments, a difference of 5% on a relative base. The latter was not at a significant level. The effects on pH and exchangable bases were statistically significant.

Table 3. Effects on pH, exchangeable bases and base saturation (BS) of liming products with varying particle size distributions. Means of year 1, 2 and 4 from start. One, two or three asterisks denotes significant levels p<0.05, <0.01 and <0.001, respectively.

Treatment, type of product	pH	Exch. bases (cmol/kg)	BS (%)
No lime	6	9.3	50.3
Fine graded	6.4	11.5	63.3
Coarse graded	6.3	10.8	60.1
Effect			
F -N	0.4***	2.1***	13.0**
C-N	0.3***	1.5***	10.5**
F-C	0.1**	0.7*	2.5

Yield results

A box-plot for relative (control=100) annual yields of spring cereals shows that variation both between and within years was considerable. Some experiments gave generally positive and some generally negative yield effects of liming, probably attributable to micro nutrient effects. An analysis of the data showed that the yield effects were most consistent the 2nd year after liming. On average yield increases with 5-7% compared with un-limed treatments were observed this year with the higher value for winter cereals.

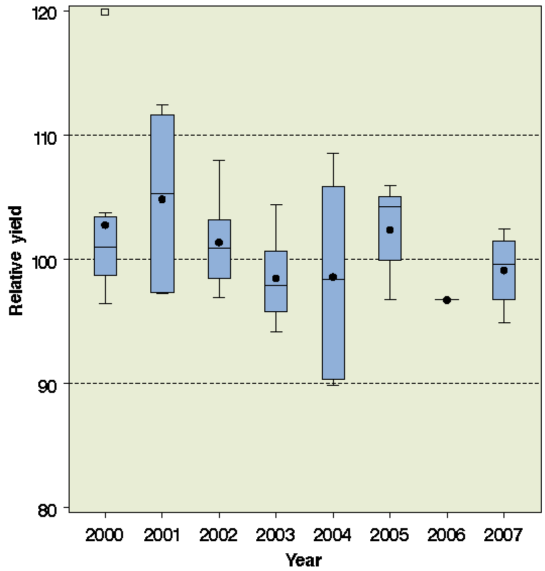

Figure 1. Box-plot for spring cereal yields. The boxes include the 25th and 75th percentile, horizontal line within the boxes represent the median value, dots are means, and squares are outliers (>1.5 the distance between 25 and 75 percentile).

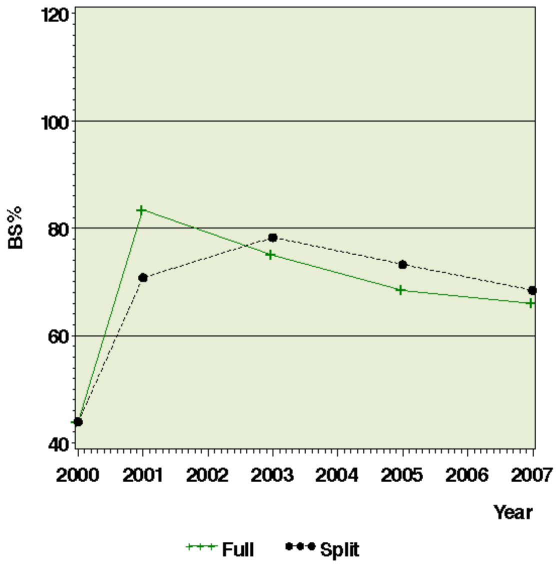

Figure 2. Base saturation response after liming with full single rate or with annual rates the first 4 years. Total rate of CaO equivalents similar in both variants. Fine graded sedimentary lime stone used.

Applying lime in a full large rate has a quick effect, which is not fully obtainable with split annual applications, but on the other hand the effect declines and the 3rd year after lime application the BS in treatments with split rates has reached slightly higher levels. The difference maintains the rest of the period.

Discussion

It was confirmed that products produced from soft raw materials reacted faster than those from hard ones. Fine graded products were more reactive than coarse graded. This was expected and in accordance with other investigations (Ohlsson and Torstensson 1955; Persson 1985; Erstad 1992). Measurements in field experiments cannot give similar precision as laboratory methods used by Erstad (1992). The results indicated that annual minor rates appear to be more effective and beneficial than single large rates over a 5 year period. Observed and measurable differences confirm that the principles which form the basis for comparing lime products for Swedish agricultural soils are valid under field conditions.

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Environmental monitoring in heterogeneous soil-landscapes; A Dutch case study

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Abstract
There is scope for developing environmental monitoring programs at the landscape level to address the feedback mechanisms at this scale. For a Dutch landscape dominated by dairy farming we have i) derived the environmental goals for atmospheric quality and water quality and ii) assessed the current environmental quality using a combination of measurements and model calculations. The analysis was limited to nitrogen (N) and phosphorus (P) compounds which are the chemical elements most closely related to agriculture. Environmental goals at the landscape scale were derived for five individual indicators: NH_3 emission, critical atmospheric N deposition, N in surface water, P in surface water and NO_3 in the upper groundwater.
In the study area, the NH_3 emission goal for 2010, is not exceeded in 2004. However, simulation results suggest that critical N deposition rates on nature areas are exceeded on more than half of the area (53%), mainly as a result from non-agricultural sources and sources outside the NFW region. For the region as a whole, annual NO_3 concentrations in the upper groundwater almost never exceed the EU threshold of 50 mg/L. The national N standards for surface water regarding N and P are only slightly exceeded

Key Words
Environmental quality, dairy farming, nitrogen, phosphorus.

Introduction

The spatial heterogeneity of agricultural soil-landscapes is mostly not taken into account in environmental policies. Most environmental goals have been defined at national level or farm level but not at the landscape level. Consequently, most environmental monitoring programs are operational at national level or farm level. There is scope however for developing monitoring programs from a regional landscape and watershed perspective because of the extent of environmental contaminants, their potential for transport through complex hydrological and atmospheric pathways and the impacts beyond local conditions (Bruns and Wiersma 2004). In this study, we used the DPSIR framework as a tool to distinguish between various environmental indicators. For a Dutch landscape dominated by dairy farming we have i) derived for environmental goals for atmospheric quality and water quality and ii) assessed the current environmental quality using a combination of measurements and model calculations (STONE and Initiator). The potential for setting up a regional environmental monitoring network that supports self governance was explored. The analysis was limited to nitrogen (N) and phosphorus (P) compounds which are the chemical elements most closely related to agriculture.

The research was performed in the Northern Friesian Woodlands (NFW), which is located in the province of Friesland in the North of The Netherlands (Figure 1). A large part of the 600 km^2 area as been appointed as a Dutch National Landscape because of the small scale parcelling structure, a high concentration of hedge-rows bordering the individual fields and the occurrence of many pingo-remnants from the Weichsel glacial period. The area dominantly consists of sandy soils (Gleyic Podzols) at elevations of 1 to 5 m above mean sea level. Clay soil and peat soil are found in the north and the west of the study area in lower landscape positions.

Agriculture dominates the landscape using 76% of the total area. Mostly this is grassland (69%) used for dairy farming. Surface water occupies 5% of the area and the remainder is used for built-up (13%) and nature (6%). In 2004, 92% (1169) of the total number of farms were animal farms, mostly dairy farms. Environmental goals at the landscape scale were derived for five individual indicators: NH3 emission, critical atmospheric N deposition, N in surface water, P in surface water and NO3- in the upper groundwater. Based on areal fractions, a provincial goal of 12 kton NH_3/yr can be calculated for the province of Friesland using the national EU derived emission ceiling as input. With the model Initiator (De Vries *et al.* 2003), the NH3 emission goal for the NFW region was calculated at 2.6 kton NH_3/yr for 2010. To derive the regional goals for critical N deposition, the inventories of Bal *et al.* (2006) were used which indicate critical N

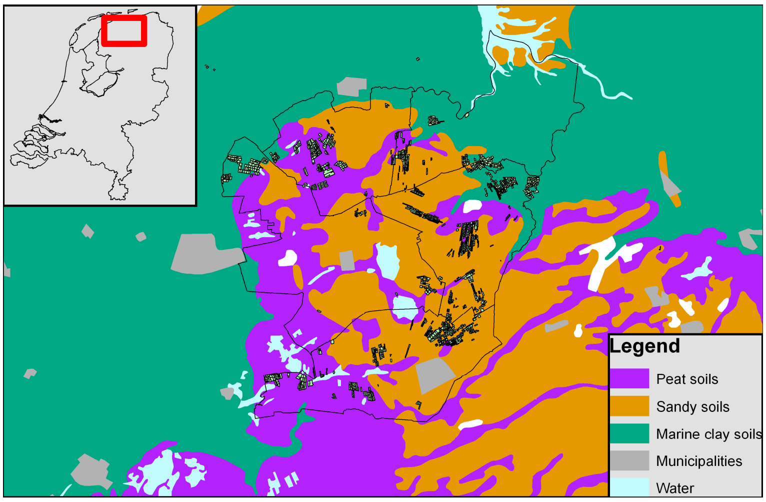

Figure 1. Distribution of soils in the study area, in the North of the Netherlands.

deposition targets for specific types of vegetation. The provincial map for nature areas was then used to map the critical N deposition targets for the NFW region. According to this approach, more than 9000 ha (15%) in the NFW region is targeted at nature area with critical N depositions ranging from 400 mol N/ha/y to 2500 mol N/ha/y. The EU threshold of 50 mg NO_3/L was adopted (EC, 1991) as a goal for nitrate concentrations in the upper groundwater for all soil types. For surface water quality, the EU Water Framework directive specifies a good ecological and chemical quality to be reached by 2015. At EU level, no specific thresholds are specified but the Dutch Commission on Integrated Water management has specified thresholds for N and P. For the summer-period (April 1 – October 1) for stagnant surface waters, the N concentration limit is set at 2.2 mg N/L whereas the P concentration limit is set at 0.15 mg P/L.

Material and methods

Calculations for the emission of NH_3 and the deposition of N in the NFW were performed for 2004 with the integrated nutrient model Initiator2 in combination with the atmospheric OPS transport model (Jaarsveld 2004). Nationally available GIS datasets were used as inputs, including the 1: 50,000 scale soil and hydrology map, the LGN land use map, the GIAB dataset on animal numbers and the national parcel registration system. A distribution module was included to simulate the application of manure N to the individual fields. The model STONE was used for mapping soil chemical characteristics at a spatial resolution of 250x250 m which was used as input for the INITIATOR model.

An assessment of water quality in the region with regard to N and P was done using a combination of modelling and measurements. The monitoring network from the regional Water Board for surface water yielded monthly data for the years 2000 to 2005 for six locations in the NFW area, four locations were in the peat area; one location was in the clay area; and one location was in the sand area. These data can be used for status monitoring through time (trend monitoring) but are not suitable for compliance monitoring that is requested by the Water Framework Directive (Knotters and Brus 2008).

Monitoring data on nitrate concentrations in the upper groundwater at the provincial scale were not available. NO_3 concentrations in the upper groundwater and N and P loading of surface waters were modelled using the STONE model. Additionally, a validation was performed for nitrate concentration in the upper groundwater for farms on sandy soils (Sonneveld *et al.* 2010).

Results

Both NH_3 emissions from point locations (stables, storage) as well as emissions from fields (manure application) appear to be uniformly distributed throughout the area. Within relatively small distances (< 1 km) large variations in field emissions can be found however ranging from < 10 kg NH_3-N/ha/y to > 40 kg NH_3-N/ha/y. For 2004, a total emission of 2.4 kton NH3/yr was calculated. This implies that for 2004 there was no exceedance of the downscaled EU NEC goal (2.6 kton NH_3/yr) for the NFW region.

The largest rates of atmospheric inputs of N are calculated for the central-eastern part of the study area (> 30 kg N/ha/y). Calculated deposition rates for most of the area are between 5 to 10 kg N/ha/y. Apart from agricultural sources inside the NFW region, also other (industrial) sources and sources outside the NFW area contribute to the total N deposition (Table 1). It appears that a major part of the N deposition, 72%, corresponding with 17.5 kg N/ha/y, is due to non-agricultural sources and NOx sources outside the NFW region. Accordingly, less than a third of the total N deposition comes from agricultural sources within the NFW region. Especially in the central part of the region, the Initiator2 model calculates for 2004 N deposition levels that exceed the critical levels substantially. For 2004, critical N deposition values are exceeded on almost 53% of the total area with (planned) nature.

Table 1. Sources for N deposition in the study area in 2004.

Sources	Deposition (kg N/ha/y)		Deposition (%)	
Total NO_x deposition + NH_3 from non-agricultural sources (background)		17.5		72
NH_3 from stables and storage facilities	2.7		11	
NH_3 from land application of manure	4.2		17	
Total NH_3 deposition from agriculture		6.9		28
Total N deposition		24.5		100

Calculated average NO_3 concentrations are below the 50 mg/L threshold throughout the entire year. Over the entire year, the NO3 concentration fluctuates more or less between 10 and 30 mg/L with an annual average of 15 mg/L. Thus, the 50 mg/L threshold is for the entire NFW region not exceeded on an annual basis. Low NO_3 concentrations are especially found in areas with peat and clay soils, probably due to higher denitrification rates, whereas higher NO_3 concentrations, sometimes locally exceeding the 50 mg/L threshold, are mostly found in the (drier) sandy regions. For the period 2000-2005 a downward trend was observed for N and P in surface water, with some fluctuations between the years. For 2005, the median N concentration was below the 2.2 mg/L threshold but the upper boundary of the confidence interval exceeded this threshold for the previous years. For P, all median concentrations in the surface water were below the 0.15 mg/L threshold.

Conclusions

In the NFW study area, the down-scaled national NH3 emission goal for 2010, based on the NEC directive, is not exceeded in 2004. However, simulation results suggest that critical N deposition rates on nature areas are exceeded on more than half of the area (53%), mainly as a result from non-agricultural sources and sources outside the NFW region. For the region as a whole, annual NO_3 concentrations in the upper groundwater almost never exceed the EU threshold of 50 mg/L. The national N standards for surface water regarding N and P are only slightly exceeded for the summer period and monitoring data indicates a decreasing trend in time. From the viewpoint of self-governance, monitoring by regional organizations has the most potential for indicators that are related to sources. Environmental monitoring networks should preferably be maintained by formal (governmental) institutions, also because of monitoring obligations. There is room for developing simple monitoring kits for farmers with the aim to establish feedback loops between monitoring and their farming strategies.

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Evaluation of agricultural soil properties and organic material management in urban areas, Osaka Prefecture in Japan

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Abstract
Properties of agricultural soils and organic matter management in Osaka Prefecture, urban areas of one of the largest city in Japan, were evaluated, as a monitoring project of MAFF (Ministry of Agriculture, Forestry and Fisheries of Japan). Many nutrient elements were higher than optimum ranges; especially Truog-P for all land use and Ex-Ca in greenhouse and for grapes. For soil C, the values for most soils were within optimum ranges, suggesting that agricultural soils in Osaka would have a capacity for C sequestration. Except in the greenhouse, less than half of farmers applied organic materials for all land uses, indicating that more promotion of organic matter application to increase soil organic matter is needed depending on the land use.

Introduction
Agricultural soils in Japan have been periodically monitored from 1960s to monitor changes in soil properties and agricultural management. From 2008, to fulfill a part of Japanese target for the second commitment period (post 2013), the number of survey points increased. Osaka prefecture, urban areas of one of the largest city in Japan, varied in agricultural land use; paddy, upland, greenhouse and orchard. In this study, the results of this monitoring survey, agricultural soil properties and organic material management in urban areas, Osaka prefecture, Japan were presented.

Materials and methods
Soil investigation
In total, 99 soil samples were collected from agricultural fields in Osaka prefecture, Japan. The number of samples with reference to land use was summarized in Table 1. It should be noted that grapes were cultivated in greenhouses, which it the major method of grape cultivation in Osaka prefecture. Soil samples were classified as Lowland Paddy soils, Gray Lowland soils, Brown Lowland soils, Gray Upland soils, Yellow soils and Brown Forest soils (Cultivated Soil Classification Committee 1995). Soil samples were mostly collected from August 2008 to January 2009 after crops were harvested, although some soil samples were collected when crops were planted. Soil pH, NO_3-N (compact nitrate meter), Truog-P, Ex (exchangeable) -K, Ca, Mg, and total-C were analyzed.

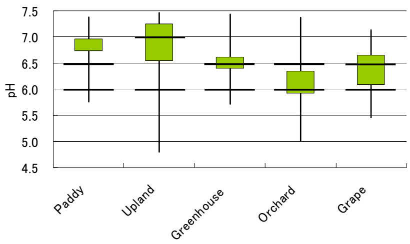
Table 1. Number of soil samples with reference to land use.

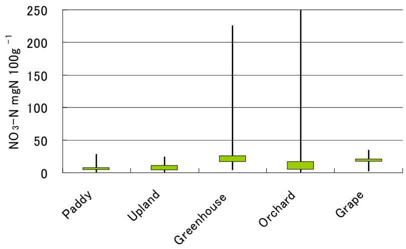
Land use	Paddy	Upland	Greenhouse	Orchard	Grape
Number of samples	36	15	26	12	10

Activity data
A questionnaire on agricultural management was conducted with farmers who provided the soil samples. In this study, addition of organic matter to the field (organic amendment and residue management) was summarized in related to land use.

Results and discussion
Figure 1 shows the box plots of soil pH related to land use with optimum range indicated by two (upper and lower) bold lines. For most land uses, pH value were within optimum range, although paddy was higher than optimum range, probably because lime was applied for production of onions, cabbages and some kinds of vegetables after rice harvest in about a half of paddy field. Figure 2 shows the box plots of NO_3-N related to land use. Soils in greenhouse and grape showed higher content than those of other land uses, reflecting less leaching. NO_3-N values were higher than those of Japanese agricultural soils (Sano *et al.* 2004), indicating quite intensive fertilizer use in Osaka prefecture. Figure 3 shows the box plots of Truog-P in related to land use. In all land use, the range of Truog-P was extremely higher than optimum range; 5 to 10 times larger. They were also higher than average value in Japanese agricultural soils (Obara and Nakai 2004). These results suggest that fertilization rate of phosphate should be drastically decreased for efficient use of fertilizer.

Figure 4 shows the box plots of Ex-K in related to land use. Except paddy soils, the values were slight higher than the optimum range. Unlike Truog-P, the values were lower than those of Japanese agricultural soils (Obara and Nakai 2003). This may be because high contents of other plant nutrient elements lead crops to take up more K than they needs. Figure 5 and Figure 6 show the box plots of Ex-Ca and Mg, respectively. Ex-Ca in greenhouse and for grape was much higher than the optimum range, similar to Truog-P. The values of Ex-Ca were comparable to those of average in Japan (Obara and Nakai 2003). For Ex-Mg, the values for greenhouse soils were slightly higher than the optimum range. The values of Ex-Mg were comparable to average values in Japan (Obara and Nakai 2003). These results suggest that a drastic reduction of phosphate fertilization should be conducted for all land uses, while application of potassium should be decreased slightly. For greenhouse and grape soils, the application rate of Ca and Mg should be also decreased. It is also important that soil test should be conducted to enable the decreased application of fertilizers or liming materials since soil properties varied among the fields.





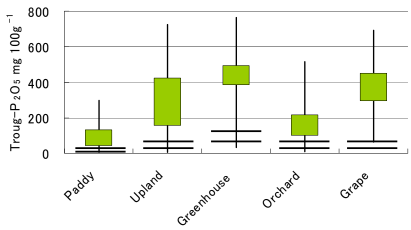
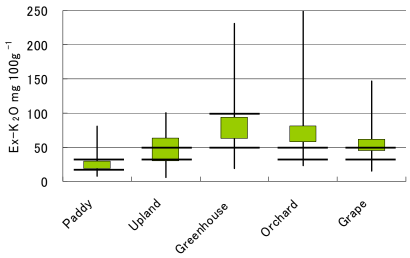
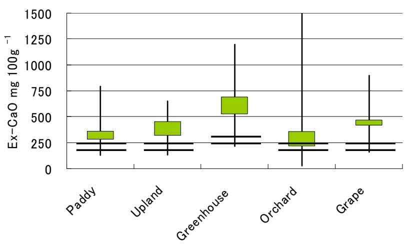


Figure 1. pH.

Figure 2. NO_3-N .

Figure 3. Truog-P.





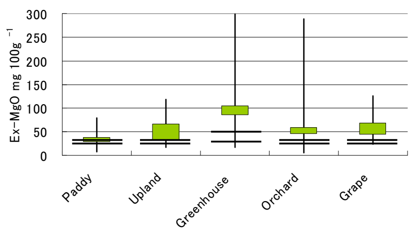


Figure 4. Exchangeable K.

Figure 5. Exchangeable Ca.

Figure 6. Exchangeable Mg.

Figure 7 shows the box plots of total-C related to land use. The soil C content was comparable among the land uses, except for soils of grape soils and one orchard soil with 20% C content. Most values were lower than that for Japanese agricultural soils (Leon *et al.* 2009), since volcanic ash soils, containing large amount are included of organic matter among Japanese soils (Sano *et al.* 2004, Leon *et al.* 2009). These soils are distributed in limited areas were present in Osaka prefecture; only one Andosol sample in 99 samples used in this study. The values were within optimum ranges, indicating that agricultural soils in Osaka have the capacity of C sequestration.

Table 2 shows the organic materials and crop residue management of farmers in Osaka prefecture, obtained by the questionnaire. For greenhouse soils, most farmers (86%) applied organic materials while for upland soils, only the 14% of farmers applied them, suggesting that, for C sequestration, application of organic matter should be increased for upland soils. In paddy, though most farmers incorporated residues, rice straw or rice hull, only about a half of them applied organic materials, suggesting that, increasing organic matter application in paddy would be effective to sequestrate C in soils. For orchard and grape soils, only a half of farmers applied organic materials, furthermore the residues were removed from fields or burned in most cases. Since most orchard and grape fields are in mountainous areas, it is difficult to apply organic materials, although is management to increase soil organic matter using a grass sward system may be effective.

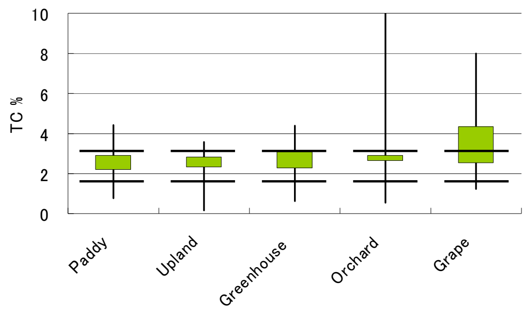


Figure 7. Total-C.

Table 2. Organic material and crop residue management by farmers in Osaka prefecture.

	Number of	Application of organic materials		Incorporation of crop residues	
	respondent	Yes	No	Yes	No
Paddy	27	11	16	24	3
Upland	6	1	5	3	3
Greenhouse	23	19	4	5	17
Orchard	12	6	6	2	9
Grape	10	6	4	3	6

Conclusion

Many nutrient elements were higher than optimum ranges; especially Truog-P for all land uses as was Ex-Ca in greenhouse and grape soils. For soil C, the values for most soils were within optimum ranges, suggesting that agricultural soils in Osaka have capacity for C sequestration. Except for greenhouse soils, less than half of farmers applied organic materials for all land uses, indicating that more promotion of organic matter application or management to increase soil organic matter is needed depending on the land use.

Acknowledgements

We are grateful to farmers of the agricultural fields we surveyed for supplying soil samples and responding to the questionnaire and staff members of the regional Office for Agriculture-forestry Promotion and Nature Conservation, Osaka Prefectural Government for their assistance in field survey and providing the questionnaire to farmers. This study was conducted as MAFF Project “Monitoring and demonstrating technologies to reduce GHG emission from farmland”.

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Fractionation and distribution of zinc in soils of biologically and conventionally managed farming systems, Western Australia

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Abstract

Understanding the distribution of zinc (Zn) fractions in soils is important for effective and efficient management of the fertilizer resources given world-wide limitations of crop production and food quality by insufficient Zn. Soils were collected from the farmers' field with the history of biological (combination of organic and conventional farming practices) and conventional management systems in Dalwallinu and Merredin, Western Australia. A sequential extraction procedure was used to fractionate water-soluble (WS), exchangeable (EX), specifically adsorbed (SA), acid-soluble (AS), manganese (Mn)-oxide-occluded (Mn-OX), organic matter occluded (OM), amorphous iron (Fe)-oxide-bound (AFe-OX), crystalline Fe-oxide-bound (CFe-OX), and residual (RES) Zn forms. There was a similar trend of distribution of Zn fractions in both farming systems from the two locations. More than 80 % of the total Zn content occurred in the relatively inactive and mineral-bound residual form (RES), whereas only a small fraction occurred in WS, EX, OM, AFe-OX, and CFe-OX fractions. Among all the fractions, water soluble and exchangeable (which are important for plant use) were higher in biological than conventional soils at both locations. Management systems, particularly biological practices, enhanced plant-available and total Zn pools in soils.

Key Words

Zinc, fractionation, biological and conventional farming systems.

Introduction

Availability of zinc (Zn) for plants is reported to be associated with the distribution of this nutrient among soil fractions. Therefore, understanding of the distribution of Zn among various fractions of soils will help to characterise chemistry of Zn in soils and possibly its availability for plant uptake. However, distribution of Zn among various chemical forms may vary significantly in response to changing soil properties (Adhikari and Rattan 2007). Sequential fractionation quantifies the element distribution between fractions of different binding strengths, as defined by properties of selected extractants. Viets (1962) defined five distinct pools for micronutrients. These are i) water soluble, ii) exchangeable, iii) adsorbed, complexed and chelated species, iv) associated with secondary minerals and insoluble metal oxides, and v) associated with primary minerals. Other scheme of Zn fractionation yielding various other distributions into measurable pools have been proposed by Shuman (1979), Iyengar *et al.* (1981), Nielsen *et al.* (1986), Elliot *et al.* (1990), and Rauret *et al.* (1999).

Zinc deficiency in soils suggests that both native and applied Zn react with the inorganic and organic phases in the soils, which influences plant-availability of Zn. Viets (1962) reported that the distribution of Zn among active and non-active soil constituents, and soil solution, is also fundamental to an understanding of the soil chemistry of Zn. Metals in the soil solution existed in different fractions (Luo and Luo 2002), with potentially different bioavailability and environmental mobility of various chemical forms. Management systems alter the Zn pools in soils; e.g. Dvorak *et al.* (2003) reported that the application of sludge together with inorganic Zn fertilization increased Zn mobility. Similarly, Qian *et al.* (2003) also revealed that addition of animal manure increased the labile pool of Zn in soils. Biological farming systems (BF) defined as the combination of organic and conventional farming systems, which aims at achieving optimum yield without compromising soil health. On the other hand, conventional farming system (CF) aims at achieving highest possible yield through the use of chemical fertilizers and other external inputs. In the study presented here we characterized the soil-Zn fractions under different farming systems in Western Australia. The aims of the research were: to assess the distribution of Zn fractions in different soils of biological and conventional management systems, and to determine the relative importance of various soil-Zn fractions in different soils.

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Material and methods

Soils: Surface layer (0-10 cm) soils with the history of biological farming (BF) and conventional farming (CF) systems from Dalwallinu (Lat. 30° 14'166" S and Long. 116 °32'377" E) and Merredin (Lat. 31° 44'530" S and Long. 118° 18' 879" E), Western Australia were collected. Soils were mixed thoroughly and sieved through a 2-mm sieve. Subsamples were taken and ground into fine powder for analysis.

Table 1. Soil properties of biologically (BF) and conventionally managed (CF) soils.

Soil properties	Merredin		Dalwallinu	
	BF	CF	BF	CF
Organic carbon g/kg	8.7	8.0	9.5	9.0
NO_3 N (mg/kg)	12	14	9.5	13
pH $CaCl_2$	5.5	5.4	5.1	4.9
pH H_2O	6.1	6.1	6.2	5.7
NH_4 N (mg/kg)	4	5	2	2
Phosphorous (mg/kg)	31	30	21	18.2
Potassium (mg/kg)	181**	349	60*	42.5
DTPA extractable Zn mg/kg	0.71**	0.32	0.58**	0.36
Total Zn (mg/kg)	14.2*	12.43	12.33*	10.33

Note: * and ** denote significant differences at the 0.05 and 0.01 probability levels, respectively, between the two farming systems for each location separately.

Sequential fractionation methods

The sequential fraction procedure (except the residual fractions) to study the distribution of Zn fractions in different soils was used as described by Adhikari and Rattan (2007) and Iwasaki and Yoshikawa (1993) (as a modified form of the fractionation scheme reported by Miller *et al.* 1986). Soil sample mass used was 1.5 g; after each fractionation step, samples were washed with 20 mL of milliQ water.

For the respective fractions, the following extractants and procedures were used. Water soluble (WS): soil samples were shaken with 25 mL H_2O for 16 h. Exchangeable (EX): 25 mL 0.5 M calcium nitrate [Ca(NO3)2]-solution and shaking for 16 h. Specifically absorbed [lead (Pb)-displaceable fraction] (SA): shaking in 25 mL of 0.05 M lead nitrate [$Pb(NO_3)_2$] and 0.5 M ammonium acetate at pH 6.0 for 2 h. Acid-soluble fraction (AS): 25 mL of 2.5% (v/v) acetic acid and shaking for 2 h. Manganese-oxide-bound fraction(Mn-Ox): samples were shaken in 50 mL of 0.1 M hydroxylamine hydrochloride solution at pH 2.0 for 30 min. Organic-matter-bound fraction (OM): 50 mL of 0.1 M potassium pyrophosphate solution at pH 10.0 and shaking for 2 h. Amorphous iron-oxide-occluded fraction (AFe-Ox): samples were treated with 50 mL of 0.1 M oxalic acid solution and 0.175 M ammonium oxalate [$(NH_4)_2C_2O_4$] solution at pH 3.25 for 4 h in the dark. Crystalline iron-oxide-occluded fraction (CFe-Ox): samples were kept in 50 mL of 0.1 M oxalic acid, 0.175 M $(NH_4)_2C_2O_4$ and 0.1 M ascorbic acid in a boiling water bath for 30 min.

Residual fraction (RES): This fraction was estimated by subtracting the sum of all Zn fractions measured as described above from total Zn (see below) as per Rico *et al.* (2009).

Total zinc (T Zn): A well-mixed sample of about 0.5 g soil was digested in 12 mL Aqua regia as mentioned by Cheng and Ma (2001). After extraction, all aforementioned samples were centrifuged and Zn was determined using an Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer 400) at The University of Western Australia, Perth, Australia.

Statistics: Data were statistically analyzed using Statistical Analysis Systems (SAS 9.1 Institute Inc., Cary, NC, USA) was used for linear correlation analysis and data analysis tool pack of MS excel used for T test.

Results and discussion

Total Zn in soils indicates the potential capacity of soils to supply Zn for crop production given the capacity of crop to exploit it. However, total Zn in soil doesn't indicate Zn availability to plants. Soil Zn fractions is influenced by different factors for e.g. Adhikari and Rattan (2007) reported that soil pH and organic matter level markedly alter the distribution of Zn among the plant available pools. Table 2 shows distribution of different fractions of Zn in soils from biological and conventional management systems from two locations (Merredin and Dalwallinu). There were significant differences in total Zn content in biological and conventional soils at both locations. Distribution pattern of Zn fractions and total Zn was found similar in both locations (table 2) except Mn-OX in both location and CFe-OX fraction in Merredin where CF having higher than BF.

Table 2. Distribution of zinc fractions (mg/kg) in two different farming systems at Merredin and Dalwallinu locations in Western Australia.

Zinc fractions	Merredin		Dalwallinu	
	BF	CF	BF	CF
Water soluble (WS)	0.20	0.17	0.10	0.10
Exchangeable (EX)	0.15	0.14	0.27*	0.21
Specifically absorbed (SA)	0.23*	0.18	0.05	0.03
Acid soluble (AS)	0.31*	0.12	0.12*	0.11
Manganese (Mn)-oxide-occluded (Mn-OX)	0.76*	0.86	0.20	0.26
Organic matter occluded (OM)	0.58*	0.35	0.78*	0.60
Amorphous iron (Fe)-oxide-bound (AFe-OX)	0.60*	0.28	0.36*	0.20
Crystalline Fe-oxide-bound (CFe-OX)	0.21*	0.34	0.28*	0.17
Residual (RES)	11	9.9	11*	8.3
Total Zn	14*	12	12*	10

Note: * denotes significance at the 0.05 probability level between the two farming systems for each location separately. CF= conventional farming systems and BF= biological farming systems.

For plant production point of view WS, and EX Zn are important which is higher in BF in both sites. However, only Ex Zn fraction was significant in Dalwallinu BF. DTPA-extractable Zn was significantly higher in biologically managed soils than in conventionally managed soils (Table 1), which is important indicator to measure the plant available Zn in soil (Cheng and Ma 2001). Here, in both sites, biological farming systems revealed increased Zn concentration than conventional farming systems, where mainly adding of organic matter contributed to that increased concentration of different Zn fractions (Table 2). Iwasaki and Yoshikawa (1993) reported that management systems particularly intensive fertilizers use had great role in accumulating Zn in soils for plant use.

Conclusion

Biologically managed soils have higher Zn content compared to conventionally managed soils. Adding the organic matter into soil and maintaining better soils health is important for better crop production as well as environmental benefits, particularly in the areas of intensive cropping systems with higher external input use. Available Zn is influenced by the management practices. Biological farming systems should be promoted to achieve better soils conditions and for sustainable agricultural development.

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Harvest equipment and soil erosion in a macadamia orchard

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Abstract
Soil erosion, in macadamia orchards in the high rainfall area of northern New South Wales (NSW), Australia, is exacerbated by mechanical harvest practices. Effects of harvest machinery (blower and sweeper) on soil under macadamia trees were measured in a mature orchard at the Centre for Tropical Research (CTH), Alstonville, NSW. Transects were set up across the tree row and inter-row to measure changes in soil elevation. Soil loss from the within tree row area occurred on the blower-treated plots. Soil was also removed by the sweeper but some soil was redistributed within the plot area. Orchard harvest practices that include sweeping and blowing will substantially remove soil over time and result in soil erosion in the vulnerable under tree region.

Key Words
Orchard-management practice, soil elevation, mechanical harvester, blower, sweeper.

Introduction
Soil erosion, exacerbated by orchard management practices, is an issue in northern NSW. Intense tropical rainfall and storms in the area can cause soil erosion from runoff, overland flow and also from water flowing down the trunk (stemflow) of a macadamia tree. Steep slopes and limited ground cover (grass and mulch) can accelerate erosion from water. Management practices, particularly the use of heavy mechanical harvest equipment, can disrupt the surface of the soil and vehicle tracks can promote erosion channels.

In a mature macadamia orchard, tree canopies shade the orchard floor limiting the growth of vegetative ground cover. Routine harvest practice in a macadamia orchard includes blowing or sweeping fallen nuts from within the tree row to the area between the tree rows, the inter row. Within the tree row, tree trunks, low branches, tree roots or irrigation pipes interfere with the harvest machinery while the inter-row area is generally free from obstructions. Thus macadamia nuts are moved to the inter row to facilitate their collection by a mechanical harvester. Sweepers and blowers have been designed to move macadamia nuts but inappropriate use can move soil and extensive root exposure has been observed. Blowers have a pipe diameter range of between 100 mm to 500 mm with an air flow velocity of up to 300 m/s. Sweepers comprise bunches of plastic bristles, up to 5 mm thick, set on a high-speed rotating circular frame.

While studies have measured the volume of dust resulting from mechanical harvesting practices (Downey *et al.* 2008), assessed particulate matter emissions and harvester improvements (Faulkner *et al.* 2009; Southard *et al.* 1997) or the effects of machinery on soil compaction and soil health (Van Zwieten *et al.* 2003; Jenkins 2004) there exists a dearth of information on actual soil loss from these practices. Studies that assessed soil condition in macadamias have not directly analysed the effects of harvest machinery on soil but they have shown distinct inferior soil conditions in the bare row where blowers and sweepers are concentrated, compared with a grassed inter row (Van Zwieten *et al.* 2003; Stephenson *et al.* 2004). To assess soil movement from mechanical harvesting, experimental plots were set up in the orchard and each plot was treated with a blower, sweeper or not treated.

Methods
The orchard was situated on an Acidic, Dystrophic, Red Ferrosol (Isbell 2002) at the Centre for Tropical Research (CTH), Alstonville, NSW. The soil can also be classified as a Nitisol (IUSS WRB 2006) or Oxisol (Soil Survey Staff 1999). The experimental site comprised nine plots, three blocks across by three blocks long in an orthogonal row column (Latin Square) design with three treatments, including the control, and three replicates. The plots, which ran along the tree lines across the slope, had five trees. Buffer trees were left between plots and between each row. Each treatment was represented within a block along a tree row across the slope. Each treatment was also represented within a block or "column" down slope.

Three replicated treatments were used:
1. Control that was not blown or swept
2. Blower (100 mm diameter pipe, velocity ~ 30 m/s measured 1 m from pipe outlet)
3. Sweeper (1.5 m diameter deck with bunches of 5 mm bristles)

Treatments were at seven day intervals in two sets over three months to represent two harvest years.

Field measurements

After each treatment, the soil surface topography along set transects was measured using an electronic fluid, or elevation, level (Technidea *ZIPLEVEL*^{TM}). Measurements were taken within 48 hours after treatments. Measurements were at 20 cm intervals, along each of two 7 m long transects, one either side of the centre tree of each plot. For each plot the two transects were parallel to each other and set 5 m apart. A tape measure between two permanently fixed pins one in each buffer row either side of the plot row delineated a transect line. At two times, before treatments started and after treatments finished, four extra transects were set up between the two regular transects. The additional transects were parallel to the regular transects and set at 1 m intervals. Measurements for all six transects were completed at 20 cm intervals using the same procedure as for the weekly measurements. For this paper, soil loss between the start and completion of the treatments was assessed.

Data analysis

Outcome of interest was declared to be the difference between final and initial elevation (final – initial) at each observation point. This put the response on an intuitive scale; values less than zero implied a soil loss while values greater than zero implied soil gain. Change in elevation was modelled as a linear response to treatment, distance and plot plus a cubic spline smoothed response to distance. The model was used to estimate the expected change in elevation along a typical transect under each treatment. Model parameters were estimated according to the methods outlined in Verbyla *et al.* (1996) through use of the asreml package (Butler *et al.* 2007) in the R environment (R Development Core Team 2008).

Results

Raw observations are shown in Figure 1. The control plots suggest consistent and small loss of elevation along transects while the observations from the blower and sweeper plots indicate relatively high disturbance at the transect centres.

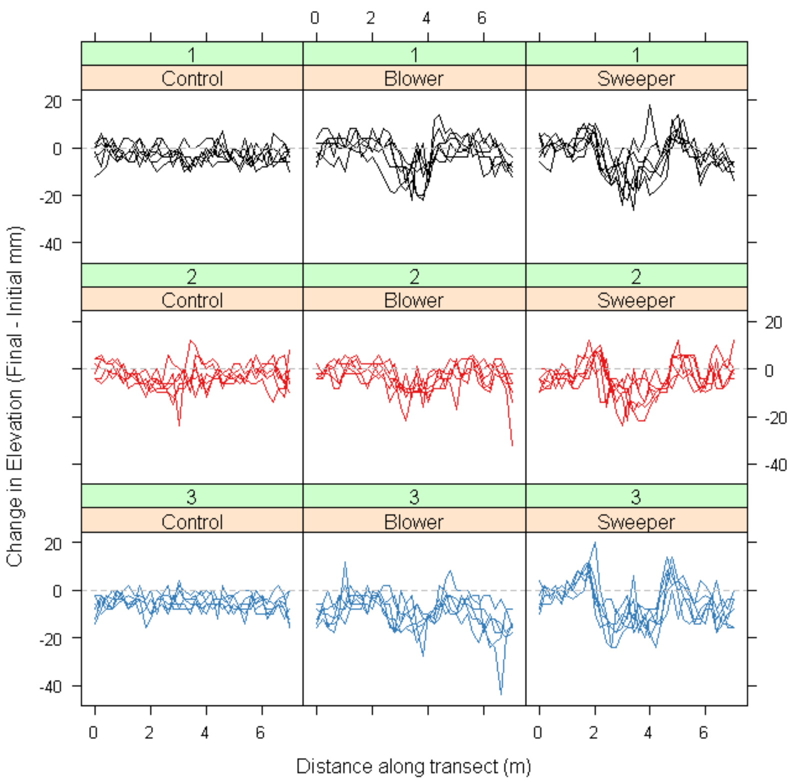

Figure 1. Observed changes in elevation along each transect showing variability within and between each plot.

The raw observations were supported by the model which indicated a statistically important movement of soil from the plot centres to the plot edges under the blower and sweeper treatments relative to the control (Figure 2).

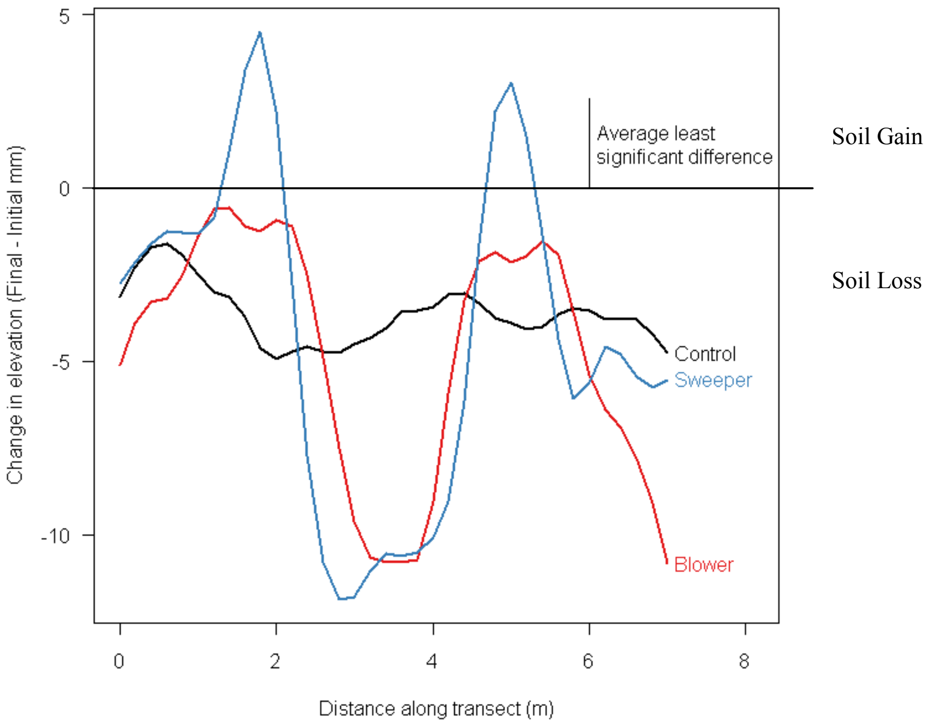

Figure 2. Predicted change in elevation under each treatment showing final observation less initial observation. Negative values indicate a loss in elevation while positive figures show a gain in elevation.

Soil loss was obvious on the blower-treated plots particularly in the centres of the plots where up to 20 mm depth of soil had been lost. This observation is reflected by the model, which shows that soil was lost from across those plots with more soil lost from the centre of the plots. Soil movement was noted on the swept plots following treatment. Here, the response predicted by the model shows that soil was moved from the centre of the plot outwards, a distance of only 1 m to 2 m. It was shown that soil accumulated in this area. For the control plots, the model shows a slight decrease in elevation. This could be explained by soil loss resulting from inherent movement of soil from wind and rainfall.

Conclusion

The harvest equipment used in this experiment moved more soil from the tree-row area than expected. Blowing removed soil from the crucial tree row and roots were exposed. While soil was also removed by sweeping, some soil was redistributed within that area. Both blower and sweeper actions produced small linear hollows, potential new erosion zones, along the tree rows. Water flow from large rainfall events will concentrate in these areas and the level of erosion that will occur will depend on the force of the water, the slope and the length of the slope. Continued orchard management practices that include sweeping and blowing will remove substantial soil volumes over time. This will result in soil erosion in the vulnerable under tree region. Not only will root exposure endanger the health of macadamia trees but soil sediments in runoff and overland flow in this high rainfall area will exacerbate water quality down stream.

The soil moved in the experiment was detached and thus at a higher risk from further erosion from rain drop, overland flow and other erosion processes (Rose 1994). Ground cover (grass or mulch) in both the tree row and inter row on the steep slope of macadamia orchards is very important in helping alleviate soil erosion from these regions (Cox *et al.* 2004; Jenkins 2004). This study has identified that the current harvest practices in macadamia orchards move large volumes of soil and this is unsustainable in the long term. Modification in the design and use of blowers and sweepers needs to be addressed to reduce the impact of soil loss.

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Identification of regional priorities for conservation and production in forest areas in SE Asia

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Abstract
Land use change is a major driver for deforestation and forest degradation in South East Asia. Natural forests in SE Asia continue to be degraded. In addition to national policies for sustainable land management, policies formulated in commodity producer countries (guided by civil society pressure), that make companies trading in the consumer countries accountable for sustainability of production, are gaining importance for sustainable land management. New evaluation methods and tools are needed to support companies and local authorities in the identification of land areas for sustainable production forms and areas that should be rehabilitated or conserved because of its environmental value. A methodology was developed and tested that indicates potential environmental hazards of land management and assesses priorities for production and conservation.

The result of the analysis is a map indicating the vulnerability of areas under current land cover and based on an analysis of ecosystem stability and resilience to the impacts of human interventions. Broad management classes are defined with indication of priority for conservation (highly vulnerable to degradation) or production (lowly vulnerability to degradation). The area of study is the Chittagong Hill Tracts of Bangladesh, comprising three districts. This study concludes that for sustainable use, CHT lands require adaptive management with conservation strategies to ensure both productive and sustainable land management. The methodology as tested identified areas according to their potential and constraints for various uses and management types. Management alternatives may be indicated for current practices where appropriate.

Key Words
Conservation, production, land use planning, biodiversity, forest management, soil and water conservation.

Introduction
Land use change is a major driver for deforestation and forest degradation in South East Asia. Associated traditional land management systems, such as slash-and-burn rotational schemes, are under pressure and cause further degradation. Natural forests in SE Asia continue to be degraded. Associated traditional land management systems, such as slash-and-burn rotational schemes that were sustainable under conditions of low population pressure, have often changed due to land access restraints and cause further degradation. Conversion of forest areas for timber extraction and the establishment of tree crop plantations, such as oil palm or teak, leads to biodiversity loss and soil degradation.

Forest should be managed in a way and in those areas where it can be done sustainably and land use in non-forested areas should be practices there were environmental impact is limited. In many countries demography is changing quickly and quality of land declines due to degradation. Policies for sustainable land management are not only formulated in commodity producer countries, but also in commodity consumer countries (guided by civil society pressure) that make companies trading in the consumer countries accountable for sustainability of production. New evaluation methods and tools are needed that identify land areas for sustainable production forms and areas that should be rehabilitated or conserved because of its environmental value.

A new methodology was tested that identifies regional priorities for production and conservation and classifies land into management recommendation domains within those classes. The methodology consists of a multi-layered analysis of environmental constraints on watershed management which may support decisions in: 1) forest management; regeneration of forest land protects the genetic resources and diversity of forest flora and fauna, which in turn is beneficial for village communities, 2) agricultural management to increase productivity and decrease degradation, 3) identification of conservation areas and areas that have a potential for production.

This study focused on the Chittagong Hill Tracts of Bangladesh (CHT) where lands are degrading due to deforestation, shortening of the shifting cultivation cycle, and consequent soil erosion, floods and water pollution. The slash and burn system (*jhum*) as practiced in the CHT is sustainable if practiced with long enough fallows, but due to an increased population and scarcity of suitable land, the fallow periods have shortened from 15-20 to 3-5 years. Inappropriate forest and plantation management also contribute to severe land degradation. Soil erosion and forest degradation, resulting in declining crop production and loss of biodiversity, also have off-site effects on downstream and urban areas, i.e: flash floods, landslides, Kaptai dam-siltation and declining water quality. Extensive erosion is a serious threat to soils in the CHT and is one of the major degradation issues.

Methods

A methodology was developed to indicate potential environmental hazards of land management and to assess priorities for production and conservation. The result of the analysis is a map indicating the vulnerability of areas under current land cover and based on an analysis of ecosystem stability and resilience to the impacts of human interventions. Based on this analysis a map was created that indicates broad management classes with indication of priority for conservation (highly vulnerable to degradation) or production (lowly vulnerability to degradation). The zonation for the assessment of priorities for conservation and recommendation for sustainable watershed management is the result of a multi-layered analysis of environmental constraints on watershed management (Tyrie *et al.* 1999). It encompasses relevant environmental constraints concerning soil erosion and land degradation, actual land cover, and social constraints through land use and tenure issues, and forest land status (RF, USF, PF). Each of the mapped classes represents a unique combination of these basic factors, which provide a basis for a sustainable management strategy.

The land classification method is based on the following features:
Land Status. Forest Reserve Land, inside or outside of Forest Reserve Land.

Erosion Risk. Calculated erosion risk threshold under bare soil conditions that indicates the potential impact of vegetation removal.

Conservation status (if known). Current conservation status regulated by law or from land management review.

Critical and Fragile Land as defined by environmental type, but based on propensity to degrade, e.g. Mountain forestland.

Ruggedness. Areas classified as having a low erosion risk, but with steep slopes are separated out at the land system level based on 3 classes of dominant slopes.

Slope
Very steep slopes (>45%) are indicative of the sensitivity of areas for degradation upon disturbance.

Land cover. Protection (C) factor is the degree of protection from soil erosion under present land cover.

Forest density. Current forest status (no, low, middle dense and dense forest cover).

Presence of downstream infrastructures. When the area is part of a watershed that drains into reservoir of hydropower installations, it is given higher priorities for conservation, rehabilitation and reforestation.

The flow diagram of land classification method is given in Figure 1.

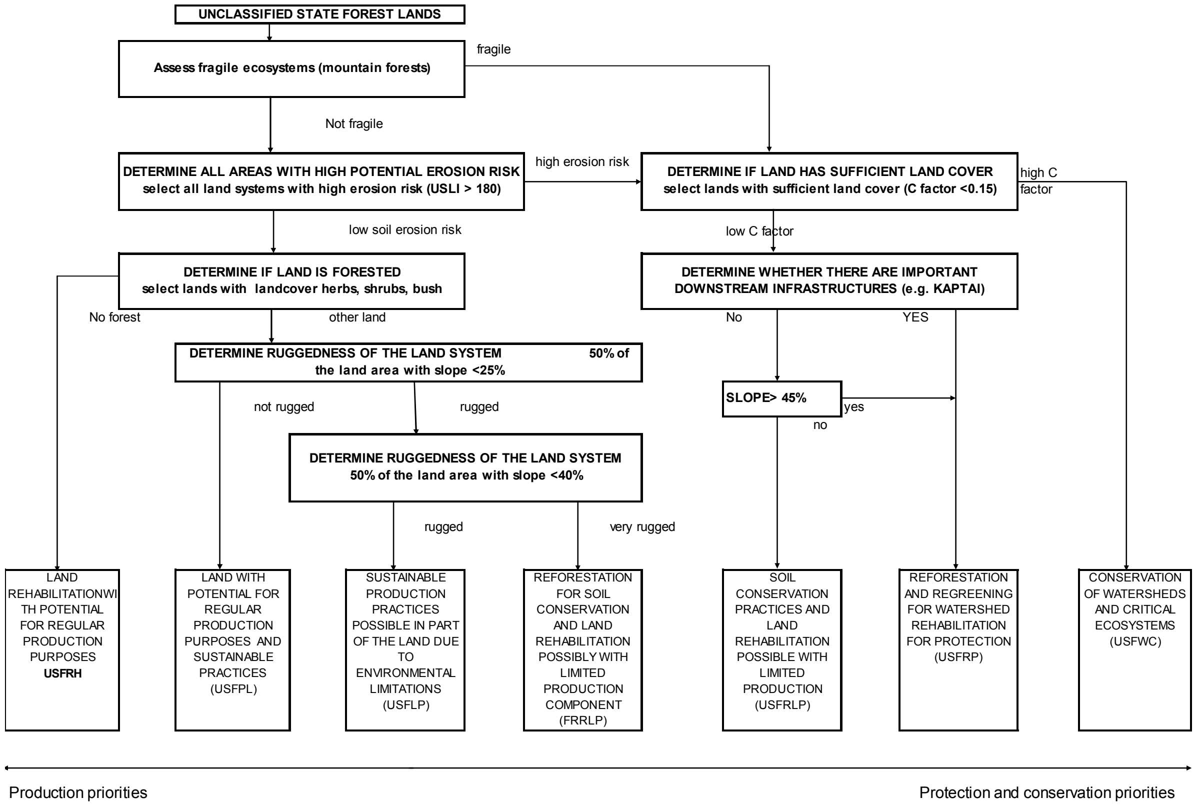

Figure 4. Flow diagram of land classification for unclassified state forest land.

The definition of each class and the management strategy recommended is given in Table 1.

Results

Table 1 shows the area of classes in the CHT with production or conservation priorities according to biophysical criteria.

Table 1. Area of land with recommended production/conservation priorities.

Conservation and production priority class	Total area (km^{-2})	Area %
Conservation & land rehabilitation	4895	41%
Conservation of critical watersheds	2709	23%
Land rehabilitation & SWC	769	6%
Soil conservation for watershed protection	578	5%
Soil conservation & land rehabilitation	12	0%
Production/ reforestation, SWC	70	1%
Reforestation & conservation	86	1%
Regular production/reforestation	176	1%
Regular production (forested)	1832	15%
Regular production (non-forested)	794	7%
Total area	11921	100%

Not all environments have the same inherent stability. From an ecological and production perspective those ecosystems which are unlikely to recover to their former quality after disturbance, such as logging or burning, can be considered critical or fragile. Thresholds are reached in such systems that will cause a change in the inherent properties and possible loss of unique biodiversity and conservation value. With change and degradation the resilience of these ecosystems often decreases and therewith productive capacity and the ability to regenerate successfully. Critical systems should not be exploited. Fragile systems should be exploited only on a limited basis or not at all. They include ecosystems such as mangroves and montane forests, forests on limestone, ultra-basic rocks, or on steep slopes and shallow soils. The methodology tested indicated that the larger area (65%) of the CHT must be under conservation area. Larger parts if the CHT should be conserved or rehabilitated because they are part of a critical watershed that have a high propensity to degrade or that drains into reservoir of hydropower installations (Kaptai dam). From a biophysical point of view an area of 9295 km-2 (78% of the total area) has limitations for use and requires some form of conservation, land rehabilitation or protection. The traditional land management systems, which were applied with long term rotational schemes under low population pressure, were sustainable. After creation of the Kaptai lake for the hydropower dam and the large influx of people in the region, small holder land management is no longer sustainable and yields are declining (Olarieta *et al.* 2007). In addition, large scale clear felling for timber harvest and teak planting was introduced in the CHT leading to severe land degradation. The analysis shows that 22% of the CHT is sufficiently stable to allow regular production without additional SWC management measures.

Conclusions

Mapping and documentation of the natural resources and their management is a way to illustrate the biophysical resources. The methodology as tested in this study may support policy prioritization with environmental information such as land cover change, erosion risks under current land cover, priority areas for forest and biodiversity conservation, and areas with potential for production forest, agriculture, and tree crops. Such information values land in an economic and environmental sense, giving options for land management and showing potential impacts of interventions.

For sustainable use, CHT lands require adaptive management with conservation strategies to ensure both productive and sustainable land management. Vulnerable areas are better left for nature conservation or rehabilitation. People downstream will benefit from better managed land, with less erosion and forest logging, through reduction of river siltation and flooding hazard and improved river water quality. Such considerations need to be based on proper information and judgment and need to be taken into account in broader cross-sectoral planning for the development of the CHT region. Making sound policies and decisions on sustainable land management requires adequate information on natural resources. The methodology as tested in this study can support policy formulation and local spatial planning by local authorities and companies. Through the process of land use planning, areas may be identified according to their potential and constraints for various uses and management types. Management alternatives may be indicated for current practices where appropriate.

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Impacts of soil compaction by livestock on crop productivity– a modelling analysis

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Abstract
A major constraint to adoption of integrated crop-livestock farming systems in Australia's Northern Grain Zone is the perceived adverse impacts of soil compaction caused by grazing livestock on crop production. Treading by livestock can reduce soil porosity and infiltration rate, and increase soil bulk density and soil strength, although these effects are mainly in the soil surface (top 5-10 cm). Despite these effects, rarely have reductions in crop performance been measured. This simulation analysis used APSIM (Agricultural Production Systems Simulator) to investigate the sensitivity of wheat crop growth and yield to reductions in root growth and water conductivity in the surface soil (0-10cm). Mild surface soil compaction was found to reduce grain yield by less than 10%. In more severe cases, crop losses could be up to 30%, especially if surface conductivity was greatly reduced and ground cover levels were low. Crop growth and yield were more sensitive to reduced surface conductivity and rainfall infiltration than to reduced root growth in surface layers.

Key Words
APSIM, simulation, grain yield, infiltration, wheat, root growth.

Introduction
One of the major concerns and constraints for increased integration of crop and livestock enterprises is the potential for livestock to cause compaction of cropping soils. Much work has shown that vehicle traffic can have significant and long-lasting effects on crop productivity, but the impacts of grazing livestock on soil properties in cropping systems is not as widely understood. Livestock have a similar static pressure to nominal tyre (74-81 kPa) and track (58 kPa) contact pressures of unloaded tractors & vehicles (Greenwood & McKenzie 2001). Pressures exerted by animals when moving can be greater because of the transfer of kinetic energy as their weight is distributed on only 2-3 hooves. For example, the pressure measured under hooves of a 530 kg walking cow was 300 kPa, greater than twice its static pressure (Scholefield *et al.* 1985). However, the wider the applied stress, the greater the depth of influence for a given contact pressure (Soehne 1958). Hence, the compaction effect of livestock is shallower than for vehicles, with livestock rarely causing soil compaction below 10 cm depth.

Many scientific studies have examined the impacts of livestock treading on soil physical conditions, but most have been concerned with grazing pastoral systems (Drewry *et al.* 2008; Greenwood & McKenzie 2001). It has been found that treading by livestock can affect three important aspects of soil physical properties – 1. increased soil strength and bulk density; 2. reduced soil porosity; and 3. reduced soil hydraulic conductivity and infiltration rate. Despite these effects, few studies have shown a significant reduction in subsequent crop growth and production after treading by livestock, possibly because effects are too small in magnitude or depth to influence plant growth greatly (Proffitt *et al.* 1995; Clarke *et al.* 2004; Radford *et al.* 2008). It may be that the harmful effects of livestock on crop or plant growth may only occur in particular years or under certain conditions which have not occurred in the few experiments conducted. Furthermore, most of the experiments have been conducted in areas with quite different climatic conditions to Australia's northern cropping zone. For these reasons the sensitivity of wheat crop growth and grain yield to different severities of surface compaction by livestock was simulated at 5 locations in Australia's subtropics using APSIM (Agricultural Production Systems Simulator), a farming system model (Keating *et al.* 2003).

Methods
Livestock treading effects on soil physical conditions were simulated by changing APSIM soil parameters to investigate how sensitive crop growth and yield are to these changes across a range of climatic conditions. Two main effects, reduced surface root growth and reduced surface water conductivity, were first explored independently and then combined. These effects were set at three severities to represent, mild, medium and severe compaction effects (Table 1). Plant root growth in the surface layer (0-10cm) was reduced by

lowering XF (root exploration factor), which regulates the potential rate that roots extend into deeper soil layers, and by lowering KL (i.e. the proportion of available soil water that can be extracted each day), which is related to the root density in a particular soil layer. Surface conductivity was reduced by increasing the Curve Number, and infiltration rate was reduced by lowering SWCon in the surface layer (0-10 cm). SWCon regulates the rate of water movement between soil layers, and soil curve number, influences the relationship between daily rainfall and surface runoff (Table 1). The effect of soil cover (another factor influencing runoff) was also explored by simulating the when crop stubble was set to 3.5 t/ha (high cover – 80%) and 1.5 t/ha (low cover – 20%) on 1 Jan each year. The model does not account for the possible impacts of waterlogging or increased disease incidence which may occur due to degraded surface soil structure.

Table 1. Adjustments to APSIM soil parameters made in the top soil layer (0-10 cm) to simulate response of crops to surface soil compaction effects of reduced root growth and reduced surface conductivity of increasing severity.

Severity of effect	Reduced root growth		Reduced surface conductivity	
	KL	XF	SWCon	Curve No.
Standard	0.06	1.0	0.30	73
Mild	0.04	0.4	0.20	78
Medium	0.03	0.2	0.15	83
Severe	0.02	0.1	0.10	88

Simulations used 50 years of historical meteorological data (1956-2006) at 5 locations from central Queensland to northern NSW, chosen to represent the range of mean annual rainfall (MAR) and summer-winter rainfall distribution (Emerald, 546 mm MAR; St George, 524 mm MAR; Clifton, 719 mm MAR; Goondiwindi, 616 mm MAR; Narrabri, 686 mm MAR). All simulations used common crop management rules and the same soil type, a grey Vertosol with a plant-available water-holding capacity (PAWC) of 218 mm. Wheat cv. Baxter was sown between the 10 May and 10 Jul after 20 mm of rain had fallen over the past 4 days and 100 kg of urea fertiliser was applied at sowing. Established plant density was 150 plants/m^2 with a row spacing of 250 mm. The standard Wheat parameter set (APSIM vers. 7.0) was adjusted so that initial root depth of wheat at germination was 40 mm (the depth of sowing) instead of 100 mm. In all simulations soil water (to 44 mm plant-available water), nitrogen (40 kg mineral-N/ha) and surface organic matter were reset on the 1 Jan each year to avoid differences between scenarios being carried forward into subsequent years and to enable crop growth each year to be compared directly between simulated scenarios.

Results

Simulated effects on root growth and rainfall infiltration

Rainfall infiltration was increasingly affected by reductions in soil surface conductivity, so that with increasing severity the average percentage of rainfall that infiltrated was reduced by 1-2%, 4-6% and 7-10%, respectively (Table 2). Under higher ground cover conditions the reductions in rainfall infiltration were smaller; on average about 75-80% of those under lower ground cover conditions. Adjustments made to soil parameters influencing crop root growth were found to slow the rate that roots explored deeper, imitating the likely impact of increasing soil strength in the soil surface layers (Table 3); but, between scenarios there was no difference in the crops final rooting depth.

Table 2. Change in average annual rainfall infiltration (mm) as a result of simulating different severities of reduced root growth in surface layers, reduced surface conductivity and when both effects are combined. Low ground cover scenarios are presented.

Location	Reduced root growth			Reduced surface conductivity			Combination of both		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild	Moderate	Severe
Emerald	0	0	- 1	- 26	- 64	- 112	- 16	- 65	- 119
St George	0	0	0	- 11	- 29	- 51	- 7	- 30	- 55
Clifton	0	0	0	- 24	- 57	- 100	- 14	- 59	- 105
Goondiwindi	0	0	- 1	- 14	- 34	- 60	- 9	- 35	- 64
Narrabri	0	0	- 1	- 18	- 44	- 77	- 12	- 47	- 83

Effects on crop growth and grain yield

Reducing root growth was found to reduce crop biomass growth more than it reduced grain yield (Fig. 1a and 1d). In fact when root growth was severely reduced, grain yield was often found to increase, despite lower crop biomass (Table 4). This occurred because early stress reduced growth of these crops allowing more water to be available during grain filling. Grain yield was more sensitive to reductions in surface

Table 3. Reduction in average crop rooting depth (mm) at floral initiation (i.e. Zadok growth stage 30) under different severities of reduced root growth in surface layers, reduced surface conductivity and when both effects are combined. Data are averaged for all locations.

	Severity of reduced root growth		
Compaction effect	Mild	Moderate	Severe
Reduced root growth	- 66	- 184	- 458
Reduced surface conductivity	- 16	- 29	-53
Combination of both	- 74	- 192	- 460

conductivity (Fig. 1b). The largest effects were at Emerald and St George with the least at Narrabri, apparently driven by the amount of in-crop rainfall (Table 4). When both soil compaction effects were applied grain yield was reduced by up to 10% in mild scenarios, by up to 20% in moderate scenarios and by up to 30% in severe scenarios (Fig. 1). Although, the average reductions in grain yield were typically less than 10% across all locations, except in the most severe scenarios (Table 4). Crop biomass was reduced by similar amounts to grain yield, except in the when root growth was severely reduced when benefits during grain filling were found (discussed previously).

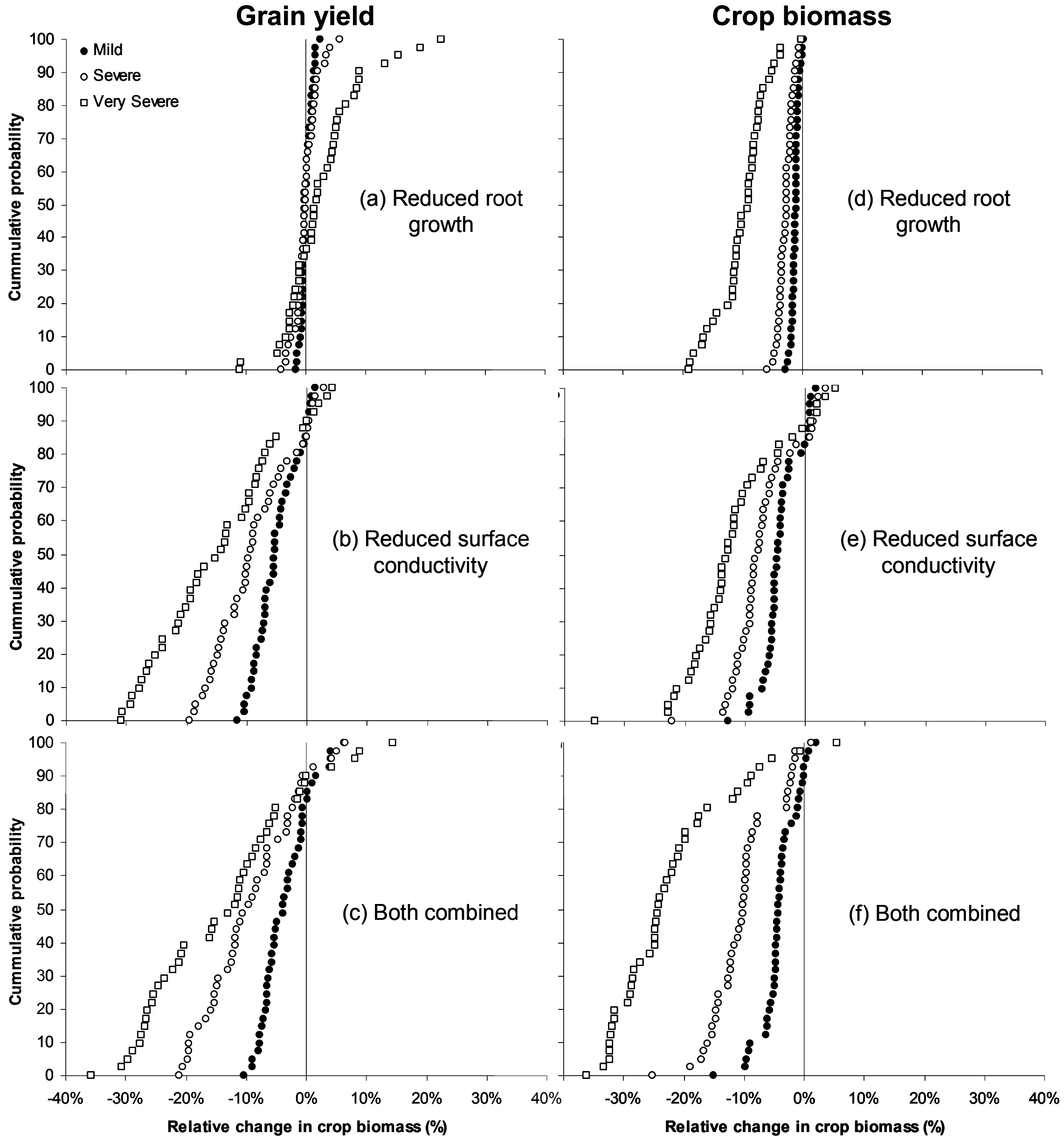

Figure 1. Cummulative probability of changes in grain yield (a-c) and crop biomass growth (d-f) as a result of simulating different severities (●- mild, ○- moderate, □- severe) of reduced root growth in surface layers, reduced surface conductivity and when both effects are combined at Goondiwindi, Queensland.

Table 4. Changes in average crop grain yield (% change from control) at five locations in sub-tropical Australia due to different severities (●- mild, ○- severe, □- very severe) of reduced root growth in surface layers, reduced surface conductivity and when both effects are combined. Low ground cover scenarios are presented.

Location	Reduced root growth			Reduced surface conductivity			Combination of both		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild	Moderate	Severe
Emerald	0	1	8	-5	-10	-18	-4	-10	-10
St George	0	0	4	-5	-9	-16	-4	-10	-12
Clifton	1	1	5	-3	-6	-12	0	-6	-8
Goondiwindi	0	0	2	-4	-8	-14	-3	-9	-14
Narrabri	1	1	3	-3	-5	-8	1	-4	-6

In scenarios where more stubble cover was maintained the effects of soil compaction on crop growth and yield were lessened (Table 5). This was mainly due to the stubble facilitating rainfall infiltration when surface conductivity was reduced.

Table 5. High stubble cover lessens reductions in average crop yield (% change from control) due to combined effects of reduced root growth and reduced surface conductivity.

Location	Mild		Moderate		Severe	
	Low	High	Low	High	Low	High
Emerald	-4	-2	-10	-6	-10	-3
St George	-4	-2	-10	-5	-12	-4
Clifton	0	2	-6	0	-8	2
Goondiwindi	-3	0	-9	-2	-14	-3
Narrabri	1	2	-4	0	-6	-1

Conclusion

This simulation study suggest that mild surface soil compaction from livestock, would result in reductions in grain yield of less than 10%. These mild compaction effects are similar to most documented changes in soil conditions after treading by livestock. This implies that in most cases the impacts of compaction by livestock on crop performance are small, which is supported by the few studies that have investigated this experimentally. Crop losses could be larger if more severe soil compaction occurred, especially if surface conductivity is greatly reduced and ground cover levels are low. Crop growth and yield were more sensitive to reduced surface conductivity and rainfall infiltration than to reduced root growth in surface layers. Better information on how crops respond to changes in soil surface condition from to livestock grazing would help to improve our confidence in modelling the impacts on crop performance over the long-term.

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Indigenous technology for adapting to water logging situation for sustainable livelihood security in low lying areas of Bangladesh

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Abstract
The southern, southwestern and the coastal areas of Bangladesh remain submerged for long periods every year, especially during the monsoon season. People in these areas have been coping with submerged/flooded conditions for generations. The people of these areas depend on agriculture. They have adopted a method of cultivation, locally referred to as "Vasoman Chash," meaning floating agriculture, since the time of their forefathers. This system is similar to hydroponics, which is a scientific method whereby the plants are grown in the water and they derive their nutrients from the water instead of from the soil. The production rate is high from this kind of agricultural practice. Floating agriculture is a possible local knowledge based technology which would help in attaining sustainable livelihood security in the vulnerable areas like waterlogged areas in Bangladesh.

Key Words
Waterlogging/flood coping strategy, sustainable livelihood, indigenous knowledge and practices.

Introduction
In Bangladesh about 8,000 hectares of waterlogged lands exist in Khulna and Jessore areas. If the sea level rises due to global warming more areas of Bangladesh will undergo waterlogging and more land will become unavailable for crop production (BARC, 1991). The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood protected areas will impede drainage and gradually increase water logging problems (Ali, 1996). This will decrease arable areas and may lead to migration of people to other parts of the country. To cope with the changed situation local knowledge based best practices may prove to be vital for sustainable livelihood security.

Floating agriculture is a farmers' innovation that is being practiced in low lying areas of middle and southern districts of Bangladesh. Floating agriculture has several advantages: (1) the fallow waterlogged area can be cultivated and the total cultivable area can be increased, (2) no additional fertilizers and manure is required unlike in the conventional agricultural system, (3) after cultivation, the biomass generated can be used as organic fertilizer in the field, (4) during the floods it can be also used as a shelter for the poultry and cattle, and (5) the fishermen can cultivate crops and fish at the same time in same area. All the activities of the practice are environment friendly and can prove to be an alternative livelihood option.

Floating agriculture by using naturally grown water hyacinth is an indigenous knowledge and technique of local farmers for growing vegetables, seedlings and flowers in waterlogged areas. In this paper we will discuss the potentiality of this practice for sustainable livelihood security in low lying areas of Bangladesh.

Farming procedure
The soil-less cultivation system was first introduced in Gopalgonj, Pirojpur and Barisal district in Bangladesh. Recently this farming system is practiced in water logged areas of Keshabpur of Jessore district. The cultivation procedures are not identical in all areas. The hydroponics farming technique of Gopalgonj is quite different from that of the Pirojpur technique. Considering the uniqueness of the technique involved only the Gopalgonj method is mentioned below.

Floating bed (*dhap*) preparation
After harvesting the Aman (cultivated in the monsoon season) paddy, water hyacinth is collected in May to July from the nearby river, canals, ditches, lagoons and from the wetland where it grows profusely. Straw and rice stubble are also used for the same purpose. The depth of the water bodies is not so significant for preparation of the bed. They can be made and managed in any depth of water. Farmers put a long bamboo on the mass of fully matured water hyacinths. Then a man stands on the bamboo and gathers immature over

mature hyacinth. He starts to pull the water hyacinths from the both sides of the bamboo and flatten them under foot. In this process he proceeds towards the end of the bamboo. This process is continued until the desired height and length of the bed is attained. Farmers again dump water hyacinths after 7-10 days later from the first dumping and then the bed is left for decomposition before sowing or planting of seedlings. The upper layer is comprised of deposits of small and quick-rotting waterworts (or small duck weed type of plant), which degrade quickly and make for good manure. It requires 15-20 days from the collection and preparation of the water hyacinth and other materials or the floating bed before cultivation can begin. Farmers carry this bed by rowing to the desired area.

Shape and size of the floating bed

The size and shape of the bed is not fixed. Farmers make the bed as their desired size and shape. Generally, the dimension of the bed is about 30 m long, 2 m width and 1 m height. The distances between beds depend on length of land. The narrow strip shaped bed is made so that it can be easily made by gathering water hyacinths and harvesting of crops is convenient.

Cultivation procedure

Sometimes farmers make a small ball called ‘Tema’ which is made by aquatic plant locally known as Dulali lata along with compost material. After making the ball farmers put sprouted seeds into it. They make seedbed on raised land around their homestead areas and put the Tema on seedbed.

In Tungipara Upazila, Gopalgonj farmers cultivate mixed crops on floating beds. At initial stage they cultivate Ladies finger, Cucumber and Eidged Gourd in the same bed during June to August. Usually two rows of Ladies finger and one row of Cucumber or Ridged Gourd are alternately cultivated. Crops are harvested from the month of August to October. The crops are harvested one after another till the next rainy season. Farmers use a small country boat to move around the floating beds and pick up vegetables from the beds.

Maintenance

Sometimes saplings on the floating bed turn yellow, farmers chop the decomposed parts of the bed, roots of water hyacinth and put them underneath the seedlings or put the chopped materials on the floating bed 30 cm away from the edge of the bed. Thus, the seedlings get nutrients and become healthy and start to grow. After planting saplings onto the floating bed de-weeding becomes a regular job of farmers. Bamboos are used as anchorage of floating beds to keep them fixed in a place and prevent from floating away by wind or water current. During the monsoon, farmers use small country boats to manage the floating agricultural land.

Cost and benefit analysis of floating vegetable cultivation

Following is a brief estimate of costs incurred and benefits accrued from a typical soil-less cultivation system in floating vegetable culture consisting of 10 Dhaps, each measuring about 15 m x 2 m = 30 m^2. Estimated cost for making 10 floating beds is BDT 10,000 while estimated income from 10 such beds is BDT 34,000; the gross benefit being BDT 24,000 per season (Table 1 and 2) (1US$ = 70 BDT).

Potential for Application

The floating agriculture practice in the southern parts of the country represents a traditional/indigenous agriculture system for the water logged or the submerged area in Bangladesh. The people of the southern parts of Bangladesh adopted the practice based on their traditions and the community’s culture and wisdom. This is an environment-friendly and beneficial practice. People use the floating agriculture practice as a model in the pond and other water bodies in other parts of the country. It could be a sustainable and profitable practice in Bangladesh as well as for other countries facing a similar situation.

Table 1. Estimated Cost for making 10 floating beds during rainy season.

Sl. No.	Cost Heads	Amount	Unit Cost (BDT)	Total Cost (BDT)[A]
1	Construction of hydroponics	60 man days	100	6000
2	Raw materials (water hyacinths and other aquatic weeds)	20 man days	100	2000
3	Seed and seedlings	10 beds	60	600
4	Nursing/maintenance, purchase of bamboo, insecti-cides and harvesting	10 beds	200	2000
Total Cost				10,000

[A]Note:1US $=70 BDT

Figure 1. A newly built floating bed.

Figure 2. A ready bed for planting.

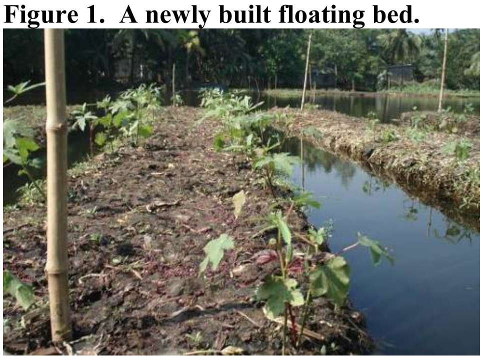

Figure 3. Red Amaranth.

Figure 4. A group of beds.

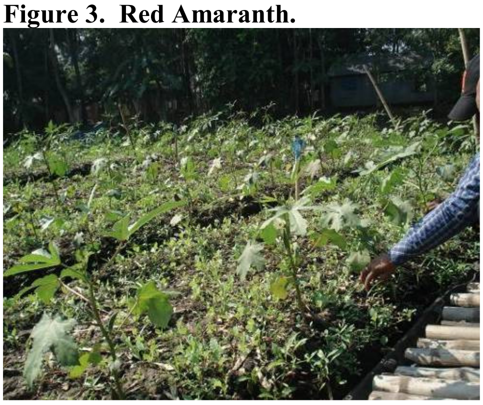

Figure 5. Intercultural operations.

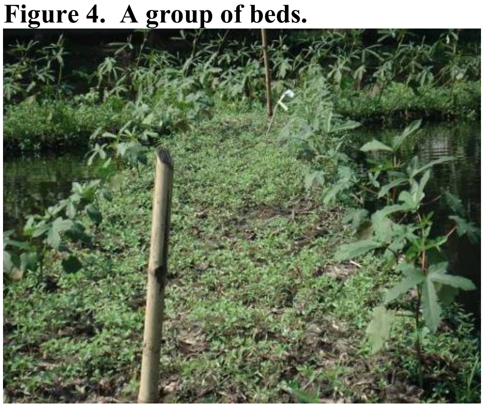

Figure 6. Coriander and Okra.

Table 2. Estimated Income from 10 floating beds.

Sl No.	Income Heads	Amount (Kg)	Unit Income (BDT)	Total Income (BDT)
1	Ladies finger	2000	6/Kg	12000
2	Ridged Gourd	400	6/ Kg	2400
3	Red Amaranth	600	8/Kg	4800
4	Taro, Indian spinach	-	60/Bed	600
5	Compost manure	30,000	0.50/ Kg	15000
Total Income				34,000

Conclusion

Food, clothing, housing, health and education are the basic needs of the people of Bangladesh. Sea level rise becomes a threat to food security by affecting basic needs and security. Bangladesh has been practicing floating agriculture for a long time (three to four hundred years). It is a useful method considering the economical, environmental and as well as social aspects. The production rate is high from this kind of agricultural practice. Floating agriculture is a possible local knowledge based technology which would help in attaining sustainable livelihood security in vulnerable waterlogged areas.

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Infillings in irrigated soils cultivated with annual and perennial crops in the Apodi Plateau, Northeastern Brazil

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Abstract
Irrigated agroecosystems have some particularities that reflect on the nutrient cycling and energy fluxes differently from non irrigated areas and the efficient and rational use of these areas is highly recommended, but generally do not occur. Within this context, the aim of this work was to evaluate the consequences of the irrational use of irrigated systems under different conditions of soils, cropping, and management. We studied micromorphological properties of calcareous soils, using microanalysis techniques for different situations of management in an irrigated area located in the Apodi Plateau, state of Ceara, Brazil. We selected four cultivated areas and their respective native vegetation areas. The selection criteria considered the time of use, cropping regime (annual=corn and beans in succession and perennial=bananas, grass and guava) and irrigation systems (microsprinkler or central pivot). Soil blocks (5×10 cm) were collected from 5-15, 15-25 and 25-35 cm layers and pedological features at optical and electronic microscope level observed using SEM-EDS. It was possible to associate the frequency and types of infillings with the soil management, with a tendency for the frequency to be higher for the cultivated area, except for Gr. Generally, for cultivated sites the types are between dense complete (DC) and dense incomplete (DI), with voids in the CB area, and in natural situations loose continuous (LC) or loose discontinuous (LD) fabrics. The SEM mapping and EDS data showed infillings voids and a greater proportion of quartz grains occupying the voids with a composition similar to the matrix. Grains of iron oxide appeared in the infilling probably due to the weathering of calcareous rocks. It is possible that a natural susceptibility to infilling formation in the soils studied associated with their genesis, management and irrigation, intensifying the frequency and types of infilling. Certainly other physical properties related to water movement and root development will be compromised.

Key Words
Soil quality, soil structure, soil management, micromorphology, microanalysis, calcareous soils.

Introduction

Investments have been applied to the enlargement of irrigated areas in the northeastern region of Brazil. This fact is strategically important, since they promote better money distribution and improve the employment generation, decreasing social differences and increasing life quality in one of the poorest region of Brazil. However, the expandsion of irrigated areas is limited. Considering all existing and future available water for irrigation, only 5% of the total area of the northeastern region can be irrigated. Thus, the efficient and rational use of these areas is highly recommended, which generally do not happen.

Irrigated agroecosystems have some particularities of nutrient cycling and energy fluxes different from non irrigated areas. Normally, the intensity of these processes is higher when compared to natural conditions, basically due to higher exportat of nutrients and biomass production (higher productivity and number of crops), higher necessity of agricultural practices, and higher external input (fertilizers, herbicides, insecticides, and fungicides). Furthermore, the hydrological behaviour is changed by the number and intensity of wetting and drying cycles of soils. Inadequate soil management practices have been noticed in some irrigated areas in the northeastern region of Brazil, reflecting environmental constraints due to soil salinity, soil compaction, and soil and water pollution by agricultural chemicals. Adopting any additional management practice aiming to reclaim these areas can result in the decrease of their sustainability and efficiency.

Within this context, studies must to be conducted in order to evaluate the consequences of the irrational use of the irrigated systems under different soils conditions, cropping, and management. Hence, the objective of this work was to evaluate the micromorphological properties of calcareous soils, using microanalysis techniques, for an irrigated area located in the Apodi Plateau, State of Ceara, Brazil.

Methods
The study was carried out in the Jaguaribe-Apodi irrigated area, located in the Apodi Plateau, municipality of Limoeiro do Norte (5° 06' S and 37° 52' W), to 199 km from the capital Fortaleza, Ceara (Figure 1). The climate classification is BSw'h', according to Köeppen classification, with annual means of temperature and rainfall of 28.5 ^{o}C and 772 mm, respectively. The main cropping systems are fruits species (e.g. bananas, melon, guava, etc) and grains (e.g. maize, beans, and sorghum). The irrigation was performed either by localized irrigation system, by using microsprinklers, or using a central pivot irrigation system. The central pivot system has been replaced due to high water demand. For this study, we selected four cultivated areas and their corresponding natural vegetation areas. The criteria for selection considered the time of use, cropping regime (annual and perennial), irrigation systems (microsprinkler or pivot central), and quality of technical management (Lacerda and Oliveira 2007).

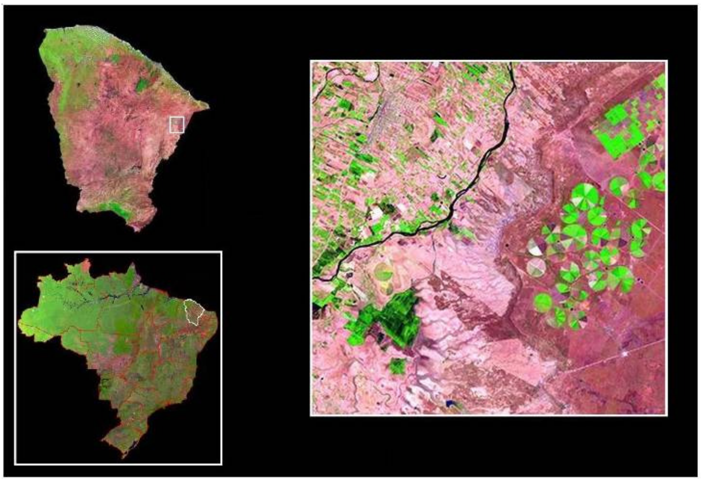

Figure 1. Location of Apodi Plateau and the Jaguaribe-Apodi irrigated area, Limoeiro do Norte-CE, Brazil.

Soil blocks (5×10 cm) collected at 5-15, 15-25 e 25-35 cm layers were impregnated with a 1:1 crystic resin: stiren mix poured onto samples under atmospheric pressure, followed by vacuum oven treatment at 50 °C for 2 h. Impregnated samples were cut into slabs of 0.5 cm thickness by using a diamond saw, and polished with corundum abrasives from 250 down to 600 mesh. After ultrasonic cleaning, the polished blocks were mounted onto glass slides followed by polishing and hand-finishing to produce 30 nm thick sections. No cover slips were used. Thin sections were examined under a Zeiss polarizing microscope (Optical Transmitted Microscopy—OTM level) using an attached Pentax camera fitted with a Zeiss exposure-meter. Pedological features at OTM level were analysed using standard micromorphological techniques (Bullock *et al.* 1985), and the selected areas described were submitted to SEM-EDS analysis. The microstructure and submicrostructure were investigated using a JEOL 6400 scanning electron microscope coupled with an energy dispersive X-ray detector (SEM/EDS), following the recommendations of Bisdom and Ducloux (1983). A flat ultrapolished, uncovered, thin section of approximately 12 cm^2 was analysed for the elemental distribution of Ca, Mg, K, Si, Al, Fe, Mn and Ti using energy dispersive spectrometry (EDS). In this paper, only pedofeature infillings are reported.

Results
Firstly, it is possible to associate the frequency and types of infillings with soil management (Table 2). Infillings are more abundant for cultivated soil, except for Gr area. Current management was less intensive in G and B areas; it used to be intensive with annuals and sprinkler irrigation by central pivot. The higher frequency at the deepest layers (25-35 cm) occurred with all cultivated areas, except the CB area, which has similar frequency for all evaluated layers. Probably cultivation affects infilling formation. The Gr area had the higher difference between cultivated and non-cultivated areas and, also, within layers (5-15 and 15-25 to 25-35 cm) mainly due to the cultivated situation.

Also, it is possible to associate the types of infillings with the influence or not of cultivation. In the cultivated areas the types varied from dense complete (DC) to dense incomplete (DI), what means that voids are completely unfilled as is the case of voids from the CB area (Figure 1). Under natural conditions, the types showed grains, aggregates, crystals or excrements distributed throughout the void and are loosely packed (loose continuous=LC) or irregularly distributed, isolated or in clusters (loose discontinuous=LD) (Figure 2).

Table 1. Location, soil classification and history of use of cultivated areas in the Jaguaribe- Apodi irrigated area, Limoeiro do Norte-CE, Brazil.

Area	Soil classification*	Historic
Corn/beans (CB) (5°10'9" S and 37°58'58" W)	Red Latosol Eutrofic cambissolic	Area with 26 ha but in the moment of soil collection only 6 ha were under cultivation. It has been cultivated for 20 years with corn and beans in succession. The irrigation was performed by pivot central system. Chemical fertilizers used were urea and ammonium sulphate. Soil preparation was done by using subsoiler followed by disc harrow and disc plow. There was use of herbicides and insecticides (Lannate BR, 7.5 L/ha/cycle). Soil from natural vegetation collected near cultivated area is Red Argisol Eutrofic latossolic.
Guava (G) (5°09'29" S and 37°59'36" W)	Cambissol Haplic Tb Eutrofic Tipic	Area with 6 ha that has been cultivated with guava for 7 years by adopting localized microsprinkler irrigation system. This area was previously cultivated during 10 years with annual crops and sprinkler irrigation by pivot central. Organic (caprine manure, 20 L/plant, applied each 2 months) and chemical fertilizers (Urea – 30 g/plant, Potassium chloride – 50g/plant, Magnesium chloride – 30 g/plant, Calcium nitrate – 30 g/plant and MAP – 300 g/plant) were applied in each cropping cycle. Soil preparation was usually done by subsoiling, but only a mechanical mow is current used in the wet season. Soil from natural vegetation collected near cultivated area is Cambissol Haplic Tb Eutrofic latossolic/Tipic.
Grass (Gr) 5°12'54" S and 38°01'52" W	Cambissol Haplic Ta Eutrofic Tipic	Area with 1,600 ha that has been cultivated for 10 years with *Cynodon niemfluesis*, adopting pivot central irrigation system. This area was previously cultivated with corn during 5 years. Chemical fertilization was done by applying urea four times per year (100 kg/ha each time), one application of MAP (50 kg/ha), and one application of simple superphosphate (50 kg/ha). The organic fertilization was performed in the same area by animals (10 animals/ha) grazing 12 hours daily. Disease and pests did not happen. Machinery was used in the hay making process. Soil from natural vegetation collected near cultivated area is Cambissol Haplic Ta Eutrofic Tipic.
Bananas (B) (5°9'15" S and 37°59'55" W)	Cambissol Haplic Ta Eutrofic Tipic	Area with 287 ha that has been cultivated for 10 years with banana adopting localized microsprinklers irrigation system. This area was previously cultivated with vegetables during 5 years. There was application of caprine manure (20 L/plant/week) and liquid organic compost (600L/plant/week). It was used chemicals to control pathogens, insects and weeds. Soil chemical fertilization was performed monthly by using urea, potassium and magnesium sulphate. Each 10 years intervals the plot is renewed, and for this purpose soil preparation is done by using subsoiler and disc harrow. Soil from natural vegetation collected near cultivated area is Cambissol Haplic Ta Eutrofic Tipic

*Soil classification using Brazilian System.

Table 2. Frequency and types of soil infillings from irrigated area under different management situations and areas under natural vegetation in the Jaguaribe-Apodi irrigated area, Limoeiro do Norte-CE, Brazil.

Area/Sample	Layers (cm)		
	5-15	15-25	25-35
Corn/Beans (CB)	Fq / DI-LC	Fq / DI-LC	Fw / DI-LC
Corn/Bean natural vegetation (CBNV)	VFw / LC-LD	Fq / LC-LD	VFw / LC-LD
Guava (G)	Fq / DI-LC	C / DI-LC	C / DI-LC
Guava natural vegetation (GNV)	Fq / LC-LD	Fq / LC-LD	C / LC-LD
Grass (Gr)	Fq / DI-LC	Fq / DI-LC	D / DI-LC
Grass natural vegetation (GrNV)	C / LC-LD	VD / LC-LD	C / LC-LD
Bananas (B)	Fq / DI-LC	D / DI-LC	D / DI-LC
Bananas natural vegetation (BNV)	D / LC-LD	C / LC-LD	D / LC-LD

Frequency: VD: Very dominant (>70%); D: Dominant (50-70%); C: Common (30-50%); Fq: Frequent (15-30%); Fw: Few (5-15%) and VFw: Very few (<5%). Types of infillings: DC: Dense complete; DI: Dense incomplete; LC: Loose continuous; LD: Loose discontinuous. According to Bullock *et al* (1985).

The mapping and EDS data showed the void infillings with a greater proportion of quartz grains occupying the voids and a composition similar to the matrix. Grains of iron oxide occurs in the infilling probably from concentration due the weathering of calcareous rocks. The iron oxide in the matrix is relatively high for soils considered equivalent to Inceptsols, but did not occur in discrete units like in the infillings.
Naturally, the studied soils seem to be susceptible to infilling formation if we consider their frequency under natural conditions. We consider what material can be associated with the parent material and consequent natural chemical properties. The developed soils exhibit the influence of calcareous rocks and are dispersible. The low stability of aggregates and loam texture of soils can contribute to the production of fine particles and small clods that occupy the voids, this increasing the frequency and types of infillings.

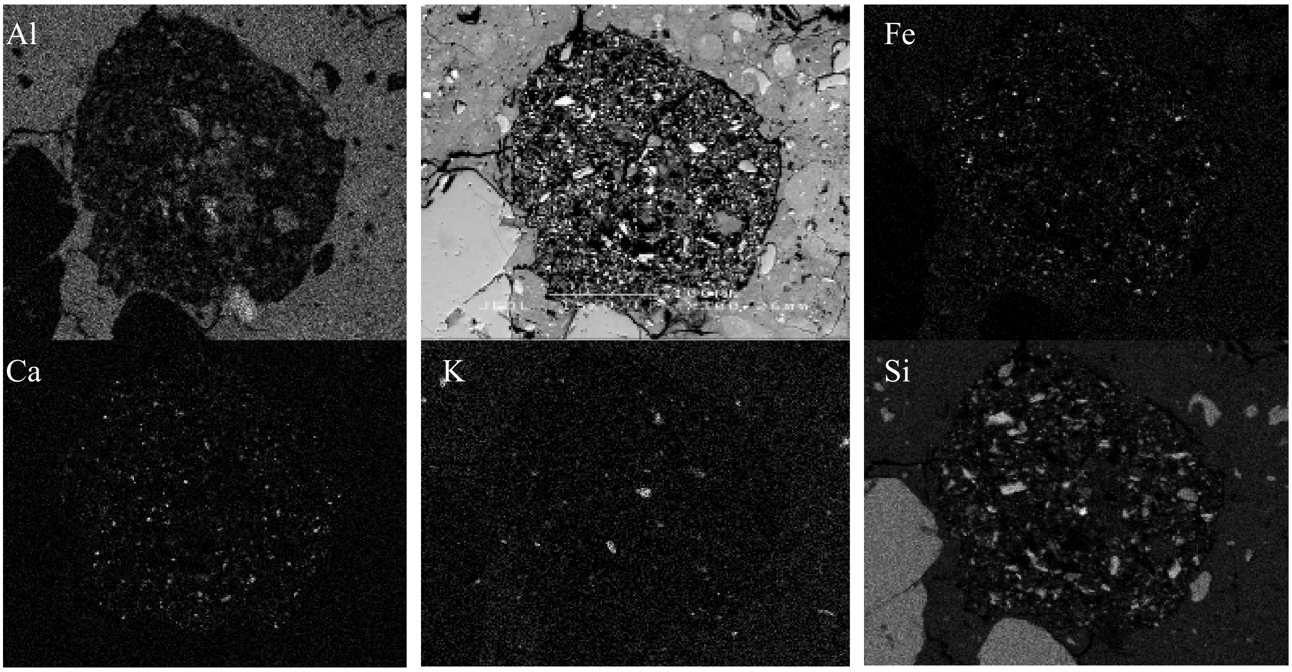

Figure 1. Dense complete void filling (upper and central photo) and Al, Fe, Ca, K and Si in soil from a Corn and Bean (CB) area located in the Jaguaribe- Apodi irrigated area, Limoeiro do Norte-CE, Brazil.

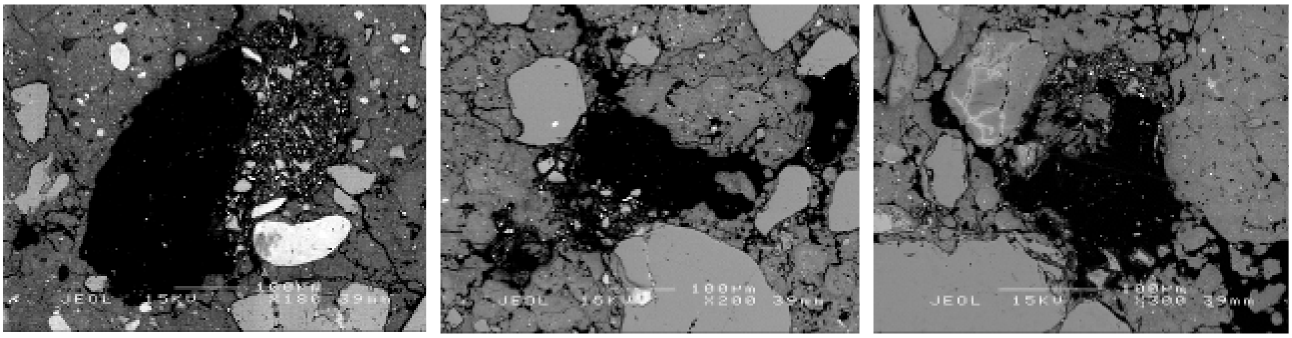

Figure 2. Void with loose continuous and discontinuous filling from soil under natural vegetation of bananas (NVB) area located in the Jaguaribe- Apodi irrigated area, Limoeiro do Norte-CE, Brazil.

Conclusion

There is a natural susceptibility to infilling formation in the studied soils which is probably associated with their genesis and the management. Irrigation increased the frequency and types of infilling. Certainly physical properties related to water movement and root development will be compromised by void infilling.

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Land management planning concerning to workability timing of soil in Souma area, using Aljarafe model

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Abstract
Workability timing is related to land management planning at a farm level. Automating and application of procedures using soil resources survey data are used to predict soil moisture and workability timing. Within the new framework of MicroLEIS DSS, the Aljarafe statistical model in terms of particle size distribution, cation exchange capacity, and organic matter content was used to estimate the optimum moisture and workability timing. For this purpose, the Souma area located in the west Azerbaijan; of about 4100 ha was selected. Soil physical and chemical data taken from 35 representative profiles were stored in SDBm plus which is designed to harmonise, store and use large amounts of geo-referenced soil profile data, elaborated in the field and the laboratory, in an efficient and systematic way. The results showed that plasticity indexes were classified as C1, C2 and C4 for 3839 ha, 126 ha and 125 ha, respectively. The number of days when the soil can be worked after rain or workability timing for the whole studied area except 126 ha were classified as moderate optimum moisture for working. Integrating the results with GIS will be useful to create geo-referenced maps to solve problems by looking at the data in a way that is quickly understood and easily shared.

Key Words
Workability timing, MicroLEIS DSS, Aljarafe model, Plasticity index.

Introduction
The soil workability status is considered as the optimum soil water content where the tillage operation has the desired effect of producing the greatest proportion of small aggregates (Dexter and Bird 2004). If the soil is drier that the optimum water content, then tillage requires excessive energy and can also produce large clods (Rounsevell and Jones 1993).The plasticity index is based on the work of Atterberg and is defined as the range of water over which a soil exhibit plastic behavior, being calculated by the liquid limit minus the plastic limit (De la Rosa *et al.* 2003). Several studies (Wagner *et al.*1992; Mueller *et al.* 2003) found the best disaggregating effect of tillage implements to occur at the water content corresponding to maximum proctor test which it is the density of a given soil can be compacted varies with water content and force of compaction. Therefore, the optimum water content for workability is equal to the water content at maximum proctor density. Although these limits can be slightly different for different tillage implements as observed by Bhushan and Ghildyal (1972), they relate to typical tillage operations in the arable layer of the soil. Automating the application of procedures in engineering soil evaluations can be useful to people engaged in planning, construction and maintenance projects, along with agricultural soil management. Finally, an attempt is made to predict soil technological and engineering qualities/vulnerabilities by studying the relationship between these properties and other more readily-available soil characteristics caused to be established Aljarafe statistical model within the new framework of MicroLEIS DSS (De la Rosa *et al.* 2003). According to the Aljarafe model for the Ahar area (Shahbazi 2008; Shahbazi *et al.* 2009a), optimum moisture for working on soils are calculated between 10% - 20% and 20% - 30% in 3422 ha and 5411 ha of the studied area, agricultural sustainability can be achieved with attention to the obtained results. The optimum water content for tillage, by application of the *Aljarafe* (soil plasticity and workability) model, in the 7 agricultural benchmark sites in Seville province, Spain (De la Rosa *et al.* 2009) showed that soils of the Campiña site (SE03: Typic Chromoxerert) and Marismas (SE05: Salorthidic Fluvaquent) present many difficulties for tillage and the lowest period with an optimum workability status because the optimum water content is very low (<15 %).

Methods
Study area and soil characteristics
Study area covers 4100 ha and includes the Havarsin, Khargosh, Aghsaghghal, Johny and Bardouk natural regions in the north-west of Iran, west Azerbaijan province which has located between 44°35' to 44°40' east

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longitude and 37°50' to 37°55' north latitude. According to previous studies in Souma region (Shahbazi *et al.* 2009b; Jafarzadeh *et al.* 2009); nine soil families and mapping units were recognised. Identification of agricultural land according to their limitations and ecological potentialities was the first major objective and the second one was to predict land suitability for a specific crop over a long period of time. In this case, 80.49% of the total area mainly covered by Typic Calcixerepts, Fluventic Haploxerepts was capable for agricultural uses and 19.51% comprising Typic Xerofluvents, Typic Calcixerepts because of high carbonate percentage and erosion risk factors must be reforested by Swamp Pine species and not dedicated to agriculture. Soil physical and chemical necessary data as weight average values used for running the Aljarafe model were calculated for a vertical section from 0 to 50cm (Table 1).

Table 1. Summary of soil physical and chemical characteristics in Souma area

USDA soil family (USDA 2006)	Ext. area (ha)	CEC (Cmol+/Kg)	OM (%)	Clay (%)
Sandy skeletal, Mixed, Mesic Shallow Typic Xerofluvents	403	10	0.8	12
Fine-Loamy,Mixed,active, Mesic Typic Clcixerepts	126	16.2	1.02	24
Fine, Mixed, active, Mesic Typic Clcixerepts	125	32	0.87	53
Fine-Loamy, Carbonatic, active, Mesic Typic Calcixerepts	343	15	1.46	31
Fine, Carbonatic, active, Mesic Typic Calcixerepts	916	24	1.4	41
Coarse-Loamy, Mixed, superactive, Mesic Fluventic Haploxerepts	223	10.5	1.03	15
Fine-Loamy,Mixed,active, Mesic Fluventic Haploxerepts	1132	15.6	1.98	36
Fine, Mixed, active, Mesic Fluventic Haploxerepts	822	18.6	1.61	37
Fine-Loamy,Mixed,active, Mesic Fluventic Endaquepts	66	21.7	1.8	29

Model calibration

Aljarafe model deals with the characteristics of a quantitative system of evaluation of soil engineering qualities, making use of computerized multiple regression techniques (De la Rosa 1979). It is a first approach to predicting plasticity index and optimum moisture based on information of a wide range of Florida (USA) soils. Statistical regression models, with appropriate calibration (De la Rosa 1979) and validation analysis for Mediterranean soils (De la Rosa *et al.* 1983), were developed to establish the relationships between soil plasticity and optimum moisture for workability with other more readily-available soil characteristics provided by standard soil surveys. Also the Aljarafe model equations have been applied under various soil and climate conditions over the World (Ohtsubo *et al.* 1984). As climate conditions are not input data in the presented model, it will be readily used in semi-arid regions (e.g. Iran) if the soil properties are included in the calibrated range of the model (Table 2).

Table 2. Range and mean for selected properties in the soils investigated (De la Rosa *et al.* 2003)

Soil variable	Range	Mean
Independent variables		
Clay content (%)	0.1-93.5	25.3
Cation Exchange Capacity (Cmol+/kg)	0.2-34.9	7.2
Organic matter content (%)	0.1-4.5	0.5
Dependent variables		
Plasticity index	0.1-116	16.6
Optimum moisture (%)	10.2-45.6	17.8

Comparing data in two presented tables shows that clay content, cation exchange capacity and organic matter content as independent variables of study area are exactly fitted in the calibrated range of those variables. Therefore, calculated dependent variables such as plasticity index and optimum moisture for Souma area must be mentioned as high accuracy. Several studies and using Aljarafe model will legalize the obtained results in this semi-arid region.

Model application

After installing the MicroLEIS DSS which is now protected and it needs to be connected with Evenor-Tech Company in Spain or others who have an agreement with that company (e.g. Shahbazi from Iran, Braimo from Japan).The software installation along with the different run options from the main screen are included: Set up, Individual mode, SDBm+ connections, Language change, and Help tabs. Selecting the individual mode option will be open a dialog box, where the required model data as a valid numeric value within the model calibration range can be introduced. Pressing the estimate option, the model will be executed and a window with the output evaluation results will appear on the screen. Example of model application and evaluating the results for the first unit of studied area is shown in (Figure 1).

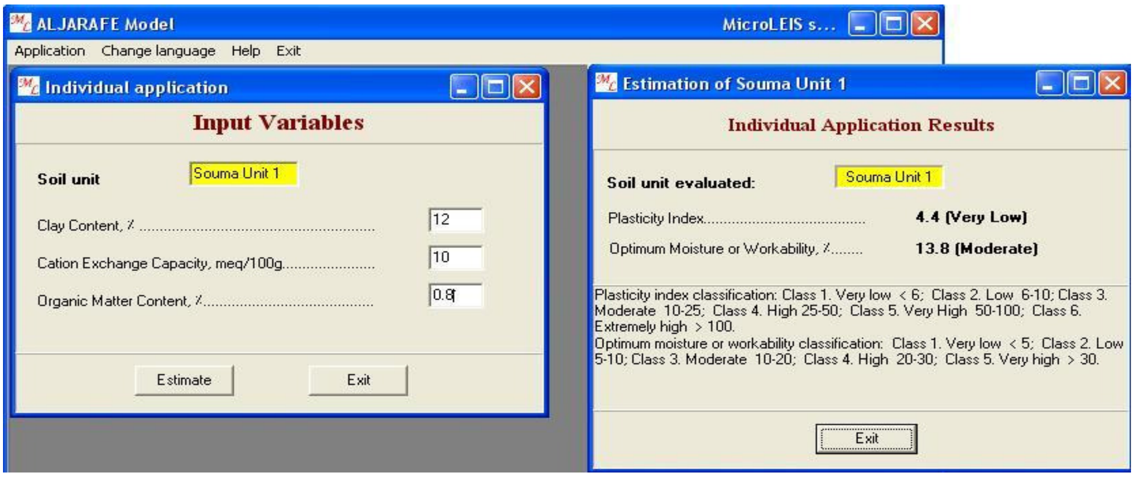

Figure 1. Screens for input data and results in individual mode of Aljarafe model

GIS spatialization

GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. It helps to answer questions and solve problems by looking at the data in a way that is quickly understood and easily shared. In land evaluation procedure, the soil survey maps (Figure 2), which in geographical format are usually polygonal multifactor maps, are the main source of basic information. Additional basic soil plasticity or optimum moisture maps in the whole studied area can be extracted by integrating the model results with GIS tools (e.g. ArcView).

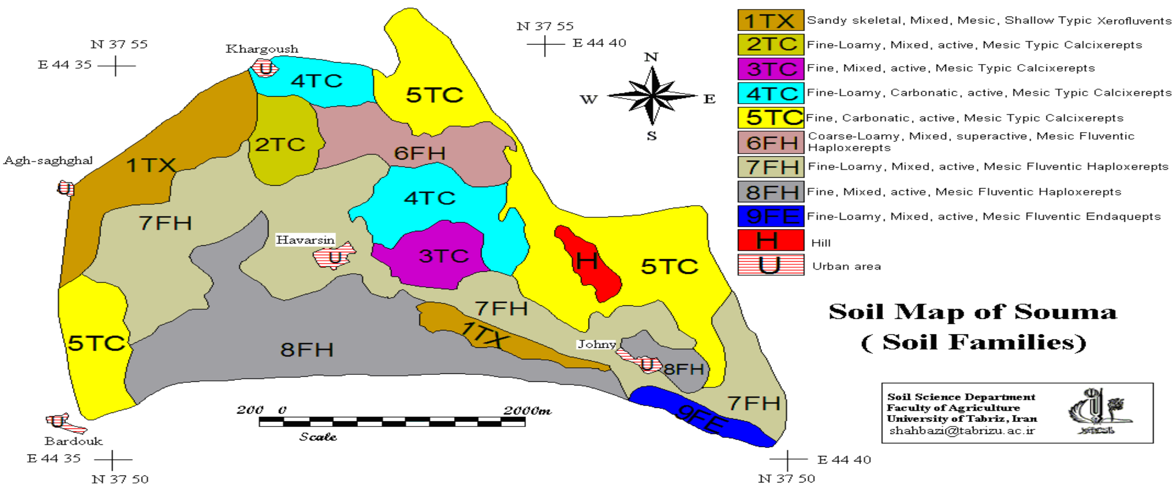

Figure 2. Soil family map of the study area

Results

Classification of the plasticity index and optimum moisture ranges according to the established model and its extension in the studied area is summarised in (Table 3)

Table 3. Summary of model application results and its base establishment

Classification	Plasticity index	Area covered (ha)	Optimum moisture (%)	Area covered (ha)
C1 (very low)	<6	3839	<5	-----
C2 (low)	6-10	126	5-10	-----
C3 (moderate)	10-25	-----	10-20	3975
C4 (high)	25-50	125	20-30	125
C5 (very high)	50-100	-----	>30	-----
C6 (extremely high)	>100	----	-----	-----

Conclusion

According to the obtained results, plasticity indexes vary from 1 to 25.1 in the studied area which is classified into 3 classes: C1, C2 and C4. On the other hand, optimum moisture for workability of studied area divided into 2 classes: C3 and C4. These results showed that there is no limitation due to optimum moisture for tillage. Attention to the results and using decision or planning support tools such as Aljarafe model within the MicroLEIS DSS and geo-referenced provided maps (Figure 3) will ebable sustainable soil management which can maintain and even improve soil quality under local soil conditions.

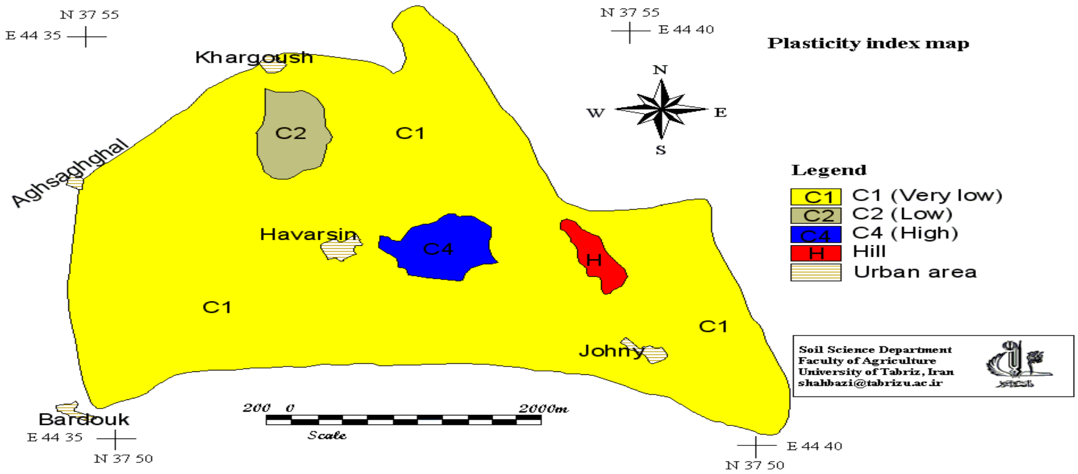

Figure 3. Map of plasticity index provided by GIS

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Leaching of nitrate due to the fertilization with litter of swine bedding, liquid swine manure and chemical fertilizer

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Abstract
The successive application of high doses of pig manure can lead to contamination by nitrate, due to the high nitrogen concentrations in these wastes, related primarily to the composition of the diet of pigs. This study evaluated changes in levels of N- NO_3^- in an Ultisol, in the city of Braço do Norte, SC, during the cycle of culture of maize in a tillage system, in relation to fertilization with litter of swine bedding, liquid swine manure and chemical fertilizer, with application of the appropriate dosage of N and twice the recommended dosage for maize. The evaluations were made at soil depths of 0-15, 15-30, 30-45 and 45-60 cm at six dates during the maize cycle. There were increases in the levels of NO_3^- in the soil, with variation of values during the cycle of the culture. The highest value was observed in the treatment fertilized with pig slurry 2x at the depth of 45-60 cm. The results indicate the occurrence of leaching of NO_3^-, but this nitrate is not yet present at critical levels in the soil.

Key Words
Swine, percolation, fertilization.

Introduction
Santa Catarina is a large producer of pork where like in other countries, the activity is typical of small farms. Often the land available for disposal of waste generated in production is insufficient, leading to successive applications in small areas. The fertilization of agricultural land with swine manure can be an important source of nutrients, which when properly managed provides an increase in productivity. However, current practices and incorrect handling of these wastes contribute to the degradation of the soil, water and air quality, mainly by contamination of the groundwater. Thus the swine culture in confinement is considered by the agencies of environmental management as an activity of high polluting potential (Pereira 2006). The chemical characteristics of wastes are related to the nutritional composition of diets of the swine, among other nutrients, is rich in N, P and K, with 60 to 70% of the N ingested by the animals being excreted in their faeces and urine (Oliveira 2000). Among the macronutrients present in the manure, N is usually the element in highest concentration and also the one that causes the largest environmental problems, caused by changes to the soil and may result in losses, mainly by leaching. The process of nitrification of the ammonium nitrogen in the manure applied to the ground occurs quickly, and can exceed the capacity of absorption by plants and microorganisms, decreasing the potential fertilization by the waste and/or increasing the pollution by potential (Franchi 2001; Aita and Giacomini 2008; Giacomini and Aita 2008). Giacomini and Aita (2008) observed that with the application of pig slurry, mainly in a dose of 80 m^3/ha, the quantities of N-and NO_3^- and their leaching in the soil increased rapidly after the application of manure. Therefore, knowing the destination of these elements in the ground is essential for assessing the environmental impact caused by the use of the manure and its impact is directly related to the soil's ability to retain the NO_3^-. This study aims to evaluate the levels of ammonium in the soil and leaching of the nitrate, at depths of 0-15, 15-30, 30-45 and 45-60 cm, in an Ultisol Red-Yellow fertilized with pig bedding, liquid swine manures and chemical fertilization in SPD, since 2002, in the city of Braço do Norte, SC.

Methods
The experiment was installed in the year 2002 in an Ultisol Red-Yellow, cultivated under a system of no-tillage with the succession oats / maize without the use of pesticides in a rural property located at the Watersheds River Cachorrinhos, in the city of Braço do Norte, SC, with coordinates 28º 15 'S and 49 º 15' W. The climate of the city is a Cfa type, according to the classification of Köppen (Epagri 2000). The treatments were applied in experimental units (parcels) of 4.5 x 6.0 m (27 m^2), constituted of: control (T) no fertilization, fertilization with swine bedding (CS), fertilization with pig slurry (DL), nitrogen soluble (AS) with urea application with three replications. All the fertilization treatments were applied with doses related

to one (1x) and two (2x) times the N recommended for culture of oats and maize. The applied values were calculated based on the Chemical Commission and Soil Fertility (CQFS RS / SC 2004). The amount of N recommended for the cultures (30 kg/ha for oats and 90 kg/ha for maize) was defined in function of the soil analysis and productivity expected of maize. The swine bedding was manually applied on the soil surface, five days before planting the maize. The application of liquid swine manure and soluble fertilizer (urea) was according to the recommendation of the CQFS RS / SC (2004). The liquid manures were collected in a midden system located in the same property. The volume of manure applied, determined from the estimated concentration of nutrients by the densimeter calibration, was 50.9 m^3/ha for the treatment once (1x) the need of N for the crop, distributed in three applications (01 / 10, 05/11 and 23/12/2007). The total amounts of nutrients applied were 89 kg N/ha, 79 kg P_2O_5/ha and 63 kg K_2O/ha for the treatment with liquid manure once the recommendation of N for the crops, and the double for the treatment two times the recommended N for the crops.

The total amounts of applied nutrients were of kg N/ha, 79 kg P_2O_5/haand 63 kg K_2O/ha for the treatment with liquid at the recommended rate of N of the crops and the double for the treatment two times the recommended rate. 10.7 Mg/ha of swine bedding on 01/10/2007 was applied at once (1x) the recommended N and 21.4 Mg/ha for double the recommendation. The total quantities of N, P_2O_5 and K_2O represented in the bedding were, respectively 90, 88.6 and 74 kg/ha for the recommendation of one dose of N and 180, 177.2 and 148 kg/ha for the double the recommendation. The levels of N- NO_3^- were evaluated in four soil layers (0-15, 15-30, 30-45 and 45-60 cm) at 0, 7, 35, 53, 73 and 142 days after the application of the bedding and the first application of liquid swine manure and urea. For each plot, 6 sub-samples of soil were taken, with help of a Dutch auger, to form a composite sample. The material was transported to a laboratory, dried and then sieved, thus obtaining the fine air dried soil (TFSA). A sub-sample for extraction with KCl 1 mol/L and determination of N- NO_3^- by distillation with semi-micro Kjeldahl equipment (Tedesco *et al.* 1995). The results for each soil layer for the different sampling dates were submitted to analysis of variance and treatment means were compared by the Tukey test at 5% significance level.

Results

The analysis of variance found that the application of swine manure promoted significant modifications in the levels of N- NO_3^- in the soil, in depth and for the different sampling dates. The levels of N- NO_3^- at 7 days after the application were higher in the treatments DL2x for the surface layer (Figure 1). At 35 days there were increases at the depth of 30-45 cm, which reinforces the hypothesis of rapid nitrification of the liquid swine manure, as the demand of maize was small. This result may be related to the fast infiltration of NO_3^-in soil where urea is hydrolyzed and the ammonium is quickly converted to nitrate, resulting in the increase of its concentration (Costa 2001). The N losses by leaching occur mainly in the early stages of crop establishment, when the root system is not yet sufficiently developed in relation to the rapid nitrification of ammoniac nitrogen from the swine manure in the soil and the low adsorption of N- NO_3^-The rate of mineralization of the waste is extremely important for nutrient availability to plants and may vary depending on the type of manure, the attributes of soil, moisture and humidity.

At 73 days after the first application of pig slurry it was observed that a higher level of the NO_3^- in the treatment DL2x in the 45 to 60 cm layer, thus confirming the occurrence of leaching, that leads to an increased risk of groundwater contamination. At day 142 toward the end of the culture cycle, there were lower levels of nitrate in the surface layer and high levels in the 45-60 cm layer, mainly for the treatment DL2x, this demonstrates that the applied values nitrogen was higher than that assimilated by the crop, even under split applications of liquid manure. Another important factor for the increase at depth of nitrate, may have been due to the high rainfall observed in this period, which probably favoured the leaching of NO_3^-. Aita and Giacomini (2008) found in RS that with the application of 0, 40 and 80 m^3/ha of pig manure a rapid increase in leaching of NO_3^- occurs, especially with the highest dose of manure.

The lowest value of N- NO_3^- was for swine bedding litter relative to the slurry, at 142 days at 60 cm depth. This can be due to slower leaching related to the bedding staying on the surface. In studies of fertilization with slurry and swine bedding litter in a Paleudalf in Rio Grande do Sul, Giacomini and Aita (2008) found a temporal variation of the quantities of N- NO_3^- in the soil to the depth of 90 cm. The slurry caused a higher amount of N- NO_3^- in the soil relative to treatments with litter. Oliveira (1993) observed that in soils submitted to applications of high levels of liquid swine manure for several years (160 m^3/ha), the level of NO_3^- in groundwater was ten times higher than found in untreated soils.

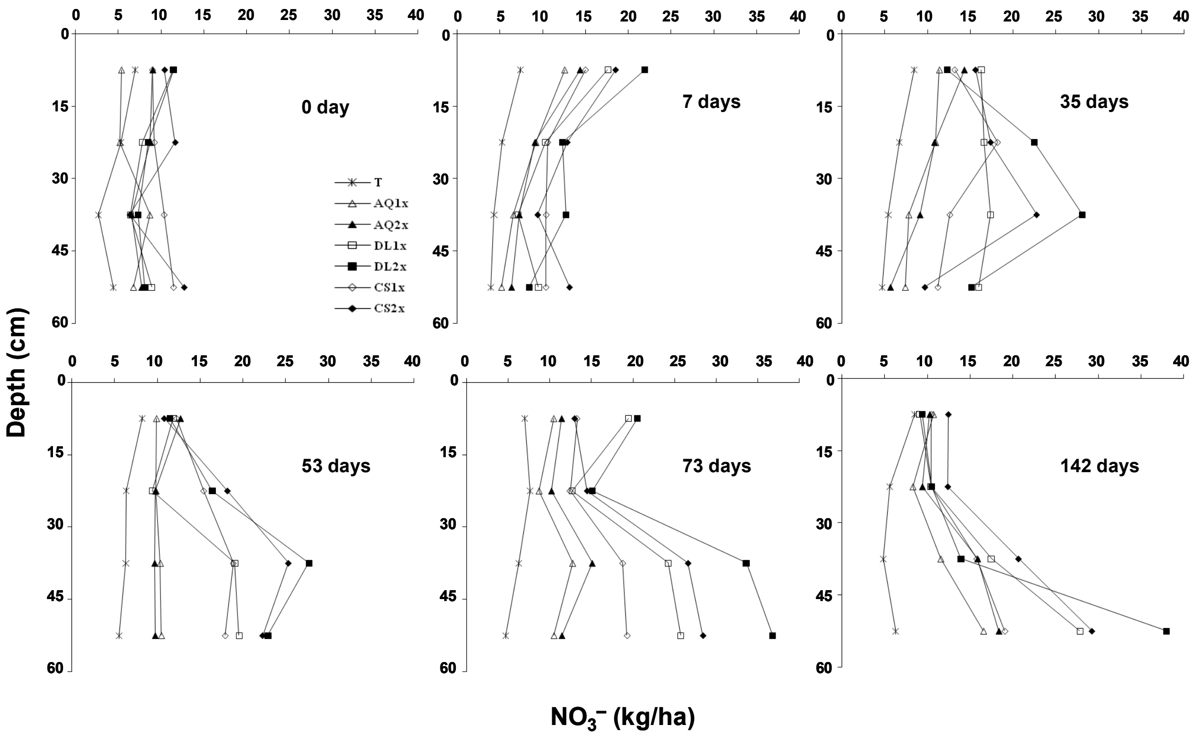

Figure 1. Levels of N- NO_3^- in soil layers to 0-60 cm during the culture of maize.

Conclusion

In general, increases in levels of nitrate had occurred in soil, receiving swine manure, but they were not considered critical to the environment. The doubled fertilization with liquid swine manure has more nitrogen than is assimilated by the crop and over time may present risk of leaching of NO_3^-. The highest concentrations were observed in the 60 cm soil at the end of the crop cycle. Criteria should be developed for dosages, range of application of manure and the adoption of SPD to minimize environmental impact due to losses of nitrate by leaching.

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Long-term liming ameliorates subsoil acidity in high rainfall zone in south-eastern Australia

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Abstract

Management of Acid Soils Through Efficient Rotations (MASTER), is a long-term agronomic experiment commenced in 1992. The primary objective was to develop and demonstrate a sustainable farming system that is agriculturally productive, economically viable and environmentally effective to manage the highly acid soils in the high rainfall region (550–800 mm) of south-eastern Australia. The experiment was a fully phased design with 3 major treatment contrasts, *a)* annual systems versus perennial systems; *b*) limed versus unlimed treatments; and *c*) permanent pastures versus pasture-crop rotations. Results showed that the soil acidification rate was 0.1 pH units per year under the production system studied, and acidity amelioration rate was 0.044 pH units per year under the liming regime used. It is estimated that the system requires 270-300 kg lime/ha/year, or 1.6-1.8 t lime/ha every 6 years, to keep the system sustainable. It was concluded that the subsoil acidity can be alleviated by surface liming over the long term.

Key Words

Aluminium, manganese, perennial pasture, annual pasture, farming system.

Introduction

Liming is one of the most cost effective ways to alleviate the soil acidity. However, surface-applied lime is often slow to move down into the root zone where it is most needed (Helyar 1991), and incorporation by tillage is not always feasible due to the risk of erosion on steep slopes and the non-arable nature of many pastoral soils (Chan *et al.* 2004). In southern Australia decreases in soil pH of about 1 unit in 50 years have been recorded under annual subterranean clover/volunteer grass pastures that are fertilised with superphosphate, and under similar pasture in rotation with cereal crops (Bromfield *et al.* 1983; Helyar 1991; Williams 1980). Management of Acid Soils Through Efficient Rotations (MASTER), is a long-term agronomic experiment commenced in 1992. The primary objective was to develop and demonstrate a sustainable farming system that is agriculturally productive, economically viable and environmentally effective to manage highly acid soils in the high rainfall region (550–800 mm) of south-eastern Australia. The paper reports the long-term trends of soil acidification rate and amelioration rate under a long-term liming program.

Materials and methods

The experiment was conducted on the property 'Brooklyn', operated by the Hurstmead Pastoral Company Pty Ltd, at Book Book (147°30′E, 35°23′S), 40 km south-east of Wagga Wagga, New South Wales, Australia. The long-term average annual rainfall was 614 mm. The soil at the site is a subnatric yellow sodosol (Isbell 1996), a Typic Fragiochrept in USDA taxonomy (Soil Survey Staff 2006). It has a strong texture contrast or duplex profile, with a loamy sand to sandy loam A horizon overlaying a clay B horizon commencing at 20-60 cm depth. The average pH in 0.01 M $CaCl_2$ (pH_{Ca}) at 0-10 cm soil depth was 4.0 and the subsurface pH_{Ca} was below 4.5 to at least 20 cm, which is typical of the more acidified soil in the region.

The experiment was a fully phased design with 6-year (phase) as a cycle. There were 8 treatments, 80 plots in total, with 3 major treatment contrasts, a) annual systems versus perennial systems; b) limed versus unlimed treatments; and c) permanent pastures versus pasture-crop rotations. Plot size was 30 × 45 m. Lime at 3.7 t/ha was initially incorporated into top 10 cm of soil in 1992. The target was to maintain pH_{Ca} in the surface 10 cm at 5.5 over the 6-year liming cycle. The maintenance lime was top-dressed every 6 years at 2.6 t/ha in the second cycle and 1.6 t/ha in the third cycle (**Figure 5**). Further details of experimental design, treatment description and grazing management were reported by Li *et al.* (2001, 2006a, 2006b).

Soil samples, comprising 20 cores (3.5 mm in diameter) per plot, were taken at the break of season in autumn annually at 0-10, 10-15 and 15-20 cm on all plots, and analysed for pH, aluminium (Al) and manganese (Mn) in 0.01 M $CaCl_2$ (Conyers *et al.* 1991), and exchangeable Al, Mn, calcium, magnesium, potassium and sodium (Gillman and Sumpter 1986).

Results

Soil acidification rate

The initial liming lifted soil pH_{Ca} from 4.1 to 5.7 at 0-10 cm in the 2nd year after liming. Soil pH_{Ca} remained largely unchanged in the 3rd year, but decreased sharply to about 5.0 after 6 years of liming (**Figure 5**). In the 2nd and 3rd cycles, similar patterns of pH changes were found in response to maintenance liming, but with slightly slow rate of pH decrease. Averaged across cycles, it was estimated that the acidification rate was 0.1 pH unit per year (**Figure 6**). In contrast, soil pH on the unlimed treatments fluctuated around 4.0–4.3 at 0-10cm (**Figure 5**), but the system was acidifying the subsoils.

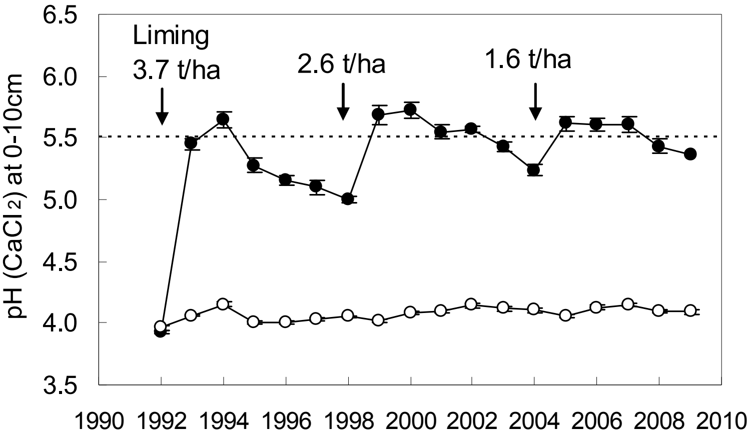

Figure 5. Soil pH_{Ca} trend at 0–10 cm in 1992-2009. ● Limed treatments, mean of plots which were at phase 1 in 1992. ○ Unlimed treatments, mean of all unlimed treatments. Vertical bars represent standard errors

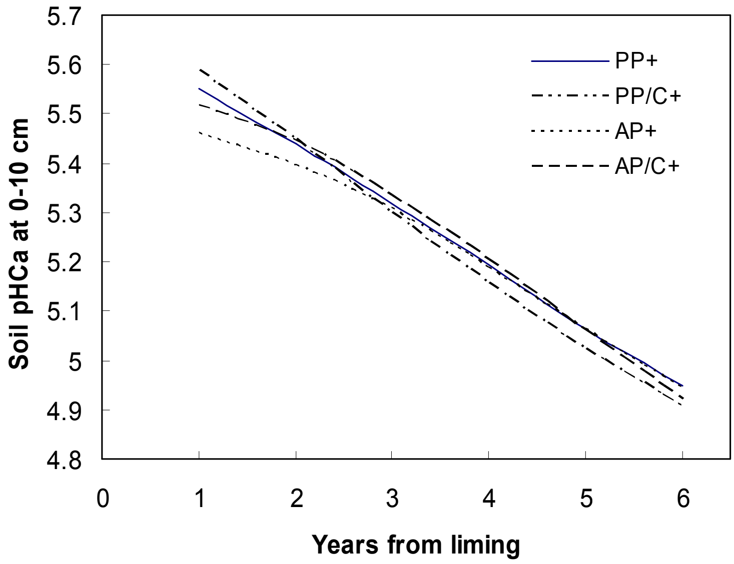

Figure 6. Soil pH_{Ca} changes at 0-10 cm from years 1 to 6 after liming. PP+, perennial pastures; PP/C+, perennial pasture-crop rotations; AP+, annual pastures; AP/C+, annual pasture-crop rotations

Soil acidity amelioration rate

Soil pH_{Ca} at 15–20 cm increased gradually at a rate of 0.044 pH_{Ca} units per year since 1992 by maintaining an average pH_{Ca} of 5.5 at 0-10 cm. The percentage of exchangeable Al at 15-20 cm decreased from 42% in 1992 to below 10% in 2005, 13 years after initial liming (**Figure 7**). It was observed that a significant number of lucerne plants survived in the limed swards at the start of the 3rd cycle of the experiment, most likely due to the incremental amelioration of subsoil acidity.

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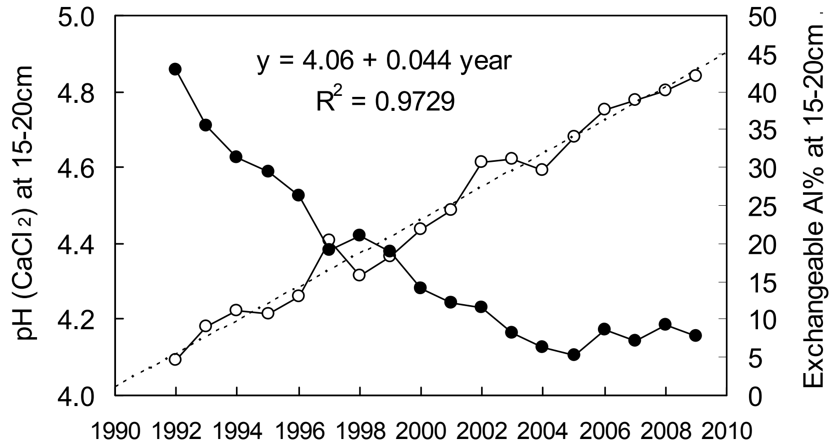

Figure 7. Long-term trends of subsurface soil pH_{Ca} (○) and percentage of exchangeable aluminium (●) at 15-20 cm on the limed treatments in 1992-2009.

Discussion

The most important finding from this long-term experiment is that the subsoil acidity can be alleviated by surface liming over the long term. Under the current lime regime at the MASTER site, the rate of amelioration was 0.044 pH units per year, which means that the subsoil pH would increase by one pH unit over 23 years. The implication of this result is that we could reverse the soil degradation associated with acidity in less than half of the time that caused by the introduction of subterranean clover with superphosphate fertilisers half century ago (Williams and Donald 1957; Williams 1980). The significant decreases in subsoil pH and levels of exchangeable Al and Mn would allow greater exploration of subsoil by acid sensitive species currently restricted by Al and Mn toxicity (Helyar 1991; Slattery and Coventry 1993). A financial analysis based on data from the MASTER site showed that liming pastures on soils that have a sub-surface acidity problem is profitable over the long term for productive livestock enterprises (Li *et al.* 2010). This gives farmers confidence to invest in a long-term liming program to manage highly acid soils in the traditional permanent pasture region of the high rainfall zone (550–800 mm) of south-eastern Australia.

Results showed that the acidification rate was 0.1 pH units per year under the current production system, which was equivalent to 281 kg/ha of lime per year based on the pH field buffering capacity on the site. It is estimated that 2/3 of 'lime equivalent' (180-200 kg/ha/year) has been used to neutralise acids added by the production system, and 1/3 of 'lime equivalent' (90-100 kg/ha/year) has been leached or physically moved into the 10-20 cm soil depth which has accounted for the increase in pH in the subsurface soil. On the unlimed treatments, although pH remained around 4.0, the system has been acidifying the subsoil and progressing toward a pH 4.0 profile to the bottom of the root zone which is much hard and costly to ameliorate.

Acknowledgments

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Managing risks of phosphorus export from sites irrigated with abattoir effluent

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Abstract
Meat and Livestock Australia sponsored the development of a risk management strategy for phosphorus loss from sites irrigated with abattoir wastewater. The project was initiated because of increased concern with the potential environmental impacts of phosphorus loss. The strategy was designed to quantify the relative risk of contamination to both surface and groundwaters. The assessment of effluent irrigated sites was based on the Phosphorus Index (PI) approach developed in the USA.

The key reason for using the PI system is that traditional agronomic and soil test approaches are inflexible and fail to take into the importance of transfer mechanisms in the rate of phosphorus export from irrigated lands.

The PI approach considers both the extent of phosphorus accumulation (source factors) and its rate of transfer through the soil to groundwater and across the site to surface waters (transfer factors). Mechanisms considered include:

- The ability of the soil profile to sorb and retain phosphorus,
- Phosphorus removed in plant harvest,
- Phosphorus export via erosion,
- Dissolved phosphorus lost in runoff, and
- Direct losses such as pond overtopping and effluent runoff in wet weather.

This paper identifies the likely relative importance of the various mechanisms across a range of Australian abattoir sites. A similar approach could be used for other contaminants and for other industries. It also offers the opportunity to extent risk assessment to a catchment wide basis.

Key Words
Phosphorus, PI, effluent, leaching, runoff, erosion.

Introduction
This project developed a Phosphorus Index (PI) for fields irrigated with abattoir wastewater. A PI is a risk management tool that can assess the extent of phosphorus export from irrigated fields to nearby surface and groundwaters. The PI concept was originally developed in the USA in response to concerns that agricultural activities were resulting in environmentally significant contamination of waterways (Sharpley 1995a). According to Weld and Sharpley (2007), the PI is more useful than a soil test or a blanket restriction on application rates because a PI can take into account both the availability of the phosphorus and the transport mechanisms by which phosphorus is delivered to waters. The approach is also relevant to other industries where large quantities of nutrient rich wastewater must be irrigated.

PI has not been used to any extent in Australia, largely because most Australian soils have a high ability to retain phosphorus compared with typical phosphorus fertilisation rates. Additionally the applied phosphorus fertilizer is usually buried. Consequently the risk of export of significant quantities of phosphorus is low. However the application of relatively high rates of dissolved phosphorus application to effluent irrigated pasture means a PI approach is relevant to abattoir sites.

The phosphorus contained in abattoir effluent is highly available to plants because over 80% of the phosphorus is in the able ortho-phosphate form. These orthophosphates are dissolved in the soil solution (and the irrigated effluent) and can be readily taken up by vegetation. They can also move through the soil within the infiltrating water (Nash 2004; Stevens *et al.* 1999). However movement into the soil is short lived and the dissolved phosphorus compounds precipitate or become held on clay particles. The type of precipitate varies with soil characteristics, especially pH and aeration. Aluminium, iron and manganese based precipitates form in acidic soils, while calcium and magnesium based precipitates form in alkaline soils. Recently formed precipitates are labile and plants can access the phosphorus to a limited extent. Over time the precipitate becomes more crystallised and this substantially reduces phosphorus availability (Barrow and Shaw 1975). In typical Australian soils less than 1% of the total phosphorus is readily available, less than 10% is labile and up to 90% is non-labile (Glendinning 1999). Additionally a significant proportion of the soil phosphorus can accumulate in the organic component in long term pasture sites. Mineralisation of this organic-P can provide orthophosphate for plant uptake as well as create the potential for phosphorus loss from the site.

There are a number of issues influencing risk of phosphorus loss from field irrigated with abattoir wastewater:

- Firstly in most parts of Australia, pasture growth is seasonal, and there can be periods of more than 6 months where there is minimal growth or phosphorus uptake. This increases the risk of loss via leaching should effluent irrigation occur throughout the year.
- Secondly, the seasonality of pasture growth also increases the risk of overgrazing, leading to bare paddocks and increased erosion risk.
- Thirdly the quantity of phosphorus accumulated by plants is often small compared with the application rate. That is, there is likely to be accumulation of phosphorus in sites receiving abattoir effluent. The gradual increase in phosphorus in the surface soil suggests increased risk of phosphorus loss to the environment.
- Fourthly, the volume of water required to meet irrigation demand in Australia is typically 5 to 10 ML/ha/y. However applying this volume of effluent also applies 2 to 10 times the amount of phosphorus that can be utilised by the pasture. The excess phosphorus remains in the soil and could eventually be leached or lost via erosion or in runoff.
- Finally the data is for plant uptake NOT removal. In many pastures the dry matter production is ingested by grazing animals. Subsequent excretion redeposits the phosphorus onto the land surface. Net removal via weight gain in grazing animals is typically 3 to 10 kg P/ha/y. This can be equivalent to a few percent of the phosphorus applied in the effluent.

Figure 1 shows the major pathways by which phosphorus can enter and exit the effluent irrigation areas. The key import processes are animal excreta and phosphorus in the effluent. The key loss processes are sorbed phosphorus on eroding sediment, dissolved phosphorus in runoff and soluble phosphorus leached to ground water (Havlin 2004). Some removal in animal tissue also occurs. Some abattoirs irrigate effluent onto pastures or crops which are later harvested and removed. This procedure can remove up to 60 kg P/ha/y; however 30 kg/ha/y is more typical (NSW Agriculture 1997).

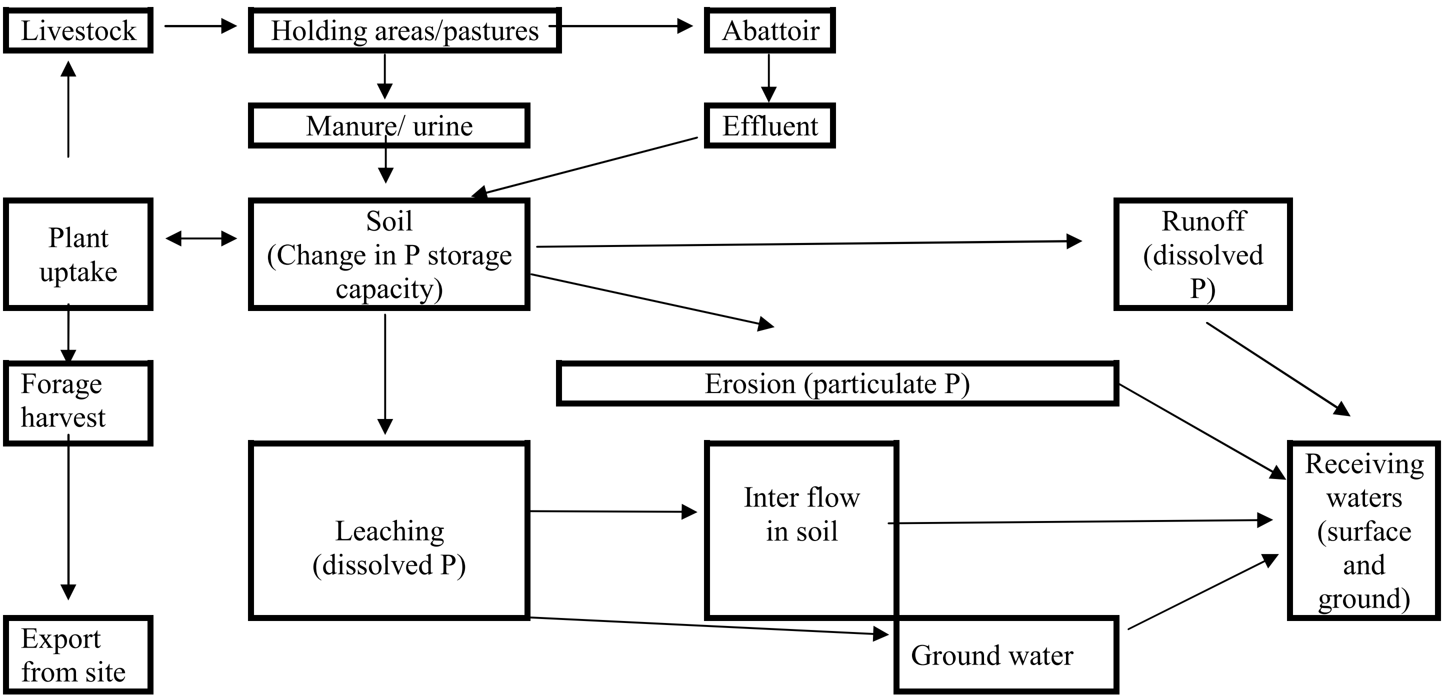

Figure 1. The phosphorus cycle for pastures irrigated with abattoir effluent.

Animal excreta deposited onto the soil surface contains a mix of organic phosphorus and ortho phosphorus. Some of the ortho phosphorus can be taken up by plants; however the bulk is sorbed onto clays and organic material at the top of the soil column. Permanent pasture will gradually increase phosphorus storage capacity in the topsoil. This is especially important in sandy soils where phosphorus sorption capacity is limited. Clays have greater ability to retain phosphorus than sands. Havlin (2004) summarised numerous investigations on clay content and phosphorus loss to suggest that the relationship between available soil phosphorus and runoff phosphorus concentration is in the ratio of organic soil (1): sands (2): loams (4): clay (10). As an example, runoff from a sandy soil with, say, 10 mg/kg of available phosphorus, will have a similar phosphorus concentration to runoff from a clay soil with 50 mg/kg of available phosphorus.

Dissolved phosphorus can runoff the site, or infiltrate the soil, and be sorbed. Bush and Austin (2001) applied 44 kg P/ha as single superphosphate and then irrigated the field. They found border irrigation significantly increased phosphorus concentration in soil water down to 0.3m in a soil containing 30 to 50% clay. That is, there can be significant movement of phosphorus even in soils where a large sorption capacity is anticipated.

According to Sharpley *et al.* (2001) the PI concept can be adapted to suit particular concerns and needs. The main components relevant to Australian abattoir irrigation sites are:

Source factors
- Soil phosphorus test value,
- Phosphorus sorption capacity,
- The volume of effluent irrigated,
- The phosphorus concentration in the effluent.

Site management attributes such as grazing intensity, irrigation efficiency and soil conservation practices require assessment of individual fields.

Transport factors
- Annualised erosion rates can be determined throughout Australia.
- Runoff Curve Number (RCN) is based on vegetation, soil type and physical condition.
- Daily runoff can be estimated from Bureau of Meteorology databases.
- Dissolved phosphorus concentration in the runoff can be estimated from established relations between soil test phosphorus, phosphorus sorption capacity and soil texture.
- Local flood history is typically common knowledge on farms.

Subsurface drainage of fields is uncommon on abattoir sites in Australia, so this factor is not relevant.

Catchment factors
- Distance to receiving water
- Connectivity between the phosphorus source and the receiving waters
- Vulnerability of receiving waters to phosphorus pollution. (in Australia, all water bodies are considered vulnerable to contamination).

Table 1. Variables used to calculate PI for Australian abattoir sites.

VARIABLE	COMPONENTS
Site management	
Vegetation	Type, species, graze/forage harvest, Fallow periods, P export
Irrigation	Area, type, frequency, volume, seasonality, runoff frequency, management level
Source factors	
Rainfall	Rainfall, effluent (mm/y), RCN, % runoff
Phosphorous in soil	For each horizon: depth, bulk density, total P, Bray 1 P& P sorption. P excretion estimate
Effluent	Volume/Y, P concentration, seasonality in quantity or quality
Risk assessment	
Overtopping of effluent storage	Volume/year
Groundwater risk	Years till P saturation
Particulate P export	RUSLE, Enrichment ratio, vegetative buffer
Dissolved P export	Dissolved P concentration (estimated), runoff volume, buffer conditions

Results

Sensitivity analysis was undertaken to identify the key variables. Key results were:

- Pond overtopping and effluent runoff were uncommon among abattoir sites, but where they did occur they were the major contributors to P export.
- Particulate P loss via erosion was normally trivial as most sites had 100% grass cover.
- Dissolved P export within rainfall runoff appears to be a significant issue at sites where rainfall plus effluent greatly exceeded evapotranspiration.

Conclusions

1. Improved management to reduce incidence of effluent pond overtopping and direct runoff of effluent is critical.
2. Vegetation management to ensure >80% ground cover is critical
3. There is insufficient evidence to accurately quantify the loss of P in runoff
4. It is obvious that even in a single field there can be large variation in the proportion of effluent/ rainfall that enters the soil. Management needs to target portions of fields especially susceptible to phosphorus loss.
5. There is a need to link modeled P export from single sites to catchment scale models.
6. Ideally PI should be expressed as kg P export/ ha/year

Acknowledgements

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Managing soil biological decline during long-fallows in cropping systems

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Abstract
No-till farming in Australia has revolutionised the way many farmers crop. Some of the moisture retention advantages of no-till farming have resulted in a reduced reliance of in-crop rain as well as increasing yields and profitability. Less clear is the effect on biological properties.

Early results of a survey of the no-till cropping soils of the central west of NSW showed that most no-till cropping areas have lower soil carbon levels and lower microbial activity than nearby uncropped soils. This indicates that many no-till cropping soils may not be as sustainable as first thought. A long-fallow field trial was conducted on "Magomadine" near Coonamble NSW Australia using surface applied amendments (straw, compost, feedlot manure, biochar and zeolite) to investigate their effect on biological, chemical and physical soil properties. Early results are suggesting that the application of 10t/ha of straw can significantly ($P < 0.05$) increased soil moisture (24%), microbial respiration (50%), microbial biomass (21%), and mean weighted diameter of soil aggregates (75%). This research has highlighted the importance that high stubble residues have in improving these soil properties during a long-fallow.

Key Words
Mulch, soil health, amendments, cover crop.

Introduction
Soil health is the result of complex interactions between chemical, physical and biological soil properties. Biological activity is linked to increased levels of nutrient recycling, retention and release (Foissner 1999; Osler 2007), disease suppression (Deacon 2006; Hodda *et al.* 1999; Yeates and Wardle 1996) and higher aggregate stability (Tisdall 1991) resulting in greater moisture infiltration (Bissonnais, Renaux and Delouche 1995). There is a general interest by farmers to regain or improve the biological properties of their soils to maintain an ecologically sustainable farming practice.

Different agricultural management practices such as tillage, stubble management, crop rotation, and nitrogen fertilisation have the potential to change some soil biological properties such as carbon mineralisation and microbial biomass (Pankhurst *et al.* 1995). Despite the many benefits that no-till has on many soil properties it has inconsistent effects on soil biological properties (Bell *et al.* 2006; Simpfendorfer *et al.* 2001; Watt, Kirkegaard and Passioura 2006).

During an extensive study of cropping soils in northern Australia, Bell *et al.* (2006) found that no-till farming did not consistently raise the level of microbial biomass compared to near by uncropped soil. They postulated that the common practice of long-fallow may be detrimental to microbial populations. Long-fallow is a practice of stopping plant growth over a long period to allow moisture to build up for use by the following crop.

Holland and Coleman (1987) have suggested that surface applied amendments might improve several soil properties. Organic materials contain carbon which is an important food source for soil microbes. During a long-fallow there may be a reduction in organic material available as a food and energy source for microbes This paper will present early findings from a farm soil survey in central west New South Wales and from a field trial near Coonamble in NSW that may indicate the potential to improve biological properties that are reduced during a long-fallow.

Methods
Farm survey
Soil samples from the top 0-5cm were taken on 20 farms in the Central West NSW during 2008 and 2009. Physical, chemical and biological properties were analysed at the University of New England and the commercial laboratories at the Southern Cross University and the Lismore Soil Foodweb.

Field trial

A split-pot field trial was established on cropping soil on "Magomadine" Coonamble in northern NSW. "Magomadine" has a temperate climate with **latitude** 30.98°S and **longitude** 148.38°E. The trial site is situated on a clay loam vertosol with 16 treatments replicated three times. The 16 treatments were divided into four major treatments, three of which had either the equivalent of 10 t/ha of barley straw, feedlot manure or farm made compost surface applied to them while the fourth treatment did not receive any organic amendment. Each major treatment was further subdivided into 4 sub plots which received the equivalent of 6t/ha of biochar, 6t/ha zeolite, both 3t/ha biochar and 3t/ha zeolite or no amendment (control) as a surface application. The trial was sprayed with herbicides to simulate fallow and to investigate the influence of the amendments on soil biological properties during a long-fallow phase.

Microbial respiration and biomass methods:

CO_2 evolution from soil (70-75% field capacity moisture) was measured in an electronic respirometry system (Respicond III, Nordgren Innovations) at 20°C. Basal respiration rate was measured over 2 days and microbial biomass was determined by the Substrate-Induced Respiration method (Anderson and Domsch 1978). Samples for total soil fungi, total soil bacteria and soil nematodes were sent to the SoilFoodWeb laboratories at Lismore NSW for analysis.

Physical and chemical methods

Total carbon and Total nitrogen were measured using a mass spectrometer (Nitrogen/Carbon/Sulphur analyser Carlo Erba NA 1500). Colwell P was measured using a spectrophotometer (Biochrom Libra S11) at 630nm and CEC measurements were taken with an ARL 3560B ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometer). Mean Weighted Diameter (MWD) was determined by dry sieving, weighing the aggregates retained by the individual sieves and calculated by using the formula

$$MWD = \sum_{i=1}^{n} x_i w_i$$

Results and discussion

The survey results indicated that cropping may generally lower respiration (up to 55%) and microbial biomass (up to 61%) in the top 0-5 cm of soil (Table 1) within the central west of NSW. The results also indicated that it is the fungal part of the microbial population that is most affected by cropping (Table 2) with values of total fungi lower by 49% on cropped compared to uncropped soil.

Table 1. Results of respiration and microbial biomass on 5 farms in Central West NSW during 2008 and 2009.

Land Use	Respiration ($mg\ CO_2$/hr/100 g DM soil)		Microbial Biomass (mg Microbial Carbon/100 g DM Soil)	
	2008	2009	2008	2009
Cropped soil	0.311	0.169	43.8	33.5
Uncropped Soil	0.687	0.327	111.0	61.4
LSD (P = 0.05)	0.262	0.120	32.4	19.4

Table 2. Results of a survey of 20 farms in Central West NSW during 2008 and 2009.

Land Use	Total Carbon (%)		Nematode (no./g DM soil)		Total Fungi (µg/g DM soil)	Total Bacteria (µg/g DM soil)
	2008	2009	2008	2009	2009	2009
Cropped soil	1.306	1.441	7.97	11.4	65.6	474
Uncropped Soil	2.166	2.469	10.04	4.0	128.7	488
LSD (P = 0.05)	0.258	0.313	3.56	4.8	30.1	90

These results indicate that the change in land use to cropping can have an adverse effect on both soil carbon and microbial populations. Bell *et al.* (2006) found similar results in southern Queensland. They found that a change from native grasses to cropping near Jimbour in Queensland reduced microbial biomass by 45%, microbial activity by 52% and total organic carbon by (55%) in the 0-5 cm soil layer.

Modern no-till farming practices involve spraying of weeds post harvest until the next crop is planted. This period of fallow can be five to seven months in between winter crops or as long as12-18 months in changing from a winter to summer crop.

Table 3. Effect of organic amendments on certain soil properties during a long-fallow phase in no-till cropping paddock near Coonamble NSW. Significant results (P = 0.05) are indicated by values being assigned different letters across treatments.

Parameter (0-5cm)	Straw	Compost	Manure	Control
Soil Moisture (%)	34.92a	29.19b	28.44b	28.14b
MWD (mm)	2.54a	1.44b	1.62b	1.45b
Respiration (mg CO_2/hr/100 g DM soil)	0.3607a	0.2628b	0.2516b	0.2393b
Microbial Biomass (mg MC/100g DM soil)	44.64a	40.78b	37.83b	36.92b
Soil pH	6.9	6.9	6.8	6.9
Total N (%)	0.12	0.13	0.13	0.12
Total C (%)	1.06	1.12	1.10	1.03
C:N ratio	8.9	8.8	8.5	8.4
Colwell P ppm	64	87	108	72
CEC (cmol/kg)	55	55	53	54
Sodium (cmol/kg)	2.16a	1.862b	1.613b	1.697b
Calcium (cmol/kg)	41	41	39	40
Potassium (cmol/kg)	3.9	3.7	3.9	3.8
Magnesium (cmol/kg)	8.7	8.8	9.1	8.7
Aluminium (cmol/kg)	0.0094	0.012	0.013	0.011

The results of surface applications of amendments on a long-fallow no-till farming paddock show that straw is superior to compost or manure in improving several soil parameters (Table 3).

Manure did significantly (P = 0.002) increase Colwell P by 49% but did not significantly increase the other physical and biological soil properties in this cropping soil during a long-fallow (Table 3). Rasool, Kukal and Hira (2008) found that application of manure at 20 t/ha to a maize crop increased MWD by 79% and water holding capacity by 21% in 0-15 cm soil layers. Altieri (1999) found that it did result in increased collembola populations and increased abundance and biomass of earthworms in cropping soils.

Compost in this research did not have any significant effect on the physical, chemical and biological properties (Table 3). This contrasts with findings by Adeli *et al.* (2007) that showed applying 6 t/ha of compost, in the form of broiler litter, three times over three years on a no-till farm significant increased phosphorus, total nitrogen, microbial biomass and structural stability in the 0-15 cm soil layer.

The straw at a rate of 10 t/ha in this trial resulted in a significant increase in soil moisture by 24% ($P < 0.001$), microbial respiration by 50% (P = 0.013), microbial biomass 21% ($P < 0.001$) and in mean weighted diameter of soil aggregates by 75% (P = 0.02). There was also a significant rise in sodium levels (Table 3). These results are similar to that reported in the literature on the effect of cover cropping on chemical, physical and biological properties (Price and Castor 2007; Blanchart *et al.* 2006; Wang *et al.* 2008).

The change in land management from open grasslands to continuous no-till cropping may have some downsides to some soil biological properties. The results from the soil surveys of the central west NSW have indicated that total carbon, microbial biomass and respiration seem to decline in cropping soils compared to near by grasslands. It seems that it is fungal rather than the bacterial populations that are most affected. This may be due to the reduction of surface mulch in cropping soils reducing food and energy sources for microorganisms.

Conclusion

The early stages of this research are indicating that while compost and manure had little effect on restoring certain soil properties, it is possible that high rates of straw (or stubble cover) is influential in raising the level of microbial activity and biomass, moisture retention and soil structure. It is important though to monitor the possible rise in sodium levels. Subsequent research will be investigating any differences between treatments when plants are actively growing. This early research is indicating that it is possible to raise the level of microbial activity and abundance in no-till farming systems when a long-fallow phase is used.

While most of the no-till farmers surveyed retain their stubble it appears that there may be a need to increase the amount of retained surface mulch to address possible soil biological decline. This research is suggesting that no-till farmers may be able to start improving several soil biological properties by concentrating on improving their stubble management and treating stubble as an asset. This may be achieved by stubble mulching of stubbles or the growing of cover crops and rolling them to produce thick mulch layers before entering into a long-fallow. This should result in the maintenance of soil quality, productivity and sustainability in no-till farming systems.

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Managing water and nutrients in sandy soils for tree crop production in Central Coastal Vietnam

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Abstract
Increasing the agricultural productivity of arenosols in hot dry tropical climates is a significant challenge for farmers and applied R&D agencies in many countries. Central Vietnam has extensive areas of sandy soils which are used for mixed farming systems. This paper reviews soil and water constraints to tree crop production by farmers in central coastal Vietnam and outlines strategies that are being evaluated to reduce them. The application of improved irrigation and nutrient management practices is impeded by inadequate farmer knowledge, labour shortages and very little capital for on farm investment. Field trials are in progress to evaluate potential changes to existing irrigation practices with the aim of improving water use efficiency, crop productivity and raising farm net income. The irrigation trials integrate nutrient management strategies. Specifically, rice husk biochar amendments applied to sandy soils are being investigated with the aim of improving soil nutrient retention. The trials also have institutional capacity building, research and extension objectives.

Introduction
Arenosols occupy 900 million ha or 7% of the earths land area (FAO 2001). These sandy soils pose many constraints to agriculture, particularly when they occur where there are seasonal hot dry climates. Arenosols in the warm climates usually have low water and nutrient holding capacity due to their low organic matter content and cation exchange capacity. Their plant available water is typically only 50-110 mm per metre of soil (Allen *et al.* 1998). Soil organic carbon is rapidly lost due to the high soil temperatures in the tropics (Jabbagy and Jackson 2000). The storage capacity for carbon of sandy soils is typically less than 1% because of the low potential to protect carbon from microbial activity (Hassink 1997; Six 2002; Mtambanengwe *et al.* 2004). The actual soil carbon contents are often much lower than this due to low plant productivity and hence low carbon input rates. Farmers reliant on sandy soils need carefully designed and well integrated water and nutrient management systems to increase their productivity and reduce adverse effects on groundwater and soil acidity.

In central coastal Vietnam there are more than 500,000 ha of sandy soils which are derived from granite weathering, alluvial deposition and windblown coastal dune systems. The region has a 6-8 month dry season which is also hot and humid. The coastal river floodplains are prone to flooding during the monsoonal wet season and are used mainly for rice production. The coastal zone and lower foothills of the river valleys are used for mixed farming using a combination of groundwater and surface water for irrigation. Upland soils are subject to erosion in the wet season and many also have acidic sub-soils. Farm incomes in the region are low and constrained by low soil fertility. This paper reviews the water and nutrient management practices used by poor small farmers in the coastal zone and lower foothills and outlines management options being evaluated to increase incomes and reduce environmental degradation.

Farmer's water and nutrient management practices
A survey of 150 farms was conducted in Ninh Thuan and Binh Dinh in 2007 to assess practices used by farmers, particularly for water and nutrient management. Whilst the landscapes and farming systems of the two provinces are similar, the rainfall is higher and water resources are more available in Binh Dinh. The survey found that;

- Seventy three percent of the farms had areas less than 2.5 ha. Most farms were mixed farms with tree, crop, vegetables and livestock components.
- Ninety five percent of farms used groundwater accessed through open wells for irrigation. Irrigation water is applied almost entirely using hand held hoses or surface flood irrigation techniques. Irrigation is labour intensive and labour is in short supply.
- All farmers indicated they had water shortages in the dry season which reduced the area of land they could grow crops on.

- Groundwater salinity was reducing the productivity of farms developed on sandy soils stretching 1 km or so inland along the coastal fringe.
- Nearly all farmers surveyed used manure for soil improvement, usually in combination with inorganic fertilisers. Livestock owners may also sell manure . Applications of manure vary from 40 t/ha on grapes to 6 t/ha on cashews.
- The application rates of mineral fertilisers vary widely and tend to be higher on the most profitable crops. Application rates are not guided by nutrient budgets.

Water and nutrient management strategies for main tree crops.
The survey was followed by 15 farm case studies to further describe the range of farm management practices for the major tree crops grown in the region i.e. cashews, mango and table grapes (Figure 1). These studies found that productivity of cashews varied from 0.4 to 2.5 t/ha depending on variety, irrigation and nutrient inputs. Many cashews receive no inputs. Farmers who irrigate cashews apply water from hand held hoses starting at flowering. This is a labourious operation so farmers tend to apply a large volume of water infrequently (e.g. every 15 days) and production remains low, typically less than 1 t/ha nut in shell.

Figure 1. Cashews, mangos and grape production on sandy soils in central coastal Vietnam.

Table grapes are a significant and expanding crop in Ninh Thuan. They are high yielding and profitable and so receive high rates of inputs. They are typically surface flood irrigated every 2-4 days. Manure and mineral fertilisers are distributed in the irrigation water. Manure rates vary from 20 to 80 t/ha. We have estimated that annual N application rates may be as high as 1500 kg total N/ha. Nitrate levels >50mg/L have been measured in groundwater sampled from adjacent to table grape farms in the area.

Mangos are a higher value expanding crop in Binh Dinh and are mainly irrigated from flowering with groundwater applied via hand pulled hoses. Irrigation intervals are highly variable between farmers, ranging between 5 to 20 days. Binh Dinh groundwater levels fluctuate from ground level in the wet season to 6 m below ground level in the dry season.

Some of the major constraints facing farmers growing tree crops are outlined in Table 1 along with management strategies that we are currently evaluating to address them. We are testing components of an integrated water and nutrient management system for tree crops on sandy soils which builds on, but modifies, existing farmer water and nutrient management practices. Poor farmers are most likely to be driven to adopt new practices that save labour and increase incomes. The effects of elements of the proposed management system (Table 2) on these drivers are being evaluated with collaborating farmer's in both provinces.

There are also micro- nutrient, agronomic, animal production and marketing constraints to farm incomes in the region. These components, together with the soil and water strategies identified above, are being evaluated as parts of an integrated project supported by the Australian Centre for International Agricultural Research (ACIAR). The collaborative project is also assisting to build institutional research and extension capacity in the southern central coastal region of Vietnam.

Table 3. Constraints to tree crop production on sandy soils in central coastal Vietnam.

Main constraints to food production in upland farms	Management strategy being evaluated
1. Soil and water constraints	
Water scarcity in dry season	Improved water management practices and irrigation systems. • Reducing plant water stress only during critical phenological stages (e.g. flowering to nut set in cashews) using on-farm evaporation pans to guide when and how much to irrigate. • Deficit irrigation technologies eg partial rootzone wetting
Low water and nutrient holding capacity of sandy soils	• Incorporation of biochar from rice husk • Use of surface mulches • Use of organic (manure and biochar) and inorganic fertiliser amendments as per recommended production guidelines.
Acidic sub-soils	Manures, lime, controlled irrigation and fertilizer practices.
Salinisation of coastal aquifers and soils	Improved irrigation water management and irrigation systems.
2. Environmental constraints	
Groundwater contamination with nitrates	Improved irrigation water and nutrient management practices and irrigation systems. Drip irrigation systems for table grapes
3. Socio-economic constraints	
Low capacity for investment	Demonstrating conservative return on investment.
Labour scarcity	Evaluating labour efficiency through improved irrigation systems.

Table 4. Current and proposed practices used by small farmers in central coastal Vietnam.

Current farmer practice	Proposed practice
Uncontrolled irrigation volumes and frequency	Water application frequency controlled using on-farm mini-pans
Uncontrolled volumes of water applied to variable sized circular bunds around each tree using hand held hose. Labour intensive.	Standardising bund to canopy edge and applying guideline water volumes using partial irrigation strategies e.g. to half of the circular bund area, alternating i.e. Alternating rootzone wetting.
Highly variable application rates of manure and inorganic fertilisers before and after wet season.	Application of manure and inorganic fertilisers applied at guideline rates based on tree size. Manure and fertiliser are applied to biochar (Figure 2) amended soil ring within irrigation bund before and after wet season and for inter-row crops e.g. peanuts.

Figure 2. Rice husk biochar amended sandy soil used for tree crops and inter-row crops.

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Microbial biomass activity in neotropical savanna soils managed during six years with conservationist cereal-cattle systems

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Abstract
In well-drained savanna soils of Venezuelan Central Plains, the changes of microbial activities produced by different agricultural managements for maize were evaluated. The perennial cover crops; *Brachiaria dyctioneura* (grass) and *Centrosema macrocarpum* (legume) were established in 2002. Two years later, they were associated with maize cultivated under no-tillage and different phosphorus sources: phosphate rock, diammonium phosphate, native mycorrhizas used as maize inoculum and the phosphorus produced by organic residues mineralization of the cover crops. Temporal variations of the microbial activity were found, showing a significant increase ($P<0.05$) with the cover crop introduction. Their dynamic patterns during six years of the essay also were different ($P<0.05$), depending of the phosphorus source-cover crop interaction. Phosphate rock and biofertilizer induced a higher mineralization activity at beginning of maize development, just when there is a major demand. The dynamic variations of metabolic coefficient (qCO_2) suggested changes in the efficiency of use of C by the soil microorganisms.

Key Words
Microbial biomass, metabolic coefficient, well-drained savannas, cover crops, maize.

Introduction
The microbial biomass is a fundamental factor of the soil fertility because it transforms all the organic residues that enter into the soil. It has an important role in nutrient availability for plants and at the same time, in nutrient conservation in organic forms, during a short period of time. When the soils have a low fertility as the well-drained savanna soils have; the role of the microorganisms and their activities increase their relative importance on the agroecosystem sustainability. On the other hand, acid soils dominate in these well-drained savanna ecosystems. These edaphic conditions; acidity and gross textures, joined to the strong climatic seasonality, produce one of the principal problems for plant production; P and N deficiency. Mineral fertilization has been a palliative solution to mitigate these deficiencies, however, the risk of N loss by lixiviation and the chemical adsorption of P in these ecosystems, places fertilization and the nutrient availability at a crucial point to consider in the agriculture management of these savanna soils.

Knowledge of the microbial biomass sensitivity to changes that are produced in the soil by the agriculture management, its activity could be used to manipulate the mineralization or immobilization of important elements in the soil. In this sense, it is reasonable to combine organic residues with distinct C/N ratios with fertilizers that promote different P availabilities for the crops. This interaction can affect the mineralization activity of the microorganisms and to create key conditions affecting the availability of nutrients in mineral form for maize.
The objective of this study was to evaluate microbial activity changes in the well-drained savanna soils with different types of agricultural management; that included the use of cover crops and type of phosphate fertilization of maize cultivated under no-tillage.

Methods
The study was conducted at La Iguana Experimental Station, which is in the Orinoco River watershed. La Iguana Experimental Station presents representative savannas of the Venezuelan Central Plains and is located in the southeast of Guarico state, Venezuela (8° 25’ N and 65° 24’ W). The region has a marked seasonality with a dry season from November to May and a rainy season from June to October. The total annual precipitation is 1369 mm and the mean annual temperature of 27ºC. The soil at the experimental site is a sandy Ultisol, acid with low fertility.

Experimental design

The experimental design corresponded to big plots without repetition, one big plot for each treatment (cover crop-fertilization). A soil spatial variability study (Lozano *et al.* 2004) was conducted in the whole sampling area to find out whether it was similarly heterogeneous, and consequently to determine the size and shape of the sampling surface, which finally corresponded to 18 x 450 m plots. From that geo-statistical study, it was also established that in each plot, the minimum number of samples per treatment of cover crops-phosphorus fertilizers should be twelve. Perennial cover crops, one grass *Brachiaria dictyoneura* (BD) and one legume *Centrosema macrocarpum* (CM) were sown in experimental plots in 2002. The preparation of the soil to sow the cover crops implicated use of tillage (four ploughs) and fertilizers added in a typical dose for these soils. Two years after starting the experiment, the aerial cover crops biomass was mechanically mown and their residues were left on the soil surface. Then, maize was sown under no-tillage management. Three type of fertilizer combination were used: 1.-Phosphate rock (RF); N-P-K with 100% phosphate rock as phosphorus source. 2.-Mycorrizal inoculation (FB); N-P-K with 25% phosphate rock + 75% P got by native mycorrhizas. 3.- Reduced inorganic fertilization (IR); N-P-K with 50% phosphorus from diammonium phosphate and 50% from phosphate rock 4.- Without fertilization (Io), the control treatment, where the phosphorus only depended of residues decomposition. Once the maize was harvested, four animals (cows) per treatment were brought in for a three to four-months period to feed on the covers and the remaining maize residues. The same management system for the maize and the cattle herd was used for three consecutive years. Annually, the perennial cover crops were mechanically mown just before the maize was sown. The cover crops naturally re-grew slower than maize. The soil was ploughed only when the cover crops were sowed; the rest of the time only no-tillage management was used.

Sampling procedure

Twelve soil samples were collected randomly (0-5 cm depth) at each sampling plot and at three different stages of the agro-ecosystem: i) before cutting the covers (AC), which corresponds to the period between the end of the dry season and the beginning of the rainy season, ii) at the flowering peak of maize (F), that is in the rainy season, and finally iii) after taking the animals out of the plots (3 or 4 months after grazing) (DP), in the dry season. The sampling dates corresponded to 0, 671, 1044, 1120, 1408, 1506, 1742, 1783, 1884 and 2094 days after the cover crops were established (ddsc) in 2002. These dates also correspond to AC, F and DP, during the three maize-cattle cycles. Soil samples were stored at field humidity in polyethylene bags at 4ºC, until analysis was performed. At the beginning of the experiment, in the rainy season just before the agronomical management was established, an initial savanna soil characterization was made, that sampling was done in the same sites where each plot treatments would be established, it also corresponded to a randomized sampling (twelve samples) at native savanna soil (SN).

Analytical methods

Twenty-gram triplicates of each sample of soil, at field humidity, were used to determine microbial biomass carbon (CBM) using the fumigation-extraction method (Sparling and West 1988). Basal respiration (CO_2) was estimated using the Alef (1995) trap method. Soil samples (50 g each, in triplicate), at field humidity, were placed in 250-ml plastic bottles and incubated at 28°C and constant humidity content. The metabolic quotient, qCO_2, defined as the specific soil respiration of the microbial biomass (mg CO_2 / (mg CBM x h)$^{-1}$), was calculated using the formula:

$$qCO_2 = ([CO_2/CBM]/24) \quad (1)$$

Where CO_2 is the C mineralized by the soil basal respiration, MB-C is the C of microbial biomass and 24 are the hours of the measurement of both processes.

Results

The microbial biomass was affected by; i.- the cover crops development and the organic nutrients supply due to the cover crop's necromass decomposition (evaluated in AC between dry-rainy season), ii.- the maize development with the different types of phosphorus fertilizers (evaluated in F in the rainy season) and, iii.- the changes produced in the soil by the cattle effect (evaluated in DP in the dry season). It was evident the spatial variability of this parameter in the study area (Figure 1). At the beginning, before the essay was introduced, existed significant differences ($P<0.05$) between *Brachiaria*´s plot and *Centrosema*´s plot with native savanna´s plot (SN). At that time, higher values of CBM were observed in the plots (BD and CM), where phosphate rock would be applied (RF). Two years later, 671 ddsc, the CBM was similar among all treatments compared to native savanna (SN). After that the maize was sown and the different types of fertilizers were applied, CBM was changing among treatments (cover crops-fertilization interaction). It was found that the same phosphorus source produced a different effect on the CBM depending which cover crops was associated to maize. An example of this occurred when 50% of phosphorus was used like diamonium phosphate (IR). Both, phosphate rock (RF) and diamonium phosphate (IR) promoted a higher microbial biomass when they were used with the legume cover crop associated to maize (CM) (Figure 1). In case of FB, the CBM has lower values in the rainy season, when the maize was flowered. On the contrary, at that same stage, the CBM was higher in native savanna (SN). The RF treatment produced a similar behavior to the observed in the SN soil. In the dry season, coinciding with the after grazing stage (DP), the CBM was higher in RF and IR with the grass, *Brachiaria*, but with the legume, *Centrosema*, the pattern was contrary and the RF soil shows the lowest value.

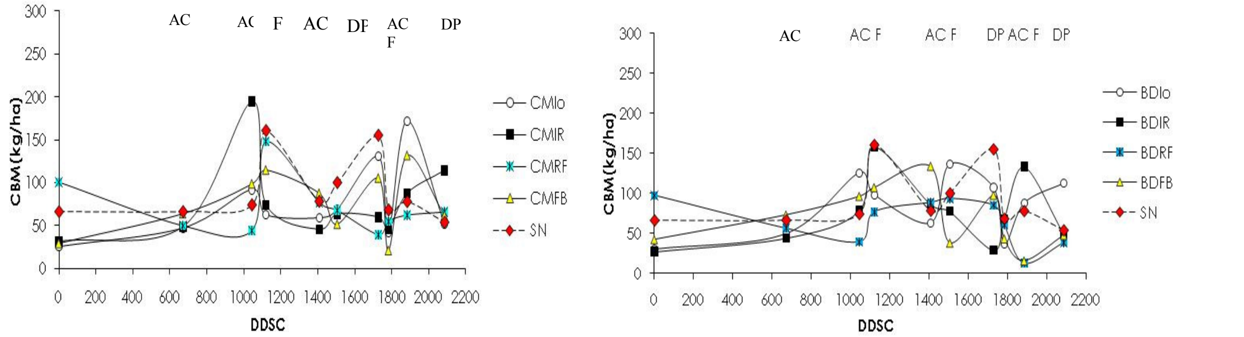

Figure 1. Microbial biomass content (CBM) during the development of the cover crops-maize-cattle system under no-tillage and fertilization types. BD: *Brachiaria dyctioneura,* CM: *Centrosema macrocarpum*, IR: diammonium phosphate, RF: phosphate rock, FB: mycorrhiza inoculation, Io: Without fertilization, SN: Native savanna. DDSC indicates the days after the cover crops were established.

The microbial respiration dynamic (Figure 2) showed fewer differences between cover crop treatments during the essay evolution. At the first four years, the CO_2 production was lower in the SN soil, and then, a significant increase ($P<0.05$) was produced in the rainy season, when the maize was flowered. In change, in the cover crops soils, the CO_2 production was significantly increasing since they were sown until the flowering of maize (F) in the rainy season. This diminution occurred in general in BD and CM, except in BDIR, where the C mineralization did not decrease. The CO_2 pattern changed at the second and third maize cycles because this parameter increased in F, especially when BD was associated to maize.

Metabolic changes of the microorganisms could occur during the six years of the production system, being the microbial biomass more efficient in the use of C per microbial biomass unity produced in some periods (Table 1). When the cover crops were introduced (671 ddsc), the metabolic efficiency decreased. It was evidenced that RF could promote minor efficient of the microorganisms in BD than CM, where there was minor constrains by N.

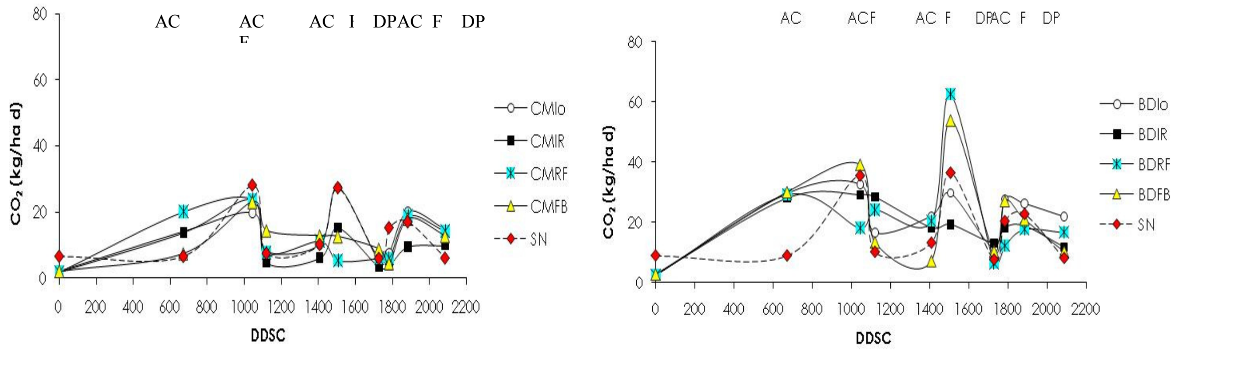

Figure 2. C mineralized by microbial biomass (CO_2) during the cover crops-maize-cattle system development under no-tillage and fertilization types. BD: *Brachiaria dyctioneura,* CM: *Centrosema macrocarpum*, IR: diammonium phosphate, RF: phosphate rock, FB: mycorrhiza inoculation, Io: Without fertilization, SN: Native savanna. DDSC indicates the days after the cover crops were established.

Table 1. Changes of metabolic efficiency (qCO_2) during the cover crops-maize-cattle system development under no-tillage and fertilization types.

Treat	0	671 (AC)	1044 (AC)	1120 (F)	1408 (AC)	1506 (F)	1742 (DP)	1783 (AC)	1884 (F)	2094 (DP)
BDIR	0,07a	0,45c	0,25bc	0,22bc	0,15b	0,17b	0,27c	0,19b	0,10a	0,17ab
BDIo	0,06a	0,44c	0,19b	0,18b	0,26c	0,13ab	0,07a	0,54d	0,22b	0,14a
BDFB	0,04a	0,29b	0,29bc	0,11ab	0,04a	0,88e	0,07a	0,46d	0,99d	0,15a
BDRF	0,02a	0,37bc	0,33c	0,22bc	0,15b	0,48d	0,04a	0,15a	1,02d	0,29b
CMIR	0,06a	0,28b	0,11ab	0,09a	0,14b	0,25c	0,05a	0,08a	0,11a	0,09a
CMIo	0,07a	0,29b	0,20b	0,18b	0,17b	0,40d	0,03a	0,18b	0,12a	0,28b
CMFB	0,06a	0,12a	0,23b	0,14ab	0,14b	0,25c	0,08a	0,21b	0,14a	0,20b
CMRF	0,02a	0,40c	0,50d	0,06a	0,15b	0,06a	0,10b	0,11a	0,30c	0,22b
SN	0,10b	0,10a	0,04a	0,05a	0,12b	0,25c	0,04a	0,24c	0,22b	0,11a

Different lowercases at the same column indicate significant differences among treatment $p<0.05$, Tukey. BD: *Brachiaria dyctioneura,* CM: *Centrosema macrocarpum*, IR: diammonium phosphate, RF: phosphate rock, FB: mycorrhiza inoculation, Io: Without fertilization, SN: Native savanna.

Conclusion

Microbial biomass was a good indicator of the agricultural management effect and seasonality of the well-drained savanna ecosystem. The cover crops with different C/N ratio could be modeling the microbial variation at the same fertilization treatment, as occurred with IR and RF treatments.

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Minimum-tillage, mechanized sowing of pulses with two-wheel tractors

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Abstract
Pulse crops in Bangladesh are mainly low-input rainfed crops with broadcast sowing. Since the 1990s, rotary tillage two-wheel tractors (2WT) have largely replaced animal draft for crop establishment. However, rotary tillage causes excessive evaporation from seedbeds in rapidly-drying soils. Therefore 2WT-based minimum tillage (MT) options were explored to optimize seedbed moisture for lentil and chickpea establishment. Two types of 2WT-mounted seeding units were manufactured, a strip tiller retaining rotary blades only in front of the tynes and a tyne seeder in which the rotary tiller shaft is removed. In some soil types, seedling emergence and grain yields of lentil and chickpea with these seeders matched those with broadcasting. In wet soils, the minimal soil disturbance with MT resulted in anaerobic conditions around seedling roots thereby limiting root growth and nodulation. In clay soils with rapid surface drying traction was inadequate for tyne tillage and strip tillage could not adequately penetrate rice paddy hardpans to allow adequate growth of seedling roots. Potential solutions to these limitations are under test so that 2WT-based MT can be adapted for more timely and economic sowing of crops, including pulses, in smallholder plots and to achieve the agronomic benefits of line sowing over broadcast sowing.

Key Words
Bangladesh, chickpea, conservation agriculture, lentil, strip tillage.

Introduction
Pulses remain a dietary staple in Bangladesh despite declines in their local production in recent decades, primarily due to competition with irrigated cereal crops. Traditionally, pulses are broadcast sown and, until recently, reliant on animal-drawn tillage and grown rainfed with few agronomic inputs. Yields of the major pulses grown in Bangladesh – lentil, lathyrus, chickpea, mung bean and black gram – remain low (<1 t/ha). Over the previous 15 years there has been a rapid increase in the use of Chinese-made 2WT which now cover >80% of the tillage operations for most crops. This increases the area of land able to be sown to pulse crops during an already short sowing window due to the soil surface drying rapidly. In soils where the surface dries quickly establishment of crops like chickpea has been impaired due to enhanced surface soil evaporation as a consequence of shallow full rotary tillage. Further, rotary tillage, like other forms of tillage, disrupts macroaggregates and exposes microaggregates (<0.25 mm) and free organic matter to microbial decomposition (Six *et al.* 2000b). Thus there is a loss of carbon and reduced nutrient sequestration in heavily tilled soils (Lupwayi *et al.* 1999; Six *et al.* 2000a). Minimum tillage practices under the concept of conservation agriculture (CA) can reverse such declines in soil quality (e.g. Kushwaha *et al.* 2001).

Following introduction of 2WTs in Bangladesh there has also been recent adoption of Chinese-made single pass power tiller operated seeders (PTOS), which drill seed behind the high speed rotary shaft (Haque *et al.* 2004). Although providing the advantages of line sowing of crops the device retains the disadvantages of full rotary tillage. The device may be modified towards MT in two ways (Hossain *et al.* 2009). Firstly, all except the blades on the rotary shaft immediately ahead of the seed delivering tynes can be removed to produce strip tillage. Secondly, the entire rotary shaft and covering drum may be removed so that the soil is penetrated only by the tynes – known as tyne tillage or zero tillage. Various further modifications have been made to PTOS-based devices to specifically suit them to sowing of rainfed pulses, but also to be able to sow other crops in the cropping cycle. This paper describes the preliminary evaluation of these strip tillage and tyne tillage units for lentil and chickpea grown in different soil types of northern Bangladesh.

Methods

Details of PTOS modification for either strip tillage or zero tillage are described by Hossain *et al.* (2009). Apart from changes to the rotary shaft and drum, other major features included press wheels behind each tyne and a fertilizer box metering and delivering triple superphosphate (TSP) near the seed outlet on each tyne.

Silt loam soils of northern Bangladesh

In the extreme north-west of Bangladesh (districts of Thakurgaon, Dinajpur, Nilphamari and Panchagarh), the soils are mainly non-calcareous brown floodplain soils (Brammer 1996). The soil surface (0-15 cm) is acid (pH 4-6) and mainly silt loam in texture. Comparison of strip tillage with conventional broadcast sowing of lentil (*Lens culinaris* Medikus var. BARI masur 4) and chickpea (*Cicer arietinum* L. var. BARI chola 5) was made by comparing plots sown by broadcasting in a date-of-sowing experiment and by strip tillage in a seed rate experiment. The experiments were adjacent to each other in four dispersed replications around a village and were sown on the same day – 10 Nov 2008 for lentil at Sasla Piala Village, Thaurgaon Sadar and 4 Dec 2008 for chickpea at Bhandardha Village, Baliadangi, Thakurgaon - and the treatments were thus comparable by paired "t" test. Broadcast plot size was 5 x 5 m and plots were cultivated with a rotary power tiller, boric acid and TSP fertilizers and seed were hand broadcast, and the plots then raked to incorporate seed and fertilizer. For strip tillage plots, plot size was 12 rows 40 cm apart and 15 m length. Seed rate in both treatments was 34 kg/ha for lentil and 37.5 kg/ha for chickpea. Seeds were primed overnight prior to sowing with Mo added to the priming water at 1.5 g $Na_2MoO_4.2H_2O$/L and *Rhizobium* inoculum at 40 g/L priming water; there was 1 kg seed/L priming water. TSP rate was 100 kg/ha, which was drilled in the case of strip tillage. Boric acid was hand broadcast at 1 kg B/ha at sowing. Crops were grown rainfed, mainly on residual soil moisture from the preceding rainy season. Three days prior to sowing, plots were sprayed with Roundup® at 1.875 L/ha in 375 L water, with follow-up hand weeding of lentil plots at 15-35 days after sowing (DAS) and of chickpea plots at 45-50 DAS. Stemphilium blight of lentil was managed by spraying Rovral-50® wp @ 0.2% at 45 DAS. Chickpea was protected from Botrytis grey mould (BGM, caused by *Botrytis cinerea*) by spraying Bavistin® at 1 kg/ha at 45-50 DAS and from pod borer (*Helicoverpa armigera*) by spraying Karate® @ 1 L/ha in 500 L water at 65-70 DAS. At harvest, 5 x 1 m^2 quadrates were cut from broadcast plots and 15-20 m row length from strip tillage plots and the grain weight measured after threshing. Chickpea demonstration plots of 1,333 m^2 were sown in farmers' fields in Nov-Dec 2008 following the same agronomy as described above. Nine plots were sown by hand in rows after full tillage and 25 plots sown by strip tillage, without any prior tillage, with 40 cm row spacing in both cases.

Hard setting clay soils of the High Barind Tract

In the High Barind Tract (HBT) grey terrace soils are predominant (Brammer 1996). These soils are acid to neutral (pH 4.0-6.5) with mostly silty clay surface horizons. There is a clay plough pan layer at 10-12 cm, resulting from repeated rainy season rice cultivation and the soil surface rapidly dries and hardens after harvest of rice in Nov-Dec. A chickpea experiment conducted at Choygati Village, Godagari Upazilla, Rajshahi District, where the surface soil was of loamy clay texture and had high water retention capacity, in 2007-08 compared sowing with either PTOS, strip tillage or zero tillage. Four sowing dates (1, 7, 11, 14 Dec 2007) were in main plots and tillage method in sub-plots (9 rows 50 cm apart and 10 m length) in a split plot design with three replicates. In 2008-09 at Choygati, and at Kantopasha Village, Godagari, where the soil was more typical of the HBT with rapid surface drying, four replicate plots of strip tillage were compared with one broadcast sowing plot with full tillage, in 15 x 3 m plots. Plots were sown on 24 Nov 2008 at Choygati and 22 and 28 Nov 2008 at Kantopasha. Also at Kantopasha in 2008-09, a split plot trial compared strip tillage with PTOS sowing of chickpea (main plots), with and without mulching with rice straw prior to sowing (sub-plots). Sub-plot size was 6 rows 40 cm apart and 10 m length and sowing date 28 Nov 2008. All HBT trials used BARI chola 5 sown at 45 kg/ha. The same agronomic practices were followed as described for chickpea in northern Bangladesh, except that Mo and *Rhizobium* was not added to the priming water (surface soil pH>5.5 and native chickpea rhizobia present) and BGM management was unnecessary.

Results and discussion

Silt loam soils of northern Bangladesh

The traction of 12 hp 2WTs, as normally used in this region of light soils, was adequate for four zero-till tynes. Initial unreplicated tests showed that both strip till and zero till options could produce adequate plant stands of lentil and chickpea. In replicated tests, respective values for broadcast and strip tillage sowing for lentil were: plant stand at 30 DAS – 53, 61 plants/m^2; plant height at 47 DAS – 25.0, 27.3 cm; grain yield – 539, 399 kg/ha. Respective values for chickpea were: plant stand at 27 DAS – 41, 47 plants/m^2; plant height at 52 DAS –21.8, 20.0 cm. Differences between broadcast and strip tillage sowing for any parameter were not significant at

P<0.05. Lentil yields in this study were low and variable among replications primarily due to seedling disease (caused by *Sclerotium rolfsii*). Yields of chickpea were not recorded due to severe damage to the crop by *S. rolfsii* and limited vegetative growth due to continuing excess soil water. In many locations, when these soils were not tilled the surface remained moist throughout the growing period, exacerbated by low temperatures and foggy conditions in Dec-Jan and high water tables in some locations. Where surface soil moisture remained at or above field capacity it was observed that root growth was minimal and nodulation poor with strip tillage. On the other hand, full tillage to 15 cm, by animal-drawn plough, 2WT, or tractor, allowed drying of the surface soil to the extent that adequate initial root growth and nodulation could occur. This was evidenced in the case of demonstration plots of chickpea sown in farmers' fields. The nine plots hand-sown after full tillage had a mean yield and standard deviation of 900 ± 49 kg/ha. Of the 25 plots sown by strip tillage 20 were abandoned due to poor growth of the crop. The five strip tillage plots harvested averaged 588 ± 167 kg/ha. It is presumed that the continuing high water content of non-tilled soil sown by strip tillage caused anaerobic conditions below the seed, limiting root growth and nodulation. For mechanized sowing under excess moisture conditions, MT does not seem possible unless there is improved aeration of initial roots and crown nodules. A wider and deeper strip, made by leaving more blades on the rotary shaft could facilitate this. Other options are sowing with full tillage (PTOS) or to sow on a permanent bed system (Sayre 2004). These options are under test in the 2009-10 season.

Hard setting clay soils of the High Barind Tract

Preliminary tests indicated that 2WT traction was insufficient for zero tillage in typical HBT soils. Strip tillage provided extra traction through the action of the rotating blades as well as opening a furrow for the following tyne. At both Choygati and Kantopasha in 2008-09, initial plant stand was higher with broadcast sowing but that with strip tillage was satisfactory for chickpea in this environment (Table 1). At Choygati with both broadcast and strip tillage sowing, chickpea grain yield was 1.8 t/ha, more than double normal chickpea yields in the HBT. On the other hand, strip tillage produced only half the yield of broadcast sowing at Kantopasha (Table 1). A comparison of tillage methods at Choygati in 2007-08, indicated less emergence with zero tillage, but there was no significant difference in yield between zero tillage, strip tillage and PTOS sowing (Table 1). At Kantopasha, however, emergence and yield were significantly lower with strip tillage than PTOS (Table 1). Here, seedling growth was less with strip tillage, probably because of impeded root penetration through the undisturbed but rapidly drying plough pan layer below the opened furrow. Modification to produce a deeper and wider furrow, along with deeper placement of seed, would be required for successful use of strip tillage in HBT soils. This modification of strip tillage is currently under test.

Table 1. Effect of sowing method on initial plant stand and grain yield of chickpea in clay-loam (Choygati) and hard-setting clay (Kantopasha) soils in the High Barind Tract of Bangladesh, 2007-08 and 2008-09 seasons.

Sowing method	Choygati		Kantopasha	
	Plant stand (plants/m^2)	Grain yield (kg/ha)	Plant stand (plants/m^2)	Grain yield (kg/ha)
	2008-09		2008-09	
Broadcast	63.8	1,824	48.5	1,082
Strip tillage[1]	40.8 ± 2.8	1,806 ± 330	29.1 ± 5.0	562 ± 129
	2007-08[2]		2008-09[3]	
PTOS	26.7	733	67	571
Strip tillage	20.5	852	40	240
Zero tillage	15.0	862	-	-
Significance	P<0.001	ns[4]	P<0.001	P<0.001

[1] Mean ± standard deviation.
[2] Main effect of tillage treatment.
[3] Values averaged across mulching treatments as no significant effect of mulching.
[4] ns = no significant difference at P = 0.05.

Conclusion

Minimum tillage seeding devices attached to 2WTs have been demonstrated to produce adequate stands of lentil and chickpea, under particular soil conditions in Bangladesh. Strip tillage is preferred as there is insufficient traction with existing 2WTs for operation of zero tillage on heavier, hard setting soils. However, narrow and shallow strip tillage is not effective in soils that remain excessively wet or in quick drying soils with a plough pan layer. Modifications to overcome these problems are feasible, through a deeper and wider strip, deeper seed placement in quick drying soils and shallower placement in wet soils, and more effective covering of the seed after placement. There is a need to classify soil conditions where strip tillage will operate satisfactorily, or where modification towards full tillage is required. Strip tillage for sowing of pulses provides the advantages of line sowing, which include better weed and disease management and easier harvesting. Other advantages of strip tillage include less labour, fuel cost and time requirement for one-pass sowing, and the possibility of reducing seed and fertilizer rates due to more optimum placement in furrows. These improvements are now within the reach of resource-poor, smallholder farmers already familiar with 2WT.

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Monitoring soil quality in intensive dairy-farmed catchments of New Zealand: implications for farm management and environmental quality

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Abstract
Soil physical and chemical quality assessments were performed for the predominant soil types within four intensively grazed dairy catchments in New Zealand during the winters of 2001, 2003, 2005 and 2007. The four catchments monitored were in the following regions: Waikato (Toenepi stream), Taranaki (Waiokura stream), Canterbury (Waikakahi stream) and Southland (Bog Burn stream). The surveys suggest that, in general, soil quality was good. Mean soil macroporosity was initially low in the Toenepi catchment but is now within the recommended range for good pasture production. All catchments, except the Bog Burn, have showed that soil macroporosity values have increased since the study began. A considerable proportion (76%) of farms within all catchments has higher than optimum concentrations of soil Olsen P. These P concentrations have been maintained despite evidence from farm surveys which suggest that P fertilization rates have decreased. However, changes in soil test status following a change in fertilization policy can be slow to manifest themselves. These high levels are likely to be uneconomic and pose increased risk of P loss to waterways.

Introduction

There is concern in New Zealand about the impacts of intensive dairy farming on soil and water quality. Concern about surface water quality is high in many regions that have seen a rapid shift from low intensity dry-stock farming to high intensity dairying. In response, the Best Practice Dairying Catchments for Sustainable Growth Project was established in summer 2001. The project aim was to quantify the benefits of integrating environmentally sustainable farming practices into a rapidly expanding dairy industry. Four predominantly dairy land use catchments were chosen for study: Waikato, Taranaki, Canterbury and Southland. In addition to providing geographical spread, the chosen catchments are typical of dairy farming climatic conditions, soil types and farm management practices for each region. Decreases in soil quality within pastoral agricultural systems have been associated with deteriorating surface water quality (Kurz *et al.* 2006). In addition to decreasing surface water quality, the loss of sediment, phosphorus and nitrogen from pastoral land represent a decrease in soil fertility and nutrient use efficiency (McDowell *et al.* 2008). Factors such as soil P concentration can determine the availability of P for loss in overland and subsurface flow (McDowell *et al.* 2003; McDowell *et al.* 2005), while others such as soil compaction by animal treading can have detrimental effects on soil physical properties that impair plant growth and enhance the transfer of contaminants in overland flow (Drewry *et al.* 2008; Houlbrooke *et al.* 2009; McDowell and Houlbrooke 2009). Some soils are particularly susceptible to treading damage under intensive grazing management (Hewitt and Shepherd 1997). Such soils are now being increasingly used for dairy farming and present a management challenge for good soil and water quality to be maintained. Soils may also deteriorate through inappropriate management of K fertility via excessive or inadequate nutrient inputs (Roberts and Morton 1999).

Methods

Transect location

The four dairy catchments are drained by the Toenepi Stream (Waikato), Waiokura Stream (Taranaki), Waikakahi Stream (Canterbury) and Bog Burn (Southland). Within each catchment, at least two transects of approximately 100 m length were sampled from each of ten different farms representing the major soil type used for dairy farming in each catchment. The soils types investigated in the Toenepi, Waiokura, Waikakahi and Bog Burn catchments were a Kereone silt loam (US soil taxonomy: Udand), a Manaia silt loam (US soil taxonomy: Udand), an Eyre very stony sandy loam (US soil taxonomy: Dystrochrept), and a Pukemutu silt loam (US soil taxonomy: Fragiochrept), respectively. In addition, within the Waikakahi catchment, ten transects were also sampled on the heavier Temuka silt loam (US soil taxonomy: Aquept).

Sampling procedure and analysis
Two sets of soil samples were taken from each transect during the winter period for each survey conducted. Soil chemical samples were obtained by collecting and bulking 20 small cores to 75 mm depth along each transect. This sampling procedure is the same as that recommended for standard soil fertility sampling on commercial dairy farms in New Zealand. Twenty 5-cm diameter core samples were also taken per transect for soil physical analyses using a coring device designed to extract an intact soil core from 1.5 to 3.5 cm depth, nominally 0 to 5 cm. All samples were analysed by an IANZ accredited commercial laboratory for the following soil properties: pH, P, Ca, K, Mg, Na, SO_4-S, total N, mineralisable N, organic S, organic C, bulk density and macroporosity (pores > 30 µm). For the purposes of this report we will present data on the following soil quality properties: Olsen P, exchangeable K (Quicktest method), organic carbon and macroporosity (pores > 30 µm at -10 kPa tension).

Statistical analyses and data presentation
Soil chemical data and paddock mean soil physical data from dairy farm sites were analysed by ANOVA using GENSTAT, with transect within farm as the block structure and catchment (with Waikakahi catchment subdivided by soil series) as the treatment. Soil quality properties from sampled dairy farms are presented as box and whisker graphs (Figure 1) to demonstrate the distribution within catchments in relation to proposed optimal criteria. Changes in soil quality over time within catchments have been determined by a change ≥ 2 SEM (Figure 2). Figures 1 and 2 compare catchment soil quality data with optimum ranges. The macroporosity and organic C criteria were based on soil quality assessment targets (Sparling & Tarbotton, 2000), while the soil K targets were from Roberts and Morton (1999). However, soil Olsen P criteria were based on values for established agronomic optimums (Roberts and Morton 1999), and the potential risk to contamination of waterways (McDowell *et al.* 2005).

Results and discussion
With the exception of the Bog Burn, mean Olsen P concentrations in all catchments, , were greater than agronomic targets for dairy farming. Furthermore, Waiokura and Toenepi Olsen P concentrations have significantly increased with time since monitoring began (P<0.05), despite a decrease in reported P fertilization rates. However, changes in soil test status following a change in fertilization policy can be slow to manifest themselves. Optimum agronomic concentrations for soil Olsen P on dairy farms are 20-30 mg/L for farms with average milk-solids (MS) production per hectare. However, higher Olsen P concentrations of 30-40 mg/L can be agronomically and economically justified at high MS/ha production if all additional pasture is utilised (top 25% milk-solids production in a supply region (Roberts and Morton 1999). Potential P losses in surface runoff to waterways can be minimised, and economic returns maximised, by maintaining soil Olsen P concentrations within the correct target ranges, depending on soil type (McDowell *et al.* 2005). From an economic perspective, excessive P fertilisation that results in soil Olsen P concentrations above the agronomic optimum has little financial merit since little additional pasture production is gained, and has a greater potential for P to be lost.

A large proportion (>25%) of soil Quicktest K concentrations for all catchments were greater than recommended targets (Figures 1 and 2). The Waikakahi, Waiokura and Bog Burn catchments showed no significant change in mean soil Quicktest K concentrations between the 2005 and 2007 surveys following a period of increasing soil Quicktest K concentrations from 2001-2005. However, the Toenepi catchment demonstrated a significant increase (P<0.05) of 2.5 Quicktest units between the 2003 and 2005 surveys. Large within-catchment variability of Quicktest K concentrations was found for all catchments (Figure 1). Trends in Quicktest K with time are presented in Figure 2. The low soil Quicktest K concentrations suggest that clover growth is likely to be restricted. Conversely, soil enriched with K can lead to high concentrations of K in pasture and subsequently cause metabolic problems such as hypomagnesaemia in grazing animals. This is commonly associated with areas receiving long term additions of farm dairy effluent (Houlbrooke *et al.* 2004).

Mean and median concentrations of soil organic carbon (SOC) were generally considered normal or enriched for all catchments (Figures 1 and 2). Well established and productive pastures are known to return large amounts of organic matter to soil via the breakdown of dead root material, litter and animal dung and these returns act as inputs into the soil organic matter pool.

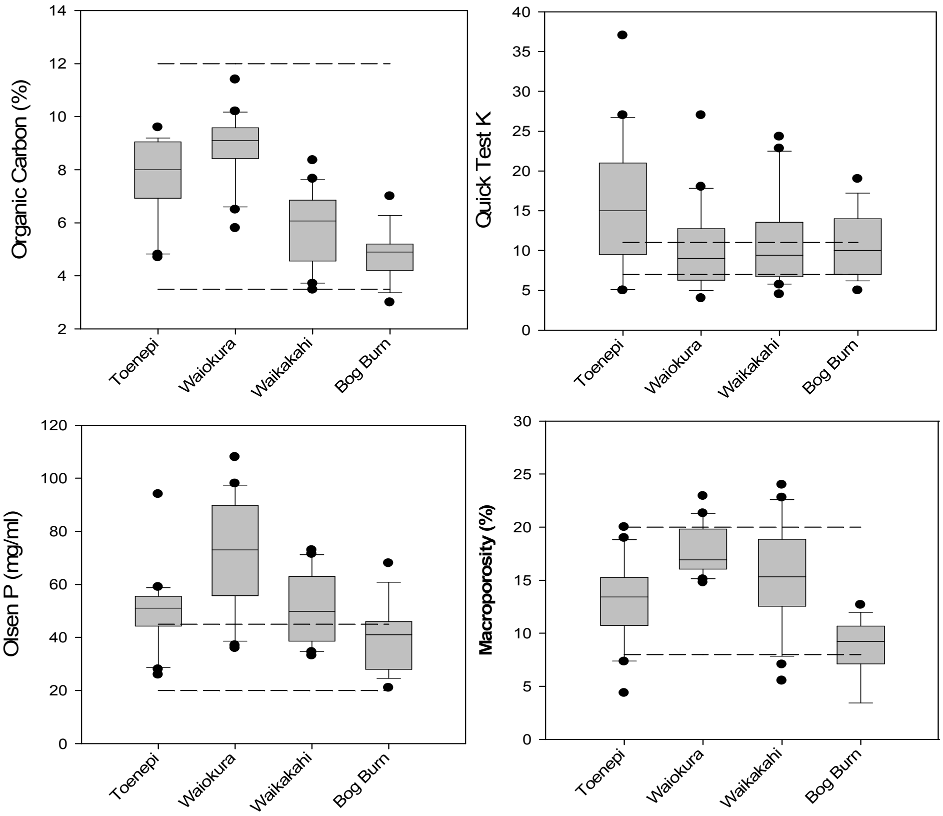

Figure 1. 2007 soil quality data showing between- and within-catchment variation compared to optimum ranges (dashed lines). To interpret a box and whisker graph, the boundaries of the box represent the 25th (lower) and 75th (upper) percentiles, and a line within the box marks the median. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles. In addition, outlying points are plotted as closed circles.

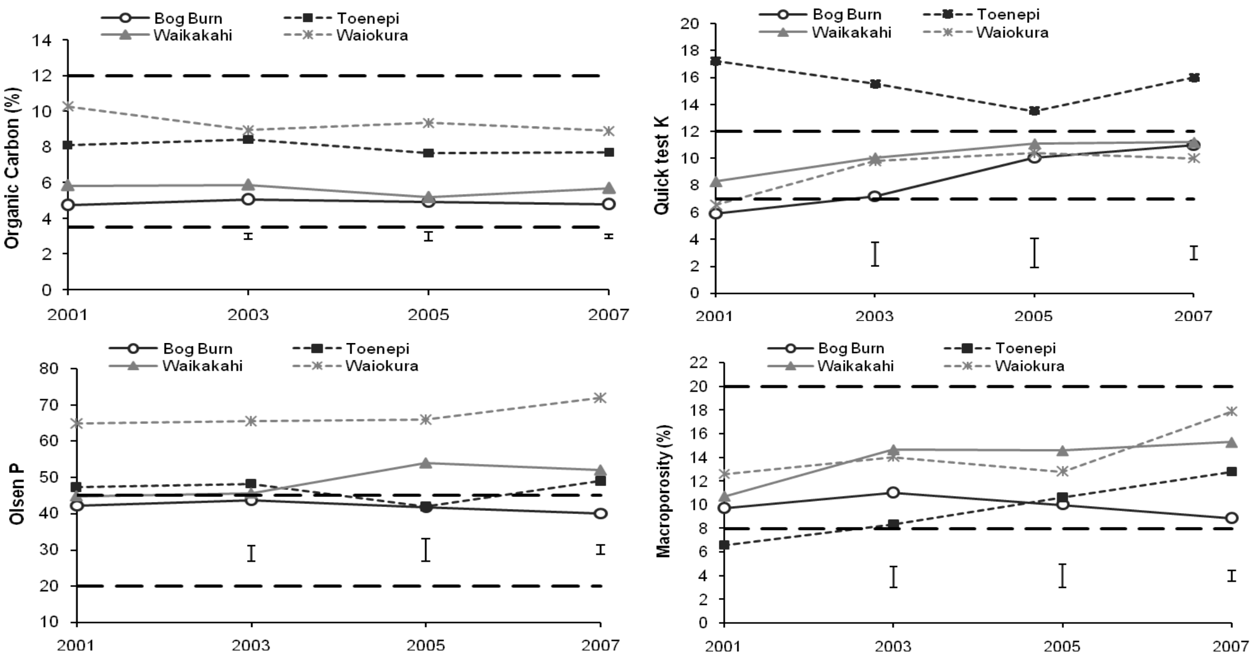

Figure 2. Changes in soil properties with time. Bars represent two SEM values for data between the current and previous year. Dashed lines represent optimum range thresholds.

Mean and median values for macroporosity were considered satisfactory for all catchments (Figure 1 and 2). The mean soil macroporosity value calculated for the Bog Burn catchment (8.7% v/v) was close to the lower end of that considered optimal for pasture production (>8%), but 33% of farms tested had a mean macroporosity value below optimum (Figure 1). Furthermore, the Bog Burn catchment demonstrated a significant ($P<0.05$) decreasing trend (c. 1% unit change) between the 2005 and 2007 surveys. The Pukemutu silt loam found in the Bog Burn catchment is highly vulnerable to degradation under intensive management (Hewitt and Shepherd 1997). We therefore recommend the strategic use of stand-off pads in this catchment for on-off grazing when the soil is very wet in order to minimise soil compaction and treading damage and associated overland flow of contaminants. It is of note that soil macroporosity consistently increased every year ($P<0.05$) from very low levels in the Toenepi catchment in 2001 to be well within the optimal range in 2007 (6% unit increase over 6 years). The volcanic soil in this catchment is reputedly quite resilient to treading damage so eliminating the frequency and severity of compaction events would have allowed for recovery.

Conclusion

Soil quality assessments have been performed for each of the major soil types within four New Zealand catchments that are intensively used for dairy farming. With the exception of Olsen P, mean results suggest that soil quality was generally considered ‘good’ overall. Enriched soil Olsen P concentrations are likely to be uneconomic and represent a potential risk to surface water quality. Recommended management strategies for dairy farmers within the catchment study are to manage nutrient inputs of K and P to keep soil concentrations within agronomically optimum levels and decrease the potential for associated animal health and environmental impacts. Farms within the Toenepi catchment have demonstrated an improving trend for soil macroporosity to well within optimum levels. However, farms within the Bog Burn catchment have, due to the presence of a soil that is vulnerable to treading and compaction damage, tended to have low macroporosities. These vulnerable soils should be strategically managed during wet periods

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Optimizing water and nitrogen management for irrigated maize in desert oases in Northwestern China

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Abstract
Understanding water and nitrogen transport through the soil profile is important for efficient irrigation and nutrient management, and to minimize nitrate leaching to the groundwater. In this study a process-based water and nitrogen management model (WNMM) was used to simulate soil water movement, nitrate transport, and maize growth under desert oasis conditions in Northwestern China. The model was calibrated and validated with a field experiment. The model simulation results showed that about 35% of total water input and 58% of the total nitrogen input was leached to below 1.8 m depth under the traditional management practice. Over 1700 scenarios combining various irrigation and fertilizer practices were simulated. We analyzed the results to derive best management practices (BMPs) that simultaneously consider crop yield, water use efficiency, fertilizer N use efficiency and nitrate leaching. The results indicated that the BMPs under the specific desert oasis conditions are to irrigate maize with 600 mm water over eight irrigation events with a single fertilizer application at a rate of 75 kg N/ha.

Key Words
Desert oasis, WNMM model, water drainage, nitrate leaching, best management practices.

Introduction
Rapid economic and population growth requires agriculture to produce sufficient food to sustain China's development. Large irrigation and N fertilizer inputs are being used to maintain and increase crop production but there is generally low water and N use efficiency. Increasing incidences of nitrate pollution and dramatic increases of groundwater nitrate concentrations in intensively farmed regions have been reported by many researchers (Hu *et al.* 2005). This issue has become very serious in desert oases of western China. The cropping of light-textured soils, excessive irrigation (typically as flood irrigation) and heavy fertilizer applications have resulted in NO_3^--N concentrations as high as 130 mg N/L in groundwater accessed in community wells in the Left Banner, Alxa league (Inner Mongolia). There are number of models such as GLEAMS, EPIC, NLEAP, LEACHM, APSIM, DAISY, RZWQM, and DSSAT that can be used to evaluate the integrated effects of soil, climate, and management on crop growth and nitrate leaching. Recently, Li *et al.* (2007) developed a process-based water and N management model (WNMM). This model can simulate water, carbon and N dynamics, as well as plant growth under various agricultural management practices, specifically for the intensive cropping (wheat-maize) systems of the North China Plain. The model has been well calibrated and validated for Chinese agroecosystems (Li *et al.* 2005; Li *et al.* 2007). The objectives of this study are to (i) validate and apply the WNMM model to simulate water movement and the fate of the nitrogen, and (ii) to optimize water and nitrogen management for maize cropping, in a desert oasis as a basis for devising best management practices (BMPs).

Materials and methods
Study area and field experiment
The study area is located in Left Banner, western Inner Mongolia, China (37°24'-41°52' N and 103°21'-106°51' E). The average annual precipitation is 116 mm of which 70-80% is concentrated during the summer season. The annual average temperature is 8.3 °C. The groundwater depth is about 40-70 m and is the only source of irrigation water. The oasis cropping system is a single crop produced annually from the middle of April to early October. The experimental site was located in the mid-south of the Chahantan oasis. A soil profile pit was excavated to 2.0 m and samples of soil textural layers were collected for analysis of basic physicochemical properties. Maize (*Zea mays L*) was planted on April 15 and harvested on Sep. 26, 2005. There were two irrigation and fertilizer treatments: traditional management practice (T1) and improved management practice (T2). The plot size was 20 m×20 m, with five replicates. For the traditional practice, the plots received 165 mm/d water for each of five irrigation events. For T2, the plots received 105, 135, 135,

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135 and 120 mm/d water for the five irrigation events, respectively, based on the suggestions from local farm experts. The irrigations occurred on day 55, 73, 93, 118 and 142 after the planting. Diammonium phosphate at 225 kg/ha was applied as a basal fertilizer on April 15. Urea was surface-applied just before the first irrigation for both treatments at a rate of 138 kg N/ha. Since the nitrogen input from irrigation under treatment T2 was less than that under treatment T1 (the average NO_3-N concentration of the irrigation water was 28.5 mg N/L), additional urea (138 kg N/ha) was applied at the third irrigation for treatment T2. In each plot for all 5 replicates, the soil volumetric water content was measured every 7 days using TDR probes at 10 cm intervals to a depth of 180 cm. Soil samples from depths of 0-35, 35-47, 47-63, 63-70, 70-80, 80-85, 85-97, 97-140, and 140-180 cm were collected at four times: before sowing, on day 82 and 117 after planting, and at harvest. Each fresh soil sample was extracted with 1 mol/L KCl and the concentrations of NH_4-N and NO_3-N were determined using a Continuous Flow Analyzer. Crop height, leaf area index, root depth and density, dry matter weights and nitrogen contents of all plant parts (root, stem, leaf, tassel and cob) at the key plant development stages were determined. Grain yield was measured at harvest.

Simulation scenarios

Crop yield, nitrate leaching, water drainage, and water use efficiency (WUE) under various agricultural management practices were simulated by the WNMM model (Li *et al.* 2007). To optimize irrigation and N fertilizer management practices 1700 numerical simulations were conducted for the following scenarios: 1) varying the total irrigation inputs from between 300 and 900 mm with increments of 60 mm; 2) varying irrigation events from 3 to 11; 3) varying total fertilizer application inputs from 75 to 300 kg N/ha with increments of 15 kg N/ha; and 4) varying the fertilizer application events from 1 to 4. The maximal irrigation rate was set to 160 mm/d and the minimal rate was set to 60 mm/d, with the same intervals between sowing and harvest. The fertilizer application dates were 0, 55, 93 and 126 days after planting which corresponded with the key stages of maize growth: sowing, jointing, heading, and grain-filling, respectively. The numbers of scenarios for water and fertilizer inputs were 68 and 25 respectively, so the total number of scenarios combining variable amounts and times of water and fertilizer practices was 1700. The modelling of the scenarios described above was conducted by varying each parameter one at a time whilst holding the values of the other parameters at their default levels.

Results

The model input parameters, including soil hydraulic properties, dispersivity and diffusion coefficients, crop development, C and N transformation parameters, were presented previously (Hu *et al.* 2009). Data from treatment T1 were used to calibrate the model. Soil nitrogen transformation parameters were adjusted by comparing the simulated and measured data. Data from treatment T2 were then used to validate the model. The preliminary results showed that the WNMM model was suitable for simulating water movement, the N cycle, and maize growth under various agricultural management practices in the study area (Hu *et al.* 2009). The simulation results indicated that nitrogen losses by ammonia volatilization and denitrification were very small from these sandy soils of the desert oasis. However, loss by nitrate leaching was very large. Under the traditional management practices about 35% of total water input and 58% of total nitrogen input were lost from the 1.8-m soil profile. The water and nitrate inputs under treatments T1 and T2 far exceeded crop requirements. To reduce the nitrate leaching risk and to conserve water and fertilizer resources it is imperative to optimize the water and fertilizer application to match crop requirements.

The results for 1700 numerical simulation showed that irrigation and fertilizer practices had significant effects on the crop yield, WUE, water drainage and nitrate leaching. Quantitative analyses of the simulation outputs were conducted to derive BMPs for water and N applications by using evaluation indices that included crop yield, WUE, fertilizer N use efficiency (FNUE) and nitrate leaching. Their weights were set as +5, +3, +2 and -5 respectively. Results of the four evaluation indices from all the proposed scenarios were then normalized over a range of 0 to 1. An integrated index was then calculated by summing the product of the normalized indices and their corresponding weights. Table 1 summarizes the evaluation results for some selected scenarios. The treatment with 600 mm irrigation input, four irrigation times and 300 kg N/ha fertilizer input had the lowest integrated evaluation index. Under this situation, the nitrate leaching was 150.7 kg N/ha, and the crop yield only reached 57% of the maximum. The FNUE was 20.8 kg/kg/N. When the fertilizer application was reduced to a single application at a rate of 75 kg N/ha and the number of irrigations increased to 8, the FNUE was significantly improved to 67.5 kg/kg/N whilst the WUE increased from 19.0 to 26.2 kg/ha/mm, and the crop yield reached the maximum. This scenario had the highest integral evaluation index and may be used as the BMPs for maize in this region. The total irrigation area in the Chahantan oasis is 1876 ha. If the BMPs obtained here are applied to the whole of the irrigated area it would save about 4.2×10^6 m^3 of water and 118 tonnes of N fertilizer per year compared with the traditional practice. It is significant for sustainable agricultural development in this desert oasis.

Table 1. Integrated evaluation index for different scenarios simulated by WNMM model in Alxa.

Total-Fert kg N/ha	Total-irri mm	Irrigation times	Yield kg/ha	WUE kg/ha/mm	FNUE kg/kg/N	N leached kg N/ha	Drainage mm	Integrated Index
300	600	4	10103	18.99	20.75	150.73	195	2.79
285	600	4	10103	18.99	21.40	150.1	195	2.82
270	600	4	10103	18.99	22.11	149.41	195	2.85
300	600	4	10103	18.99	20.75	146.16	195	2.87
255	600	4	10103	18.99	22.86	148.67	195	2.89
90	600	8	17679	26.15	63.82	14.05	29	9.43
75	660	10	16465	29.83	59.25	9.66	24	9.47
75	540	8	16734	25.94	68.00	4.1	10	9.48
75	720	10	17138	30.39	58.33	20.09	43	9.49
75	600	8	17679	26.15	67.48	14.05	29	9.55

Discussion and conclusion

We conclude that the WNMM model can be used to simulate the water movement and N transport as well as maize growth under conditions prevailing at desert oases, and as a tool to optimize water and nitrogen management. Under the traditional management practices about 58% of total nitrogen input was leached out the 1.8-m soil profile. Crop yield, WUE, FNUE and nitrate leaching were selected as evaluation criteria to identify the BMPs. We concluded that the BMPs for maize production in the oasis are to irrigate with a total of 600 mm applied over 8 irrigation events per season, and to fertilize the soil at the rate of 75 kg N/ha in a single application just before first irrigation. Implementation of this BMP would reduce annual leaching of nitrate from approximately 255 kg N/ha under current practices to 14 kg N/ha, without reducing maize yields. Those results were generated by the WNMM model based on a single year's data. The 75 kg N/ha nitrogen fertilizer rate in the BMPs was obtained because of the accumulation of mineral N in the soil profile (about 360 kg N/ha), which is similar to the prevailing situation in the NCP (Fang *et al.* 2008). The mineral N in the soil profile will decrease when it is depleted by crops. The decrease of mineral N in the soil profile should be taken into account for longer-term simulations.

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Paper industry residues can be utilized to improve quality of a Humic Cambisol

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Abstract

The pulp and paper industry generates large amounts of residue that can cause environmental damage. On the other hand, the use of such residue in adequate amounts can improve soil quality. This study aims to evaluate chemical and physical properties of a Humic Cambisol and yields of annual crops after surface application of an alkaline residue (dregs) and limestone. The experimental design was randomized complete blocks with four replications, started in 2004 with liming on the soil surface. The treatments were: control with no correction; doses of limestone corresponding to 0.5 and 1 SMP; and doses of alkaline residue corresponding to 0.25, 0.5 and 1 SMP. The dose of 1 SMP was calculated to reach pH 6.0 in the layer of 0 to 0.10 m (CQFS RS/SC, 2004). Physical and chemical soil properties and crop yields were analyzed. The use of alkaline residues improved chemical properties, and did not modify soil physical properties. The yields of wheat and bean increased with correctives, and the highest production was obtained at the highest corrective rate. It is possible to use alkaline residue of the pulp industries when applied on the surface of the acid soil, without tillage.

Key Words

Liming, yield, dregs, soil acidity.

Introduction

In recent years, the pulp industry in Brazil has been expanding its production considerably. However, despite this growth, there is a prescent concern on solid waste management, some with potential for using in agricultural soils. The use of residues as a corrective may improve soil chemical and physical properties, and consequently increase crop yield. However, the replacement of limestone by alkaline residues from the pulp industry can be limited by the presence of sodium in these products, which can disperse clays and decrease aggregates stability (Albuquerque *et al.* 2002), and saturated hydraulic conductivity and form crust on the surface of bare soils. Another limitation is the high Ca/Mg ratio, which can reduce crop development (Medeiros *et al.* 2008). Thus, the use of residues for agricultural purposes will be dependent on their chemical characteristics and soil properties. Almeida *et al.* (2007) stated that this residue can correct soil acidity and is a source of plant nutrients. Such positive effects can also be detected in agricultural areas, however, in order to use this waste it is necessary to establish appropriate doses in long term experiments. This study aimed to evaluate the use of an alkaline residue to correct soil acidity and improve chemical and physical properties of a Humic Cambisol and associated crop yields.

Methods

The experiment was carried out under field conditions in Lages, SC, Brazil. The climate is humid mesothermal subtropical (Cfb, Köppen) and well distributed rains during the year, with average rainfall of 1.550 mm yr^{-1}. The maximum and minimum mean annual temperatures are 21.7 and 11.5ºC, respectively. The soil is classified as Humic Cambisol, clay loam, with a slope of 0.10 m m^{-1}, thickness of the A horizon of 0.60 m, previously used with native grasses for production of dairy cattle.

The experimental design was randomized blocks with 24 plots of size 8 x 8 m, with four replications. The treatments were: control with no correction; doses of limestone corresponding to 0.5 and 1 SMP; and doses of alkaline residue corresponding to 0.25, 0.5 and 1 SMP. The dose of 1 SMP was calculated to reach pH 6.0 in the layer of 0 to 0.10 m (CQFS-RS/SC, 2004). The composition of the residue used in the experiment was as follows: Ca = 300 g/kg; Mg = 10 g/kg; Na = 34 g/kg; and relative capacity of neutralizing value of 90 %. The limestone was composed of: Ca = 289 g/kg; Mg = 118 g/kg; Na = 0.1 g/kg; and relative capacity of neutralizing value of 86 %.

The correctives were spread on the soil surface after mowing the native grass cover. Half of the dose was applied in June 2004 and half in June 2006. During this period, the area was grazed. After 2006 the pasture was dissecated to grow annual crops in no-till system. Fertilization was based on analysis of the soil layer of 0 to 0.20 m depth, as recommended by CQFS-RS/SC (2004). Soil samples with altered and preserved structure were collected in layers of 0 to 0.05 m, 0.05 to 0.10 m and 0.10 to 0.20 m to determine soil chemical and physical properties: pH, total acidity, K, Na and extractable P, Ca, Mg and Al contents, organic carbon (OC), soil water content, total porosity, macroporosity, microporosity, bulk density, particle density, flocculation degree and mean weight diameter (MWD) of aggregates. Measurements of pH were performed according Tedesco *et al.* (1995); the total acidity (H + Al) was extracted with a solution of calcium acetate 0.5 mol/L at pH 7.0 and quantified by titration with sodium hydroxide (NaOH); K, Na and P were extracted by Mehlich with an acid solution of HCl 0.05 mol/L and H_2SO_4 0.025 mol/L; P was quantified by colorimetry; Na and K were quantified by flame photometry; Ca and Mg were extracted with neutral solution of potassium chloride (KCl) 1 mol/L and quantified by atomic absorption spectrophotometry; exchangeable Al determined by neutralization titration with NaOH; the OC was quantified by the method of Walkley & Black (Tedesco *et al.* 1995).

The porosity was measured in samples with preserved structure, using a sand tension table (EMBRAPA, 1997) with the suction of 0.60 m; bulk density was determining by drying the soil to 105°C (Blake and Hartge, 1986); the particle density was determined according EMBRAPA (1997); total porosity was calculated by ratio between bulk density and particle density; the degree of flocculation was calculated as the ratio between total clay and natural clay determined by the pipette method (Gee & Bauder, 1986); the mean weight diameter (MWD) was calculated to express the aggregate stability according to the method of Kemper & Chepil (1965). The wheat and beans yields were measured during three growing seasons.

Results

Sampling in 2004 was done 120 days after the application of lime. The organic carbon (OC) and extractable phosphorus were not affected by treatments, but the OC content decreased from 35 to 29 g/kg and phosphorus from 6.3 to 4.9 mg/kg with depth (Table 1). The analysis of the residue shows that it had a very high content of calcium, potassium and sodium (Albuquerque *et al.* 2002). The addition of limestone increased calcium and magnesium, and the residue increased calcium and sodium content. With the C50 magnesium increased in the layer of 0 to 0.10 m, while with C100 increased in the layer of 0 to 0.20 m. The residue added more calcium and less magnesium than the limestone. Thus, the Ca/Mg ratio increase, possibly causing imbalance of cations in the soil. In the 0 to 0.05 m the Ca/Mg ratio increased from 5.5 in control to 21.0 in the D100. The amount of sodium added was high, and increased its content in the layers of 0 to 0.05 and 0.05 to 0.10 cm (Table 1), mainly in the D100. The addition of basic cations increased the sum of bases (SB) in the control of 1.8 to 3.8 cmolc/L at C100 and to 4.1 cmolc/L in D 100, thus, the basis saturation increased and Al saturation decreased, mainly in the 0 to 0.05 cm.

Surface application of the residue and limestone increased pH only in the layer of 0 to 0.05 cm due to low solubility of the components used and the high soil acidity. The pH increased from 4.9 in the control to 5.3 in the C100 and 5.4 in the D100. With increasing pH, the Al saturation decreased from 36% in the control to 1% at 100C and 2% at D100.

In 2006, started the soil cultivation for grain production, and correctives were re-applied to raise pH to 6.0. Thus, the soil chemical properties were further amended with a greater increase in pH and reduced Al (data not shown). However, even with the soil cultivation under no-till system, soil physical properties did not change. In 2004 the degree of flocculation was of 79 %, the bulk density was 1.23 g/cm^3, the total porosity was 0.50 m^3/m^3, macroporosity was 0.04 m^3/m^3, and the weighted mean diameter was 5.8 mm. In 2007, after started the soil cultivation, the degree of flocculation was of 73 %, the bulk density was 1.26 g/cm^3, the total porosity was 0.50 m/m^3, and the weighted mean diameter was 6.2 mm. There was an increase in macroporosity from 0.04 to 0.08 m^3/m^3, possibly due to the localized tillage to sown annual crops. According to these results, the Humic Cambisol has a good physical quality.
With the changes in soil chemical properties, crop yields differed among the treatments with highest yield in the highest dose of correctives applied (Table 3). Even with lower doses of the residue and limestone, increases were effective for minimizing the toxic effect of Al to plants.

Table 1. Exchangeable cations, phosphorus, pH, organic carbon (OC), sum of bases (SB), effective capacity of cation exchange (CTCef), hydrogen plus aluminum, and aluminum saturation (m) after applying corrective in Humic Cambisol. Lages, SC, Brazil, 2004.

	Na	K	Ca	Mg	P	Al	pH	OC	SB	CTCef	H+Al	m
	- - mg/kg - -		- - $cmol_c$/kg - -		mg/kg	cmolc/kg		g/kg	- - - - cmolc/kg - - - -			%
						0 to 0.05 m						
Control[A]	27 B[B]	226	1.9	0.3 BC	6.6	1.6 AB	4.9	35	2.9	4.5	6.0	36
D25	56 B	192	3.9	0.2 C	6.1	1.9 A	5.0	35	4.9	6.8	5.0	28
D50	55 B	229	5.4	0.3 C	6.3	0.6 AB	5.3	35	6.5	7.2	5.7	9
D100	97 A	206	6.3	0.3 C	5.7	0.1 B	5.4	34	7.5	7.6	5.5	1
C50	24 B	213	3.6	0.7 AB	6.8	0.6 AB	5.2	36	4.9	5.6	5.7	11
C100	31 B	212	4.7	0.9 AB	6.4	0.1 B	5.3	37	6.2	6.3	4.9	2
Mean	48	213 a	4.3 a	0.5	6.3 a	0.7	5.2 a	35 a	5.5 a	6.2 a	5.4 b	12 b
						0.05 to 0.10 m						
Control	23 B	132	0.8	0.1 NS	5.8	2.8 NS	4.6	30	1.4	4.2	6.5	67
D25	43 AB	123	0.9	0.1	4.9	2.6	4.8	30	1.5	4.1	6.5	63
D50	44 AB	133	1.6	0.2	5.1	2.9	4.7	29	2.3	5.2	6.8	56
D100	69 A	125	2.0	0.1	5.4	2.4	4.8	30	2.8	5.1	6.3	46
C50	28 B	172	1.5	0.2	5.1	2.5	4.8	31	2.2	4.7	6.6	52
C100	25 B	132	2.1	0.4	5.4	2.0	4.8	32	2.9	4.8	6.4	41
Mean	39	136 b	1.5 b	0.2	5.3 b	2.5	4.8 b	30 b	2.2 b	4.7 b	6.5 a	54 a
						0.10 to 0.20 m						
Control	22 NS	93	0.6	0.1 NS	5.2	3.1 AB	4.6	29	1.0	4.1	7.0	75
D25	37	104	0.6	0.1	4.6	2.9 AB	4.8	29	1.1	4.0	6.6	72
D50	26	86	1.3	0.1	4.7	3.5 A	4.6	27	1.7	5.2	7.1	67
D100	56	104	1.4	0.1	4.9	2.6 AB	4.9	28	2.0	4.6	6.3	57
C50	18	109	0.9	0.2	4.7	2.7 AB	4.7	30	1.5	4.2	6.9	65
C100	24	109	1.7	0.3	5.2	1.6 B	4.7	30	2.4	4.0	6.5	40
Mean	30	101 c	1.1 b	0.2	4.9 b	2.7	4.7 b	29 c	1.6 b	4.3 b	6.7 a	63 a
						Mean of 0 to 0.20 m						
Control	24	150	1.1 B	0.2	5.9	2.5	4.7	31	1.8 B	4.3	6.5	59 A
D25	45	139	1.8 AB	0.2	5.2	2.5	4.9	31	2.5 AB	5.0	6.0	54 AB
D50	42	149	2.8 AB	0.2	5.3	2.3	4.9	31	3.5 AB	5.9	6.5	44 ABC
D100	74	145	3.2 A	0.2	5.3	1.7	5.0	30	4.1 A	5.8	6.0	35 BC
C50	23	165	2.0 AB	0.4	5.5	1.9	4.9	32	2.9 AB	4.8	6.4	43 ABC
C100	26	151	2.8 AB	0.5	5.7	1.2	4.9	33	3.8 A	5.1	5.9	27 B

[A] Control = no correction; D25, D50 and D100 corresponds to doses of residue corresponding to 0.25, 0.5 and 1 SMP and C50 and C100 corresponds to doses of limestone corresponding to 0.5 and 1 SMP.
[B] Upper case letters on column indicate significant differences between treatments in the same layer, or on the mean of the layers. Lower case letters on column indicate significant differences between layers on the mean of treatments. ns = means between treatments did not differ by Scheffe test (P<0.05). The absence of letters indicates that the effect of the treatment or layer was not significant by F test.

Table 2. Flocculation degree, bulk density, total porosity, macroporosity, microporosity and mean weight diameter (MWD) after application of correctives in the Humic Cambisol. Lages, SC, Brazil, 2004.

Flocculation degree	Bulk density	Total porosity	Macroporosity	Microporosity	MWD
%	g/cm^3	m^3/m^3	m^3/m^3	m^3/m^3	mm
		Mean of 0 to 0.10 m			
79	1.23	0.50	0.04	0.46	5.8

Table 3. Wheat and beans yields, after application of residues in the years of 2004 and 2006, to a Humic Cambisol. Lages, SC, Brazil, 2009.

Treatment	Crop/year		
	Wheat/2006	Wheat/2008	Beans/2009
	kg/ha	kg/ha	kg/ha
Control[A]	1,700 b	545 b	1,770 b
D25	2,253 ab	1,360 ab	2,308 ab
D50	2,475 ab	1,450 ab	2,694 ab
D100	2,993 a	1,784 a	3,050 a
C50	2,580 ab	1,590 a	2,699 ab
C100	2,919 a	1,827 a	2,736 ab

[A] Control = no correction; D25, D50 and D100 corresponds to doses of residue corresponding to 0.25, 0.5 and 1 SMP; and C50 and C100 corresponds to doses of limestone corresponding to 0.5 and 1 SMP respectively. Means followed by the same letter did not differ by Scheffe test (P<0.05).

Conclusion

The use of alkaline residues increased soil pH, the content and saturation of exchangeable bases, the cationic exchange capacity and the Ca/Mg ratio, and reduced Al saturation. However, it did not modify soil physical properties. The highest yields of wheat and beans were for the higher corrective rate. It is possible to use alkaline residue of the pulp industries when applied on the surface of the Humic Cambisol cultivated with no-till system to improve soil chemical conditions, with positive effects on crop response.

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Permanent raised bed configurations and renovation methods affect crop performance

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Abstract
Permanent raised bed (PRB) configurations and renovation methods vary throughout the world depending on soil type, cropping pattern, farmer preferences, available machinery and local expertise. An increase in the bed width generally increases land use efficiency due to a smaller cropped land loss due to furrows. However, PRB configuration and seasonal pre-sowing renovation need careful selection due to their influence on crop production. Two experiments investigating PRB systems used for wheat-maize rotations were conducted over a ten year period on a silty clay loam in Pakistan. The use of PRBs generally resulted in higher yield, lower water application and higher Gross Production Water Use Indices (I_{GP}) compared to traditional flat basin systems. Wide (180 cm) beds produced higher wheat (15%) and maize (26%) yields than the flat basin treatment during the first experiment. Maize yields were 10% higher than the basin treatment in the second experiment involving narrow (65 cm) and medium (130 cm) width beds while wheat yields were only marginally (<5%) higher. The lower water application in the PRB compared to basin treatments was found to be closely related to bed width. The narrow beds used 3-7% less water than the basins while the medium and wide beds used 16-17% and 18-22% less, respectively. The difference in I_{GP} between the basin and PRB treatments was also found to be closely related to bed width with the I_{GP} ranging from 13-18%, 30-31% and 43-70% higher for the narrow, medium and wide beds, respectively. Substantial differences in both bulk density and hydraulic conductivity were also found between the basin and bed treatments. Within the PRB treatments, the soil bulk density was lower and hydraulic conductivity higher when machinery track widths were matched to furrow spacing and bed renovation was conducted using horizontal blades which minimised bed disturbance and soil inversion.

Key Words
Irrigation performance, lateral wetting, land preparation, zero till bed planter.

Introduction
The agriculture sector is under increasing pressure to sustainably produce higher yields with less inputs due to declining land and water productivity potential (McGarry 2001), increasing cost of production (Tullberg and Murray 1988), variable market conditions and increasing world population. Permanent raised bed (PRB) farming systems combine most of the elements of conservation agriculture and have produced encouraging production results under various environmental conditions. PRBs offer the opportunity of reducing field compaction and restoring physically degraded soil structure (McHugh *et al.* 2009) as well as the potential to reduce irrigation water and increase crop yield (Akbar *et al.* 2007) while reducing the risk of waterlogging (Hamilton *et al.* 2005). PRBs also have lower land preparation costs (Ortega *et al.* 2006) by reducing field operation time, facilitate crop residue management (Talukder *et al.* 2002) by minimum tillage and mitigate weed infestation (Hulugalle and Daniells 2005) through better mid-season field access. Different PRB configurations are used throughout the world depending on soil type, available machinery, farmer preference and expertise. In general, increasing the width of the bed reduces total water used and increases land use efficiency and yield by reducing the uncropped furrow area (Jin *et al.* 2007). In Australia, bed widths of 2 to 3 m are common while 0.6 to 1.5 m widths are common in China, Pakistan, India and Bangladesh (Sayre *et al.* 2005). However, there are a number of factors which affect optimal bed widths including the potential for bed compaction by mismatched machinery operation, inadequate lateral movement of water into the centre of furrow irrigated bed, soil subsidence due to rainfall hammering and bed renovation practices. This paper reports on a ten year program in Pakistan to evaluate the effect of bed configuration and renovation on crop performance.

Methods

The experimental site was located on a uniform clay loam soil in Mardan, north-west Pakistan. This area is semi-arid with a mean seasonal rainfall of 250 mm during the Kharif (summer) and 300 mm during the Rabi (winter) seasons. The mean maximum temperature ranges from 27-30°C during June while the mean minimum temperature ranges from 5-8°C during January. A wheat-maize cropping rotation was grown from 2000 to 2009 over two experimental periods. During the first experimental period (2000 to 2004) four wheat and five maize crops were grown using flat basin (control) and wide beds (180 cm between furrow centres) treatments. During the second experimental period (2005 to 2009) four wheat and maize crops were grown using flat basin (control), narrow bed (65 cm centres) and medium bed (130 cm centres) treatments. The furrow top width was approximately 50 cm for all bed treatments. A local maize variety was used during the first experimental period and Pioneer 3025 Hybrid seed in the second experiment. Similar quantities of fertilizers and herbicides were applied to all treatments. A completely randomized block design was used with three replicates of each treatment.

The flat basin treatment was prepared using a cultivator followed by rotary hoeing and seed broadcasting. A seed drill was used for the flat basin treatment during the second experimental period. Only minor renovation and reshaping of the beds were conducted before each crop planting. A zero till bed planter was used for sowing the maize and wheat crops on the PRBs. The first experiment involved the use of machinery with mismatched track widths and involved shallow rotary hoeing of the beds to remove weeds. The second experiment used matched track width machinery and there was no rotary hoeing of the beds. Renovation of the beds during the second experiment was conducted using a horizontal blade plough that cut the beds at the base of furrows without inverting the soil. Soil hydraulic conductivities were measured using a double ring infiltrometer at harvest and bulk density was measured using core sampling both prior to sowing and harvest of each crop.

Results

Effect of PRB configuration

The use of PRBs generally resulted in a higher yield and lower water application compared to traditional flat basin systems (Table 1). The wide beds produced higher wheat (15%) and maize (26%) yields than the flat basin treatment during the first experiment. However, average wheat yields during the second experiment were only slightly (<5%) higher on the narrow and medium beds compared to the basin. In this experiment, the maize yields were approximately 10% higher on the beds compared to the basin treatments. The reduction in applied water was found to be closely related to bed width confirming that this is related to hydraulics of the surface irrigation application. The narrow beds used 3-7% less water than the basins while the medium and wide beds used 16-17% and 18-22% less, respectively. The Gross Production Water Use Index (I_{GP}) was substantially higher for all PRB configurations compared to the basin treatments. The difference in I_{GP} between the basin and PRB treatments was also found to be closely related to bed width with the wheat I_{GP} being 13%, 31% and 43% higher for the narrow, medium and wide beds, respectively. Similarly, the maize I_{GP} was 18%, 30% and 71% higher than the basin I_{GP} for the narrow, medium and wide beds, respectively.

In the second experiment, the high water demanding maize crop produced a marginally lower (~2%) yield on the medium bed than on the narrow bed. Anecdotal observations suggest that this may have been due to problems with lateral water movement (subbing) across the beds and lower soil moisture storage in the crop root zone as the bed width increases. This is likely to be a more significant problem for crops with high water demands grown during the hot summer season. The wheat yield on wide beds may have been less affected by subbing problems because of the lower evapotranspiration demand and the presence of sufficient in-season rainfall to reduce the reliance on the irrigation applications. Alternatively the increase in wheat cropping area with increases in bed width may have masked any yield reductions due to subbing. However, it should be noted that the furrows fitted within the normal maize crop rows so in this case there was no impact of bed width on cropped area.

Table 1: Effect of bed configuration on yield and water use for a wheat-maize rotation on a clay loam soil (Mardan, Pakistan). Means with range shown in brackets.

	Crop	Experiment 1(2000 to 2004)		Experiment 2 (2005 to 2009)		
		Flat Basin	180cm Bed	Flat Basin	65cm Bed	130cm Bed
Yield (t/ha)	Wheat	3.9 (3.8-4.0)	4.5 (3.9-4.9)	4.4 (2.9-4.4)	4.5 (3.1-5.3)	4.6 (3.2-4.8)
	Maize	3.4 (1.7-6.4)	4.3 (2.7-8.0)	7.7 (6.9-8.4)	8.7 (7.3-10.0)	8.5 (7.4-10.0)
Water Applied (mm)	Wheat	448 (353-575)	348 (317-508)	523 (326-666)	508 (320-663)	434 (262-589)
	Maize	627 (220-767)	517 (198-575)	841 (666-953)	785 (663-884)	707 (587-807)
Gross Production Water Use Index (kg/ha/mm)	Wheat	8.3 (6.7-11.5)	11.9 (7.6-14.1)	8.4 (5.7-13.1)	9.5 (6.1-13.9)	11.0 (6.9-17.2)
	Maize	6.1 (4.2-9.4)	10.4 (5.7-17.1)	9.3 (7.5-10.5)	11.0 (7.5-12.9)	12.1 (9.9-13.5)

Effect of PRB renovation method

The hydraulic conductivity of the beds (Figure 1) were 62% higher than the basin treatments in the first experiment and more than 100% higher during the second experiment. The average bulk densities were also 7%, 13% and 6% lower for wide, medium and narrow PRBs respectively than flat basin in their respective experiments. The lower bulk density and higher hydraulic conductivity suggests that the beds have much improved soil structural properties including a larger macropore volume and better pore connectivity leading to improved infiltration and internal drainage. The improved soil structure also facilitates the development of root mass, accelerates biological activities and increased soil aeration. These benefits are likely to have contributed to the higher crop yields observed on the PRB compared to flat basin treatments (Table 1). The lower bulk density and higher hydraulic conductivities observed on the beds in the second experiment compared to the first experiment are most likely associated with the better matching of machinery track widths and the implementation of horizontal renovation blades which reduced bed disturbance and inversion. This renovation practice was observed to leave crop residues in place, maintain root channels and presumably also caused minimal disturbance to microorganisms within the root zone.

Conclusions

Permanent raised beds have been shown to produce higher yields, require less water and have higher gross production water use indices than traditional flat basin systems in north-west Pakistan. The volume of irrigation water applied was found to be a function of the bed width with wider beds typically having smaller water application volumes. However, the yield achieved on the beds was less affected by bed width. Anecdotal evidence suggested that wider beds experienced difficulty with lateral water movement from the furrows but wider beds also typically had a larger infield cropped area due to fewer furrows. Investigations of soil structural properties in the beds indicated that matching the machinery track width to the furrow spacing and using horizontal blades for renovating beds without soil inversion resulted in lower soil bulk densities and higher hydraulic conductivities within the root zone.

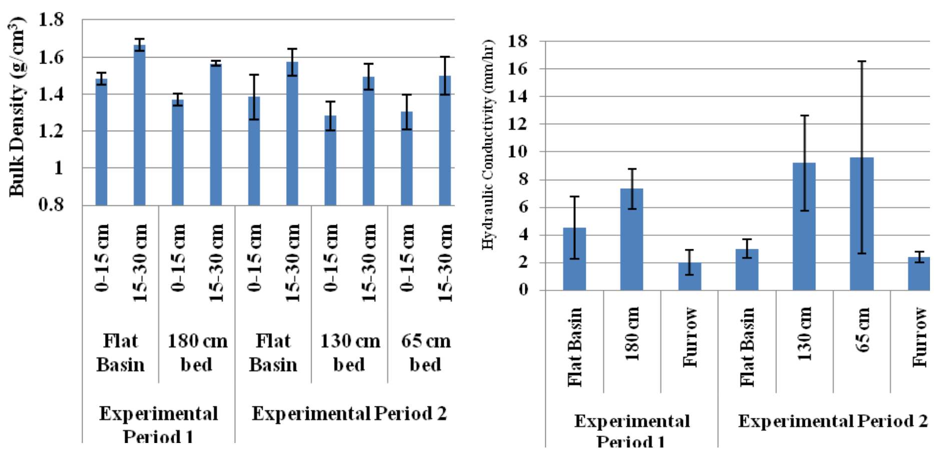

Figure 1. Effect of bed configuration and renovation on hydraulic conductivity and bulk density of a clay loam soil (Mardan, Pakistan). Bars show +/- standard deviation.

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Phosphorus distribution in fire managed grassland soils

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Abstract
Native warm season grasses are recommended for wildlife habitat and soil conservation. These areas are often managed with fire to control invasive species and reinvigorate the grasses. An area of the Department of Agriculture, Geosciences and Natural Resources field laboratory was planted to native warm season grasses in 2002. In 2004 the area was blocked into 50 x 60 foot plots to compare management practices of the grasses including mowing and fire. The soil of these plots have been sampled annually following the burn and analyzed for soil chemical (organic matter, nitrogen, phosphorus) and physical (bulk density) properties. The objective of this study was to evaluate the impact of an annual burn of grass plots on soil physico-chemical properties, specifically phosphorus. Forms of P to be evaluated include labile, organic, iron and aluminum bound, calcium bound, and residual fractions along with soil properties such as pH and organic matter. Thus far, annual burning of these grass plots has not significantly altered the soil stores of carbon and phosphorus. In soil dominated by Fe and Al chemistry fire has little influence on soil P stores. Knowing the impact of fire on the chemistry of phosphorus in soils is important in developing best management practices for this nutrient.

Key Words
Phosphorus, nutrients, carbon, grasslands, fire, loess.

Introduction
Native warm season grasses are recommended for wildlife habitat and soil conservation. These areas are often managed with fire to control invasive species and reinvigorate the grasses. An area of the Department of Agriculture, Geosciences and Natural Resources field laboratory was planted to native warm season grasses in 2002. In 2004 the area was blocked into 50 x 60 foot plots to compare management practices of the grasses including mowing and fire (Pelren *et al.* 2007). The soil of these plots have been sampled annually following the burn and analyzed for various physico-chemical properties. The results of these studies have been presented at several professional conferences (Gale 2008; Gale *et al.* 2006; Gale *et al.* 2005).

Conventional wisdom on the impact of fire has been that fire results in a decrease of volatile nutrients such as carbon and nitrogen but does not affect the availability of minerals such as potassium and phosphorus (Neff *et al.* 2005 and Samsonov *et al.* 2005). In contrast, Duguy *et al.* (2007) observed a decrease in total and available phosphorus following fire in eastern Spain. Studies in the New Jersey pine barrens suggest that the phosphates may form insoluble metal phosphates during combustion (Gray and Dighton 2006). All of these studies were conducted in forested ecosystems, raising the question of changes in phosphorus availability in grassland soils following fire.

Phosphorus is an essential plant nutrient whose availability is often limited by the chemical reactions that occur in soil. The chemistry governing phosphorus behavior in soils is strongly influenced by both the presence of metal cations and dissolved organic matter (Gjettermann *et al.* 2007). Phosphorus is also a potential threat to water quality and land use is often the best indicator of its potential as a water pollutant (Dunne *et al.* 2007). Thus, knowing the impact of fire on the chemistry of phosphorus in soils is important in developing best management practices for this nutrient.

The objective of this study involved collecting soil samples from the native warm season grass plots on the UTM campus and analyzing them for various forms or fractions of phosphorus. These will include labile, organic, iron and aluminum bound, calcium bound, and residual phosphorus fractions. From these data we will be able to ascertain the affect of burning these plots on the chemistry of phosphorus in these soils.

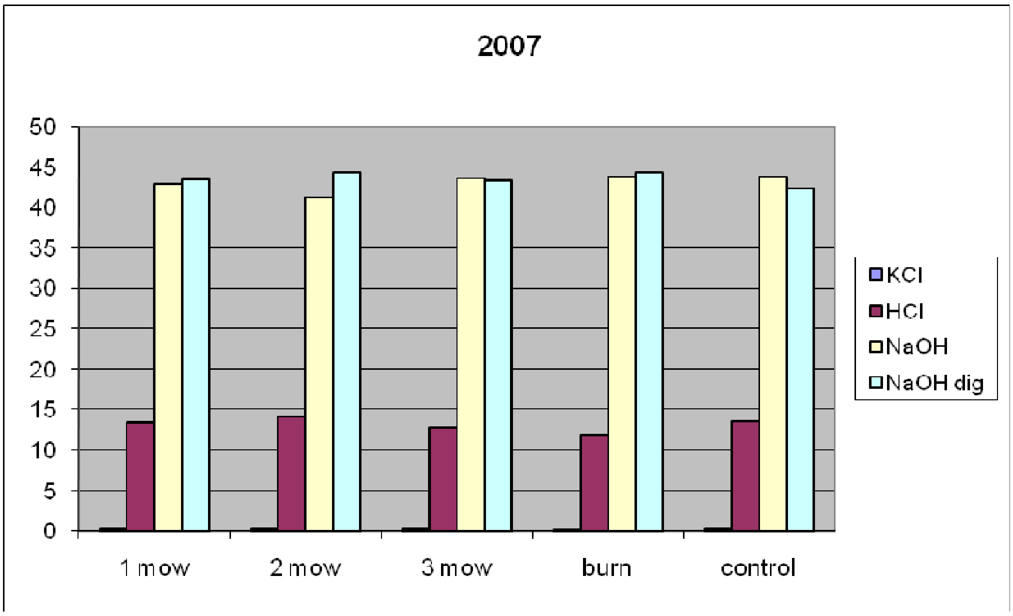
Materials and methods

The experimental design of the native warm season grass plots is a randomized complete block with treatments that include burning and mowing to control the vegetation. There are four replications of each treatment. We have been collecting soil samples annually from these fields since the experiment was started in 2004.

The soil samples were analyzed for various forms of phosphorus using a sequential chemical extraction and phosphorus availability will be evaluated with an incubation technique both of which the PI has used before (Gale *et al.* 1994). The chemical fractionation technique involves sequentially extracting a soil sample with a weak salt solution, followed by a weak acid solution and then a weak base solution. Each extractant is then analyzed for phosphorus using a spectrophotometer to detect a phosphormolybdate complex. Phosphorus availability will be determined using an incubation technique in which the soils samples are flooded and incubated and the phosphorus released to the water column is analyzed.

Results and discussion

The figure below is illustrative of the types of data that have been collected in these experiments. In the figure the percent of the total phosphorus found in each extract is depicted as a function of grassland management (whether mowing or burning). As can be seen from the data the burning of the vegetation has little effect on the soil, if properly done.



Conclusions

Annual burning of these grass plots has not significantly altered the soil stores of carbon and phosphorus. In soils dominated by Fe and Al chemistry, fire seems to have little influence on P distribution. Knowing the impact of fire on the chemistry of Phosphorus in soils is important in developing best management practices for this nutrient.

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Phosphorus fertilization impacts on maize yield and nutritional status with emphasis on P and Zn in leaves and grain

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Abstract
Four field experiments with increasing rates of P fertilization (kg P_2O_5/ha: up to 2000, 1000, 1500, and 1500, for the exp. A, B, C and D, respectively) were started between spring of 2002 and 2004. The experiments were performed in four replicates (basic plot, depending on the trial, from 32 to 92 m^2). Monoammonium phoshate (MAP: 12% N + 52% P_2O_5) in experiments A-C and triplephoshate enriched with sulphur and zinc (45% P_2O_5 + 1,2% S + 0,06% Zn) in experiment D were used as P fertilizers. In general, P fertilization (the exp. A) had moderate yield effects probably due to acid soil reaction. Only application of the highest P rate had residual influences on maize yields for the 2003 growing season (7.74 and 8.38 t/ha, for the control and the highest rate of P, respectively). In the experiment B, fertilization resulted in significant yield increases up to 16%. In the exp. C maize yields were similar for applied P treatments. However, maize responded drastically to P fertilizations by yield increasing up to 32% , 17%, and 40%, for 2004, 2005, and 2006, respectively (the exp. D). An acceptable range of P:Zn ratio from 15 to 180 was mainly found in our study. For example, leaf P:Zn ranged from 38 to 80 (the exp. A), from 77 to 100 (the exp. B), from 35 to 69 (the exp. C) and from 73 to 168 (the exp.D). Grain P:Zn ratios were higher than leaf P:Zn (from 151 to 194 and from 124 to 168, for the exp. B and D, respectively). Phosphorus fertilization mainly increased P:Zn.

Key Words
Maize, phosphorus fertilization, yield, leaf and grain P and Zn status.

Introduction
Some soils in Croatia have limited fertility, mainly because of less favorable physical and chemical properties. Acid reaction and nutritional unbalances, mainly low levels of plant available phosphorus (P), as well as unfavorable physical properties are limiting factor of some soils fertility in Croatia (Petosic *et al.* 2003). Soil improvement by ameliorative treatments (for example P fertilization) could overcome soil fertility limitations and result in field crop yield increase under these conditions. Aim of this study was to survey our recent investigations (Banaj *et al.* 2006; Komljenovic *et al.* 2006, 2008; Kovacevic *et al.* 2008; Loncaric *et al.* 2005) of maize response to P fertilization with emphasis on P and Zn status in plants.

Methods
The field experiments
Four field experiments were started in spring from 2002 to 2004 by using different rates of P fertilizers in Brod-Posavina County (locality Zivike: experiment A), Bjelovar-Bilogora County (locality Maslenjaca: experiment B), Pozega-Slavonian County (locality Badljevina: experiment C) in Croatia and in Potkozarje area (locality Medjuvodje, northern Bosnia: experiment D). In two experiments (B and C) P fertilizers were applied alone or combined with potassium (KCl form). Maize was sown from the end of April/beginning May and harvested manually (4 rows from each basic plot) in October. The results of these experiments in details are shown in previous studies (Banaj *et al.* 2006; Komljenovic *et al.* 2006, 2008; Kovacevic *et al.* 2008; Loncaric *et al.* 2005). Monoammonium phosphate (MAP: 12% N + 52% P_2O_5) in experiments A-C and triplephosphate enriched with sulphur and zinc (45% P_2O_5 + 1,2% S + 0,06% Zn) in experiment D were used for P fertilization. This P was in additions to ordinary fertilization at start of the individual experiments, while in the next years residual effects were tested and the experiments were fertilized in range of ordinary fertilization only. The experiments were conducted in four replicates. Sizes of basic plots were, depending on the trial, from 32 to 92 m^2. reatments of individual experiments were as follows: experiment A (kg P_2O_5/ha): a) control = 125, b) 625, c) 1125 and d) 2125; experiment B (kg P_2O_5/ha and/or kg K_2O/ha): a) control = 125, b) 625 P, c) 825 P, d) 625 K, e) 625 P + 625 K; experiment C (kg P_2O_5/ha and/or kg K_2O/ha): a) control = 150 P, b) 650 P, c) 1150 P, d) 650 K, e) 650 P + 600 K, f) 1150 P + 1100 K; experiment D (kg P_2O_5/ha): a) control = 80, b) 580, c) 1080, d) 1580.

Sampling and chemical analysis

The soils were sampled at the start of the experiments. The ear-leaf at flowering and grain at maturity were sampled for chemical analysis. The total amounts of P and Zn in maize leaves and grain were determined using ICP after microwave digestion by conc. $HNO_3+H_2O_2$. Soil pH was determined electrometrically in a soil suspension in water and in a solution of 1 mol/ L KCl (ISO, 1994). Soil organic matter was determined by sulfochromic oxidation (ISO, 1998). The soil samples were analyzed by AL-procedure (Egner *et al.* 1960) and extraction with NH_4-Acetate+EDTA solution (pH 4.65) according to Lakanen-Erviö (1971). Analyses of Ca, Mg and Zn in soil extracts and plant samples were performed with a Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest, Hungary.

Soil properties

The experiments were conducted under different soil conditions. Very acid reaction and low levels of available Ca were main characteristics of the soils of experiments A and C. Poor levels of available P were found in soils A and D and very poor levels in soils B and C. Available Zn status was mainly satisfied with the exception of the soil of experiment D (Table 1).

Table 1. Soil properties (0-30 cm depth) at starting (just before fertilization) of the experiments.

Soil pH, available P and K (AL-method); Ca, Mg and Zn (Ammonium Acetate – EDTA: pH 4.65); humus															
pH		mg/100 g		mg/kg			%	pH		mg/100 g		mg/kg			%
H_2O	KCl	P_2O_5	K_2O	Ca	Mg	Zn	Humus	H_2O	KCl	P_2O_5	K_2O	Ca	Mg	Zn	Humus
Experiment A: Brod-Posavina County (Croatia)								*Experiment B*: Bjelovar-Bilogora County (Croatia)							
5.67	4.26	6.8	15.6	2475	240	2.4	1.87	6.90	6.48	7.6	9.8	3591	336	4.5	0.93
Experiment C: Pozega-Slavonian County (Croatia)								*Experiment D*: the northern Bosnia (B&H)							
6.12	4.30	4.5	6.3	670	148	4.6	2.10	7.65	6.90	11.3	17.4	28880	176	1.0	4.08

Results

In our study, considerable differences in maize yields were found between tested years, mainly due to weather conditions (precipitation and temperature regimes, especially in July and August. The 2003 and 2007 growing seasons were less favorable because of drought and high air-temperatures (Tables 2-5). Nutritional status of maize (leaf and grain P and Zn) was dependent on P fertilization but it was in the normal range. In general, P fertilization (exp. A) had a moderate effect on yield probably due to acid soil reaction (Banaj *et al.* 2006) . Only application of the highest P rate had residual influences on maize yield for the 2003 growing season: 7.74 and 8.38 t/ha, for the control and the highest rate of P, respectively (Table 2). Influences of P fertilization were reflected in the Zn status of maize leaves (growing season 2002: 78 and 40 mg Zn/ kg, for the control and 2000 kg P_2O_5/ha, respectively).

Table 2. Influences of P fertilization (experiment A) on maize yields (Banaj *et al.* 2006).

Fertilization impacts on yield and maize nutritional status (dry matter of ear-leaf at flowering – July 2002)											
Spring of 2003	The growing season			%	mg/kg	Precipitation (mm) and mean air-temp. (^oC):					
Fertilization	2002	2003	2004	2002 (Leaf)		Slav. Brod (LTM = long-term means: 1971-1990)					
(P_2O_5 kg /ha)	Grain yield (t/ha)			P	Zn	Month		2002	2003	2004	LTM
125	12.3	7.74	9.69	0.30	77.9	July	mm	78	61	47	87
625	12.0	7.96	9.73	0.31	66.6		^oC	22.4	22.6	21.3	20.6
1125	12.5	8.03	9.55	0.30	44.5	Aug.	mm	122	51	36	71
2125	12.3	8.38	9.78	0.32	39.9		^oC	20.7	23.8	20.9	19.9
LSD (P 0.05)	n.s.	0.47	n.s.	0.01	4.5	Sum	mm	200	112	83	158
LSD (P 0.01)		n.s.		0.02	6.8	Mean	^oC	21.6	23.2	21.1	20.3

In experiment B, fertilization resulted in significant yield increases of 14% (2003: PK- treatment), 7% (2004: K-treatment), and 16% (2005 and 2006: PK and P-3, respectively) compared to the control. Also, significant effects of applied fertilization were found only on P concentrations in maize leaves in both tested growing seasons, while leaf Zn was significantly reduced due to applied P only in the 2004 growing season (Table 3). In exp. C (Table 4) maize yield was similar for all applied treatments. However, leaf P increased and leaf Zn decreased (2-year means: 0.29% P and 0.33% P, 63.4 mg Zn/kg and 53.2 mg Zn/kg, for the control and 1150 kg P_2O_5/ha, respectively) due to P fertilization. Maize responded to P fertilizations by yield increasing up to 32% , 17%, and 40%, for 2004, 2005, and 2006, respectively (Table 5). In the first year of testing, P fertilization resulted in leaf Zn decreases. However, in the third year of testing both leaf and grain Zn had increased due to P fertilization. Mobilization Zn added as triple superphosphate enriched with Zn could be a possible explanation of this phenomenon.

Table 3. Response of maize to fertilization (Kovacevic *et al.* 2008) –experiment B.

Fertilization in spring of 2003 (kg/ha)		Grain yield and maize P and Zn status in leaf (ear-leaf at flowering) and grain at maturity											
		The growing season				Percent (P) and mg/kg (Zn) on dry matter basis							
		2003	2004	2005	2006	2004 growing season				2005 growing season			
		Grain yield of maize t/ha				Leaf		Grain		Leaf		Grain	
P_2O_5	K_2O					P	Zn	P	Zn	P	Zn	P	Zn
125	125	7.37	13.3	10.7	8.7	0.36	46.9	0.28	18.5	0.33	38.6	0.28	15.4
625	125	7.57	13.7	11.1	9.64	0.35	42.4	0.29	16.5	0.4	42.3	0.31	16
825	125	8.07	13.8	12.2	10.1	0.39	39	0.31	17	0.36	39.1	0.29	18.8
125	625	7.21	14.3	12.1	9.57	0.36	61.9	0.28	18.4	0.36	44.2	0.27	18.6
625	625	8.46	14.1	12.5	9.55	0.37	45.6	0.31	19	0.37	43.7	0.3	18.2
LSD	(P 0.05)	0.46	0.5	0.8	0.77	0.02	7.9	0.02	ns	0.03	ns	0.06	0.8
July	mm	38	65	106	19	86							
	°C	22.2	20.4	20.8	22.5	20.6	Precipitation (mm) and mean air-temp. (°C) in						
August	mm	46	63	166	160	91	Daruvar (underlined = 30-y means: 1961-1990)						
	°C	23.7	20.2	18.5	18.6	19.7							

Table 4. Influences of fertilization (experiment C) on maize properties (Loncaric *et al.* 2005)

Fertilization (spring 2003) effects on grain yield of maize, P and Zn nutritional status							
Fertilization in spring of 2003		The growing season*: yield and leaf (ear-leaf at flowering) nutritional status					
		2003	2004	2003 Leaf status		2004 Leaf status	
(kg/ha)		Grain yield		Percent (P) and mg/kg (Zn) on dry matter basis			
P_2O_5	K_2O	t/ha		P	Zn	P	Zn
150	100	9.77	11.95	0.24	68.5	0.34	58.3
650	100	10.12	11.85				
1150	100	9.92	11.91	0.29	54.1	0.36	52.3
650	600	10.07	12.31				
1150	1100	10.71	12.23	0.29	57.5	0.35	46.2
LSD (P 0.05)		ns	ns	0.02	6.4	ns	5.9

* Weather data in July and August of 2003 and 2004 (Daruvar Weather Bureau: Table 2)

Table 5. P fertilization (experiment D) impacts on maize in Bosnia (Komljenovic *et al.* 2006, 2008).

Phosphorus fertilization (spring 2004) effects on grain yield of maize, P and Zn nutritional status												
Fertilization P_2O_5 kg /ha	Yield (t /ha)				Leaf and grain status (on dry matter basis)							
	The growing season				2004 growing season				2006 growing season			
					Leaf		Grain		Leaf		Grain	
	2004	2005	2006	2007	P	Zn	P	Zn	P	Zn	P	Zn
80	7.90	7.27	7.34	3.33	0.33	45.2	0.27	21.8	0.33	37.3	0.27	20.0
580	9.18	8.53	9.73	3.33	0.30	37.3	0.30	21.3	0.35	37.0	0.29	20.5
1080	9.85	8.38	10.3	3.44	0.32	28.2	0.30	19.9	0.35	35.3	0.28	20.1
1580	10.4	8.42	9.81	3.55	0.31	23.7	0.32	19.0	0.37	40.3	0.29	25.0
LSD (P 0.05)	0.37	0.29	0.37	ns	ns	9.4	0.02	n.s.	0.02	ns	ns	2.8
July mm	45	104	73	26	77							
°C	21.3	21.7	23.3	23.5	20.8	Precipitation (mm) and mean air-temp. (°C) in						
Aug. mm	61	182	202	55	85	Sisak (underlined = 30-y means: 1961-1990)						
°C	21.1	19.0	19.2	21.7	19.8							

For data interpretation an appraisal of the nutrient status of the ear-leaf of maize at the flowering stage according to Christensen was used (cit. Mengel and Kirkby, 2001) as follows (on dry matter basis): deficient (< 0.1 % P, <5 mg Zn/kg), low (0.1-0.2 % P and 15-20 mg Zn/kg), adequate (0.2-0.5 % P, 20-70 kg Zn/kg) and high (0.5-0.8% P, 70-150 kg Zn/kg). Amounts above 0.8% P are reported as excess. In our study, P and Zn in maize leaves were in the adequate ranges (Tables 2-5). Maize is a zinc-intensive plant with high zinc-demand. Antagonism between P and Zn is well known (Bergmann 1992; Mengel and Kirkby 2001). Blasl and Mayr (1978) reported an optimum P:Zn ratio of about 65 and acceptable range from 15 to 180. According Trier and Bergmann (1974), optimal values for the P:Zn ratio in maize are between 200 and 50 and values out of this range are indications of latent zinc deficiency (from 300 to 201), acute zinc deficiency (>300) and zinc excess (<25). Rahimi and Bussler (1975) give the following P:Zn ratios for old leaves of corn: optimal 54-122, zinc deficiency above 211 and phosphorus deficiency below 42. In our study, P:Zn ratios were in an acceptable range. For example, leaf P:Zn were in ranges from 38 to 80 (exp. A), from 77 to 100 (exp. B), from 35 to 69 (the exp. C) and from 73 to 168 (exp. D). Grain P:Zn were higher in comparison with leaf P:Zn (from 151 to 194 and from 124 to 168, for exp. B and D, respectively). Phosphorus fertilization mainly increased P:Zn. Similar observations regarding P effects on Zn status were found Bogdanovic *et al.* (1999, 2003) for a chernozem in Vojvodina (Serbia) .

Conclusion

The grain yield of maize was mainly moderately increased by ameliorative P fertilization, especially under acid soil conditions. Leaf and grain P and Zn, as well as P:Zn ratio were more influenced by fertilization than was yield, but these properties were in normal nutritional ranges.

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Potential contribution by corn and Bollgard II cotton roots to soil carbon stocks in a furrow-irrigated Vertisol

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Abstract
Potential contribution by roots of corn and genetically-modified Bollgard II cotton to soil carbon stocks was evaluated in two experiments near Narrabri, north-western NSW. In one experiment a Bollgard™ II-Roundup Ready™-Flex™ variety was compared with a Roundup Ready™-Flex™ variety, and in another, corn grown as a monoculture was compared with corn sown in rotation with cotton. Root growth in the surface 0.10 m was measured with the core-break method, and that in the 0.10 to 1.0 m depth with a minirhizotron and I-CAP image capture system. These measurements were used to derive root length per unit area (L_A), root C added to soil through intra-seasonal root death (C_{lost}), C in roots remaining at end of season (C_{root}) and root C potentially available for addition to soil C (C_{total}). C_{total} averaged 5.0 t/ha with cotton-corn and 9.3 t/ha with corn monoculture, with average C_{lost} accounting for 11%. In contrast, C_{total} with genetically-modified cotton ranged from 0.6 to 0.9 t/ha with C_{lost} contributing 43%. Intra-seasonal root death makes a significant contribution to soil carbon stocks by cotton roots whereas only a small proportion was contributed through this pathway by corn. L_A was higher with corn monoculture than with cotton-corn, and was higher in Bollgard II cotton which was resistant to the *Helicoverpa* moth larvae than in cotton which did not possess the Bollgard II gene.

Key Words
Minirhizotron, Haplustert, image analyses, rotation, genetically-modified organisms.

Introduction
Row crops commonly grown under irrigation in north-western New South Wales, Australia, include summer crops such as cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.). SOC dynamics in such cropping systems have been analysed primarily in terms of inputs of above-ground material and root mass towards the end of a growing season. Addition of root material to SOC stocks either in the form of roots dying and decaying during and after the crop's growing season may, however, be significant (de Kroon and Visser 2003). Hulugalle *et al.* (2009) reported that when root death during the cropping season is accounted for potential contribution by cotton roots to SOC in Vertisols ranged between 0.5 and 4 t/ha. The statistical models developed by these authors also suggested that in comparison with non-Bollgard cotton varieties, Bollgard varieties may contribute less carbon due to a more sparse root system. Direct comparison of the two cotton types were not, however, undertaken in their study. The potential contributions to soil C by corn roots in irrigated Vertisols do not appear to have been quantified, although Amos and Walters (2006) in a review of 45 studies estimated that in a range of climates and soil types, corn roots could contribute between 1.5 and 4.4 t C/ha. None of the papers reviewed by these authors accounted for C contributed by root death during the cropping season. The objective of this study, therefore, was to determine the potential contribution by roots of corn and Bollgard II™ cotton to SOC stocks in irrigated Vertisols, both through root turnover during the growing season and decay of root systems thereafter.

Materials and methods
Cotton root growth was measured in two experiments at the Australian Cotton Research Institute, near Narrabri (149°47'E, 30°13'S) in New South Wales, Australia. Narrabri has a sub-tropical semi-arid climate with a mean annual rainfall of 593 mm. The soils in both experiments were Vertisols and classified as fine, thermic, smectitic, Typic Haplusterts (Soil Survey Staff, 2006). Particle size distribution in the 0-1 m depth of Experiment 1 (corn experiment, see below) was 53% clay, 23% silt and 24% sand, and in Experiment 2 (cotton experiment, see below), 61% clay, 11% silt and 28% sand. In northern NSW, cotton is sown in October and picked during late April/early May after defoliation and corn, is sown between September and December and harvested between February and April. Both experiments were sown after good spring rains,

but were furrow irrigated with 100 mm of water when in-crop rainfall was insufficient to meet evaporative demand. The rows (beds) were spaced at 1-m intervals with vehicular traffic being restricted to the furrows. Experiment 1 consisted of four cropping systems: Cotton monoculture, corn monoculture, cotton-wheat (*Triticum aestivum* L.) and cotton-corn rotations sown during the growing seasons of 2007-08 and 2008-09 in plots 20 m long and 8 rows wide. The experiment was designed such that both phases of the rotation were sown every year in the rotation treatments. Corn root growth was measured only in the corn monoculture and cotton-corn rotation. Cotton roots were not monitored in this experiment. In Experiment 2, two cotton varieties, Sicot 80BRF (a Bollgard II™/Roundup-Ready™-Flex™ variety) and Sicot 80 RRF (a Roundup-Ready™-Flex™ variety) were sown during the growing season of 2008-09 after conventional tillage (slashing of cotton plants after harvest, followed by disc-ploughing and incorporation of cotton stalks to 0.2 m, chisel ploughing to 0.3 m followed by bed construction) in a cotton-wheat rotation. The experimental design was 2RCB and individual plots were 200 m long and 4 rows wide.

Root growth in the surface 0.10 m was measured with the core-break method (Drew and Saker 1980). The live roots in a sub-sample of the cores were separated from the dead material after washing, and length measured using a modified Newman's line interception method (Smit *et al.* 2000). These root samples were then oven-dried, weighed and. carbon concentration measured by combustion with a LECO CHN 2000 analyser. Relationships were derived between root number, root length and root weight, and the root length and weight in each core estimated. Relative root length (root weight /root length) was also calculated. Root growth in the 0.10 to 1.0 m depth was measured at 0.10 m depth intervals with a "Bartz" BTC-2 minirhizotron and I-CAP image capture system (Bartz Technology Corporation, 2007). The video camera part of the minirhizotron was inserted into clear, plastic acrylic minirhizotron tubes (50 mm diameter) installed within each plot, 30^{o} from the vertical. The operating and measurement procedures used were those described by Johnson *et al.* (2001). Measurements of cotton roots were made during vegetative growth, flowering, boll initiation/filling and boll filling/opening, and of corn roots during early/mid vegetative growth, tasselling, silking, grain filling/maturity between early December and late March. Root images were captured in two orientations, left and right side of each tube, at each time of measurement and analysed with RooTracker 2.03 (Duke University 2001) to estimate selected root growth indices. The data for each orientation and over the entire measured profile were summed to assess root growth over a 360^{o} plane of vision. The indices evaluated were the length and number of live roots at each time of measurement, number and length of roots which died (i.e. disappeared between times of measurement) and net change in root numbers and length. The above, together with the previously-described relative root lengths and root C concentrations were used to calculate several other indices of root growth; *viz*. (1) Root length per unit area to a depth of 1 m, L_A; (2) Root carbon at end of season, C_{root} (3) Root carbon added to the soil during season, C_{lost}, and (4) Root carbon which could be potentially added to soil organic carbon stocks = (2) + (3), C_{total}. Data were analysed after $\log_e$ transformation with analysis of variance.

Results and discussion

In Experiment 1 (corn experiment), corn root densities, particularly towards the latter part of the growing season, were generally higher with corn monoculture than with cotton-corn rotation (Figure 1). Values of L_A (cm/cm^2) at crop maturity under corn monoculture ranged from 975 at 125 days after sowing (DAS) during the 2007-08 season to 1097 at 120 DAS during the 2008-09 season. L_A values for corn in the cotton-corn rotation at the same time were 365 and 606 during the 2007-08 and 2008-09 seasons, respectively. This may be related to the greater amount water stored in the soil after corn than with cotton (Devereaux *et al.* 2008). The shorter growing season of the corn (5-6 months) results in a longer fallow period between corn crops whereas the longer growing season of the cotton (~6 months) results in a shorter fallow. Subject to late summer, autumn and winter rainfall, more water is therefore, likely to be stored under a corn monoculture than with a cotton-corn rotation.

C_{total} and C_{root} of corn differed significantly ($P < 0.05$) between rotations and seasons. Significant ($P < 0.05$) interactions also occurred between years and seasons. C_{lost} of corn was not significantly affected by seasons or years. C_{total} and C_{root} were higher ($P < 0.05$) with corn monoculture (Figure 2). Average corn C_{total} with monoculture was 930 g/m^2 (9.3 t/ha) and with cotton-corn was 503 g/m^2 (5.0 t/ha), and average C_{root} with corn monoculture was 770 g/m^2 (7.7 t/ha) and with cotton-corn was 409 g/m^2 (4.1 t/ha). Among both cropping systems mean C_{lost} was of the order 76 g/m^2 (0.8 t/ha). These data also suggest that carbon addition to soil through C_{lost} was small with corn; *viz*. averaging 11% of C_{total} in both years. This is much lower than that of cotton, which ranged from 25-29% in the same field (Hulugalle *et al.* 2009).

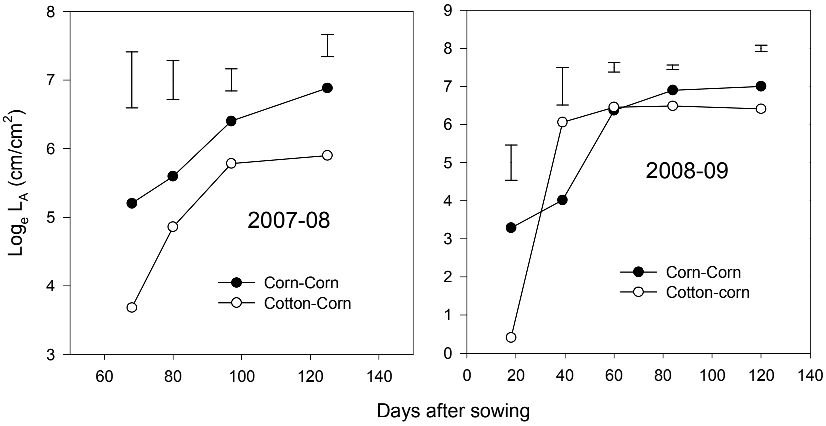

Figure 1. Effect of corn monoculture and cotton-corn rotation on root length per unit area, L_A, of corn to a depth of 1 m. Vertical bars are SEM's.

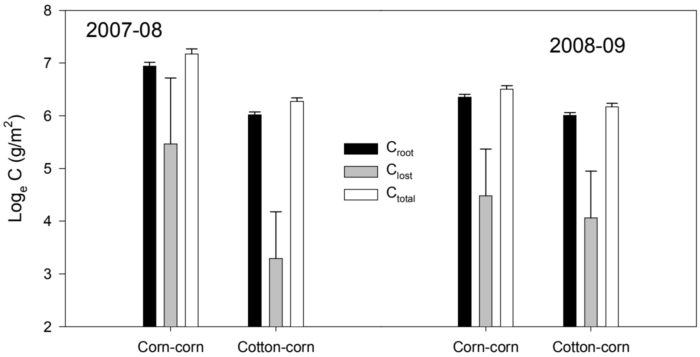

Figure 2. Effect of corn monoculture and cotton-corn rotation on root C indices. C_{root}, carbon at end of season; C_{lost}, root carbon added to the soil during season; (3) C_{total}, root carbon which could be potentially added to soil organic carbon stocks = C_{root} + C_{lost}. Vertical bars are SEM's.

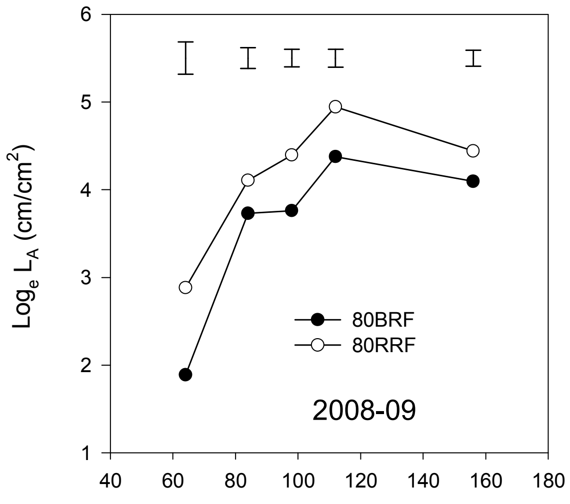

Figure 3. Effect of cotton variety on root length per unit area, L_A, to a depth of 1 m. Vertical bars are SEM's.

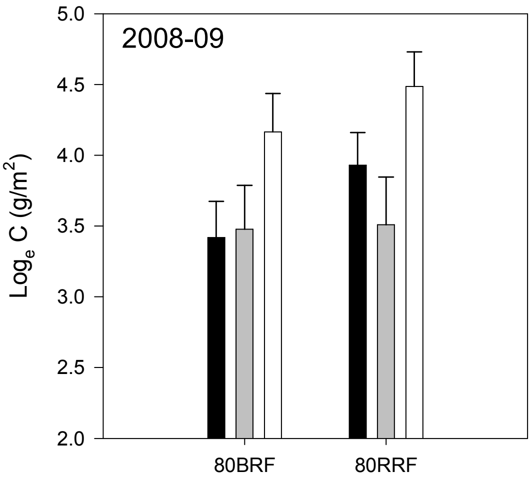

Figure 4. Effect of cotton variety on root C indices. C_{root}, root carbon at end of season; C_{lost}, root carbon added to the soil during season; (3) C_{total}, root carbon which could be potentially added to soil organic carbon stocks = C_{root} + C_{lost}. Vertical bars are SEM's.

In Experiment 2 (cotton experiment), root densities were higher ($P < 0.01$) with 80RRF than with 80BRF. Values of L_A (cm/cm^2) at crop maturity under Sicot 80RRF was 60 cm/cm^2 and 85 cm/cm^2 under Sicot 80BRF (Figure 3). Hulugalle *et al.* (2009) have suggested that this may be related to the higher boll retention in Bollgard II cotton, and thus a higher carbon and nutrient demand by above-ground organs. Carbon and other nutrients may therefore, be distributed preferentially to above-ground organs relative to roots in Bollgard II varieties, resulting in a lower rate of root initiation and consequently, lower root densities. Significant differences were absent between the two varieties with respect to the root carbon indices. C_{total} was 64 g/m^2 (0.6 t/ha) with Sicot 80BRF and 89 g/m^2 (0.9 t/ha) with Sicot 80RRF. Similarly, C_{root} was 31 g/m^2 (0.3 t/ha) with Sicot 80BRF and 51 g/m^2 (0.5 t/ha) with SicotRRF. C_{lost} was 33 g/m^2 (0.3 t/ha) with both varieties. These values are similar to the lower range of values previously reported by Hulugalle *et al.* (2009). At the same time, carbon addition to soil through C_{lost} was relatively high; viz. averaging 43% of C_{total}.

Conclusions

C_{total} averaged 5.0 t/ha with cotton-corn and 9.3 t/ha with corn monoculture, with average C_{lost} accounting for 11%. In contrast, C_{total} with genetically-modified cotton ranged from 0.6 to 0.9 t/ha with C_{lost} contributing 43%. Intra-seasonal root death makes a significant contribution to soil carbon stocks by cotton roots whereas only a small proportion was contributed through this pathway by corn. L_A was higher with corn monoculture than with cotton-corn, and was higher in Bollgard II cotton which was resistant to the *Helicoverpa* moth larvae than in cotton which did not possess the Bollgard II gene.

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Quantification of some soil properties as affected by land use, and its implication for vegetable farm systems

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Abstract
Sustainability of vegetable farms depends on development of farming systems that can at least arrest soil deterioration, and ideally improve soil fertility. We assessed of soil quality as baseline for a larger study on farming systems redesign in Uruguay. Specific aims were to quantify soil properties in vegetable crop fields on different soils; to evaluate the effect of past land use on these properties; and to assess how this changes could affect soil moisture supply capacity. Samples were taken from 4 cropped fields and from adjacent undisturbed land in pairs on 16 farms with soils representative of the region, Hapluderts and Argiudolls. In cropped fields, SOC at 20 cm depth was 14.9 g/kg on average, and 11.3 g/kg on the coarser Argiudolls. Compared to the undisturbed situation SOC depletion was 35% on average, and 41% on coarser Argiudolls. Geometric mean diameter of stable aggregatates decreased from 2.72 mm to 2.36 mm. Soil moisture supply capacity - a main function of soil is negatively affected by the depletion of SOC and decreased aggregation. Given the increasing frequency of drought and constraints on irrigation capacity, soil management alternatives that improve these properties are needed.

Key Words
Horticulture, deteriorated soils, soil quality, physical fertility, Molisols, soil organic matter

Introduction
Vegetable production is the third most important agricultural activity in Uruguay in terms of number of farms and labour. The activity is concentrated in the departments of Montevideo and Canelones, with 27000 ha or 70% of the total area dedicated to vegetable crops (DIEA, 2001). The region has been identified as the area with most severe erosion in the country (RENARE, 1999). Country-wide the number of farms specialized in vegetable production decreased by 20% in 10 years (DIEA, 2001), and by 34% in the south of the country (DIEA, 1999). Farmers that remained had to produce more to maintain their income level (PRONAPA, 1997). Such intensification of the production increased pressure on already deteriorated soils and led to production inefficiencies (Dogliotti, 2003).

The importance of reducing soil erosion and improving physical and biological fertility for sustainable development of vegetable farms in South Uruguay was highlighted by Dogliotti *et al.* (2005). In a context where fertilizers are widespread but major constraints exist for irrigation, one of the main causes of reduced soil productivity might be the reduction in soil moisture supply capacity (SMS). A reduction in SMS is linked to a depletion in SOC, reduced porosity and structural stability (Brady and Weil, 2002). Quantification of changes in those properties in relation to past management supports reflection on directions for re-design of soil management strategies. In addition, a baseline soil quality assessment is needed to evaluate the effectiveness of implemented re-designs. Such information is currently not available for vegetable farms in the South of Uruguay. The purpose of this work was to provide an assessment of soil quality as baseline for a larger study on farming systems redesign in Uruguay. Specific aims were to quantify soil properties in vegetable crop fields on soils representative of the region; to evaluate the effect of past land use on these properties; and to assess how this changes could affect SMS.

Methods
Sites description
The study was conducted in Southern Uruguay, and is part of a project (EULACIAS, EU FP6 INCO DEV) which aims to design, implement and evaluate sustainable vegetable farming systems through a co-innovation process based on a group of pilot farms. Sixteen farms in Montevideo and Canelones were selected to represent the variation in existing vegetable production systems. Re-design on the participating farms included changes on erosion control support measures, use of rotations with forage and cover crops, and incorporation of plant residues and animal manure.

Edaphic environment and soil characteristics are described in Table 1. The climate is sub humid, subtropical to temperate. Potential evapotranspiration in summer is greater than precipitation. Rainfall varies greatly between years.

Table 1. Soil type, characteristics, and edaphic environment of fields sampled.

Soil type	Texture in the topsoil	Edaphic environment
Typic Hapluderts	Clay, Clay loam, Clay silty loam	Gently rolling to strongly rolling highlands. Soils developed from quaternary or tertiary sediments, deep, black or brown.
Paquic (vertic) Argiudolls	Clay, Clay loam	
(Abruptic) Argiudolls	Loam, Silty loam	Strongly rolling highlands. Soils developed from sediments and influence of crystalline, moderately deep, and brown. And flat lowland landscape. Soils developed from quaternary sediments, deep, brown soils, rather lixiviated.

Land use on all farms was intensive vegetable farming during at least 20 years, with inverting soil ploughing twice a year on average.

Samples collection and analysis

On 16 farms topsoil (0-20cm) paired samples were collected from 4 cropped fields and a location that had not been cultivated during the past 20 years (under an old fence in most of the cases). This resulted in a total of 61 samples since in 3 cases no near-undisturbed situation was found. Samples were analysed at the Soil Laboratory of the MGAP for particle size by the hydrometer method, organic carbon by the dichromate oxidation technique, pH (1:2.5 soil-water and soil KCl suspension), and exchangeable bases by the sodium acetate method.

After two months from the last tillage operation, samples were taken for estimating physical properties at the Laboratory of INIA Las Brujas. A total of 16 duplicate samples of soil clods at 20 cm depth were collected with a spade for structural stability analysis. Structural stability was assessed by wet sieving and the geometric mean diameter calculated according to methodology described in Kemper and Chepil (1965). A total of 12 triplicate undisturbed samples at 5-10 cm and 15-20 cm depth were collected on each site with rings 5 cm wide and 3 cm height for estimating bulk density, the moisture-retention curve, and porosity, samples were processed in a pressure plate. Estimates of weight water content at wilting point were also made using the following empirical function adjusted for Uruguayan soils (Silva *et al.* 1988):

$$\%Ww \text{ at } 1500 \text{ kPa} = -58{,}1313 + 0{,}3718\,(\%SOM) + 0{,}5682\,(\%sand) + 0{,}6414\,(\%silt) + 0{,}9755\,(\%clay) \quad (1)$$

Confidence intervals at 95% probability were calculated for all variables.

Results and discussion

Measured SOC in the "undisturbed" situation confirmed that even though those soils had not been cultivated for a long time, their SOC values were less than half those reported for the same soil types in Uruguay in pristine conditions (Duran, 2007). This study thus assesses the depletion of SOC over the last 20 years (Table 2).

Table 2. Mean and 95% confidence interval of soil organic carbon (g/kg) and percentage depletion at 20cm depth by soil type and land use.

Current use of land	Typic Hapluderts Cl, ClSiL, ClL[1]	Argiudolls Cl, ClL	Argiudolls SiL, L	All Samples
		g carbon / kg of soil		
Undisturbed for more than 20 yr	25.1 [21.8; 28.5]	21.5 [18.8; 24.1]	19.2 [16.2; 22.2]	22.8 [19.5; 26.0]
Vegetable cropped fields	16.9 [15.1; 18.7]	14.0 [12.4; 15.6]	11.3 [8.1; 14.4]	14.9 [13.6; 16.1]
		%		
SOC depleted	32.6 [30.5; 34.6]	34.8 [30.5; 39.2]	41.4 [38.5; 44.3]	34.6 [32.7; 36.4]
n	29	21	11	61

[1] Cl is clay, Si is silt and L is loam

On the “undisturbed” soils a trend of decreasing SOC was observed from Hapluderts to silty loam and loam Argiudolls (Table 2). A depletion of 34.6% of SOC was observed on average in all crop fields with respect to the “undisturbed situation”. Percentage SOC depletion was higher in L and SiL Argiudolls than in Hapluderts. As a consequence, on the vegetable cropped fields, SOC was higher in Hapluderts than in L and SiL Argiudolls (Table 2). Average lost SOC was 20.0 Mg/ha in an equivalent soil mass of 2500 Mg/ha with respect to the “undisturbed” sites.

The stronger depletion of SOC in coarser textured soils was expected, because these soils are more erodible, the reported average 50% enrichment of organic carbon in sediment transport by erosion processes for similar soils (Victora *et al.* 1998), and because of coarser soils have less capacity to protect SOC (Hassink *et al.* 1997). This points to the need for extra attention for soil management techniques on these coarser textured soils.

Geometric mean diameters of aggregates stable to wet sieving (GMD) on 16 farms were on average 0.36 mm smaller than their undisturbed pairs and contained 43.8% less SOC (Table 3). These results are consistent with the literature that established a positive relationship between SOM and water stable aggregates (Carter, 2002) and negative relationship with tillage (Liebig *et al.* 2004). No differences in GMD were found among the three soil types sampled.

Table 3. Mean and 95% confidence interval (n=16) of structural stability and soil organic carbon on paired samples from vegetable farms at 20cm depth.

Current use of land	Structural stability GMD[1] (mm)	SOC (g/kg)
Undisturbed for more than 20 years	2.72 [2.55; 2.89]	24.0 [19.5; 28.5]
Vegetable crop fields	2.36 [2.19; 2.53]	13.5 [11.5; 15.5]

[1] GMD = geometric mean diameter (Kemper and Chepil, 1965).

Bulk density, macroporosity, water retention at 10 kPa, and total porosity did not differ statistically between cropped and undisturbed either at depth of 5 to 10 cm or at depth of 15 to 30 cm. Water retention at field capacity tended to be higher in the undisturbed soils (Figure 1A) than in the cultivated soils, averaging 6 mm more water per ten cm of soil. We estimated the reduction of water availability to be 17% on average in cropped fields compared with their undisturbed pairs (Figure 1B). The higher water retention in undisturbed samples was mainly explained by higher organic matter content compared to the cultivated soils. The pedotransfer function of Silva *et al.* (1988) underestimated water retention by 19 and 12% on average in cultivated and undisturbed soils, respectively, deserving future research.

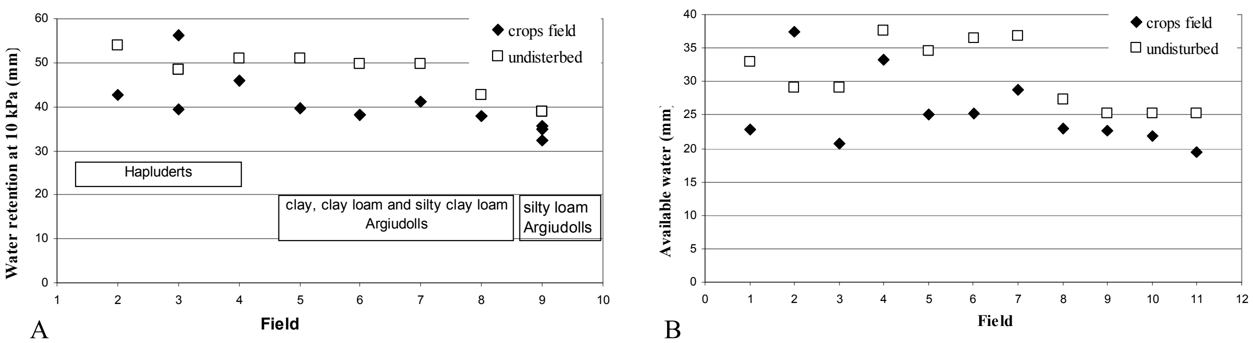

Figure 1. A) Measured soil water retention in the top 10 cm depth on different farms’ fields. B) Available water = (measured Wv retention – estimated Ww at 1500 kPa with the equation by Silva *et al.* (1988)* bulk density).

The capacity of soils to supply water to the crops is a crucial soil function in a context of increased frequency of drought events and constraints to irrigation. Processes that affect the soil moisture supply (SMS) are infiltration, root exploration, available water capacity and transpiration. Air and water infiltration and available water capacity are influenced by SOM content and soil aggregation (Carter, 2002). Root exploration would be larger in non compacted, and well aggregated soils as well. Our measurements indicate that past management in vegetable fields is negatively affecting the SMS through a reduction of SOM content and stable aggregates. Reduction in SMS is likely to be higher than the estimated reduction in available water since a reduction in water infiltration and root exploration is expected due to reduced aggregate stability and compaction by tillage. Further research is needed in order to quantify the magnitude of the relation between SMS and infiltration and root exploration to aid the design and evaluation of improved soil and crop management practices aimed to increase SMS in different soil types under rain-fed vegetable production.

Conclusion

Vegetable crop fields in South Uruguay, grown on already deteriorated soils, have been managed so intensively during the past 20 years, that average loss of 20.0 Mg/ha of SOC in an equivalent soil mass of 2500 Mg/ha with respect to undisturbed soil pairs was detected. Soil moisture supply, a major function of soil, is negatively affected by the depletion of SOC and associated weaker soil aggregation. Further research is required to quantify the magnitude of the relationship between SOM and SMS in the studied systems, to evaluate the impact of current soil practices, and to design new management strategies. Soil management recommended for L and SiL Argiudolls should be more conservative than for Hapluderts.

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Reading the land: influences of property management planning courses on landholders' soil management activities in border rivers-Gwydir catchment management authority

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Abstract
Property management planning (PMP) training for farmers is an opportunity to improve land management practices. An evaluation of the impacts of PMP training (Farming Management Systems, FMS) funded by the Border Rivers-Gwydir Catchment Management Authority (BR-G CMA) in NSW was undertaken. The analysis reported here focuses on interviews with farmer participants who had completed PMP training. The physical property plan was considered useful by farmers and continued to be used well beyond the training period. Interviewees generally recalled the need to maintain in excess of 70% groundcover for soil protection and to increase rainfall infiltration, and claimed to be using this threshold in their grazing management decision making. However, two issues emerged that require attention in designing subsequent training courses. One, the low level of natural resource condition monitoring by farmers even though this was strongly emphasised during the course, and two, the need to develop a stronger link in physical property planning between land capability assessments and farm management decision making.

Key Words
Property management planning, land capability, physical farm monitoring, soil testing, ground cover.

Introduction
Property management planning (PMP) has been an evolutionary process. In its original form the emphasis was on the completion of a physical farm plan based on soil type and land capability, with later iterations of PMP including: financial, enterprise, human resources, and biodiversity management into a strategic planning process. The incorporation of financial and human resource elements into the PMP process arose out of a number of reviews of pilot programs for PMP, where it became clear that only after the financial position and succession planning issues for family-operated properties had been addressed, could effective consideration and adoption of sustainable land practices take place (Chudleigh *et al.* 2003).
Legislative approaches to soil conservation issues have not been overly effective in bringing about large scale adoption of more sustainable land management practices. The PMP approach is viewed as a voluntary approach to drive change in attitude and increase adoption rates of best management practices (BMPs), by capacity building through training, and altering ways of thinking. In Australia, it has been reported in the National Land and Water Resources Audit, that formal monitoring of pasture and vegetation (25% of farms), regular monitoring of water tables (21 % of farms), and soil and plant tissue testing (59% of farms), are all examples of rural landholders adopting sustainable management practices (NLWRA 2002). However, monitoring alone will not lead to sustainable land management but is a necessary precursor for its achievement. For instance, the practice of soil testing is most likely used for determining fertilizer requirements (Nelson *et al.* 2004) - which in itself could be masking a loss of soil condition - and not often as a basis for monitoring soil condition.
In NSW, PMP Courses have included Farming for the Future (FFF, 1993-2001) (Chudleigh *et al.* 2003) and the Property Management Pilot Program (PMP Pilot) (Prior 2005), Farm Management Planning (FMP) and the current iteration of PMP referred to as Farm Management Systems (FMS, 2002 onwards). The area under investigation was the Border Rivers-Gwydir CMA (BR-G CMA). The BR-G CMA wanted to identify the influence of past and current PMP courses on:

- landholders' awareness of land management practices, and any associated changes in related activities.
- farm practices by course participants that demonstrate the principles espoused in the PMP course.

Specifically, a set of 'key land management criteria' as the minimum level of land management practice required for long term sustainability of the natural resource base of agricultural land (BR-G CMA 2008, p53). These criteria are at all times maintain: a minimum of 70% ground cover; a minimum of 1500 kg GDM/ha of pasture mass; a diverse range of annual and perennial grasses, shrubs and trees that enable rain to be used where it falls; continuous large surpluses of organic matter (litter) to improve soil structure and limit evaporation (minimum 2 t/ha); wind protection; and nutrient balance in soils.

Methods

Location of and background to study area

The BR-G CMA services the entire Gwydir Catchment (approx 26,500 km^2) and the NSW portion of the Border Rivers Catchment (approx 24,000 km^2). Both of these catchments are located within the Murray-Darling Basin. They are bounded by the Queensland border in the north and west, the Great Dividing Range in the east, and the Namoi Catchment in the south. The most recent versions of the BR-G CMA PMP courses are currently referred to as FMS. During 2007-08, the property management planning team worked with 207 landholders, and made approximately 100, one-on-one property visits. In total, over the last three years almost 550 landholders have completed property management planning with the Border Rivers-Gwydir CMA (BR-G CMA 2008).

The research was divided into 4 stages. This paper will focus on the results from stage 4. Stage 1 evaluated the course materials delivered in PMP courses over the last 15 years. This analysis was achieved by comparing the content and presentation of learning materials in the FFF and the FMS manuals. Stage 2 collated all course participant responses to course exit surveys. Exit surveys for 12 different PMP course cohorts were analysed in accordance with the study's objectives. Stage 3 assessed the quality of 62 applications (about 12 percent of the current FMS participants) for BR-G CMA incentive funds for on-farm projects and 4 on-ground works applications to gauge producer knowledge of sustainable land management practices. Incentive funds are only available to farmers who had undertaken PMP course and have an approved property management plan (BR-G CMA 2008). Applications were compared from participants who had undertaken training with both external and internal PMP course providers to determine if there were differences in their applications. Stage 4 conducted telephone interviews with PMP course participants over a range of PMP experiences, and time since completion. All interviewees had experienced FMS PMP course, and the majority (79%) had experienced the course recently (say in the last 3 years), with only two people having attended previous iterations of PMP before FMS PMP.

Stage 4: Telephone interviews with PMP course participants

The focus of the interviews with course participant (n = 19) was on several themes which included: social profile of participants, FMS PMP course experience, comparison to other courses attended by participants, the construction of the farm map and assessment of the natural resource base, assessments of the quality of the PMP course learning materials, and financial and physical monitoring of the farm business. This paper will concentrate on the results from interviews with course participants on the farm mapping exercise (1 day of a 6-8 day course) and farm-level monitoring of physical aspects such as soil, pasture and ground cover.

Current land management surveys

At the time this PMP course evaluation was conducted, there were also two larger land management surveys being undertaken. One, by the Bureau of Rural Sciences (BRS) of 1441 people in the BR-G CMA and had a 64.1% response rate (Hanslip *et al.* 2008). The other, conducted by the Australian Bureau of Statistics for 2007-08 over all 56 regional organisations in Australia, and sampled 33 000 agricultural businesses and had an 87.4% response rate (ABS 2009). These two surveys serve as reference points for corroboration of qualitative data collected from interviews.

Results and Discussion

Farm mapping exercise and land capability

17 of the 19 people interviewed had completed the farm mapping exercise, and only two were still not satisfied with the more recent version of the aerial photograph of their farm due to poor resolution. As well as mapping infrastructure, the majority had also mapped soil types and problem areas (74%). There needs to be additional training and support in the understanding of land management within capability, and how to assess land capability and its relationship to land management practices. Few interviewees had considered a remnant vegetation management plan or assessed the need for revegetation (13% of interviewees). Concerns regarding the extent to which PMP programs were achieving native vegetation and biodiversity conservation outcomes have been raised previously (Chudleigh *et al.* 2003). Sixty three percent of people interviewed still used or consulted the aerial photograph of their property post-training, some occasionally (25%), and others more frequently (75%). The majority of the course participants interviewed (68%) had completed the 'blue sky' mapping exercise where they were asked to plan for their property in an imaginative fashion, putting aside for the moment current infrastructure, and resource constraints on future developments. While many interviewees understood the concept of considering their property a 'blank canvas' for this exercise, most

only considered making ‘realistic’ modifications of their current infrastructure. To render this exercise more effective will require better preparation of participants so that they are not constrained by ‘what is’ but are open to ‘what could be’.

Physical farm monitoring
15 of the 19 people interviewed could recall at least four of the key land management criteria, but not necessarily all of the specific values related to the criteria, except for those who attended in the last 12 months. The message that strongly resonates with PMP participants is the necessity to maintain at least 70% ground cover (80% of the 15 people). Interviewees expressed the view that if ground cover was maintained at this level, then other issues such as soil protection, reduction of evaporation, increased water infiltration, and pasture recovery were automatically addressed. This finding is corroborated by the ABS survey (ABS 2009) that showed that in the BR-G CMA that 38% of farmers had set a minimum target of ground cover at 76%. Also in the BRS survey (Hanslip *et al.* 2008) 79% of the respondents agreed with the statement that maintaining greater than 70% ground cover will improve the long-term productive capacity of the land. Sixty three percent of the PMP course participants had made changes since completing the PMP course, with those changes ranging from enterprise shift, fencing to land capability, and modify grazing practices. These results are also supported by the ABS survey (2009) that showed 37% of farmers in the BR-G region had changed grazing practices to increase ground cover. Most interviewees claimed that they were made more aware of the need to provide sacrifice paddocks for drought feeding through the PMP course, but still found the implementation impractical, and resorted to using travelling stock routes for drought feeding.

Several of those interviewed, who had attended PMP courses on multiple occasions, have also attended additional grazing or land management courses such as Grazing for Profit, Beefanomics, LANDSCAN™, Principle Focus, and Holistic Management, as well as being Landcare members. Fifteen out of the 19 people interviewed continued to have contact with the BR-G CMA, with 60% of those landholders applying or receiving funding to carry on-ground works. Several of the interviewees (5 of the 19 people) had spent several years implementing on-ground works that would constitute sustainable land management practices (Nelson *et al.* 2004). These works include: establishment of tree corridors and shelter belts, engineered woodlands, erosion control, fencing of riparian zones, conservation of remnant vegetation, amelioration of degraded cropping land, and providing alternative watering points for stock away from watercourses. All interviewees reported moving towards a greater degree of rotational grazing and away from set stocking.

About 21% of the course participant interviewed had completed a written strategic business plan, even though this was one of the tasks required of course participants to complete. More of the people interviewed (68%) had completed a ‘blue sky’ mapping overlay, and one response was “I think if I went back and looked at that overlay that I would have all but completed my aims over the last ten years.” Another response was “I have completed all the improvements that I want to do, and it was now just a matter of maintenance into the future.” Most interviewees reported that they monitored ground cover (85% of the 47% that indicated they were monitoring), but they did not measure and record the information. This is also corroborated by the ABS survey (2009) that showed for the majority of BR-G CMA farmers who monitored ground cover it was by visual means (60%). A minority of interviewees conducted time or plan grazing, and kept records using specifically designed farm record-keeping software. This level of commitment also included taking multiple photographs and keeping detailed records of the cattle grazing enterprise, but such examples were in the minority. A well-respected course participant, who had contributed substantially to the promotion of sustainable land management practices, commented: “what is the purpose of keeping written records if it doesn’t actually contribute to anything in the long run”. One response was “Over what period of time would you need to keep records in order to observe a real trend and by that time what was the usefulness of the records. We don’t all want to be scientists.”

Most course participants interviewed (59%) expressed an interest in a monitoring tool kit, especially if it was custom-designed for the particular user, and took a minimal amount of time to complete. The interest in a monitoring tool kit was the creation of opportunities to have CMA staff examine their enterprise, and have more immediate feedback on their grazing management activities. Nearly all the course participants interviewed had conducted soil tests. However, it is apparent that soil testing was conducted for tactical reasons and not for information on soil condition or identifying land capability. Some people interviewed adjusted fertilizer rates on a paddock-by-paddock basis due to increasing cost of inputs forcing them to be more strategic. Those interviewees that had attended the Industry and Innovation NSW, LANDSCAN™

course commented that it was an "essential partner to PMP training." Responses to the new exit survey for BR-G PMP course, participants interviewed claim to be monitoring indicators of financial and physical farm health, but were not able to provide formal records. This may have some relationship to the lack of completion of strategic business plans. Either the purpose of these plans and the information required to complete them does not appear to be of value to landholders, or inadequate exercises are completed during the PMP course that would enable participants in PMP to construct such a plan. One interview participant did specifically comment that if work from the workshops was not completed close to the time of presentation then the work did not get done.

Conclusion

Property management planning and implementation of management strategies identified in those plans is a core target for the BR-G CMA under Schedule S1.4 of the BR-G CMA strategic plan (BR-G CMA 2008). Property planning is viewed as a critical component of engaging landholders in the adoption and enhancement of management practices that sustain and improve the natural resource base on which these businesses depend. Specifically, the management target states that "by 2015, 1,500 landholders will have developed property plans and at least 500 of these will have implemented improved farm management" (BR-G CMA 2008). The BR-G CMA can provide those producers who complete a PMP course with incentive and/or on-ground works funding to assist with the initial development of infrastructure that will move those businesses towards implementation of sustainable land management practices.

While many learning and behavioral outcomes linked to sustainable natural resource management were achieved through PMP training, the participants' involvement with their own farm monitoring was generally poor. Future PMP training should clearly define the purpose, tools, and management decision choices to justify the ongoing monitoring of key land management criteria. A clear purpose and justification for continued monitoring of the key land management criteria needs to be established. Virtually all survey respondents named 70% ground cover as the primary and critical key land management criteria for sustainability. Participants are using this criterion as a critical threshold for making decisions on when to move, agist or sell stock, rather than as a long term monitoring tool. Participants are applying those land management criteria that relate to specific decision making thresholds for short term management required to maintain profit, rather than for long term monitoring for changes in overall natural resource outcomes.

The ultimate aim is that the producer will continue to build upon that initial investment to bring about changes in land management to contribute to catchment targets that reduce long-term negative impacts and produce a net improvement in resource condition. Indeed, Hanslip *et al.* (2008) re-affirm this aim with over 70% of respondents having as the two top priorities for managing their property as: financially viable business and maintain resource condition. Browne (2004) concluded that the best outcomes for sustainable natural resource use were achieved when environmental outcomes were included in a whole farm business strategic management plan. Hence PMP should be supported as a effective strategy for raising awareness and enabling adoption of sustainable land use practices because it part of a whole farm management strategic planning process.

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Recycling rate of N, P and K in animal feed and bedding material and use efficiency of manure N, P and K in agro-ecosystems

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Abstract
The losses of N and P in farmlands are of major concern due to their effects on economic and environmental sustainability in agro-ecosystems. We conducted a 9-year study to assess the cycling of N, P and K in farm produces and the use efficiency of manure N, P and K. It was found that the feeding-composting cycle caused an average loss of N, P and K in the harvested produces by about 55%, 15% and 10%, respectively. Under high-yielding conditions, the amounts of recycled N, P and K from the harvested produce and the feeding-composting cycle were about 30-50 kg N/ha, 8-14 kg P/ha and 18-30 kg K/ha, respectively, equivalent to 25-33% N, 36-65% P and 30-50% K fertilizers applied to the farming systems. The use efficiency of N, P and K in organic manures in the current season increased with the extended fertilization, indicating a contributing factor of soil residual effects. The use efficiencies of N, P and K in organic manures over the 9-year period were 58%, 38% and 44%, respectively. The results suggest that nutrient recycling in farming systems improves soil fertility and nutrient use efficiency, and also reduces the use of fertilizer.

Key Words
Feeding-composting system, recycling rate, use efficiency.

Introduction
Long-term fertilizer experiments worldwide have proved that balanced fertilization using fertilizers with organic manures can improve the nutrient status of the soil and maintain high crop yields and increase the SOC concentration. Many studies have demonstrated the effect of long-term manure applications on the chemical, physical and biological properties of soils. Such influences may be either direct or indirect. In general, the effects have focused on one or two aspects, such as Soil organic matter dynamics, N transformations, C mineralization and immobilization and the Nutrient cycling (Biederbeck *et al.* 1996; Velthof *et al.* 1997). Organic manure has been used as the main nutrient source for crop production in China for some thousands of years. However, in last two decades, there has been a large increase in the use of fertilizer with a concomitant decrease in the use of manure. These situations have contributed to many environmental questions. Recently, there is a revival of recycling organic manure, but now combined with fertilizer. Many studies have examined the influences of combined applications of animal manure and fertilizers (Fan *et al.* 2005). However, available information is still absent and incomplete about the nutrients recycling rates through feeding-composting cycle.

The consumption of farm produces by human-being and livestock, and the return of their excrements to the farmlands constitute a component of nutrient recycling in the agro-ecosystems. However, the amounts of recycled nutrients via a feeding-composting cycle are only a part of total nutrients in harvested produces. The course in which animals absorb N, P and K contained in fodders is affected by many factors, such as the animal species, age, raising conditions and fodder composition (Foth 1978). The loss of nutrients in excrements depends upon the ways of storage and composting. This study aimed at estimating the recycling rate of nutrient in harvested produces through a feeding-composting cycle and the use efficiency of nutrient in organic manure in northeastern China.

Materials and methods
Experimental site, design, and treatments
A long-term field experiment has been conducted since 1990 at the experimental station of the Institute of Applied Ecology, Chinese Academy of Science (Latitude 41°32'N, Longitude 123°23'E). It has an average elevation of 31m and a mean annual temperature of 7.5℃. Its annual precipitation is about 700 mm. The soil of the experimental field is an Alfisol, which is the main soil type used for agricultural production. The initial properties of the surface soil (depth 0-20 cm) were as follows: soil texture, clay loam; pH, 6.5; soil organic matter, 20.9 g/kg; total N, 1.13 g/kg; total P, 0.44 g/kg; total K, 16.4 g/kg; available P, 10.6 mg/kg; and

available K, 88.0 mg/kg.The experiment had eight treatments: no fertilizer (CK), recycled manure (M), N, NM, NP, NPM, NPK and NPKM treatments. Only four treatments with manure were involved in this paper. N, P and K fertilizer were applied at the rates of 150, 25 and 60, kg/ha/year in the form of urea, double superphosphate, and potassium chloride, respectively. All P and K fertilizers were basal-applied prior to sowing; 40 kg/ha N fertilizer was basal-applied before sowing, and 110 kg/ha N was top-dressed at the stem-elongation stage. Each plot area was 162m^2, with a buffer zone of 2.0m. Initially, in 1990, the experiment was started with a soybean-maize-maize rotation. Each treatment consisted of three replications. Through feeding-composting cycles, 80% harvested seeds, 100% soybean straw, and 50% corn stalk were returned to the original treatment. This completed a nutrient-recycling process that consisted of "fertilization-crop yield-absorption-feeding-composting-return to fields." All the feeding stuffs and bedding materials are just come from the harvested crop material. There are much different for the amount of manure among the treatments because the yields of crop were different. Although the feeding-compost trial was started from the fall of 1990, all the data in this paper is from 1999 to 2008.

Sampling and chemical analysis

Pig manure samples were taken before fertilization in the next spring and divided into two sub-samples. One was for the water content measurement and another was dried and ground for analysis of N、P and K. All the crop samples were taken after harvest and divided into two sub-samples. One sub-sample for the water content and another was dried at 70℃ for 24 hours and ground for analysis of N、P and K. A Vario EL Ш elemental analyzer was used to determine total N for soil, manure and crop samples. Crop P was made by colorimetry after digestion (Olsen and Sommers 1982). Crop K was made by flame photometer after digestion. Soil P and manure P was measured by colorimetry after high-temperature ignition in muffle furnace with Na_2CO_3 fussion at 920℃ (Jackson 1958). Soil available P was also measured by colorimetry after extraction with 0.5 mol/L $NaHCO_3$ (pH=8.5) (Olsen *et al.* 1954). Soil K and manure K was determined by flame photometer after NaOH fusion in a muffle furnace at 720℃ (Jackson 1958). Soil available K was determined by flame photometer after extraction with 1.0 mol/L NH_4OAc (Carson 1980).

Results and discussion

Nutrients recycle of feed stuffs and bedding materials

The residual rate of organic matter in the feeding stuffs and bedding materials through a feeding-composting cycle was about 0.22 (Table 1), slightly lower than the residual rate of organic matter applied to the soils for one year. This was mainly because the feeding stuffs had no longer mixed with soil since 1999 and the residual rate was decreased due to the absence of soil absorption. When the feeding stuffs were mixed with soil, similar residual rates were observed between the feeding-composting cycle and the application in soil.

Table 1. Mean residual rates of organic matter in feeding stuffs and bedding materials through a feeding-composting cycle during 1999-2008.

Treatments	Pig manure				Pig manure +N				Pig manure +N+P				Pig manure +N+P+K			
Parameter	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Mean	239.7	59.72	0.24	0.76	330.0	75.5	0.21	0.79	350.2	79.88	0.22	0.78	367.4	82.49	0.22	0.78

A: dry wt. of stuffs and materials (kg); B: dry wt. of pig manure (kg); C: residual rate; D:decomposition rate.

The loss rates of N, P and K contained in harvested materials though the feeding-composting cycle were in average 55%, 16% and 10 % respectively, over the 9-year study (Table 2). The higher loss rate of N was due to the easy vaporization of ammonia, whereas the loss of P is mainly due to the digestion by pig. This experiment did not separate the loss of nutrients by pig digestion from that by composting. If a base estimation that animals absorb 20% of N and 10% of P is used (Foth 1978), the loss of P through composting is insignificant, but the loss of N is much higher. The loss of K through the feeding-composting cycle is negligible. Moreover, the study showed that the recycling rate of N differed slightly in different fertilizer practices. With the increase in fertilizer use, the recycling rate of N decreased from 52% to 42%, but the recycling rate of P and K was similar (86-82%; 92-87%, respectively).

Use efficiency of N, P and K in pig manure

Manures are an important source of nutrient supply in farming systems, especially in northeastern China. Using the amount of nutrients in the pig manure and the amount of nutrients in harvested materials of the recycling treatments year by year, we calculated the use efficiency of N, P and K in pig manure (Table 3). The average amount of N in the pig manure recycled farmland was 38-50 kg/ha, equivalent to 25-33% of N

Table 2. Mean loss rates of nutrients contained in feeding stuffs and bedding materials through a feeding-composting cycle during 1999-2008.

Treatment	Nutrients in stuffs and materials(kg)			Nutrients in pig manure(kg)			Recycling rate of nutrients			Loss rate of nutrients		
	N	P	K	N	P	K	N	P	K	N	P	K
Manure	3.47	0.49	0.98	1.83	0.42	0.90	0.52	0.86	0.92	0.48	0.14	0.08
Manure+N	5.08	0.57	1.23	2.21	0.47	1.09	0.41	0.83	0.89	0.59	0.17	0.11
Manure +N+P	5.38	0.73	1.28	2.34	0.61	1.22	0.44	0.84	0.92	0.56	0.16	0.08
Manure +N+P+K	5.89	0.82	1.65	2.42	0.67	1.44	0.42	0.82	0.87	0.58	0.18	0.13

fertilizer (150 kg N/ha) and was an important nutrient source for crop production. Although N use efficiency of the organic fertilizers varied between years, there was limited residual effect of organic fertilizer. In addition, N use efficiencies of the pig manure in the current season increased with the extended fertilization, indicating an existence of residual effects. Continuously applying organic fertilizers not only increases soil N-supplying capacity and N use efficiencies in the current season and adaptability to variation of rainfall in rain-fed agriculture area, but also reduces the dosage of mineral fertilizer use. This study showed that the pig manures provided an average amount of 9-14 kg P/ha and 18-30 kg K/ha to the recycled farmland, which was equivalent to 36-65% of P and 30-50% of K from fertilizers. With the increase of fertilizer use, the recycling rate of P and K decreased in terms of the requite lapse rate. Moreover, the study showed that P and K use efficiencies of pig manure in the current season increased with the extended fertilization, indicating a strong existence of residual effects (Foth 1978). The P and K use efficiency of organic manure were slightly higher than that of fertilizer P and K that was because the organic matter in pig manure had decreased P fixation by soil.

Table 3. Mean nutrients use efficiency of pig manure during 1999-2008.

Treatments	Pig manure			Pig manure +N			Pig manure +N+P			Pig manure +N+P+K		
Parameter	A	B	C	A	B	C	A	B	C	A	B	C
N	37.76	26.64	0.72	45.48	32.45	0.71	48.22	25.10	0.52	49.76	18.14	0.36
P	8.63	4.54	0.55	9.70	4.62	0.48	12.48	3.96	0.32	13.69	2.79	0.20
K	18.43	9.58	0.52	22.51	11.55	0.52	25.07	8.22	0.33	29.55	11.61	0.40

A: Nutrients in pig manure applied (kg/ha); B: Nutrients harvested (kg/ha); C: Nutrients use efficiency of pig manure.

Conclusion

The use of nutrients recycled in farming system improves soil fertility and nutrient use efficiency, and therefore reduces the use of mineral fertilizers. Under high-yielding conditions (150 kg N/ha, 25 kg P/ha and 60 kg K/ha), the average amounts of recycled N, P and K from 80% of harvested materials and through a feeding-composting cycle were 38-50 kg N/ha, 9-14 kg P/ha and 18-30 kg K/ha, equivalent to 25-33% of N, 36-65% of P and 30-50% of K from fertilizers applied every year. Over the 9-year period of study, the loss rates of N, P and K in harvested materials though a feeding-composting cycle were about 55%, 16% and 10%, respectively. Through composting, the loss of P and K was insignificant, but the loss of N was much higher, indicating P and K recycling was more efficient. N, P and K use efficiencies of the pig manure in the current season increased with extended fertilization, probably due to residual effects of pig manure. The averages of N, P and K use efficiency of pig manure were 58%, 38% and 44%, respectively. The increased P and K use efficiency of pig manure compared with fertilizer P was because the organic matter in pig manure had decreased P fixation by soil.

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Relation between soil organic matter and physical properties of a degraded Oxisol in recovery with green manure, lime and pasture

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Abstract
Cultivation of species that accelerate soil chemical and physical balance is an option for accelerating the recovery of degraded soil. The objective this work was to study the spontaneous occurrence of native tree species and pasture development of an Oxisol in process of recovery for 11 years using green manures, soil correction and gypsum. The experimental design was completely randomized with nine treatments and four repetitions. We used *Stizolobium aterrium, Cajanus cajan* and *Canavalia ensiformis* until 1999 which was then replaced by *B. decumbens.* The treatments were installed in 1992 and remained for seven years. In 1999 we planted pasture. We evaluated soil bulk density, aggregate stability and soil organic matter for the depths 0.00-0.10; 0.10-0.20 and 0.20-0.40 m. The physical properties of the soil were measured and soil bulk density was a good indicator of soil quality.

Key Words
Soil reclamation, soil quality, soil structure.

Introduction
Due to population growth the economic development of environmental resources is submitted to strong pressure, providing in the last decades large impacts on the environment. Among the natural resources most degraded by man, the soil is most changed in its natural characteristics due to improper exploitation. The history of soil use shows that this change always carries a new unsustainable ecological system, thus, soils used, intensively and in inappropriate way, are led to degradation (Alves and Souza 2008).
In Brazil, deforestation and agricultural activities are the main factors of degradation of soils. The engineering works (roads, railways, dams) and the activities of mining in the open sensitize the population in general. This is because these activities have high impact.
From the 60s, with the population growth and demand for greater quantities of energy, the Brazilian government began efforts to supply their needs. Thus, several hydroelectric power plants were designed for this purpose. While hydroelectricity as an alternative for energy production may be more environmentally advantageous compared to other options, because it uses a renewable natural resource and is non-polluting, the formation of reservoirs involves the occurrence of multiple impacts on the environment (Cesp 1998).
As consequences of construction, many areas, enclosed or not within the body of the work, tend to show sharp deterioration, which manifests itself in the form of disruption of the balance between the lithosphere (especially in its weakest part, the soils), the hydrosphere and biosphere (especially land cover). The areas where this process is more aggravating, are the areas of loan (excavation), the unstable slopes and boggy areas, flooded areas, etc. (Alves and Souza 2008). These locations, where the materials are taken to supplement the volume of soils necessary for the performance of earthwork and foundations, are "loan areas" (Lopes *et al.* 1994).
The areas of loan consist of degraded ecosystems, because their means of biotic regeneration were eliminated. The seed bank, seedlings and sprouts were removed along with the mature vegetation. Therefore, the sites have low resilience, i.e., their return to the previous state may not occur or is extremely slow.
For the recovery you must select and identify suitable species for the new edaphics conditions and accelerate the organization and formation of more superficial horizons of soil (Carpanezzi *et al.* 1994). The adaptation and development of these species depend on physical, chemical, biological and hydrological and microclimate conditions of the site.
Research has been developed with the purpose of generating solutions to mitigate the exposed surface. Restoring ecosystems is the name that has been attributed to the arduous challenge of, through planned interference, rebuilding the structure and creating conditions that restore the natural ecological processes of each ecosystem.

Boni *et al.* (1994) evaluated the contribution of green manure in improving physical characteristics of a degraded soil, they found that the legume species *Crotalaria juncea* and *Cajanus cajan* reduced soil bulk density and consequently increased the porosity of the compacted layers. Melo (1994) working in an area of loan found that forage species associated with chemical manure promoted improvements in physical and chemical characteristics of soil.
Alves *et al.* (2007) working in the recovery of degraded area remaining from the construction of a hydroelectric power station used the addition of sewage sludge, green manure, cultivation of native species and pasture to increase 27 times the production of *Brachiaria decumbens* evaluated 274 days after sowing. The same authors evaluated the diameter and height of plants of *Astronium fraxinifolium* and found that the best performance was for a treatment with *A. fraxinifolium + sewage sludge + B. decumbens* and physical conditions of soil improved.
Therefore, with the purpose to evaluate the recovery of an Oxisol that for over 11 years, gypsum and pasture were used, soil bulk density, aggregate stability and soil organic matter were measured.

Methods

The experiment was conducted at the Teaching and Research Farm, belonging to the Faculty of Engineering, Campus of Ilha Solteira of the Universidade Estadual Paulista (UNESP), municipality of Selvíria, Mato Grosso do Sul, Brazil. It is located on the right bank of the Paraná river, with the geographical coordinates of 51° 22’ west longitude of Greenwich and 20° 22' south latitude, with height of 327 meters. Average annual precipitation, temperature and humidity of air: 1370 mm, 23.5° C and 70-80% respectively.
The original soil of the study area was classified as an Orthic Ferralsol according to the FAO classification (FAO 1990).
The hydroelectric power plant of Ilha Solteira, São Paulo, Brazil begin its construction in the 60's, the area under study had soil removed for earthworks and foundation of the storage dam, resulting in a degraded area. A layer of 8.6 meters was removed from the original soil profile, and the subsoil of the area under study had been exposed since 1969 (Alves and Souza 2008).
Physical-chemical characterization of the exposed soil gave values of, soil bulk density = 1,76 kg/dm^3; P = 0,5 mg/dm^3; M.O. = 5,5 g/dm^3; pH ($CaCl_2$) = 4,1; K = 0,2 mmol$_c$/dm^3; Ca = 2,0 mmol$_c$/dm^3; Mg = 1,0 mmol$_c$/dm^3; H+Al = 20,0 mmol$_c$/dm^3; SB = 3,2 mmol$_c$/dm^3; CEC = 23,2 mmol$_c$/dm^3 e Base saturation = 14 %.
The treatments were installed in 1992 and remained for seven years, until 1999 with *B. decumbens* in all plots. In 2006, to evaluate the spontaneous presence of native savannah tree species the experimental design was completely randomized, consisting of nine treatments and four replications. The size of each plot was 10 m *x* 10 m, spaced 2 m between them.
The treatments were: one control (tilled soil without culture) until 1999 after implanting of *Brachiaria decumbens*; *Stizolobium aterrium* until 1999 after the planting of *B. decumbens*; *Cajanus cajan* until 1994 and then substituted by *Canavalia ensiformis* and since 1999 was planted *B. decumbens*; lime+*S. aterrimum* until 1999 after the planted the *B. decumbens*; lime+*C. cajan* until 1994 then substituted by *C. ensiformis* and since 1999 planted with *B. decumbens*; lime+gypsum+*S. aterrimum* until 1999 after the *B. decumbens*; lime+gypsum+*C. cajan* until 1994 and then substituted by *C. ensiformis* and since 1999 was planted with *B. decumbens*, and to two control, native vegetation (savannah) and exposed soil (without recuperation practice).
Soil bulk density, aggregate stability and soil organic matter were measured at depths 0.00-0.10; 0.10-0.20 and 0.20-0.40 m. Chemical analysis of soil (organic matter) was carried out according to the methodology described by Raij and Quaggio (1983) and physical analysis of soil (soil bulk density and aggregate stability represented by mean weight diameter (MWD) were carried out according to the methodology described by EMBRAPA (1997) and Angers and Mehuys (2000), respectively.
The data were analyzed by performing regression and the Excel computer program was used to perform the statistical analysis.

Results

Comparing soil organic matter to soil bulk density showed that with higher contents of soil organic matter the lower was soil bulk density for the three depths. Surface samples (0.00-0.10 m) showed a greater reduction in soil bulk density in all treatments of soil reclamation, due to the higher concentration of the root system of *B. decumbens* in this depth, developing much organic matter.
At the depths 0.10-0.20 and 0.20-0.40 m there were similar results, with a lower content of organic matter and therefore a higher value of soil bulk density. This indicates show that soil reclamation mainly benefits

the surface soil horizon. Addition and balance of organic matter are essential in maintaining and improving soil physical conditions and can only be achieved through macro and microbial activity and decomposition of organic matter (Andrade Junior 2004).
Similar results were found by Alves and Suzuki (2004) who studied the use of cover crops combined with the succession of crops (maize and soybeans) under no-tillage and observed improvements in soil porosity, soil bulk density and penetration resistance. Campos and Alves (2006) studied penetration soil resistance in the degraded area similar to this study and found that reclamation has reached a depth of 0.00-0.05 m, this study shows that the effect of organic matter has reached to a depth of 0.10 m.
The relationship between organic matter and the mean weight diameter was the same for the three soil depths (0.00-0.10 and 0.20-0.40 m), with increasing content of soil organic matter resulting in higher mean weight diameter. Results of this study agree with the claim that Campos *et al.* (1995) and Campos and Alves (2008) that the continuous supply of organic matter by litter and/or root excretions, whose products are made of organic molecules in various stages of decomposition, act as agents of formation and stabilization of aggregates, providing a better soil structure.

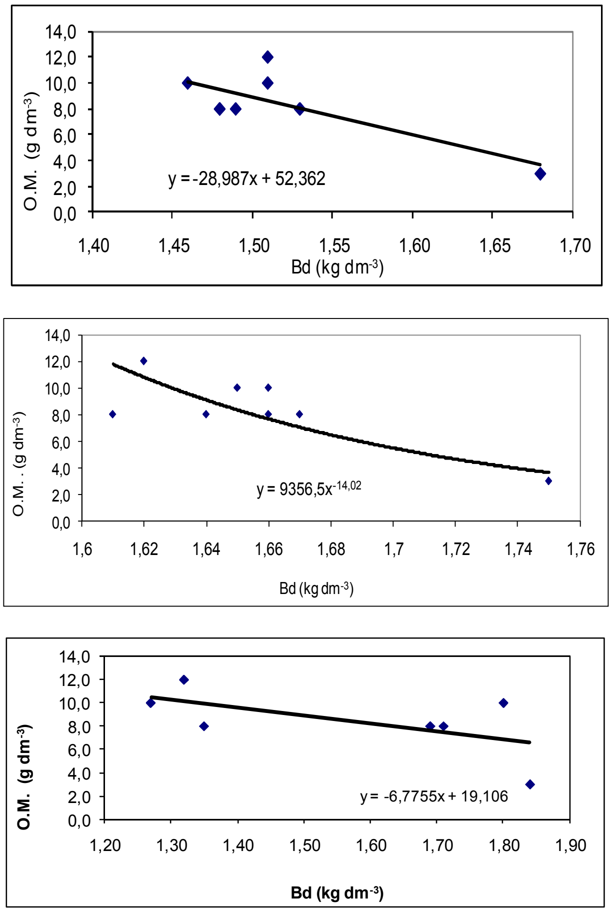

Figure 1. (a) Relationship organic matter (O.M.) x bulk density (Bd) in the depth 0.00-0.10m. (b) Relationship organic matter (O.M.) x bulk density (Bd) in the depth 0.10-0.20m, (c) Relationship organic matter (OM) x bulk density (Bd) in the depth 0.20-0.40 m.

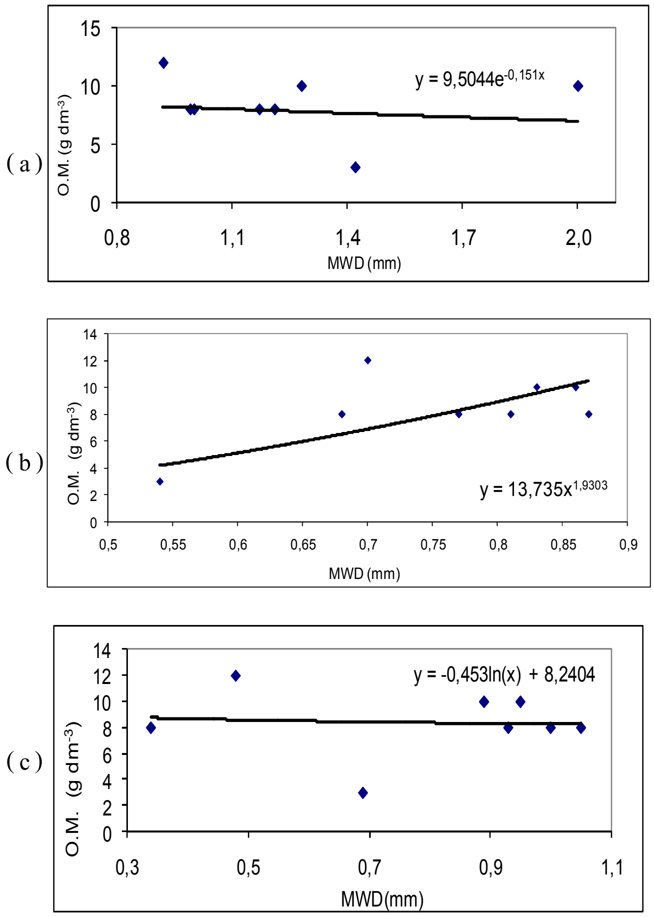

Figure 2. (a) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.00-0.10 m, (b) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.10-0.20 m (c) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.20-0.40 m.

Alves (2001) states the influence of organic matter on soil aggregation is a dynamic process, as it adds organic material to soil, the activity is enhanced, resulting in products that play roles in the formation and stabilization (cementing agents) of clusters. Jastrow *et al.* (1998) state that the presence of stable aggregates enhances the ability to store water, reducing the loss of particles and nutrients by erosion and facilitates the physical protection and accumulation of soil organic matter.

For the depth of 0.20-0.40 m an opposite behavior was observed, and there was a positive relationship between mean weight diameter and the amount of soil organic matter.

Conclusion

The physical properties of soil are being reclaimed, and soil bulk density was a good indicator of soil quality and the physical properties studied showed good relationships with the amount of soil organic matter.

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Remote sensing of land cover and land management practices affecting wind erosion risk in NW Victoria, Australia

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Abstract
Wind erosion from farmed land in the Mallee region of NW Victoria occurs annually, varying in degree according to the season and the land management practices. Ground based surveys of erosion and land use practice have been carried out for more than twenty years in the Mallee but these surveys are limited to roadside transects across the region. We have interpreted satellite data (Landsat and MODIS) to provide coverage for the whole region and interpret land management factors that contribute to soil protection or to wind erosion susceptibility. The interpreted management factors have been combined with soil landform information to improve monitoring of wind erosion likelihood in the region.

Key Words
MODIS, Landsat, wind erosion, land management.

Introduction
North western Victoria is considered to be one of the areas at highest risk of wind erosion in Australia and the Mallee Catchment Management Authority requires a consistent and robust method to quantify wind erosion in the region in order to set and monitor targets. It is difficult to assess wind erosion directly from remotely sensed imagery. This is partly due to the unpredictability of wind erosion events and the often ephemeral nature of the aftermath. There is no steady build up of observable features preceding a dust storm and much of the physical evidence can disappear soon after the event if it is followed by rain that sets the tractors ploughing the paddocks. Given the likelihood that the observation period may be very short and the vagaries of cloud cover, it is often difficult to make direct measurements of wind erosion using airborne or satellite borne sensors. We have therefore used satellite imagery to map management factors that occur regularly through every season and contribute either to protection of the land from wind erosion or to increasing the likelihood of wind erosion. This management data was combined with estimates of land susceptibility based on expert knowledge in a risk assessment framework known as the Land Use Impact Model (LUIM) to generate regional maps of likely land degradation resulting from wind erosion for a given season. This paper describes the remote sensing component of the LUIM for wind erosion in the Mallee.

Methods
Rationale for the method is based on assumptions regarding the relationship between land management and soil protection. Key management factors are:

- crop type/ landcover,
- biomass in spring,
- the degree of ground cover,
- tillage practices,
- stubble management practices and
- stock management.

DPI agronomists have suggested that some land cover types present a greater risk of wind erosion than others. It is possible to directly assess this factor using remotely sensed data collected in spring.
Dry matter production (biomass) in the growing season is likely to have a significant influence on the vulnerability of soil to wind erosion, and low biomass production in a cropping season may increase the risk of wind erosion the following year. This land cover factor can be qualitatively assessed using remotely sensed time series data over the growing season.

Bare soil has a higher risk of soil erosion than soil with a good cover of well attached vegetation, either actively growing or as residual crop stubble. Soil cover post-harvest is a function of crop biomass produced in the growing season, farm management operations in preparation for sowing the next crop and stock management. It is not within the capability of remote sensing to discriminate between various tillage practices, stubble management practices and stock management that may increase the risk of soil erosion. However, remote sensing can directly assess the percentage of bare ground at a given time.
An on-ground survey and satellite imagery were used together to create reliable data layers for the region and provide information on summer and winter land management.

Ground truth data collection
Ground data was collected to calibrate the remote sensing analysis and to validate predictions.
Land cover type and management phase data was collected as part of the Mallee wind erosion survey (Wakefield, 2008) from 149 sites in spring. These sites were revisited in early autumn to record: management phase, estimated erosion severity, visual estimate of green and brown vegetation cover and a count of green and brown vegetation cover. Fixed attributes such as soil colour and texture were also recorded for each site.
In addition, land cover in spring, and 2007 crop yield and management data prior to the 2007 harvest, were collected from 348 paddocks on 17 farms across the Mallee via a postal survey. In late summer, counts of green and brown vegetation cover were made at nine 1 ha plots in paddocks at Speed and 12 plots at Swan Hill. DPI staff from Swan Hill made a visual estimate of erosion at the end of April 2008, soon after a major wind erosion event in the Mallee, collecting a photographic record and location of 49 paddocks significantly affected by that event.

Image data
Image analysis was based on single date Landsat 5 images in mid-spring, mid-summer and a time series for all 2007 constructed of images captured by the Moderate Resolution Imaging Spectrometer (MODIS) sensor. The MODIS time series was based on the MOD13Q1 v5 product produced by the National Aeronautics and Space Administration (LPDAAC, 2008).

Image pre-processing
All Landsat 5 images were rectified to a map grid using GDA94 as Datum and a Universal Transverse Mercator (UTM) projection for zone 54 (MGA54) and calibrated to a base image, using a national image mosaic developed for the Australian Greenhouse Office (AGO) carbon accounting procedure in 2000 (Furby, 2002). The MOD13 EVI product is produced from atmospherically corrected bi-directional surface reflectance that has been masked for water, clouds, heavy aerosols, and cloud shadows. Atmospheric correction has been applied to remove residual atmosphere contamination caused by smoke and sub-pixel thin cloud clouds (LPDAAC, 2008). Little pre-processing was required except to re-project the EVI layer to MGA54. A time series was then created by stacking 24 images for all of 2007 and clipping them to the Mallee catchment management region.

Identifying land cover type in spring
DPI agronomists suggested that it would be easiest to discriminate between different land cover types when crops had achieved full leaf cover and commenced to flower. This usually occurs between mid August and late September. Analysis to identify land cover type was based on the pre-processed Landsat 5 images from this period and the MODIS time series data for all of 2007. Varying environmental conditions between regions may require development of different indices and/or thresholds to discriminate land cover types for each region (Furby and Clark 2004). Prior to analysis the Landsat 5 images were stratified so that particular vegetation and landuse features produced a similar spectral response within each zone. Within each stratified region, a maximum likelihood classification was run on the single date Landsat 5 images based on training data selected from the ground data. The training data generally comprised no more than 20% of the ground data with the remainder used for validation. At this point, the classifications were tested against the remainder of ground data (the validation data) to determine if confusion existed between any of the cover classes. The MODIS time series was examined in conjunction with the training data to identify temporal patterns of vegetation growth that may correct any classification errors. To produce the final classification for land cover type, the MODIS data were incorporated into the classification using a decision tree based on the maximum likelihood classification of the single date Landsat 5 image. For an accuracy assessment, the final classification was tested against the validation data.

Estimating biomass in the growing season.

To limit the analysis to agricultural paddocks over the growing season, the MODIS EVI time series data was restricted temporally to the growing season, i.e. the period from 30/4/2007 till 7/10/2007, and spatially to exclude forested areas and water bodies. The EVI values for each pixel were summed and their minimum, maximum, mean and standard deviation calculated. The data were divided into groups with equal numbers of members, i.e. one third of the population in each group, representing low, medium and high biomass over the growing season.

Estimating ground cover post harvest

The method used to estimate vegetation cover post harvest was developed by Roberts *et al.* (2007) and employed a suite of tools designed to select the optimal end-members or reference spectra for Spectral Mixture Analysis (SMA) and then calculate and interpret SMA and Multiple End-member Spectral Mixture Analysis (MESMA). The method is described in detail by Roberts *et al.* (2007). The MESMA estimates were compared to the ground measurements of ground cover and a linear regression was fitted to the data. The regression equation was used to rescale the MESMA estimates to the ground measurements and the ground data and the mean MESMA estimates of averaged wind erosion risk for each plot were each assigned to their wind erosion risk class.

Results

Image analysis to identify landcover type in spring

The final classification for land cover in spring was assessed against validation data in each stratification zone and the results are shown in
Table 5.

Table 5. Error matrix for the combined land cover classification for the whole Mallee in pixel numbers

	Ground truth (Pixels)										
Image Class	cereals	canola	legume	pasture	fallow	scrub	bright soil	irrigated	hay cut	stubble	Total
cereals	129539	1298	3627	3282	3383	4	13	160	6	11	141323
canola	3678	4379	408	820	79	0	0	2	0	0	9366
legume	7183	1185	4571	1215	462	0	0	44	3	0	14663
pasture	3137	7	678	8561	2107	21	5	0	367	100	14983
fallow	5334	224	8	3682	16707	829	0	86	0	0	26870
scrub	79	0	23	47	18	19196	0	357	0	0	19720
bright soil	207	3	615	200	47	52	4974	0	0	2	6100
irrigated	0	0	0	53	0	7	0	3547	0	0	3607
hay cut	337	20	9	1128	0	0	1	0	2628	21	4144
stubble	0	0	31	195	0	0	0	0	0	542	768
Total	149494	7116	9970	19183	22803	20109	4993	4196	3004	676	241544

Image analysis to estimate biomass in the growing season

Figure 8 shows typical examples of the temporal signature for pixels in the low, medium and high biomass classes.

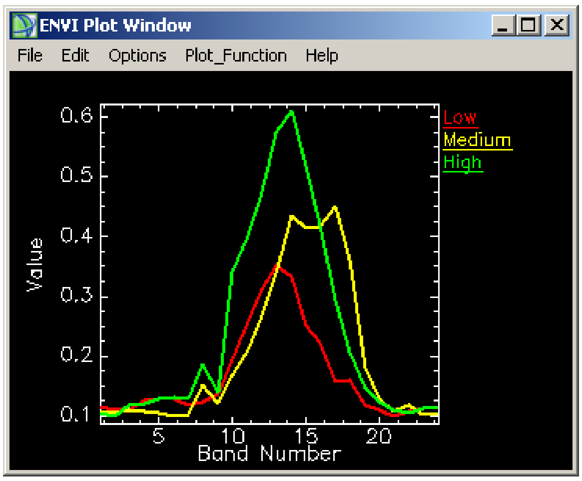

Figure 8. Plot of MODIS EVI time series data over the 2007 growing season for typical examples of pixels

demonstrating low, medium and high biomass production

Image analysis to estimate ground cover post harvest

The calculated R^2 value of 0.4513 indicates that only a moderate relationship exists between the MESMA estimates and ground measurements of ground cover. A comparison of the ground wind erosion risk to the mean MESMA estimates produced an overall accuracy of 51/70 or 73% correctly classified.

Conclusion

We have used remote sensing to interpret wind erosion risk factors in the Mallee for the 2007-2008 season. The principal findings and issues with regard to the methods are:

1. A single Landsat image in Spring and another in mid to late Summer combined with the MODIS time series is sufficient to estimate the major factors that contribute to the likelihood of wind erosion.
2. For spring cover type, cereal crops were discriminated accurately and reliably, but canola and legumes tended to be confused with each other and with cereals and, to a lesser extent, with pasture. If we combined all crop types plus the ‘haycut’ class into a single ‘crop’ group it was discriminated from all other groups very accurately and reliably. ‘Fallow’ and ‘pasture’ classes, tended to be confused with each other and with the cereal class. This is partly due to the inconsistent use of terminology by agronomists and farmers for ‘pasture’ and ‘fallow’ types that occur in the Mallee and needs to be resolved. Highly reflective patches of bare soil (usually dune crests likely to be susceptible to wind erosion) were discriminated from all other classes very accurately and reliably. Combining the MODIS time series data with the Landsat single date image improved the classification accuracy.
3. Although there was no validation data available, the estimates of biomass production levels seemed to make sense. However, future estimates should be based on class thresholds developed using long term data to cope with climatic variation between seasons.
4. The MESMA estimates of ground cover only had a moderate relationship with the ground measurements (R^2 value of 0.4513), although when converted to wind erosion risk classes the overall accuracy was 73%. However, not all classes were adequately represented in the ground data and this needs to be addressed in the future.
5. To produce the best quality ground data for calibration and validation of the image analysis, ground data should be collected as close as possible to the date of Landsat image acquisition.
6. Cloud cover may significantly limit the usefulness of remote sensing analysis in some seasons.

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Responses of PLFA and NLFA to Fertilization in a Chinese Arable Mollisol

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Abstract
The effects of 17y pig manure (PM) (organic matter, 9 t/hm^2 each year) and inorganic fertilizer [N, 150 kg/hm^2 each year (urea); P, 32.73 kg/hm^2 each year (calcium hydrogen phosphate)] amendments on phospholipids fatty acid (PLFA) and neutral lipid fatty acid (NLFA) in different soil microbial communities were investigated. The fertilizer treatments were as follows: CK, N (nitrogen), NP (nitrogen + phosphorus), MCK (PM only), MN (PM + nitrogen), MNP (PM + nitrogen + phosphorus). The result of PLFA analysis showed that the addition of PM, nitrogen or phosphorus fertilizer significantly increased soil microbial biomass. As fungal-to-bacterial PLFA ratio for CK was dramatically higher than for the PM treatments, it was reasonable that the fungi might be adapted to nutritional deficiency more easily than bacteria. As 17 years of cropping with single N application resulted in low P availability and led to a great increase in fungal NLFA contents, P was confirmed to be the important limiting nutrient for fungal growth in this arable Mollisol.

Key Words
PLFA, NLFA, soil microorganisms, fertilization, Chinese Mollisol.

Introduction
As one of three major black soils in the world, Chinese Mollisol's cultivated area is 7×10^6 hm^2 which accounts for above 50% of total cultivated areas of Heilongjiang and Jilin province of China. Soil microorganisms in this Mollisol under different fertilization and land management practices have been studied mainly about soil microbial biomass, soil enzymes activities and quantity changes of culturable microbes (Li *et al.* 2004; Shi *et al.* 2004). Fewer articles about the living soil microbial community structure and physiological status affected by different fertilization were reported in this area. The objectives of this study are to find out: 1. How the native fungi and bacteria react to the pig manure (PM) and chemical fertilizers application, 2. Weather the NLFA or NLFA/PLFA ratio can be used to indicate the physiological status of not only soil fungi but also soil bacteria, and 3. Which kind of soil nutrients is absolutely necessary to microbial community?

Methods
Basic properties
Total carbon and nitrogen contents were determined by dry combustion using a C/N analyzer, the pH was measured in a 1:1 soil/water suspension, readily available K was extracted by ammonium acetate and determined by flame photometer method, available P was extracted by sodium bicarbonate and determined by molybdate blue colorimeter method, available N was indicated as alkali-hydrolysable nitrogen (Lu RK 1999). Soil microbial biomass C (SMB-C) or soil microbial biomass N (SMB-N) was determined by the chloroform fumigation-extraction method using a 0.5 M K_2SO_4 extracting solution (Brookes *et al.* 1985). SMB-C and SMB-N were calculated using extraction efficiency factor (K_{ec}) of 0.38 and 0.45 respectively. The soil physical and chemical properties were shown in Table 1.

PLFA and NLFA analysis
NLFA and PLFA analyses were performed using the modified Bligh and Dyer method (Bligh and Dyer, 1959; Frostegard *et al.* 1993).

Table 1. Basic soil properties of 6 fertilization treatments.

Treatment	pH	Organic matter	Total N	Alkalytic N	Available P	SMB-N	SMB-C
		g/kg		mg/kg			
CK	8.43	32.86	1.656	95.92	2.009	12.90	92.47
N	8.40	33.84	1.757	112.5	1.467	13.62	107.8
NP	8.41	33.01	1.747	99.15	4.207	16.21	113.0
MCK	8.08	49.63	2.479	175.3	100.2	27.92	203.2
MN	7.68	54.87	2.633	182.2	114.2	44.55	235.6
MNP	7.68	56.93	2.954	210.0	109.6	37.68	274.5

Note: 1. All values about soils are given as dry weight. 2. SMB-C, soil microbial biomass carbon; SMB-N, soil microbial biomass nitrogen.

Results

3.1 PLFA contents in different fertilizer amendments

PLFA 16:0 (BioPLFA), a biomarker of soil viable microbial biomass, increased significantly with PM amendment as the amounts of PLFAs in MCK (4.53 nmol/g) and MN (5.05 nmol/g) and MNP (4.62 nmol/g) were much higher than those of CK (2.6 nmol/g) and N (3.06 nmol/g) and NP (3.18 nmol/g). In spite of the order in no-PM system (NP>N>CK), the increase of PLFA 16:0 in MN was greater than MNP (MN > MNP > MCK) (Figure 1). The trend of total bacterial PLFAs (bacPLFA) of i15:0, a15:0, 15:0, i16:0, 16:1ω9, i17:0, cy17:0 in different fertilizer amendments were very similar to that of PLFA 16:0, as MN (10.3 nmol/g) and MNP (9.83 nmol/g) were significantly higher than MCK (8.85 nmol/g), and NP (7.62 nmol/g) > N(5.97 nmol/g) > CK (4.95 nmol/g) (Figure 1). The fungal PLFAs (FunPLFA), indicated as the sum of 18:2ω6,9 and 18:1ω9, were also significantly promoted by PM addition. The highest ones occurred in MNP (6.26 nmol/g), and the amounts of MN (5.7 nmol/g) and MCK (5.48 nmol/g) were significantly higher than those of N (3.8 nmol/g), NP (3.77 nmol/g) and CK (3.59 nmol/g) (Figure 1). In addition, the application of chemical fertilizers did not significantly affect fungal PLFAs contents in no-PM system. The fungal-to-bacterial PLFA ratios (Fun/bac), a measure of the sum of 18:2ω6,9 and 18:1ω9 to total bacterial PLFAs of i15:0, a15:0, 15:0, i16:0, 16:1ω9, i17:0, cy17:0, did not show great variation among PM or no-PM system, except that NP (0.49) was significantly lower than CK (0.73) (Figure 1).

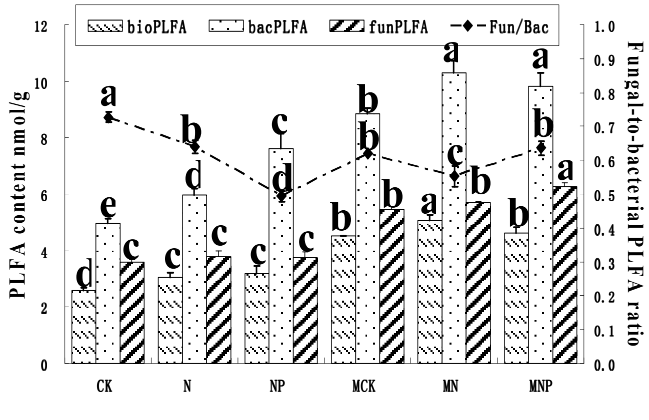

Figure 1. PLFAs of biomass, fungi and bacteria in different treatments.

3.2 NLFA contents in different fertilizer amendments

Microbial biomass biomarker NLFA 16:0 decreased with PM amendment [N (5.2 nmol/g) > MN (4.42 nmol/g) or CK (4.58 nmol/g) > MCK (4.19 nmol/g)] except those treated with P [MNP (5.14 nmol/g) > NP (2.54 nmol/g)] (Figure 2). Although combination of PM and NP increase NLFA 16:0 significantly (MNP>CK), mineral N+P dramatically decreased NLFA 16:0 (CK>NP). The sum of NLFAs i15:0, a15:0, 15:0, i16:0, 16:1ω9, i17:0, cy17:0, indicating total bacterial NLFAs, were much higher in PM amendments than no-PM, as the order was MNP (14.02 nmol/g) > NP (4.44 nmol/g , MN (10.40 nmol/g) > N (7.05 nmol/g), MCK (9.75 nmol/g) > CK(5.29 nmol/g) (Figure 2). Chemical N amendment stimulated bacterial NLFA but N+P inhibited the bacterial NLFAs (N>CK>NP). The fungal NLFAs of 18:2ω6,9 and 18:1ω9, decreased significantly with PM addition [N (8.73 nmol/g) > MN (4.49 nmol/g) or CK (6.13 nmol/g) > MCK (4.91 nmol/g)] except the amendments with NP [MNP (6.94 nmol/g) > NP (4.70 nmol/g)](Figure 2). The amount of fungal NLFAs in chemical N amendment was nearly 1 times higher than NP or MN. The fungal-to-bacterial NLFA ratios, a measure of the sum of 18:2ω6,9 and 18:1ω9 to total bacterial NLFAs of i15:0, a15:0, 15:0, i16:0, 16:1ω9, i17:0, cy17:0, decreased dramatically almost 1 to 2 times in PM amendments, as the order was N (1.24) > MN (0.43), CK (1.16) > MCK (0.50), NP (1.06) >MNP (0.50) (Figure 2). The application of single N fertilizer increased the fungal-to-bacterial NLFA ratio, but NP decrease it (N>CK>NP), and there was no great variations among the ratios of PM system.

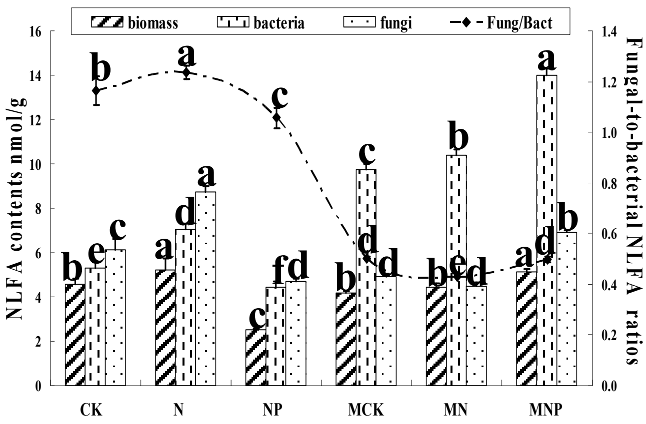

Figure 2. NLFAs of biomass, fungi and bacteria in different treatments

3.3 PCA of PLFA (nmol%) and NLFA/PLFA ratios

Principal components analysis (PCA) of 13 different PLFAs did not differentiate clearly PM from no-PM treatments (Figure 3a), while PCA of NLFAs and NLFA/PLFA ratios did divide no-PM and PM treatments into two parts: the first principal component had a significant PM effect, as the addition of the PM shifted the treatments to the right; while the second component was affected significantly by inorganic fertilizer, as CK, N and NP treatments were found to the upper PC graph (Figure 3c, 3e).

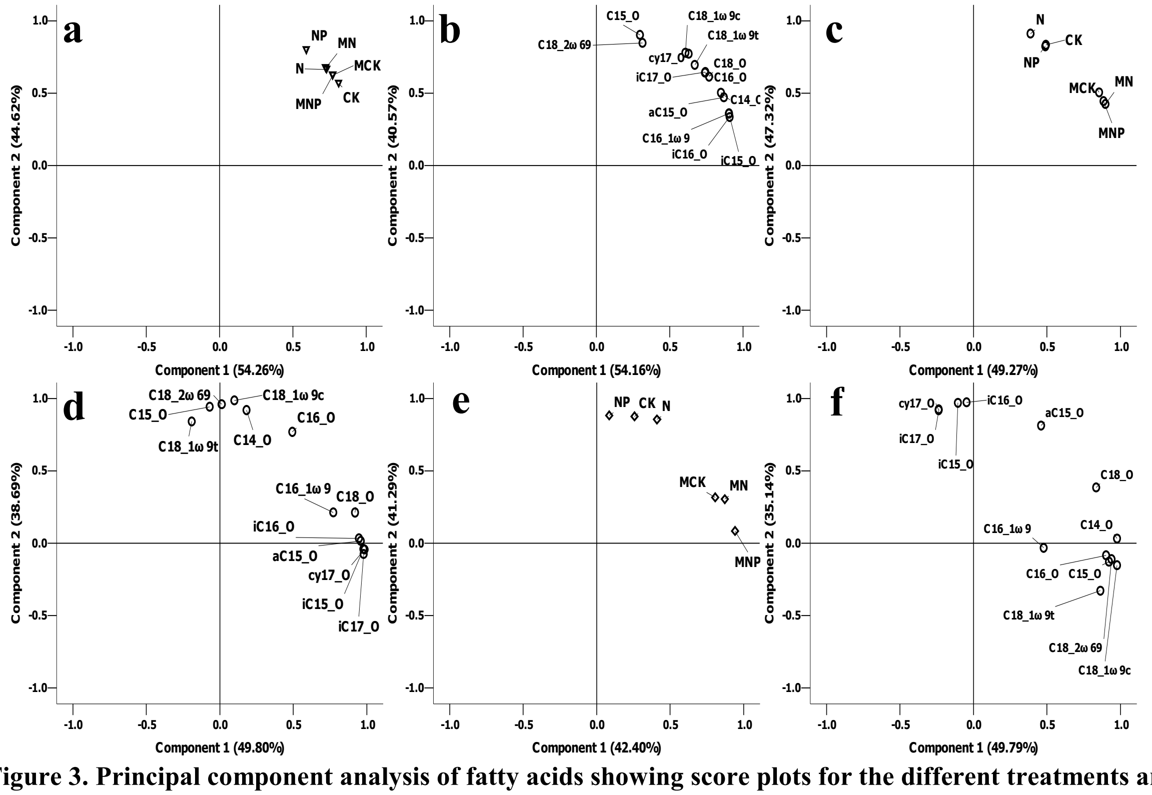

Figure 3. Principal component analysis of fatty acids showing score plots for the different treatments and loading values for the individual fatty acids

The loading values for the individual PLFAs, NLFAs and NLFA/PLFA ratios changed in different ways (Figure 3b, 3d, 3f). As for PLFAs, i16:0, i15:0 and 16:1ω9 increased with CK, while 15:0 and 18:2ω6,9 increased greatly with NP treatment. However, i15:0, a15:0, i16:0, i17:0, cy17:0 and 18:0 NLFAs significantly increased with PM application, and 14:0, 15:0, 18:2ω6,9, 18:1ω9c and 18:1ω9t NLFAs increased with chemical fertilizers application. Loading values of the NLFA/PLFA ratios PCA indicated that 14:0, 15:0, 16:0, 18:2ω6,9, 18:1ω9c, 18:1ω9t and 18:0 were mainly influenced by PM addition, while i15:0, i16:0, i17:0, cy17:0 and a15:0 were significantly affected by chemical fertilizers application.

Conclusion

The live soil microorganisms were dramatically affected by 17y PM and chemical fertilizer amendments with the great variation of soil basic properties such as pH, organic matter, total N and available P. Available P was the most important limiting factor for the variation of soil microbial physiological condition. Though fungi were much more tolerant to the nutrient deficiency than bacteria, PM plus chemical nutrients dramatically activated fungal growth. The NLFA contents are particularly useful to indicate the Mollisol bacterial and fungal physiological status. The pathway of fungal or bacterial NLFAs accumulation in the condition of nutritional deficiency was very different from that in the nutritional sufficiency. PCA of NLFA-to-PLFA ratios was more useful than NLFAs or PLFAs to determine the change of microbial community structure and physiological status caused by the long-term application of different fertilizers.
It was obvious that the long term application of PM with or without chemical fertilizers had changed the pathway of organic matter and energy transformation in the different communities of soil microbes by changing the microbial structures.

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Runoff losses of dissolved carbon and nitrogen in mountain Mediterranean agro- and forest ecosystems

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Abstract
The objective of this research was to estimate the dissolved carbon and nitrogen loads lost by runoff from soils under agricultural and forest land uses, in a Mediterranean mountain basin in Catalonia. Twelve Gerlach boxes and sixteen 0-tension lysimeters were installed under forest, agricultural and pasture land uses, and 172 water samples were analysed for total dissolved carbon and mineral nitrogen ($N\text{-}NO_3^-$), from October 2007 to December 2008. Total C losses were between 10 and 200 kg/ha/year. Most of them through subsurface runoff, since surface runoff coefficients are very low in these soils (less than 0.5 %). Nitrogen losses were lower, between one to two orders of magnitude. No differences were observed depending on land use cover, but when considering single rainfall events, *Pinus nigra* forest have more C losses than the rest. Pastures and crops are the land uses that export more N by surface and subsurface runoff respectively in some single events. The results suggest that OM with a low degree of polymerisation is responsible for OM mobility. According to these results, the control of runoff volume by appropriate management practices is one of the key factors determining the C and N loads from these environments.

Key Words
Dissolved carbon, $N\text{-}NO_3^-$, surface runoff, subsurface runoff, Mediterranean soils, mountain soils.

Introduction
Runoff is one of the sources of non-point diffuse pollution in agricultural soils. Losses of nutrients and carbon not only affect the fertility of soils, but also the quality of water resources. They increase the risk of eutrophication of downstream waters and nitrate pollution of aquifers, among other effects (Govers 1991; Martin *et al.* 1998). These processes have to be studied through a multiscale approach, from field to watershed, in order to see the pathways of the elements and their relation with the biotic components, as well as with the different compartments of water storage in the watershed.

Strong land use changes are affecting large agricultural areas in Europe in the last century, due to set-aside policies and to socio-economical changes that have brought about the abandonment of agricultural land. The transformation to pastures or forest has changed the water balance components, mainly by changes in soil characteristics. The Catalan Pre-Pyrenees are one of these regions where the soil water regime is determined by the land use (Loaiza-Usuga and Poch 2009) and where the effects of the land use on the hydrochemistry of the watersheds has been shown (Orozco *et al.* 2006). The objective of this study is to assess the contribution of dissolved nitrogen and carbon lost through runoff waters from soils under different land uses (crops, forest, pastures), both surface and subsurface, at field scale.

Methods
The physical environment
The Ribera Salada drainage basin is located in the Catalan Pre-Pyrenees (NE of Iberian Peninsula). It drains an area of 222.5 km^2, and has an altitude between 2385 m and 420 m. Mean annual precipitation is around 800 mm, with a seasonal minimum in winter (160 mm). Average annual potential evapotranspiration (estimated using the Thornthwaite equation) is around 700 mm. The soil temperature and the water regimes (Soil Survey Staff 2006) are mesic and ustic respectively, changing to udic in the highest areas. The substrate consists of folded limestones Triasic to Eocene age, marls and some evaporites (gypsum and salts) at the headwaters, and an extense Eocene-Oligocene molassic sequence in the central and lower parts of the basin. Calcareous sediments of both structures are partly karstified. The soils are shallow, calcareous and stony and are characterized by a low water-holding capacity and moderate to high infiltration rates (Orozco *et al.* 2006). Decarbonated soils occur in the highest parts of the basin. Land use is mainly pine and oak forest (60%), followed by agricultural areas (24.5%).

Experimental design
Six locations were monitored (Table 1), in order to collect surface and subsurface runoff. Subsurface flows were measured by tension zero lysimeters per site (rectangular metal plate 20 x 30 cm inserted horizontally into the soil) at depths ranging from 20 to 50 cm, depending on the soil type. The collection area for the subsurface runoff was 0.059 m^2. Surface runoff was measured by means of modified Gerlach boxes with widths of 50 and 100 cm, collecting runoff from areas ranging between 9.4 and 48 m^2 and delimited by galvanized plates when possible. Slopes of these areas ranged between 22 and 45%. Hourly rainfall was obtained from the *Xarxa Agrometeorològica de Catalunya* meteorological station of Lladurs for La Torra, Altés, Canalda and Cogulers locations; and Baró meteorological station (*Centre Tecnològic Forestal de Catalunya*) for Ramonet locations. The period of monitoring was from October 2007 to December 2008.

Table 1. Location and characteristics of the experimental plots

Location	Land use	Soil (SSS 2006)	Gerlach boxes	Lysimeters
La Torra	Oak forest (*Quercus ilex*)	Typic Calciustept	2	2
Ramonet	Pasture (*Onobrychis viciifolia*)	Typic Calciudoll	2	2
	Crop (potatoes, *Solanum tuberosum*)	Typic Calciudoll	2	2
	Pine forest (*Pinus sylvestris*, *Pinus uncinata*)	Typic Calciudoll	2	2
Prat	Pasture (poliphytic)	Typic Haplustept	2	2
Altés	Pine forest (*Pinus nigra*)	Typic Udorthent	2	-
Cogulers	Pine forest (*Pinus sylvestris*, shaddy)	Typic Ustorthent	-	2
	Pine forest (*Pinus sylvestris,* sunny)	Typic Calciustept	-	2
Canalda	Brook forest (*Pinus sylvestris, Buxus sempervirens ,Quercus ilex*)	Typic Ustifluvent	-	2

Sampling and analyses
Runoff and subsurface water volume was measured in the field and water samples were collected fortnightly or after every rainfall event. They were kept frozen until the moment of the analysis. Mineral nitrogen was determined using the Merckoquant® test strips and a Nitracheck® reflectometer. Total dissolved carbon was measured with a LECO total analyser. Ninenty two samples of surface runoff and eighty samples of subsurface runoff, from ten rainfall periods from October 2007 to December 2008, were analysed. The total rainfall in this period was around 1000 mm. In order to obtain the nitrogen and carbon exported the results were referred to the collection area. Runoff coefficients and infiltration water percentages were calculated for each event.

Statistical analyses consisted in studying differences of the variables depending on land use: *Pinus nigra*, *P. sylvestris, Quercus ilex*, pastures and crops, through ANOVA. The analyses considered both the whole monitoring period and also individual rainfall events.

Results and discussion

The results corresponding to the whole period of analysis are reported in Tables 2 and 3. No significant differences are found between treatments, except for higher total dissolved carbon in surface runoff under *Q. ilex* (P<0.01) and higher nitrogen as nitrate in subsurface runoff under crops (P<0.001). Fertiliser leaching is probably the reason for the latter. The total carbon losses are between 10 and 200 kg C/ha/year, similar to those found by Jacinthe and Lal (2001), who estimate losses due to erosion in agricultural watersheds ranging from 5 to 100 kg C/ha/year. Measurements in the Venezuelan Andes by Bellanger *et al.* (2004) show C losses in eroded soil between 2.1 and 270 kg C/ha/year under different crops. Estimates of the range of dissolved organic carbon (DOC) loss from non-cultivated temperate ecosystems range from 1 to 146 kg C/ha/year (Hope *et al.* 1994).

The main C and N losses are due to subsurface runoff, since runoff is very low (runoff coefficients < 0.5%). Average total carbon concentrations are higher in surface (0.161 g/L) than in subsurface runoff (0.089 g/L), but the higher volume of subsurface flow substantially increases the carbon loss by percolation. In the case of mineral nitrogen, there are no significant differences in concentration, but losses are two orders of magnitude higher in subsurface flow, due to the higher runoff volume. Considering that the origin of dissolved carbon is mainly organic (the baseline of inorganic carbon is constant for all sites due to the same substrate), higher losses of C would correspond to OM with a low degree of polimerisation, rich in fulvic acids. It is surprising the large difference in the composition of water in the oak forest (*Quercus ilex*), where the subsurface flow contains much more nitrogen than surface runoff. This fact points to the difficulty of

Table 2. Amount of surface runoff and C and N loads depending on land use. Estimations for a measurement period of 381 days. Values followed by the same letter are not different with a significance level of *P*<0.01.

Land use	$N\text{-}NO_3^-$ (g/ha)	Total Dissolved Carbon (kg/ha)	$N\text{-}NO_3^-$ (mg/L)	Total Dissolved Carbon (g/L)	Runoff (mm)	Runoff coefficient (%)
Pinus nigra	37.6	3.02	10.33	0.150b	1.08	0.10
Pinus sylvestris	18.7	0.98	15.72	0.085b	1.49	0.16
Quercus ilex	25.6	12.90	25.91	0.385a	3.37	0.33
Pastures	53.5	2.68	9.29	0.170b	1.95	0.19
Crops	48.6	3.75	17.03	0.084b	2.41	0.26

Table 3. Amount of subsurface runoff and C and N loads depending on land use. Estimations for a measurement period of 349 days. Values followed by the same letter are not different with a significance level of *P*<0.001.

Land use	$N\text{-}NO_3^-$ (g/ha)	Total Dissolved Carbon (kg/ha)	$N\text{-}NO_3^-$ (mg/L)	Total Dissolved Carbon (g/L)	Percolation (mm)	Percolation coefficient (%)
Pinus sylvestris	3583	156.27	12.85b	0.104	41.33	4.45
Quercus ilex	2100	17.28	23.11b	0.063	25.63	2.81
Pastures	817	70.79	7.35b	0.057	33.14	3.78
Crops	7510	196.33	142.17a	0.111	38.23	4.26

humification of organic matter from oak leaf residues, indicated by the higher total carbon values in surface waters under this treatment, which circulate through the O horizons. This environment has a more degraded soil and has a more xerophytic character than the coniferous forests, and thus, the incomplete humification of plant residues.

When considering individual events, significant differences ($P<0.05$) were found between land uses for the variables shown in Figure 1. Nitrogen losses through subsurface flow are higher for crops in two rainfall events, which indicate the effect of the external source of mineral N (fertilisation), at a given moment of the crop management. In surface runoff, the losses are higher in pastures only in one event, probably linked to the availability of animal manure on the soil surface. Regarding carbon losses, they are higher in *Pinus nigra* in most of the events. No significant differences were found in runoff volumes, therefore these losses are due to a higher concentration of dissolved organic carbon when water flows on their surface. These are shallow and humid entisols on limestones, with a well developed O horizon that may favour, more than under other types of cover, the formation of humic compounds that can be incorporated as dissolved fractions in runoff water.

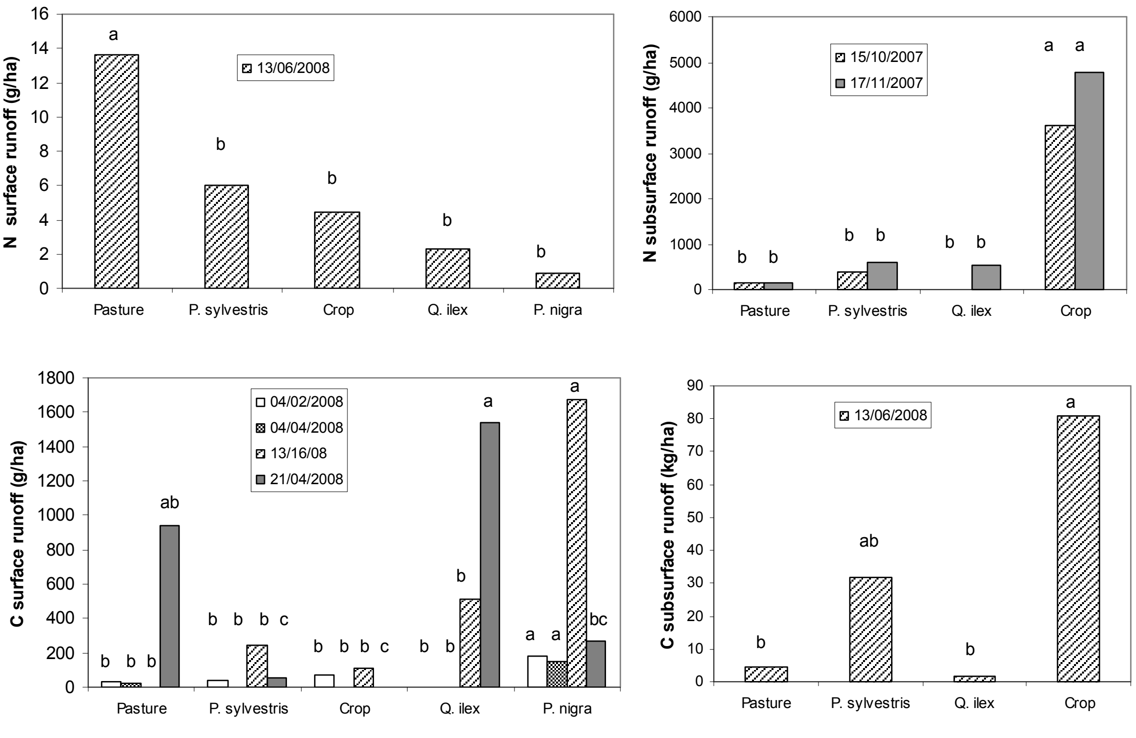

Figure 1. Variables and dates with significant differences depending on land use, in subsurface and surface runoff. Bars with the same letters indicate no differences (*α*=0.05) between land uses for the same date according to Duncan Multiple Range Test.

Conclusions

Carbon losses through runoff are normal values for a natural system, and much higher than those of nitrogen. This is probably due to OM with a low degree of humification, which is more mobile, although no analyses of OM composition are provided. The losses are much higher (one to two orders of magnitude) in subsurface flow than in surface flow, maily due to high infiltration rates.

According to the results, the most effective management techniques to minimize these losses should try to minimize runoff volumes and also to favour a better humification of the organic matter, that could be attained by a rational fertilisation and forest management techniques that maintain soil quality. This is suggested by the fact that C losses by surface runoff are higher under a *P. nigra* forest in some single events, and not under crops.

Acknowledgements

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Screening of tolerant maize genotypes in the low phosphorus field soil

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Abstract
Exploring the genetic resources of crops is an alternative method of coping with reduced phosphorus (P) availability in soils. In this study, 116 maize inbred lines with various genetic backgrounds collected from several Agricultural Universities and Institutes in China were employed in a field experiment to indentify maize genotypes tolerant of low P soil. Overall, 15 maize inbred lines were selected from the field experiment according to the 100-grain weight in P-deficient soil at maturity when compared to the value in plants grown in P-sufficient soil. All of the selected lines were then subjected to a second field experiment to evaluate indexes for assessment of low-P tolerant maize genotypes. Based on the results of the two experiments, adventitious root angle, PO representing decrease rate of the root length, root surface area and root volume were preliminarily defined as the screening indexes of low-P tolerant genotypes in the seedling stage of the field experiment. Additionally, the 100-grain weight and grain P utilization efficiency were found to be suitable for screening indexes of low-P tolerant genotypes during the mature stage in the field experiment.

Key Words
Low-P stress, four quadrant analyses, root morphology.

Introduction
As many other plants, maize is sensitive to P and confronted with the dilemma of "P-deficiency in heredity" (Usuda and Kousuke 1991). In recent years, some researchers have involved in screening and improving the tolerance to P deficiency in maize cultivars (Yao Qi-lun *et al.* 2007; Zhang Jing *et al.* 2004; Yan Liu *et al.* 2004). However, many trails results are based on hydroponics and pot experiments and the selected genotypes have not been validated in the field. Therefore, this research was conducted to screen tolerant maize genotypes in low P soil. To accomplish this, 116 maize inbred lines with various genetic backgrounds collected from several Agricultural Universities and Institutes in China were employed in the field experiment I, which resulted in selection of 15 maize inbred lines that were evaluated in the field experiment II to identify an index system for assessment of low-P tolerant maize genotypes. The results presented here should aid in screening for seminal germplasms tolerant to P-deficiency and apply available materials for breeders.

Materials and methods
Plant materials
116 maize inbred lines with various genetic backgrounds were employed in field experiment I in 2007. Overall, 15 maize inbred lines were selected from the experiment I based on the difference in their 100-grain weight. Specifically, the low P-tolerant genotypes DSY-30, DSY-2, DSY-31, DSY-20, DSY-21, DSY-39, DSY-101, DSY-33, DSY-32, DSY-23 and DSY-93 and the P-sensitive genotypes, DSY-113, DSY-79, DSY-129 and DSY-48 were selected for use in field experiment II in 2008.

Treatments
Field experiment I and II employed a randomized complete block design. Two treatments with different P application levels of 0 and 120 kg P_2O_5/hm^2 corresponded to the treatments of PO and PI; i.e., P-deficiency and P sufficiency. Urea, superphosphate and potassium chloride were supplied with N (225 kg N/hm^2 in total, 1/2 N as basal, the other 1/2 N as top-dressing at bell-mouthed stage), P (as basal application), and K (105 kg K_2O/hm^2 as basal application), respectively.

Measurement
Field experiment I: the 100-grain weight and grain P content of the different maize inbred lines were measured. Field experiment II: In the seedling stage, roots and shoots were determined morphological traits. Then the 100-grain weight and grain P content were determined.
Equations
PO decrease rate (%) = (value analysis of PI - value analysis of PO) / (value analysis of PI) × 100%

Results
Effect of low P stress on the100-grain weight of different maize genotypes in the field experiment I and II
The histogram in Figure1 indicated the PO decrease rate of the 100-grain weight of different maize genotypes. As a whole, through testing (KS test, Z value was 0.928, P value of two-tailed test was 0.356) and confidence, confidence interval, the results met the normal distribution. Selection of maize genotypes tolerant to low P soils indicated that 100-grain weight was increased under low-P stress and the changes rates of PO decrease rate were on the left of -2.5% of confidence, as well as the PO decrease rate were lower than 5%. Low-P sensitive genotypes were selected, when PO decrease rate was higher than 10%.

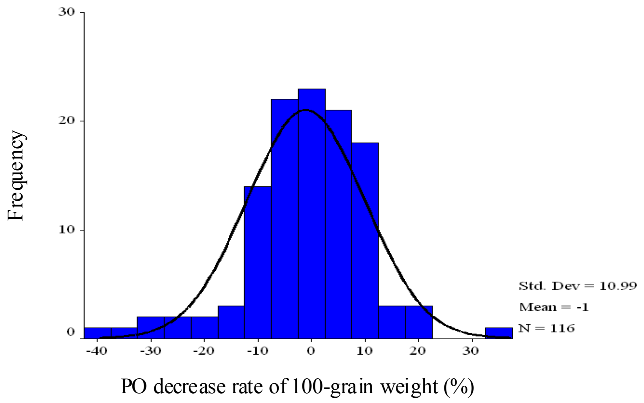

Figure1. Histogram of PO decrease rate of the 100-grain weight of 116 maize inbred lines.
Four quadrant analyses of the 100-grain weight for the selected typical maize genotypes revealed that low-P tolerant maize genotypes were primarily distributed in the first and fourth quadrants in the field experiment I, which indicated efficient genotypes. However, low-P sensitive maize genotypes were mainly distributed in the second and third quadrant, which indicated inefficient genotypes (Figure 2). Based on the PO decrease rate of the 100-grain weight and the four quadrant analyses, the following 15 inbred lines were selected for further analysis: low P-tolerant genotypes, DSY-30, DSY-2, DSY-31, DSY-20, DSY-21, DSY-39, DSY-101, DSY-33, DSY-32, DSY-23 and DSY-93; P-sensitive genotypes, DSY-113, DSY-79, DSY-129 and DSY-48. The same result was obtained in the field experiment II.

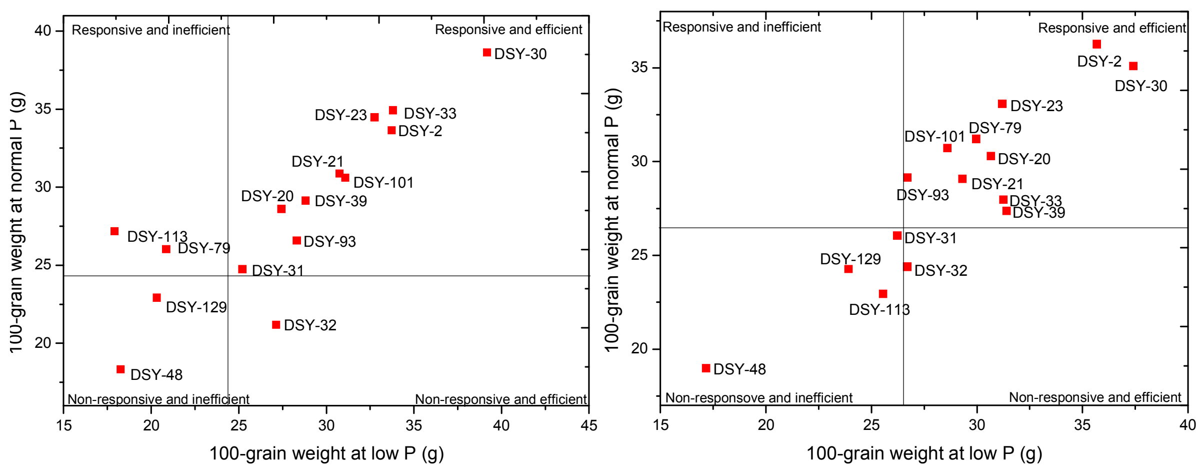

Figure 2. The 100-grain weight of typical inbred lines of maize under PO and PI treatments in field experiment Ⅰ (left) and II (right)

Effect of low P stress on grain P utilization efficiency of different maize genotypes in the field experiment I and II

Grain P utilization efficiency by 15 typical maize genotypes was investigated in field experiments I and II (Figure 3 and Figure 4). There was a significant difference in grain P utilization efficiency between low-P tolerant and sensitive maize genotypes (P<0.05). The Grain P utilization efficiency of low-P tolerant genotypes was higher than that of low-P sensitive genotypes in the field experiment I and II, regardless of whether the plants were grown in P deficient or sufficient soil. The grain P utilization efficiency of P sensitive genotype DSY-48 was lower than that of other genotypes under P deficiency and sufficiency conditions.

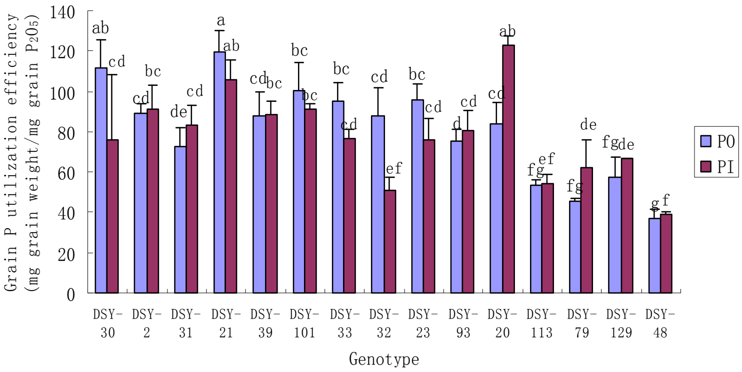

Figure 3. Grain P utilization efficiency under different P treatments in field experiment I .

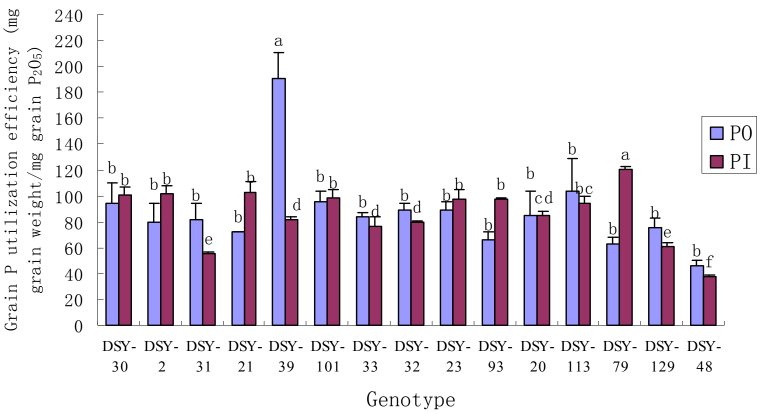

Figure 4. Grain P utilization efficiency under different P treatments in field experiment II.

Effects of low P stress on root indexes of different maize genotypes during the seedling stage in the field experiment II

Root architectural plasticity may be an important factor in the acquisition of immobile nutrients such as P by plants. The results of this study suggested that an adventitious root angle may be correlated with low P adaptation. Adventitious root angles of maize genotypes under PO treatment were smaller than those under PI treatment (Figure 5). Adventitious root of DSY-48 (low-P sensitive genotype) had deepest growth angle, while those of DSY-30; DSY-33 (low-P tolerant genotype) had shallower growth angles than the other genotypes under low P stress. Our results demonstrated that variation for adventitious root angle existed in maize, but that P could modulate root shallowness independently and that a shallower root system was beneficial for plant performance in maize grown under low P conditions.

Root morphological parameters such as PO decrease rate of root length, root surface area and root volume were shown in Table 1. Increased root lengths were observed for maize varieties grown under low-P stress. Specifically, 64% of the genotypes that were tolerant to low P showed increased root lengths under low-P stress, while only 25% of the genotypes that were sensitive to low P showed increased root length under low P treatment. The PO decrease rate of DSY-93 was significantly higher than that of other genotypes. The total root surface area and root volume of low-P tolerant genotypes were higher than those of low-P sensitive genotypes under low P stress, except for DSY-113. These findings indicated that low-P tolerant genotypes could accelerate root growth under low P conditions, resulting in roots exploring more soil space for the uptake of nutrients.

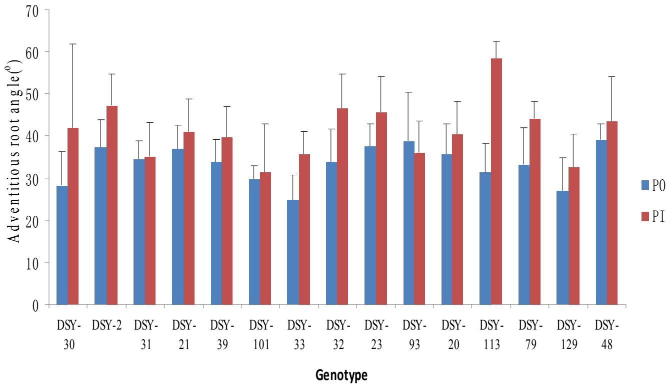

Figure 5. Influence of the P treatment on the adventitious root angle of typical maize genotypes.

Table 1. PO decrease rate of root morphology during the seedling stage in field experiment II.

Genotype	No.	Root length PO decrease rate (%)	Root surface PO decrease rate (%)	Root valume PO decrease rate (%)
P tolerant	DSY-30	-6.91	-16.08	-25.60
	DSY-2	-56.65	-10.11	22.05
	DSY-31	11.01	18.10	25.00
	DSY-21	-17.25	5.48	23.81
	DSY-39	-7.38	8.28	21.24
	DSY-101	-1.11	-5.42	-9.91
	DSY-33	50.25	34.35	13.04
	DSY-32	34.14	40.00	45.03
	DSY-23	11.82	5.32	-1.00
	DSY-93	-127.40	-53.17	-2.97
	DSY-20	-45.45	-47.57	-49.68
P sensitive	DSY-113	-68.90	-56.37	-45.57
	DSY-79	17.60	26.66	34.46
	DSY-129	28.21	22.67	16.67
	DSY-48	2.27	3.31	4.43

Conclusion

This field study clearly demonstrates that species differ in their ability of P to take up from the soil and that these differences were attributed to the morphology and physiology of plants relative to their germplasm base. Based on these results, an effective method of increasing P-efficiency is to develop P-efficient cultivars that can achieve a high yield under P deficient conditions. The results of this study also indicated that soil P availability during maize seedling development is critical for early growth and grain yield of maize. In this study, adventitious root angle, PO decrease rate of the root length, root surface area and root volume were preliminarily defined as the screening indexes for low-P tolerant genotypes during the seedling stage. In addition, the 100-grain weight and grain P utilization efficiency were defined as the screening indexes of low-P tolerant genotypes during the maturing stage in the field.

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Short-term effect of organic materials application on properties of agricultural soils in urban areas, Osaka Prefecture in Japan

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Abstract
Short-term effect of organic materials on soil properties of agricultural lands (paddy and greenhouse) in Osaka Prefecture, around one of the largest cities in Japan, was investigated. In both sites, only a few years application of cow manure compost increased total-C and other plant nutrients, especially Truog-P, suggesting that short term application of organic matter to agricultural fields was significant for C sequestration and soil nutrient accumulation. Effect of organic materials on organic fractions in greenhouse soils is also discussed.

Introduction
It is indispensable to apply organic materials in agricultural practice for sustaining soil quality. To assess the effect of organic materials on soil quality, soil properties under long-term experiments were investigated extensively (Karbozova-Saljnikov *et al.* 2004, Triol-Padre *et al.* 2005, Yan *et al.* 2007). Short term effect of organic materials on soil quality should also be investigated, because most organic materials contains considerable amount of plant nutrient elements, which often lead to high accumulations of nutrients in agricultural soils, and some studies (Tatsumi *et al.* 1985, Biederbeck *et al.* 1998) demonstrated that soil properties on organic fractions were changed in only a few years. The objective of this study is, therefore, to investigate short-term (a few years) effect of organic materials on soil properties in agricultural lands (paddy and greenhouse) in Osaka Prefecture, Japan.

Materials and methods
Climate
The climate of Osaka Prefecture is humid temperate. Mean annual temperature is 16.6 degrees centigrade, and mean annual precipitation is 1194 mm (Sakai city, near the both experiment site 2008). The temperature in summer is very hot; it sometimes exceeds 35 degrees centigrade, probably due to relatively low precipitation in summer and radiation of heat from the city area (heat island).

Paddy
The experiment was conducted in the experiment paddy field of Research Institute of Environment, Agriculture, and Fisheries, Osaka Prefectural Government, Habikino-City, Osaka, Japan. The experiment was carried out since 2005. Soil was classified as Typic Epiaquepts (Soil Survey Staff 1999). Design of the experiment is shown in Table 1. The characteristic of this experiment was that frequencies of application of cow compost manure (CM) are different in each plot (Table 1). Soil samples were collected in March 2009, and soil physico-chemical properties were analyzed. The grain yield and protein content of rice is also investigated in October 2008.

Table 1. Experimental design of paddy field.

Name	Treatment	Frequency of CM application
CF	Chemical fertilizer	None
M1	Chemical fertilizer and CM	Every year
M2	Chemical fertilizer and CM	Every 2 years
M3	Chemical fertilizer and CM	Every 3 years
M5	Chemical fertilizer and CM	Every 6 years

Application rate of CM was 15t/ha.

Greenhouse
The greenhouse site was located in Senshu region (Kumatori town), where the agricultural production was largest in Osaka Prefecture. Soil was classified as Typic Epiaquepts (Soil Survey Staff 1999). From 2003 spring, 3 treatments were used; (1) no organic material (**C**), (2) rice straw (**RS**), and (3) cow manure compost

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

(**CM**)). Main crop was crown daisy (*coronarium*. Syn, *Leucanthemum coronarium*) planted 4-5 times by year, and taro (*Colocasia esculenta Schott*) planted every 2 years. Soil samples were collected in February 2009 before taro was planted. Soil physico-chemical properties and contents of labile organic matter (determined by sequential extraction with 0.5M K_2SO_4 (**SE**), phosphate-buffer (**PB**) and hot-water (**HE**) (Sano *et al.* 2009) and light fraction organic matter (**LF**)) were also analyzed.

Results and discussion

Paddy

Soil data are indicated in Table 2. Due to the CM application, many properties increased, except for pH and exchangeable Mg. Total-C was highest in M1 treatment, lowest in CF. Soil C content in the M1, M2, M3, and M5 treatments increased 68.0%, 38.5%, 24.6%, and 4.9% compared to the control, respectively, suggested that a few years of organic matter application is effective in sequestering C to soil. Every 2 or 3 years application of CM (M2 and M3) also had positive effect of C sequestration, though the amounts of additional C (difference from CF plot) were lower than that of M1. Truog-P, exchangeable K and exchangeable Ca also increased by CM application. Especially, Truog-P in soils of M1, M2, M3 plot were considerably higher than that in CF plot. Since the price of P fertilizer has risen, effective use of soil P would be effective in cutting the cost of fertilizer. The rice grain yield and protein content in the experimental plot are also shown in Table 2. CM application affected grain yield as well as protein content, probably due to an accumulation of soil labile N.

Table 2. Physico-chemical properties of soils and rice properties in experiment field (paddy).

	pH 1:5	Total-C %	Total-N %	Truog-P P_2O_5mg/kg	Ex-K_2O mg/100g	Ex-CaO mg/100g	Ex-MgO mg/100g	Grain yield t/ha	Protein %
CF	6.86	1.22	0.123	29.6	9.5	261	34.4	3.24	5.1
M1	6.72	2.05	0.193	67.7	23.5	313	37.3	3.76	5.6
M2	6.92	1.69	0.173	63.5	17.6	287	36.5	3.73	5.7
M3	6.76	1.52	0.145	51.6	22.4	272	42.3	3.40	5.3
M5	6.77	1.28	0.126	27.2	15.2	223	34.4	2.99	4.9

Ex- K_2O, CaO and MgO mean exchangeable K_2O, CaO and MgO, respectively.
Grain yield was determined using unpolished rice.
Protein content was determined using polished rice.

Greenhouse

The content of total-C, Truog-P, and exchangeable K in soils are shown in Figures 1, 2, and 3, respectively. Total-C content considerably increased in CM relative to the control and slightly increased in RS. CM application also increased the content of phosphorus and potassium content, indicating that reduction of fertilizer use is needed in an agricultural field where CM was applied. Labile C content (PB, HE and LF) are shown in Figures 4, 5, and 6, respectively. CM application slightly increased PB-C and HE-C and considerably increased LF-C. These results suggest that light fraction organic matter contributed to high content of total-C in CM. Management and measurement of light fraction organic matter may be essential to achieve C sequestration in the short-term.

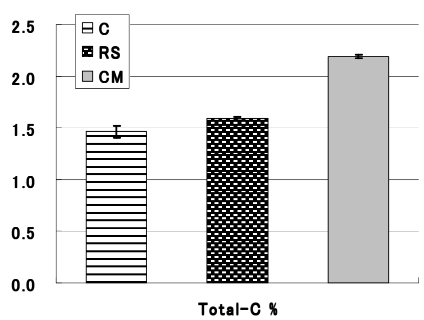

Figure 1. Total-C content.

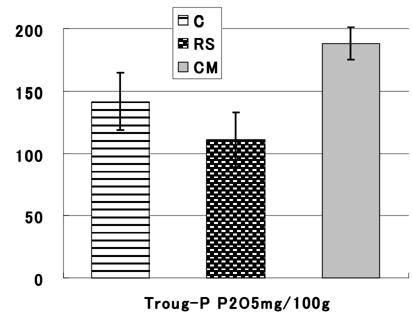

Figure 2. Truog-P content

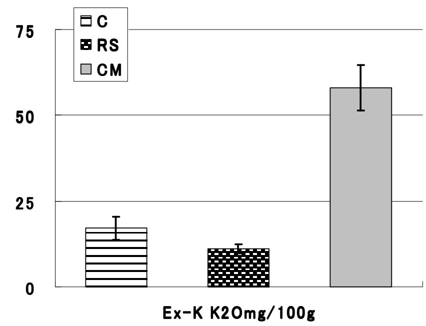

Figure 3. Exchangeable K content.

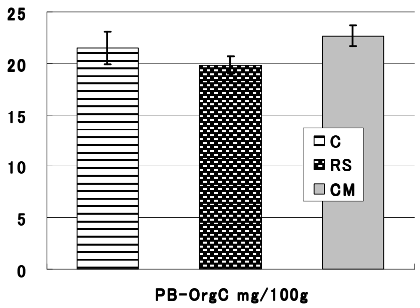

Figure 4. PB-C content.

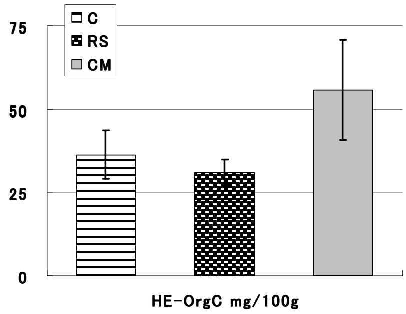

Figure 5. HE-C content.

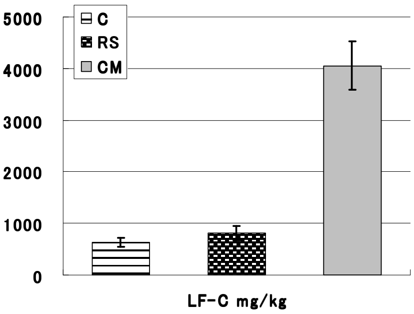

Figure 6. LF-C content.

Conclusion
The short term effect of organic material on agricultural soils (paddy and greenhouse) was examined in Osaka Prefecture, Japan, where temperature sometimes exceeds 30 degrees centigrade in summer. Short term application of organic matter to agricultural fields was significant for C sequestration and other nutrient elements also accumulated; especially, phosphorous which was increased by cow manure application at both sites.

Acknowledgements
We are grateful to farmers of the greenhouse plot for maintenance of the field experiment and supplying soil samples, and staff members of Senshu Office for Agriculture-Forestry Promotion and Nature Conservation, Osaka Prefectural Government for their assistance in the field survey. We also thank staff members of our institute involved in the maintenance of the field experiment paddy plot. This study was conducted as the MAFF (Ministry of Agriculture, Forestry and Fisheries of Japan) project "Monitoring and demonstrating technologies to reduce GHG emission from farmland".

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Soil carbon stocks in Southwest Goiás, Brazilian Cerrado: land use impact and spatial distribution

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Abstract
Soil Organic Matter (SOM) conservation is essential for environmental services maintenance, mainly in the tropics, where this component is essential for soil fertility, structure and biological activity. Although the Brazilian Cerrados presents the largest area available for cultivation and livestock production, contrasting findings have been reported on the impact of land use on soil carbon stocks and dynamics. This work aimed at evaluating how the prevailing land use types impact Cerrado soil carbon stocks and at presenting the spatial variability of this attribute in great part of Southwest Goiás, Brazil. The mean estimated soil carbon stock values obtained from land under agricultural use indicated that, although some cultivated areas showed higher C stocks than native vegetation, in general, conversion to agriculture, under the major management practices in use in Southwest Goiás, result in partial loss of the original soil carbon stocks. On average the Eucalyptus and pasture areas are those with lowest carbon emission potential to the atmosphere. Most of the soil carbon is stored under the native vegetation. Considering the fact that it occupies only 1/3 of the mapped region, policy makers should direct efforts to the conservation of these fragments, their vulnerability, and to their potential as greenhouse gas emitters if converted to agriculture, without soil management practices that lead to conservation. Greater effort is needed to generate a larger spatially explicit dataset, expanding the existing knowledge on carbon dynamics under different crops and soil management scenarios.

Key Words
Remote sensing, mapping, soil organic matter; land use and land cover.

Introduction
Soil Organic Matter (SOM) conservation is essential for environmental services maintenance, mainly in the tropics, where this component is essential for soil fertility (source of nutrients and providing most of its cationic exchange capacity), structure and biological activity. Despite Brazil being the largest contributor to Greenhouse Gas (GHG) emission derived from land use changes and deforestation, the emission reduction potential of the agricultural sector is significant and not yet sufficiently explored. Agroforestry systems, reduced tillage, fertilizer management, mixing or rotating crops with nitrogen fixing species, and improved feeding strategies for livestocks, can help in mitigating nitrous oxide, carbon dioxide, and methane emissions (Sisti *et al.* 2004; Silva *et al.* 2004, Bayer *et al.* 2006). These issues were addressed by the agenda of the 15th Conference of Parties on the UN Framework Conservation on Climate Change negotiations, in Copenhagen in December 2009 (Nelson 2009).

According to Nelson (2009) several countries have reduced their funding for national statistical programs and some tools like remote sensing systems are still inadequate to the task of monitoring global change in a workable scale. Therefore, any effort directed to data collection related to land use and its effects at the local scale, and dissemination of this information in a spatially explicit framework should be encouraged. Geographic Information Systems (GIS) and other geotechnologies could be used to support the decision makers (Burrough and McDonnel 1998). Although the Brazilian Cerrados extend throughout more than 200 million hectares (Goedert 1980), and presents the largest area available for cultivation and livestock production, contrasting findings have been reported on the impact of land use on soil carbon stocks and dynamics. This high variability could be related to different management practices applied to the soil combined with the spatial heterogeneity of the land use pattern, as well as local and regional edaphoclimatic conditions. Sano *et al.* (2008) reported that 80 million hectares of the biome Cerrado are under different uses, which correspond to 39.5% of total area. The most representative land use types reported in this work were cultivated pasture and agricultural crops, occupying 26.5 and 10.5% of the Cerrado, respectively. A higher dynamics could be observed in its southern portion and most of the natural vegetation is located in its northern region. As data on the spatial distribution of C stocks in these "hotspots" areas are scarce, this work aimed at evaluating how the prevailing land use types impact Cerrado soil carbon stocks and at presenting the spatial variability of this attribute in great part of Southwest Goiás, Brazil.

Methods

Description of the study area

The case study area includes six municipalities (Rio Verde, Montividiu, Santa Helena de Goiás, Santo Antônio da Barra e Acreúna) of Southwest Goiás State (SW). This area comprises 1.63 million ha inserted in the central part of the Cerrado biome (Brazilian Savanna). It is located between geographic coordinates 14º09'S, 19º27'S and 48º31'W, 53º12'W. This area was selected because it is one of the most productive agricultural areas of Brazil, mainly for the production of grain crops. The climate of this region is humid tropical, typical of savanna regions, with a strong dry season from May to September. The mean annual rainfall is approximately 1,600 mm, the mean annual temperature is 21.3 ^{o}C and the mean temperatures in the warmest and coolest months are 27.6 ^{o}C and 16.2 ^{o}C, respectively. The annual mean relative humidity is approximately 71%. According to the Brasil (1981) database, the predominant soil orders in this region are Oxisols ("Latossolos Vermelhos") and Quartzipsamments ("Neossolos quartzarênicos", (Embrapa 1999). The natural vegetation includes different vegetation physiognomies like open Cerrado (dominated by grasses) and Cerrado *stricto sensus* (with an expressive arboreal component).

Soil sampling and analysis

Sixty nine sites under different land uses (14 sites under agriculture, 15 under pasture, 25 under silviculture, and 15 under natural vegetation - Cerrado) were sampled in the study area. Under each site, soil samples were collected from three pits in a virtual square of ~50 x 50 m. Samples for chemical and physical analyses were collected from depths of 0-5, 5-10, 10-20 and 20-40 cm and from each depth a pooled sample was prepared. All soil samples were air dried and sieved through a 2 mm mesh to remove stones and root fragments, before analyses. In the same pits and for the same depths, soil bulk density was determined by use of a steel ring with a known volume (Kopecky rings). Soil organic carbon (SOC) content (oxidisable carbon) was analysed according to Walkey (1954) in the Department of Soil Science of Rio Verde University (FESURV) at Goiás State. Soil particle size measurements, comprising sand (2.00-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002 mm) were estimated by the hydrometer method using Na-hexametaphosphate as a chemical dispersant, as described by Embrapa (1997).

Soil C stocks calculation

The total soil C stock was estimated as the total C concentration multiplied by the weight of soil present in samples from 0 to 40 cm depth, under each system. Several studies reported differences in soil bulk densities under agricultural and natural vegetation, suggesting that a correction factor should be applied to the calculations considering a reference value for the soil mass present in the target soil depth. This was not applied in this case because of the large distances between sampled sites, which could result in errors in the estimation of land use effects on soil carbon stocks, per unit area. The mean bulk density values for the different land use types showed an increase of 16.4%, 5.7% and 4.2% in soils under pasture, agriculture and silvicultural systems, in comparison with those under natural vegetation. To calculate the potential of soil C sequestration or emission by specific land uses it is needed to take the soil C stock values under the natural vegetations as baseline data. The significance ($p<0.05$) of land use effects on organic C stocks was obtained using the Student t-test.

Soil C stocks mapping considering land use

Initially, the land use map of the study area was obtained by processing Landsat 5 satellite images (30 m resolution). These images were georreferenced using a cartographic base at a scale of 1:250,000, available in SIEG (2008). Image processing was done using the SPRING software, version 4.3.3, applying the segmentation tool (thresholds: similarity, 13; area, 70) followed by supervised classification. In the classification step, the Bhattacharya Distance algorithm was applied to allocate areas to one of four land use classes: natural vegetation, silviculture, pasture and agriculture. Algorithm training was done using ground truth data collected from 70 field spots. The mapping units were the polygons obtained from the land use map. The sum of the soil C stocks values, from 0 to 40 cm depths, was associated to each land use type, using ARCGIS 9.3 tools (ESRI). The mean value was used for mapping and interpretation. The land use class “agriculture” included mainly soybeans, sugar cane and cotton crops. The class “Other uses” was created, related to urban areas and areas covered by shadows and clouds. This step allowed the calculation of the total C stocks associated with each land use type present in the study area, using ARCGIS 9.3 tools.

Results

Soil carbon content

Agricultural land use, in average, reduces the soil C concentration in relation to native vegetation (NV). Soil organic carbon contents (SOC) under NV were 15.4 ± 2.2 g/kg (means ± *SE*) and under eucalyptus, agriculture and pastures were, respectively, 13.2 ± 1.1, 12.6 ± 2.5 and 8.7 ± 1.1 g/kg in the 0-5 cm layer; showing the same trend in deeper layers. Our results should be analyzed with concern because these values represent the arithmetic means. In fact, some sites were characterized by a trend to an enhanced C sequestration activity, in other words, the C stocks in these areas were higher than NV. On other hand, while several authors observed an increase in soil organic carbon content, stocks and fertility of soil Cerrados, under different land uses, we observed a reduction tendency on SOC under agri- and silvicultural uses.

Effect of land use on soil C stocks

In despite of a large variability in soil C stocks data obtained from each of the other land uses sampled, the results are consistent with several studies because they suggest that soil management could influence markedly on soil C stocks. For NV, soil C stocks (0-40 cm) ranged from 11.75 to 83.28 Mg/ha, with the average (± *SE*) value about 48.36 ± 5.31 Mg /ha. The mean soil C stock values obtained from soils under eucalyptus, pasture and agriculture were 42.22 ± 3.74, 37.8 ± 2.67 and 36.04 ± 6.32 Mg/ha, respectively. Using the mean value and the NV as a reference or baseline, these results show that land use stimulated degradation of both old and recently fixed soil C, suggesting that conservation agriculture practices were not generally adopted in Southwest Goiás and need to be improved, to reduce C emissions and stabilize the C sequestered.

Soil C stocks map

Pastures and agricultural areas prevail in the mapped region, occupying 13.3 and 57.5%, respectively, of the total area (Figure 1). Even though, the native vegetation represents approximately 28.1% of the area. It is very much fragmented, present in both pasture (Paraúna Municipality and part of Rio Verde Municipality) and agricultural (Acreúna, Montividiu, Santa Helena de Goiás, Santo Antônio da Barra and the southwest of Rio Verde Municipality) landscapes. This represents a threat to biodiversity conservation and indicates a condition of vulnerability of the ecosystems that should be investigated. Total soil carbon stocks in the studied area was estimated in 69,830.24 Mg. Distribution of the total soil C stock value through the land use classes is: 22.029,43 Mg for native vegetation, 39,438.64 Mg for agriculture, 8,149.55 Mg for pasture and 212.62 Mg for silviculture.

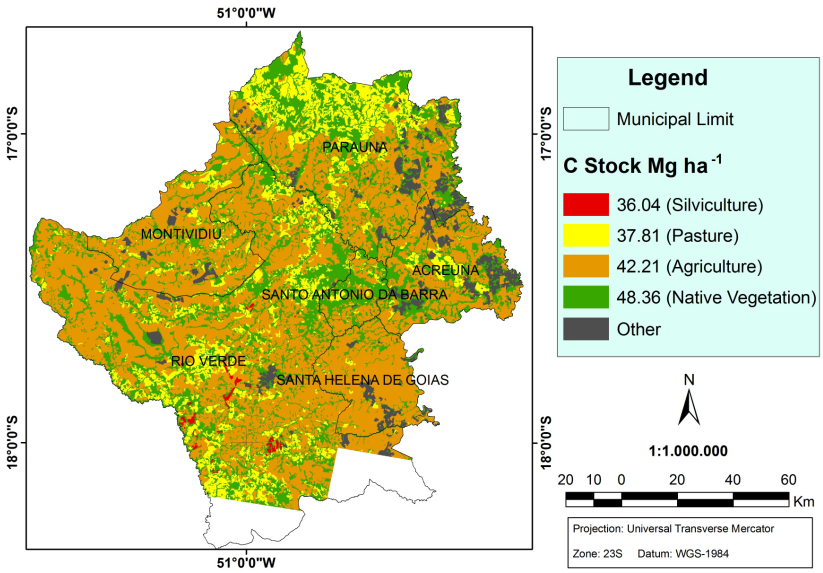

Figure 1. Soil carbon stocks (Mg /ha) map by land use classes.

Conclusions

(i) Most areas sampled under agriculture use showed a reduced level of conservation of soil carbon stocks, when compared with natural vegetation areas. Those occupied by Eucalyptus and pasture (and five sites under agricultural use) showed the lowest potential of soil carbon loss to the atmosphere;

(ii) Most of the soil carbon is stored under the native vegetation. Considering the fact that it occupies only 1/3 of the mapped region, policy makers should direct efforts to the conservation of these fragments, considering their vulnerability, and their potential as greenhouse gas emitters if converted to agricultural land use under conventional soil management strategies;

(iii) The results reveal trends of soil carbon stocks status under different land uses that could aid in the description of future scenarios, and in the proposal of novel agricultural management techniques, such as integrated crop-livestock-forestry systems, aiming to enhance carbon conservation and sequestration to the soils. Greater effort is needed to generate a larger spatially explicit dataset, expanding the existing knowledge on carbon dynamics under different crops and soil management scenarios.

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Soil carbon stocks under improved tropical pasture and silvopastoral systems in Colombian Amazonia

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Abstract
Soil carbon stocks of primary forest, degraded pasture, and four improved pasture systems in Colombian Amazonia were compared in a flat and a sloping landscape. The improved grasslands were *Brachiaria humidicola*, and *B. decumbens*, both in monoculture and in combination with a legume (*Arachis pintoi*). The age of the treatments was 30 years for degraded pasture and 10 or 15 years for each of the improved pastures. Carbon fractions were Total C, Oxidizable C, and Stable C. Stocks were compared using a fixed soil mass base. Although forest soils reputedly have the highest C stocks, this is not necessarily true if the forest is on poorly drained soil. The degraded pasture in the flat landscape was abandoned and dominated by weeds, while that in the sloping area was overgrazed. The latter has much lower C stocks than the former. *B. humidicola* monoculture had the highest stocks in both areas, while the effect of the other three treatments varied. The effect of improved pastures, although they tend to increase soil C stocks, depends strongly on both soil and management practices.

Key Words
Soil carbon, land use, Amazonia.

Introduction
Since the studies by Lugo and Brown (1993) and Fisher *et al.* (1994) it has been recognized that soils of well-managed tropical pasture systems may contain amounts of soil organic carbon (SOC) equal or even superior to those under native tropical forest. To understand the major cycles that influence soil organic matter under cleared lands is vital for predicting the consequences of continued conversion of tropical forest to cattle pastures and agriculture (Cerri *et al.* 2007) and for devising management technologies that enhance the sustainability of these areas slowing down further deforestation. This work presents differences in soil carbon stocks related to changes in land use.

Materials and methods
Field experiments were carried out on three farms in the Amazonian humid tropical forest, both on flat and mildly sloping topography, at 800 m.a.s.l., 1.8^{o} N, 75.7^{o} W, with an annual precipitation of 3500-4000 mm. Soils of the region are acid (pH<5) and have low phosphorus content and high aluminum saturation. The soils of the flat areas are Haplic Acrisols, while those in the mild slope areas are Haplic Ferralsols.

Blocks of different land uses were chosen at experimental farms where the history of land use had been documented. These were La Guajira and Santo Domingo for the flat area, and Los Balcanes and Pekin for the sloping landscape. The different land uses were Natural Forest, degraded pasture, and four improved pastures, i.e., *Brachiaria humidicola* in monoculture; *Brachiaria decumbens* in monoculture; *Brachiaria humidicola* + legume; *Brachiaria decumbens* + legume. The improved pastures were all established in previously degraded pasture. The age of the various systems was different. Within each topography, there were three replications in each land use and four soil sampling depths (0-10; 10-20; 20-40, and 40-100 cm). Litter was also sampled in triplicate.

Carbon determinations were carried out in the Analytical Services Laboratory at CIAT (Centro Internacional de Agricultura Tropical) Cali, Colombia. Oxidizable Carbon was determined spectrometrically according to Walkey-Black modified by Kurmies (Temminghof *et al.* 2000). Total Carbon was also determined spectrometrically but after a digestion time of two hours at 120 degrees. For a valid comparison of C stocks between land uses, the calculations were based on fixed soils mass (Ellert *et al.* 2002; Amezquita *et al.* 2008), and not on fixed soil depth. The results are given in t/ha.m/equiv (m-equiv is the soil mass of the

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profile that had the lowest mass to 1 m depth). Data were statistically analysed by SPSS 11.5. An Anova was done to determine statistical differences between treatments.

Results and discussion

Separate calculations were made for total, oxidizable, and stable C. Stocks of Stable C are obtained by subtracting stocks of Oxidizable C from those of Total C. In both areas there are wide differences between stocks under the various treatments. In the flat area, stocks range from 104 to 137 and in the sloping area from 94 to 152 t/ha/meq (Table 1). In the flat topography, the degraded pastures belong to the group with the highest C stocks, while it belongs to the lower group in the sloping area. This is mainly due to the fact that 'degraded pasture' is a varying concept. In the flat area, it denotes a pasture that is largely colonized by shrubs, while in the sloping area it is still dominated by grasses and over grazed.

Table 1. Soil carbon stocks (t/ha) of 1m equivalent depth under various land covers. Recalculated from Amezquita *et al.* (2008) omitting bad data and with new measurements of C content in degraded pasture samples.

	Total C stocks		Oxid C stocks		Stable C stocks		
	Mean	SD	Mean	SD	Mean	SD	*N*
FLAT Forest	104.0 ^{d}	12.6	55.0 ^{c}	10.9	49.0 ^{d}	6.5	27
Br. humidicola	137.2 ^{a}	10.5	73.5 ^{a}	10.4	63.6 ^{a}	5.7	27
Br. decumbens	114.2 ^{c}	10.0	55.1 ^{c}	9.2	59.1 ^{b}	5.3	9
Br. Hum+Leg.	131.1 ^{a}	12.8	76.1 ^{a}	9.8	55.0 ^{c}	5.2	27
Br. dec+Leg.	121.6 ^{b}	8.7	64.5 ^{b}	7.9	57.0 ^{bc}	2.8	25
Deg. Pasture	132.5 ^{a}	9.3	76.8 ^{a}	16.0	55.7 ^{bc}	13.3	15
SLOPE Forest	151.5 ^{a}	23.8	74.4 ^{a}	19.6	64.6 ^{b}	8.6	8
Br. humidicola	141.1 ^{a}	10.9	72.0 ^{a}	9.1	58.0 ^{c}	7.7	9
Br. decumbens	102.0 ^{b}	12.0	61.5 ^{bc}	11.4	40.4 ^{d}	5.2	9
Br. Hum+Leg.	93.9 ^{b}	9.5	56.1 ^{c}	5.4	37.8 ^{d}	7.9	9
Br. dec+Leg.	153.4 ^{a}	7.5	80.2 ^{a}	9.0	73.2 ^{a}	4.9	9
Deg. Pasture	103.8 ^{b}	18.5	60.7 ^{bc}	15.2	43.1 ^{d}	15.2	12

*Different letters denote statistically significant differences between land uses ($p<0.05$) within one topography.

In the flat landscape, the primary forest had the lowest total Carbon stocks, while the degraded pasture and both improvements with *B.humidicola* had the highest. As long as the soils are not permanently water-logged, poorly drained soils may have lower C contents than better drained ones close by, as also found for grassland soils invaded by shrubs in the US (Albrecht and Kandji**.** 2003). In the sloping area, highest stocks were found under forest, *B.decumbens*+legumes and *B.humidicola* in monoculture. Stocks under both *B.decumbens* monoculture and *B.humidicola*+legumes attained only 2/3 of those of the former group and were not different from those under the degraded pasture. Stable carbon stocks are between 42 and 52 % of total stocks in the flat area and between 40 and 48% in the sloping area. The level of the stable stocks therefore increases with the total stocks.

There seems not to be a clear tendency on the stocks when comparing landscapes. In flat areas the *Brachiaria humidicola* treatments showed the highest Total C content and were different from the other treatments. The Forest treatment showed the lowest content. In sloping areas however, Forest showed the highest total C content and *B. humidicola*+legumes and *B. decumbens*, the lowest. As far as the stable C contents, in flat landscape Brachiaria humidicola showed the highest contents and Forest the lowest but in the sloping landscape Degraded pastured and *B. humidicola* +Legumes showed the lowest and Forest and *B. decumbens*+legumes the highest.

Comparing the total C stocks of the improved pastures with those of the Degraded Pasture, it is encouraging to find that in sloping areas Brachiaria humidicola and Brachiaria decumbens+legumes, show increases of 40 to 50 t/ha. This difference was obtained in (less than) 15 years. In flat areas, improved pastures did not increase C stocks when compared with degraded pasture.

In general, decreases of soil carbon stocks occur when forests are converted to other land uses, but there are contrasting reports on the effects of forest to pasture conversion. Powers and Veldkamp (2005) found that mean values of soil C storage were similar in primary forest (80.5 Mg C ha^{-1}) and pasture (76.7 Mg C ha^{-1}) across a large region in Costa Rica (1400 km^2), though variation was high within the region and best explained by topographic features and soil mineralogy. Whether pasture soils are a net sink or a net source of carbon depends on their management, but an approximation of the fraction of pastures under 'typical' and ‘ideal' management practices indicates that pasture soils in Brazilian Amazonia are a net carbon source, with an average release of 12.0 t C/ha. (Fearnside and Barbosa, 1998). However, a study of the 0–30 cm layer in soils in Rondônia, Brazil by Moraes, cited by Fearnside and Barbosa**,** 1998, indicated that, over the long term, there is an increase in the stock of soil carbon in well-managed pasture as compared to nearby primary forest. In a soil under very well-managed pasture at an agricultural station near Manaus, carbon in the top 20 cm returned to approximately the level of the original forest, eight years after clearing (90 t C/ha under forest vs. 96 t C/ha under pasture, without correction for soil compaction), following a decline by 21.4% reached two years after clearing. Trumbore *et al.* (1995) compared C budgets for forest and pastures in the eastern Amazon. In a rehabilitated and fertilized pasture of *Brachiaria brizantha*, they estimated gains, relative to forest soil C stocks, of over 20 Mg soil C/ha in the top 1 m of soil and a loss of about 0.5 Mg C/ha in the 1–8 m soil depth interval during the first 5 years following pasture rehabilitation. These contrasting patterns are suggestive of variable soil C dynamics following land use change and/or the partitioning of soil C between active and passive pools across soil types and ecosystems.

In our case, *Brachiaria humidicola* monoculture had highest stocks in both topographies. *B. decumbens* did not perform well in the flat area, but in combination with legumes, it had stocks as high as that under forest in the sloping area. In the sloping area, *B. humidicola* and *B decumbens*+legume showed an increase of 37 and 50 t/ha C with respect to the degraded pasture.

Conclusions

Although improved pastures tend to have carbon stocks that are superior to those in degraded pastures, the differences are sometimes obscured by variation in the concept of *degraded pasture*. If pastures are overgrazed, they tend to have the lowest carbon stocks, but if they are abandoned or undergrazed, weeds tend to establish and carbon stocks can go up considerably.

Of the four improved systems investigated here (*Brachiaria humidicola* and *B. decumbens* in monoculture and in combination with the legume *Arachis*), only the *B. humidicola* monoculture increased C contents and stocks both in the flat and the sloping landscape. The other combinations had varying success, but the variation is partly due to different time from establishment and different management.

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Soil erosion modeling in terraced landscapes-examples from the Three-Gorges-Area, China

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Abstract

The construction and impoundment of the Three-Gorges-Dam in China fosters an extremely high land-use dynamic. Soil erosion is expected to increase dramatically. In the mountainous landscape farming is mainly practiced on terraced land. Thus, the conceptual *TerraCE* model (Terrace-Condition-Erosion) was developed to assess the spatial variability of terrace condition and the resulting soil erosion risk potential. Our investigations in the Xiangxi catchment confirm the model assumptions. The conditions of terraces were found as a key factor to determine soil erosion. They can be classified in 4 clusters, (a) well maintained (20 %), (b) badly maintained (48%), (c) partially collapsed (15%), and (d) completely collapsed (6%). Further, our investigations show that the distance to the inundated area and to the road network are significant covariates to predict the spatial distribution of soil erosion risk. The mean distances to the new shoreline vary between 614 m (well maintained) and 128 m (completely collapsed). The mean distances to the main roads are 588 m and 148 m respectively. A first spatial prediction of the terrace condition of the *TerraCE* model combined with a random forests multi-regression approach show promising results with a spatial accuracy of 70%.

Key Words

Soil erosion, *TerraCE* model, terrace design, quality of terrace maintenance, conceptual model, bench terraces, risk assessment, Three-Georges-Dam, Yangtze river.

Introduction

Soil erosion is worldwide a severe problem and its control a major future challenge (Brady and Weil, 2008). In China, the Yangtze catchment shows the highest rates of soil erosion by water of the whole country (Zhou 2008). 33 % (560.000 sqkm) of the catchment area, an area as large as middle Europe, is affected, mostly concentrated on the upper and middle Yangtze river. The world's largest dam project, the Three-Gorges-Dam (TGD) is widely expected to foster soil erosion in an unforeseeable dimension. Due to the river impoundment, large areas became inundated. One consequence is the near and distant resettlement of several million people (McDonald *et al.* 2008; Tan *et al.* 2003; Tan *et al.* 2005). This triggers road construction to improve infrastructure and new land reclamation for smallholder agriculture and cash crop production. Typical natural settings of the scenic Three-Gorges-Area are very steep slopes with shallow soils on various kinds of parent material. Food production takes place on newly build bench terraces as well as on reactivated formerly abandoned terraces. Assuming that the terraces present an equilibrium of geomorphic settings and anthropogenic use (c.f. Brancucci and Paliaga 2006), they are a fairly and sound basis for economic growth and an important engineering tool for water and soil conservation in mountainous areas (Cao *et al.* 2007). However, inadequate construction and mismanagement can lead to a dramatic increase of soil erosion in such areas like the Three-Gorges-Dam in China (Brancucci and Paliaga 2006; Inbar and Llerena 2000; Lesschen *et al.* 2008; Sang-Arun *et al.* 2005). In our study, we try to develop a conceptual model that explains the spatial distribution and quality of bench terraces in the Three-Gorges-Area. The model allows us to understand and to spatially extrapolate the distribution of the quality of terraces in terms of their ability to protect against soil erosion based on data mining techniques. Further, the erosion risk of large catchments can be assessed easily with a high spatial accuracy and resolution.

Materials and methods

Study area

The research area covers the Xiangxi catchment (3,200 sqkm) located in Hubei Province, Central China. The Xiangxi originates in the Shennongjia Forest region (about 3,000 m asl) and reaches the Yangtze river almost 40 km westward of the TGD as a first class tributary. 73 % of the catchment area has slopes with inclinations above 20° (mean slope angle 39°, standard deviation 22.8°). The soils (Luvisols, Alisols, Cambisols, Regosols, Leptisols, Fluvisols and Gleyisols) are closely linked to the subtropical monsoon climate with an annual precipitation of 1,000 mm mainly from June to September, and an annual average temperature of 16.9 °C (1961-1990). Land-use is characterized by subsistence farming mixed with cash crop production, typically on terraced farmland with contour cultivation. Crops are oranges, rice, rape, wheat, maize and garden fruits. Due to the TGD project the impoundment of the Xiangxi river reaches from the outlet approx. 25 km northwards to the central catchment. In this backwater area (500 sqkm), resettlement, land use change, road construction, landslides and soil erosion are common features that result in a highly dynamic ecosystem.

Data and Covariates to parameterize TerraCE
In the Xiangxi catchment data are rarely available and access to terrain is limited. This is a typical feature of such mountainous areas, especially in developing countries. Thus, a data-integrative approach is used to apply the conceptual *TerraCE* model (Schönbrodt *et al.* 2009a). Available data (Fig. 1) are the digital elevation model (DEM) based on SRTM Data Version 4 (Jarvis *et al.* 2008) resampled to a resolution of 45 m, a SPOT image (September 2007) in 5 m resolution, and data on terrace conditions, design and soil erosion features from field investigations.

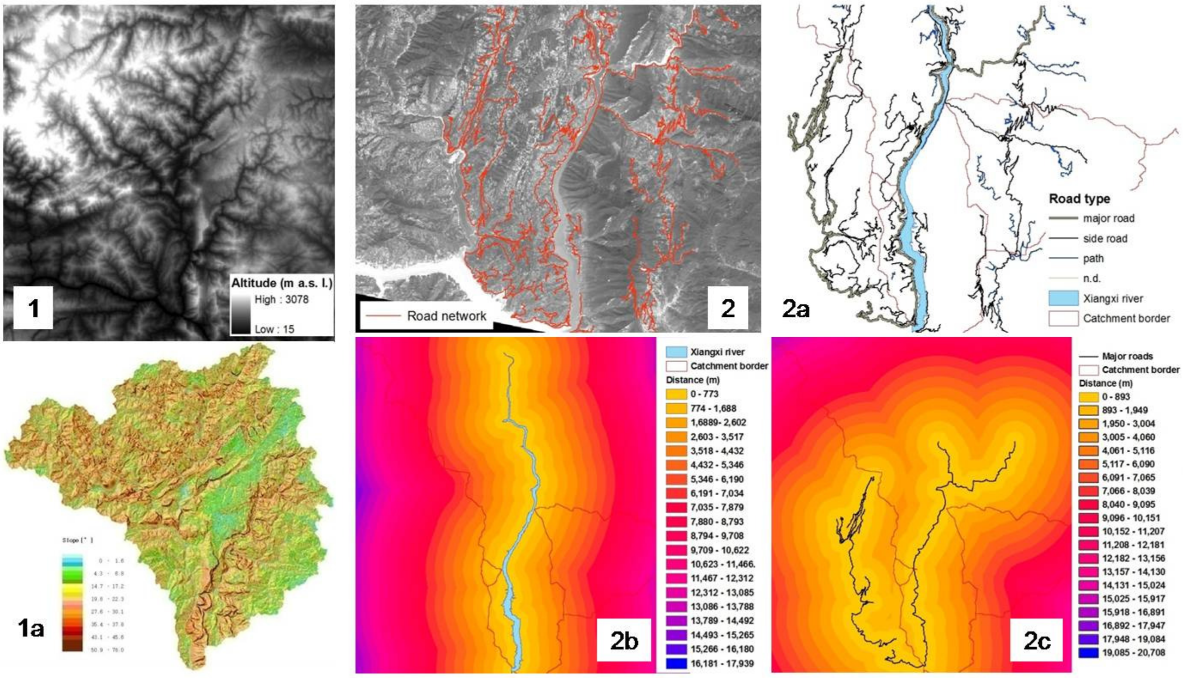

Figure 1. The derivation of covariates for the *TerraCE* model based on the Digital Elevation Model and the SPOT image. (1) DEM of the Xiangxi catchment, and (1a). the slope angle. (2) The SPOT image (5 m), (2a) the road network and new Xiangxi shoreline digitized from the SPOT image with (2b) the euclidian distance (m) from the Xiangxi, and (2c) the main roads.

The DEM-based parameters such as slope angle, curvature, and exposition refer to the relief-based terrace design. More than 50 parameters were tested. Based on the SPOT image the new shoreline of the Xiangxi after impoundment by the TGD, and the road network were digitized. In a detailed inventory of terrace condition information on the type, frequency and intensity of terrace wall disorders referring to the quality of terrace-maintenance and on the physical infrastructure of terraces (e.g. land slope, terrace slope, height of terrace wall, terrace interval) were taken. Furthermore, an inventory on the type of recent soil erosion forms, its intensity as well as the properties of topsoil and land-use was conducted on randomly chosen plots and tested using a random forest approach. In total, 80 terraces have been assessed in detail and 593 farmland units have been mapped using a simplified documentation scheme along the Xiangxi shoreline.

Results and discussion

As explained above, terraces are common agricultural practice in the Three-Gorges-Area. Preliminary erosion surveys in the Xiangxi catchment close to the TGD (Schönbrodt *et al.* 2009b) have shown a strong connection between the condition of terraces and the occurrence and intensity of soil erosion. Terraces with wall disorders such as failures and a technically poor adapted design show higher soil loss and runoff than well adapted terraces. Another key factor is the quality of maintenance dependent on the human influence. These factors build the framework of the conceptual Terrace-Condition-Erosion model *TerraCE* (Schönbrodt *et al.* 2009b). The model is based on the assumption that the erosion frequency and intensity in terraced landscapes depend on the condition of the terraces. The later is explained as a function of (a) the relief-based terrace design and (b) the quality of maintenance depending on the human influence. The distances of a terrace to settlements and roads reflect the farmer's motivation to maintain the terraces well whereas the immediate inundate area is seen to be attractive for rapid land reclamation for cash crop production because of easy access.

Four distinct categories were found that describe the quality of terrace-maintenance: well maintained (20 %), badly maintained (48 %), partially collapsed (15 %), and completely collapsed (6 %). Typically, the worse the condition of walls with an increasing number and intensity of wall failures the worse the quality of terrace-maintenance. While well maintained terraced still show a good and effective structure, the original structure of completely collapsed terraces got lost and the erosive slope length and thus soil erosion risk is increased.

7 % of the farmland was not terraced, although located on steep slopes, and considered as a new class. The mean distance of well and badly maintained terraced from the new Xiangxi shoreline is 614 m (SD 318 m) and 474 m (SD 292 m). Partially and completely collapsed terraces show in average a distance of 209 m (SD 292 m) and 128 m (SD 82 m) to the Xiangxi. Regarding the main roads, the quality of terrace maintenance also increases with increasing distance. The mean distances from the main roads to the well and badly maintained terraces are 588 m (SD 396 m) and 720 m (SD 526 m) respectively. For the partially collapsed and completely collapsed terraces the mean distances to the main roads are 298 m (SD 354 m) and 148 m (SD 217 m). Assuming the backwater area as potentially completely terraced, the terrace condition was modeled using spatial prediction with an overall accuracy of 70 %.

Conclusions

Terraces are typical erosion control measures in the Xiangxi catchment however they strongly differ in their condition. The condition of terraces is regarded as a striking erosion factor and defined by the design of terraces and the quality of maintenance. Four categories of terrace maintenance are identified: well maintained, badly maintained, partially collapsed, completely collapsed. The closer the terraces to the new Xiangxi shoreline and to the main road network, the worse the terrace condition with a higher frequency and intensity of wall disorders. It is concluded that a fast access to potential farming land via main transportation routes within the immediate and highly dynamic inundated area is regarded as reason for the degradation of terraces. Moreover, the seasonal, artificial water level fluctuation of 30 m per year is also regarded to destroy the terrace structure and thus to increase the soil erosion risk potential. Terraced farmland that is more distant from the immediate reservoir area characterized by construction of new infrastructure seems to be less attractive for new land reclamation for cash crops and therefore less influenced by the high land-use dynamic. A first prediction of the terrace condition in the backwater area shows good results (overall accuracy 70%). First results of the *TerraCE* model indicate that in a strongly human influenced area such as the Xiangxi catchment the spatial effectiveness of terraces to protect soil against erosion seems vary with the condition of terraces resulting from an intensification of agriculture.

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Soil fertility and land suitability assessment of the different abaca growing areas in Leyte, Philippines

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Abstract

This study was conducted to assess the soil fertility status and land suitability of the different abaca growing areas of Leyte. Brief description of the sampling areas, agro-climatic data, and topographic parameters were recorded. Soil samples were collected and analyzed for the different soil fertility indicators. Soil pH, Available P, Exchangeable K, Exchangeable Ca, Extractable Cu, Extractable Zn and Extractable Fe were considered as MSFI for the different abaca-based production systems. Good relationships were observed in Avail. P (exponential), Exch. K (sigmoidal), Soil pH (quadratic), Ca, Fe, Cu (Gaussian) and Zn (logistic) that follows different patterns with respect to the biomass production of abaca. Samples collected at the mid-eastern portion of the island registered the highest SFI value of 8.05. FCC analysis suggests that more than three-fourths (i.e. 80%) of the sampling areas have Sandy soils while the modifiers revealed that acidity("h") is one of the major constraints for abaca production. Land suitability assessment of the sampling areas revealed that highly suitable (S_1) areas for abaca production are those found in north-western and mid-eastern portion of the island. There were areas identified as moderately suitable (S_2) for abaca production distributed throughout the province. Field fertilizer experiment in soils with some limitations (Paleudalf soil) revealed that fertilization significantly affected the growth performance and biomass production of abaca. N, P_2O_5 and K_2O application significantly influence the growth and biomass production of abaca.

Key Words

Soil fertility, land suitability, soil fertility index (SFI), soil fertility capability classification (FCC), abaca.

Introduction

Abaca is considered as one of the pillars among the export commodities of the Philippines from raw fiber, handicrafts, pulp and paper, and other related products. Aside from the raw fiber, manufactures is one of the important abaca-based products of which the Philippines is the sole exporter and has the edge over other producing countries. Likewise, the growing concerns for environmental protection and forest conservation of the whole world have further provided limitless opportunities to abaca-based raw materials. The country had been producing the greatest bulk of the global abaca fiber requirement for more than 5 years. In 2006, the country supplied nearly 85% of the global natural fiber requirement which accounted to not less than $88M worth of exports (FAO 2007). However, majority of the abaca growing areas of the country is concentrated in hilly lands where fiber production and quality had been affected. Yield reduction due to continuous cultivation and lack of appropriate nutrient management could lead to soil degradation. Soil degradation is an anthropogenic process that has detrimental effect on the performance of the abaca plant. Soil fertility decline is believed to be the predominant degradation process occurring in most of the abaca growing areas. Intensive abaca cultivation in these areas has been done for more than two decades without applying any fertilizer as supplement to the crop. This would lead to the depletion of the nutrient reserve in the soil that would cause significant reduction of the fiber yield. Hence, assessment of the soil fertility and land suitability of the intensively cultivated areas in the province is one of the major concerns that would serve as bases in formulating research and development options in these areas.

Methods

In the process, samples were collected and analyzed as an input for the soil fertility capability classification (FCC), and soil fertility index (SFI) determination of the major abaca growing areas. In each sampling area, important features necessary for site characterization were gathered specifically on the different production systems dominant in the area. In each site, samples from the surface and sub-surface horizons that has the same soil type were collected and considered as a representative for a particular land-use type. These samples were analyzed for nutrient availability indicators based on the minimum data set (MDS) for soil fertility capability classification (FCC) and soil fertility index (SFI) determinations. These were quantified based on soil pH, soil organic carbon, Total N, Avail. P, Exch. Bases (K, Ca, Mg, Na), CEC and Exch. acidity ($H^+ + Al^{3+}$). With these indicators, relationships between soil fertility and yield performance of abaca were determined. Soil fertility index (SFI) was obtained following the conceptual model developed by Andrews *et al.* (2004) while soil fertility capability classification (FCC) was done following the limits set by Sanchez *et al.* (2003). In like manner, suitability rating was done based on the available secondary data and analytical results. This was assessed based on soil property, topography climate and marketing factors. Information generated both from the soil fertility and land suitability assessment was used in the field fertilizer experiment conducted in soils with some limitations (Paleudalf soil). Results obtained in the field fertilizer experiment were the basis for the determination of the optimum performance of the abaca plant. Likewise, possible research and development options were formulated in relation to the different soil fertility indicators identified as possible determinants for sustainable abaca fiber production in Leyte province.

Results

Soil fertility assessment

There were two approaches used namely Soil Fertility Index (SFI) and Soil Fertility Capability Classification (FCC). Among the indicators, soil pH, Available P, Exchangeable K, Exchangeable Ca, Extractable Cu, Extractable Zn and Extractable Fe were selected as Minimum Soil Fertility Indicators (MSFI). With these indicators, samples collected in the southern part of the province was found to be high in soil pH that resulted to high availability of Ca in this area. Wide variability of P availability was noted which can be due to the extent of cultivation in these areas while the change in fertility level could be due to anthropogenic influence. Likewise, areas grown to abaca as monocrop and those grown to abaca in association with coconut have higher pH compared to areas with abaca grown in association with tree-legumes. When relationships were established between the identified MSFI, Avail. P(exponential), Exch. K (sigmoidal), Soil pH (i.e. quadratic), Ca, Fe, Cu (i.e. Gaussian) and Zn (logistic) follow different patterns with respect to the biomass production of abaca. Integrated scored value of the MSFI's revealed that among the areas sampled, east-central portion of the province showed the highest SFI value of 8.05. On the other hand the lowest SFI was noted in the northern part of the province with the value of 0.72. It was noted that this particular area exhibited a chronic problem of soil pH, Avail. P, Exchangeable K, Exchangeable Ca and Extractable Zn (Figure 1a). Following the FCC protocol, it was found that more than three-fourths (i.e. 80%) of the sampling areas have Sandy soils while the modifiers suggest that acidity is the major constraint for abaca production. Diagnostic report of the FCC system recommends that frequent small application of lime or K fertilizer will be used with close monitoring and appropriate use of soil test for those areas with some limitations. In extreme cases caused by acidity and aluminum toxicity, the use of Al tolerant crop varieties is also suggested.

Land suitability assessment

There were four factors considered for scoring in this particular assessment study. This includes the soil property, topography, climate and marketing factors. Result of the land suitability assessment showed that most of the sampling areas were moderately suitable for abaca production (Figure 1b). The highly suitable (S_1) areas are those sites located at the north-western and those in the east-central portions of the island. These areas are considered as highly suitable which could be attributed to the different factors associated to the scoring of values. There were also areas identified as moderately suitable (S_2) for abaca production distributed all-throughout the province. When all of these approaches were integrated (SFI, FCC and Land Suitability), it was noted that areas with very low soil fertility index were marginally suitable with a very minor limitation of Aluminum toxicity in the FCC system. An area in the east-central portion of the island obtained the highest suitability score (94.05) and was assessed as S_1 (i.e. highly suitable for abaca production).

Field fertilizer experiment in soils with some limitations

Data obtained from site characteristics, soil fertility and land suitability assessments were considered and served as basis in the development of an intervention through field fertilizer experiment for sustainable abaca production in Leyte. This was conducted in Paleudalf soil since this particular site was identified to have some fertility problems. It was observed that fertilization significantly influenced the growth performance and biomass production of abaca grown in this particular soil type. N, P and K application significantly improved the growth and biomass performance of abaca (Figure 2). However, biozome application (i.e. believed to be source of micronutrients blend with highly concentrated beneficial microorganisms) did not show any significant effect on the growth performance and biomass production of abaca

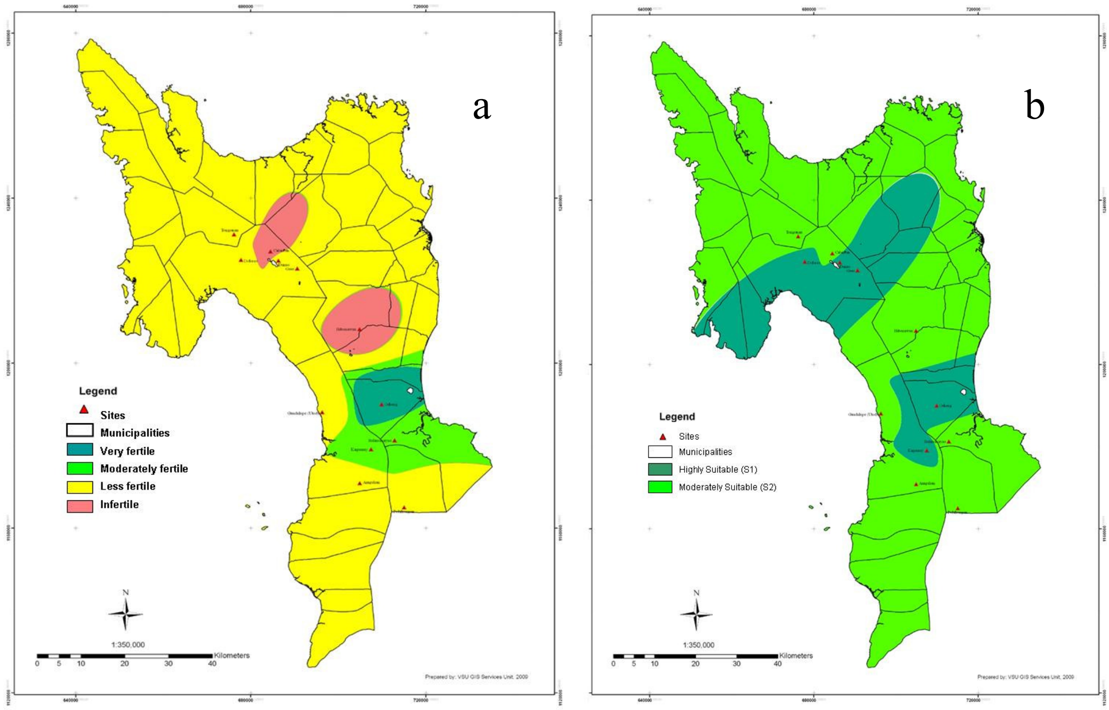

Figure 1. Soil fertility (a) and Land suitability (b) maps for abaca production in Leyte, Philippines.

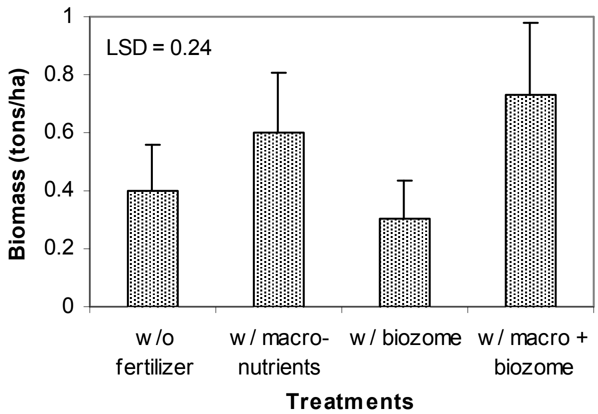

Figure 2. Biomass contents of abaca with applied macronutrients and biozome grown in Paleudalf soil (SE bars represent only the upper limit)

Suggested research and development options for abaca

Any research and development agenda should be feasible and holistic for sustainable nutrient management for abaca. A successful nutrient management planning should include assessment of the nutrient balance of the system, stakeholders involvement, and economic benefits of a particular intervention. It is envisioned that a more holistic nutrient management approach should focus on the limitations in the major abaca growing areas in Leyte. Research on lime application, which would help alleviate the nutrient availability (i.e. basic cations) and reduce aluminum toxicity should be taken into consideration. Another potential area for research is the development of acid or aluminum tolerant abaca varieties that could withstand areas with low soil pH.

Conclusions

Results from this scientific investigation proved that soil fertility is one of the causes of low productivity among the abaca growing areas in Leyte. Tools used in assessing the soil fertility conditions of the abaca growing areas in Leyte such as Soil Fertiliy Index (SFI) and Soil Fertility Capability Classification (FCC) were able to approximate the general fertility of soils planted to abaca. Likewise, integrating the SFI and FCC data can help assess the land suitability of the abaca growing areas in Leyte. In soils with some limitations (Paleudalf soil), N, P_2O_5 , and K_2O application significantly improved the performance of abaca.

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Soil physical conditions that limit chickpea emergence with particular reference to the High Barind Tract of Bangladesh

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Abstract
Sowing of chickpea in the heavy textured soils of the High Barind Tract of Bangladesh with minimum tillage technology aims to increase the timely planting of large areas during a relatively short sowing window before soil water limits germination and emergence. However, the seedbed conditions into which chickpea is sown needs to be better quantified, so that limiting factors which affect germination and emergence can be identified. The soil physical characteristics of importance are soil water, strength and aeration. Growth cabinet studies have identified the fastest germination and emergence of chickpea to be in soils which have gravimetric water contents of 17 to 18 %, at soil water contents above and below this germination and emergence are delayed. Field experiments in Bangladesh have been monitored to determine in-field conditions at sowing. These field and laboratory experiments will be used to quantify the soil physical properties which limit the germination and emergence of chickpea in the HBT of Bangladesh.

Key Words
Germination, minimum tillage, soil water, Desi type.

Introduction
Chickpea (*Cicer arietinum* L.) crops in the High Barind Tract (HBT) of Bangladesh are grown mainly on residual soil moisture after rainy season rice and are subject to a range of stresses which may result in poor germination, emergence and stand establishment. After harvest of the rice crop, the region has high evaporation and temperatures which result in rapid loss of surface soil moisture, even though subsurface layers retain high soil water content. This results in sub-optimal surface soil water conditions for germination and emergence of chickpea seed. In the HBT it is important that chickpea seeds germinate and emerge quickly before the surface soil dries, such that a vigorous root system develops to support adequate nodulation and access soil moisture at depth.

The soil physical conditions of aeration, temperature, water content and strength affect the germination and emergence of a seed. These soil physical conditions are dependent on properties such as particle size distribution and bulk density which influence pore size distribution and aggregate size. These soil physical properties affect seed germination by controlling the seed-soil contact, water holding capacity and aeration. The seed water potential, soil water potential and the seed-soil interface are important factors in the initial water uptake phase required for seed germination (Hadas 2004). During the period from germination to emergence, when the seeds continue to require water and oxygen, and utilize their seed reserves for nutrients (Baker 2006) may be the critical period for successful chickpea emergence in the HBT due to the accelerated drying of the surface soil.

Previous research in a Vertisol soil, has determined the soil water contents at which emergence of Desi type chickpea seeds becomes limited. The volumetric water content at which chickpea failed to emerge was less than 20 % (Saxena 1987). This was a soil reported to have a field capacity of 34 % and wilting point of 19 %. Hosseini *et al.* (2009) found that as soil water content decreased to 50 and 25 % of field capacity the time to chickpea emergence (both Kabuli and Desi types) increased and early growth was suppressed.

Surface soils (0 -15 cm) in the HBT have been reported to have high silt and sand contents (up to 40 % of each), and have bulk densities between 1.5 and 1.6 g/cm^3 (Ali 2000). These two characteristics of soil in the HBT lead to a seed bed which is not optimum for chickpea germination or emergence in combination with an environment which quickly dries the surface soil after planting. In addition to soil physical constraints inherent in HBT soil, the development of new minimum tillage techniques adds another dimension to the management of these soils during the sowing of chickpea. The soil physical conditions in the slots of disturbed soil may limit the emergence of the seed: if there is inadequate seed coverage by the soil; if the soil covering the seed is not of an appropriate tilth; if the seed is not sown at the appropriate depth into the moist zone and; if the soil is too wet at sowing, creating surface smearing in the furrow. All or one of these may lead to accelerated drying of the seed bed soil and increased soil strength through which the root and shoots have to emerge.

This research aims to determine the soil physical conditions found in the seed bed during the establishment period of chickpea in the HBT of Bangladesh, and how these conditions influence emergence. Research involves growth cabinet studies to determine the critical limits of soil water, soil strength and bulk density as well as field studies to quantity soil physical conditions at sowing after minimum tillage. This paper outlines progress towards defining the seed bed requirements for germination and emergence of chickpea in regards to soil water content.

Methods

Three laboratory experiments were conducted to investigate germination and emergence of chickpea at different water contents. Experiment 1 and 2 were conducted using surface (0 - 10 cm) soil from Merredin, Western Australia with a sandy clay loam (57 % sand, 14 % silt and 28 % clay) and a bulk density of 1.3 g/cm^3 (Russel 2005). Experiment 3 was conducted on surface soil from the HBT in Bangladesh. Previous studies in the region have reported a silty loam soil texture with 43 % sand, 32 % silt and 20 % clay and a bulk density of 1.6 g/cm^3 (Ali 2000). All soils were air-dried and passed though a 4 mm sieve. Soil was wet-up to the treatment water contents and mixed before being left in a sealed container to equilibrate for 48 hours. Seeds of Desi chickpea cv. Genesis 836, were sorted for size and uniformity. In each experiment, gravimetric soil water contents were determined for each treatment at sowing and at harvest. At harvest, seeds were inspected to determine if germination had occurred (radical > 2 mm in length), and if so, root and shoot length were measured and total mass of the seedling taken. If the seed had not germinated it was placed in a petri dish with moist filter paper to determine viability of the seed. Seedlings were classed as emerged when they were first visible on the soil surface. When the seedling emerged the pot was removed and the pot destructively sampled.

Experiment 1 was conducted to determine the soil water content at which chickpea germination is limited. Soil water content treatments were 10, 12, 15, 20, and 25 % by weight. There were three replications of each treatment, which were each destructively sampled over 12 days. Half the soil was placed before eight seeds were evenly sown across a petri dish (1 cm deep, 8 cm diameter) then the other half of the soil was placed on the top of the seeds. The petri dishes were sealed and placed in a growth cabinet at 25 ºC. On days 3, 6, 7, 10, 11 and 12, three replications of each treatment were removed and destructively sampled.

Experiment 2 was conducted to determine how soil water content affected emergence of the chickpea seedlings. Soil water content treatments were 0, 5, 8, 10, 12, 15, 20, and 25 % by weight with eight replications. Soil was placed into square pots 18 cm high and 9 cm wide. Soil was placed into the pots at a bulk density of 1.3 g/cm^3. However, soil water contents of 0, 5, 20 and 25 % all settled to below this value resulting in bulk densities of 1.6, 1.4, 1.6 and 1.8 g/cm^3, respectively. One seed was sown per pot at 3 cm depth. The pot was placed in a sun bag (Sigma-Aldrich) and the sealed bag placed in a growth cabinet at 25 ºC. After sowing, the pots were monitored daily to determine if seed had emerged. Twelve days after sowing all remaining pots were removed and destructively sampled.

Experiment 3 was conducted to determine the soil water content at which chickpea emergence is limited in a soil typical of the HBT in Bangladesh. Soil water content treatments were 8, 10, 12, 15, 18 and 20 % by weight with eight replications. Soil was placed into cylindrical pots 6 cm high and 4 cm diameter. Soil was placed into the pots at a bulk density of 1.3 g/cm^3. One seed was sown per pot at 3 cm depth. The pots were placed in sealed plastic bags and placed in a growth cabinet at 20 ºC. After sowing the pots were monitored daily to determine if seedlings had emerged.

Results

In experiment 1, the actual soil water contents at sowing of the five treatments were 13, 14, 18, 23 and 28 %. At the driest water content (13 %), the rate of emergence at 3 days after sowing (DAS) was 45 %, and rose to 100 % at 11 DAS. With increasing soil water contents the time to germination decreased and at a soil water content at sowing of 18 % germination was 100 % at 3 DAS (Figure 1). As the soil water content at sowing increased to 23 % and 28 %, the number of germinated seeds increased with DAS. Shoot development was also related to soil water content at sowing. At soil water contents ≥ 18 %, germinated seeds showed signs of shoot development at 6 DAS. The number of seeds which had developed a shoot decreased (67 % down to 21 %) when soil water content at sowing increased from 18 to 28 %. With increasing DAS the numbers of seeds with shoot development increased.

Experiments 2 and 3 were conducted to determine the time taken for the chickpea to emerge over a range of soil water contents at sowing and to quantify early differences in root and shoot growth. In the Merredin soil, the soil water contents at sowing covered the range 3 to 27 % (Figure 2). Emergence did not start in any treatment until 4 DAS, and no further emergence occurred after 8 DAS. At 12 DAS, all remaining pots were harvested. At soil water contents of 3, 8, 10 and 27 %, no chickpea seeds emerged over the time of the experiment. In treatments with 12, 14 and 17 % soil water contents at sowing all seedlings emerged. The 17 % soil water treatment had the fastest rate of emergence, with emergence of all seedlings complete by 5 DAS. Chickpea seeds sown into drier soil water contents had delayed emergence, taking 4 to 6 DAS for 14 % soil water and 5 to 8 DAS for 12 % soil water. The 23 % soil water content treatment had 12.5 % of seeds emerge both on 4 and 8 DAS. Of the soil water treatments where no emergence occurred, germination only occurred in 50 % of the seeds sown into a soil water content of 10 %. Of the seeds remaining all the seeds from the 3, 8 and 10 % soil water contents were viable seed, whilst 63 % of the seeds from the 23 and 27 % soil water contents became mouldy.

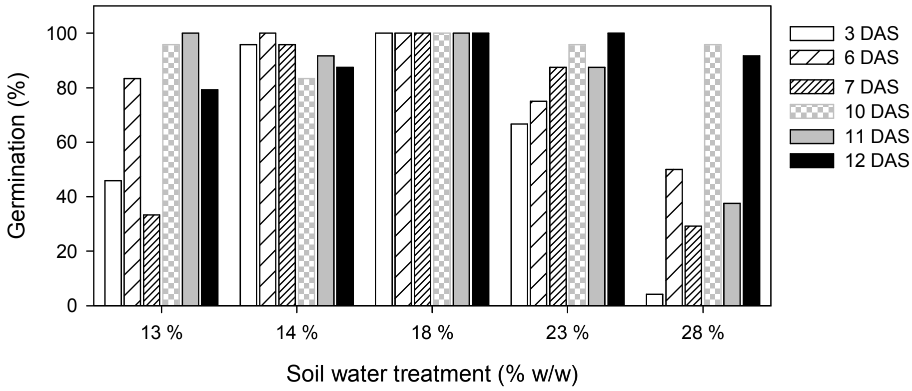

Figure 1. Days to germination of chickpea seeds sown at water contents ranging from 13 to 28 % (w/w) in a Merredin sandy clay loam. Values are means of 3 replicate from experiment 1.

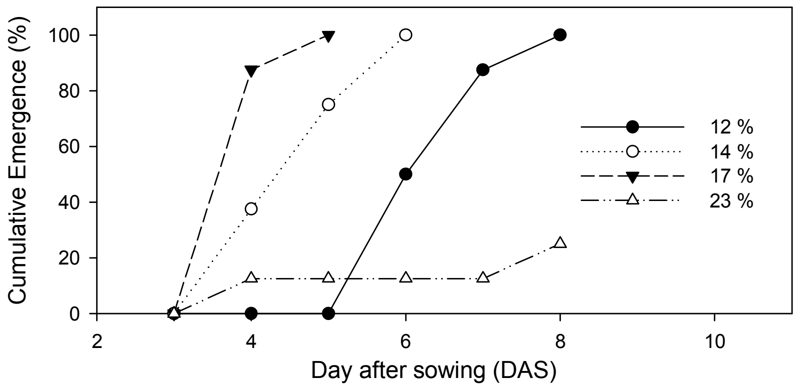

Figure 2. Rate of emergence of chickpea seeds sown into the Merredin sandy clay loam at water contents ranging from 12 to 23 % (w/w) from experiment 2. Note that no seedlings emerged at the soil water contents of 3-10 and 27 %. Eight replicates were sown for each treatment.

In the HBT soil the soil water contents at sowing were from 12 to 23 %. No chickpea plants emerged at the soil water content of 12 %. The soil water content of 19 % had the fastest rate of emergence, although only 75 % of seeds emerged 5 DAS (Figure 3). The rate of emergence of chickpea sown into soil water contents of 16 and 22 % were similar, with 100 % of emergence reached 9 DAS in the 22 % soil water content. The drier and wetter treatments of 14 and 23 %, respectively, had delayed emergence and did not reach 100 % emergence. The chickpea seedlings in the HBT soil pushed up large aggregates of soil in order to emerge, while in the Merredin soil, seedlings were able to break through the soil crust.

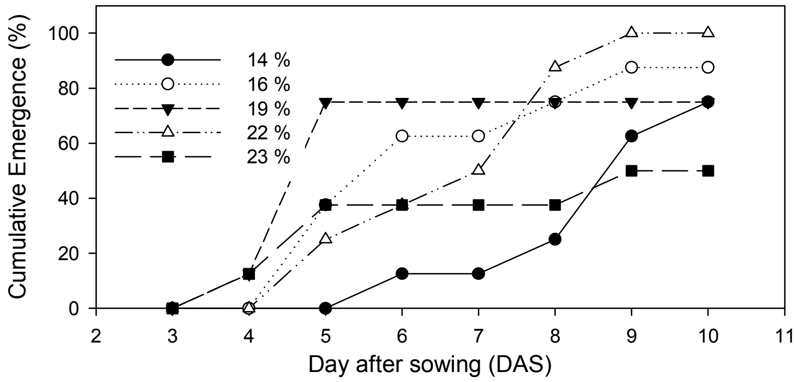

Figure 3. Rate of emergence of chickpea seeds sown into High Barind Tract soil of Bangladesh at water contents ranging from 14 to 23 % (w/w) from experiment 3. Eight replicates were sown for each treatment.

Conclusion

The rate of germination and emergence of chickpea seeds was fastest in soils which had soil water contents at sowing between 17 and 18 %. As the soil dried to 12 %, emergence may be delayed and below 10 %, germination may not occur. In wet conditions above 23 % soil water, germination and emergence are both limited and delayed if they do occur. The two different soil types had different rates of emergence of chickpea depending on the soil water content at sowing. In the Merredin soil type chickpea emergence seemed to be more successful when sown at soil water contents between 12 and 17 %, whereas in the HBT soil, chickpea had slower emergence, but the soil water contents at sowing of 16 to 22 % were the most successful. These differences may be associated with the different soil texture and water holding characteristics of the soil which affect the seeds' requirements for water and aeration for successful germination. These different soils also had different characteristics in regards to aggregates size and distribution that also affected the way the seedling was able to push though the soil to the surface.

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Stemflow runoff contributes to soil erosion at the base of macadamia trees

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Abstract
Soil erosion in macadamia orchards on the north coast of New South Wales (NSW) is a major issue due to several erosive forces. Stemflow (water flowing down a tree trunk) is a potential contributor that has not been assessed for macadamias. Observational studies were established to measure soil movement from beneath trees and stemflow volumes from macadamia trunks. Soil micro-topography around the base of eight trees was measured using the distance from an elevated platform at monthly intervals over 16 months. Stemflow volume was measured using a plastic vessel attached around each of eight trees. The water captured was funnelled into a tipping bucket flow gauge that continuously logged for the same period. Soil movement away the base of trees averaged 6.5 mm/m^2/year, with the development of surface gullies and root exposure evident. Stemflow volume was highly and positively correlated with rainfall volume in a close to linear relationship (r^2 = 0.83 to 0.99). The percentage stemflow captured varied from 0 to 28% with an overall average stemflow of 7% and a monthly range of 5 to 10%. This study confirms that stemflow runoff contributes to the redistribution of soil away from beneath macadamia trees. With tree spacings typically used by the industry, this soil movement could amount to 3.8 t/ha/year.

Key Words
Micro-topography, root exposure, soil surface monitoring, electronic fluid level.

Introduction
Soil erosion is a major issue in macadamia orchards, especially on the Acidic, Dystrophic, Red Ferrosol (Isbell 2002), or Nitisol (IUSS WRB 2006) soil of northern NSW where several erosive processes contribute to the problem. Trees in orchards older than 15 years generally have dense canopies that shade a large proportion of the orchard floor. In many cases there is insufficient light to maintain any groundcover species and the orchard floor is mostly bare. Where enough light is present in the inter-row region, sweet smothergrass (*Dactyloctenium australe*) has been selected as an effective groundcover (Firth *et al.* 2002). Harvesting nuts from the orchard floor is typically mechanised with powerful blowers or sweepers used to move nuts into the path of the harvester. Both of these harvest aids also displace soil from beneath trees. Overland water flow during intense rainfall events in this subtropical region also contributes to soil erosion in orchards. One study measured soil losses at 2 t/ha/yr on a 5 degree slope with bare soil (Reid 2002).

Another process that may contribute to the movement of soil from under macadamia trees and subsequent erosion of soil is stemflow. Stemflow can be defined as canopy intercepted rainfall that flows down and runs off the base of the plant and has been reported as high as 56% for some plant species (Crockford and Richardson 2000). In one study conducted in a tropical forest, stemflow was recorded at 6 000 to 70 000 litres per tree from 7800mm of rainfall over two wet seasons (Herwitz 1986). In tropical forest (Herwitz 1986) and eucalypt tree forests (Zhou *et al.* 2002) stemflow has been shown to contribute to substantial soil erosion with up to 9.1 kg/ ha soil lost per mm rainfall (Zhou *et al.* 2002). In older macadamia orchards, soil loss leading to severe root exposure at the base of trees is frequently observed. The extent to which stemflow contributes to this phenomenon for macadamias has never been investigated. This paper reports on the observational studies carried out over 16 months to quantify soil movement around macadamia trees and to assess the contribution of stemflow to soil erosion and tree root exposure.

Methods
Soil erosion
Micro-topographical measurements were made to assess soil erosion resulting from stemflow in a macadamia orchard at the Centre for Tropical Horticulture, Alstonville, NSW. These measurements were made using a purpose-built aluminium elevated measurement platform which was designed to permit 220 measurements at 10cm intervals across a 1.4m x 1.5m grid. At each of eight, nine year old trees, the

platform was set up in exactly the same vertical and horizontal position at monthly intervals over 16 months. On each occasion, a laser distance meter (Leica *DISTO*™) and electronic fluid level (Technidea *ZIPLEVEL*™) were used to position the platform accurately using permanent reference markers. Distances from the platform to the soil surface were measured with the laser distance meter with readings electronically transferred to a handheld computer (Hewlett Packard Pocket PC). Soil surface topographical maps were created from the data.

For each grid of observations, broad scale trends and features such as slope and relatively large valleys were approximated by using a function of cubic splines of the spatial coordinates (x,y). Local variability was modelled by a nugget effect plus an exponential covariance function based on the distance between pairs of coordinates. The two components were combined to form a predicted soil surface (Lark *et al.* 2006). A numerical integration algorithm used the models to provide predicted heights at specific points on the surface in order to estimate the volume of air in the space enclosed by the elevated platform. The space occupied by the tree trunk was not included in the calculation. Change in air volume was assumed to correspond exactly to change in soil volume relative to the initial observation on each tree. Thus gain or loss in air volume was used to indicate decrease or increase in soil volume over time. All analyses and graphical presentations were conducted in the R environment (R Development Core Team 2008). The spatial modelling component was managed by use of the asreml-r package (Butler *et al.* 2007). The adapt package was employed for the numeric integration of the modelled surfaces.

Stemflow

Stemflow was intercepted using cylindrical-shaped vessels built from thick polyurethane and fitted to the trunks of seven macadamia trees. Each vessel was set 25 mm from the tree trunk, was 175 mm deep and attached approximately 1 m from the ground. The vessels were designed to transfer the stemflow resulting from a rainfall event of 50 mm in a 15 minute period, assuming the tree canopy diameter did not exceed 4 m and that 20% of the intercepted rainfall was stemflow. Stemflow was directed from the vessels into a tipping-bucket flow gauge (Unidata, Australia) with data logged (Starlog, Unidata, Australia) every 15 minutes. Stemflow data was compared with rainfall data recorded by the Alstonville Automatic Weather Station (located 400m from the study area) for the same period.

Results

An average 6.5 mm/m^2/year net soil loss from around the base of the trees occurred in the orchard over 16 months (Figures 1 and 2). Soil loss was gradual and small gullies were observed developing over this time. Preferential flow lines also became visible along tree roots radiating out from the base. Where an orchard contained the standard 312 trees/ha, the calculated soil movement would equate to 3.8 t /ha /year.

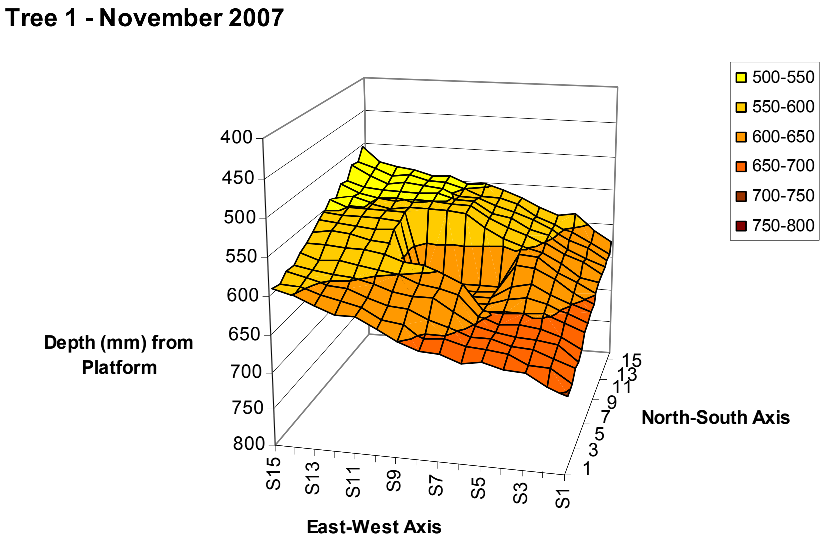

Figure 1. Soil surface topographical map (1.5 x 1.4m) around the base of a 9 year old macadamia tree at the start of monitoring at Alstonville, NSW, Australia.

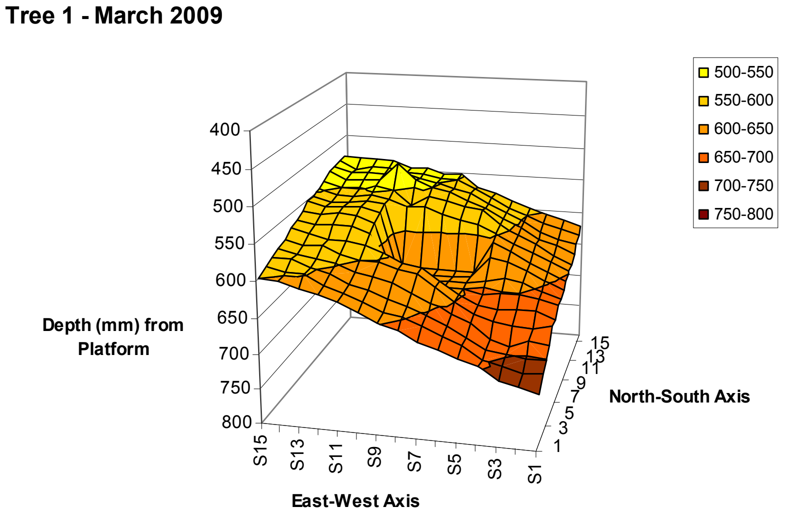

Figure 2. Soil surface topographical map (1.5 x 1.4m) around the base of the same tree from figure 1, 16 months after commencing monitoring at Alstonville, NSW, Australia.

Stemflow volume was highly and positively correlated with rainfall volume (r^2 ranged from 0.83 to 0.99 per month, data not shown). Every month, as daily rainfall increased, the amount of stemflow increased and although the relationship was close to linear, polynomial functions more accurately described the relationship. On 21 May 2009, a major flood event in the region registered 217 mm rainfall in 32 hours. The corresponding average stemflow was 1,100 L for that time. Overall, stemflow as percentage of rainfall captured by each tree increased with increased rainfall up to a point where further rainfall did not generate further stemflow (Figure 3) as the tree reached its capacity. Percentage stemflow varied from 0 to 28% with an overall average stemflow of 7% and a monthly range of 5 to 10%.

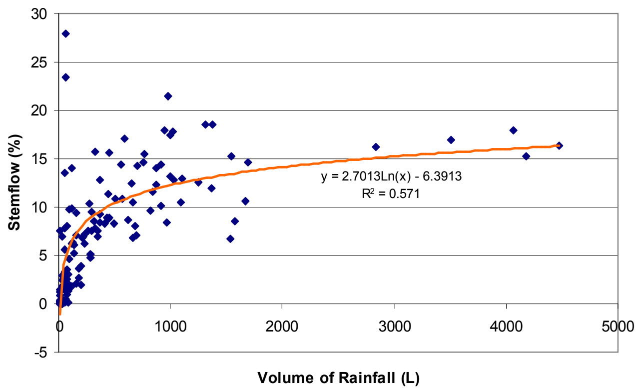

Figure 3. Stemflow as a percentage of rainfall captured by the tree canopy (L/tree/day) for November 2008 to June 2009. A volume of 1000L is equal to 29mm rainfall, and 3000L to 88mm over average canopy area of 36 m^2.

Conclusion

The results of this study indicate that stemflow runoff made a substantial contribution to soil movement away from the base of macadamia trees. We measured 6.5 mm/m^2/year net soil loss from the base of the trees (2.1m^2) which in orchards with typically 312 trees/ha, could equate to soil movement of 3.8 t /ha/yr. The extent of the soil movement was unexpected, although confined to small areas of the entire orchard. Several factors may have accentuated the severity of soil redistribution, including inherently erodible soil type, bare soil management, tree canopy architecture and storm intensity in this region. Soil particles may not have moved far beyond the under tree area, but as they have become detached from the bulk soil, they are at a higher risk of subsequent movement by future erosive events (Rose 1994). The outcomes of this study suggest that management of soil erosion in macadamia orchards should focus on protecting soil within the tree row to reduce the impact of stemflow. Mulches of a suitable size fraction could be used by growers to buffer against stemflow and to also contribute organic matter back into the soil (Cox *et al.* 2004). The industry is now aware of the extent to which stemflow contributes to redistribution of soil and subsequent development of tree root exposure and will explore alternative management practices.

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Subsoil amelioration with organic materials improves canola growth and water-use efficiency

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Abstract
Field trials examined the growth, water-use and grain production of a canola crop grown on a Sodosol that was ‘subsoil manured’ two years prior to the study. After three seasons of crop production, the organic-amended treatments continued to out-perform the non-amended treatments with 50-80% additional grain yield. The yield gain was attributed to the additional nutrient uptake, and water use mostly in the subsurface layers below 40 cm deep. Furthermore, the largest change in the subsurface structure was associated with the treatment effect on growth of crop plants.

Key Words
Organic amendments, sodic subsoil, grain yield, soil water.

Introduction
The amelioration of high clay, poorly structured, sodic subsoil is quite a challenge in terms of cost and the available technology. In Australia, the use of deep-ripping with application of gypsum has resulted in increased grain and pasture yields (Clark 2004; Ellington 1986; Greenwood *et al.* 2006; Hamza and Anderson 2003). Rarely have these methods achieved sustained increased grain yield. The use of organic matter as an ameliorant for high clay sodic soil will likely provide improved soil structure, thus providing a vastly improved environment for plant root growth. While Armstrong *et al.* (2007a; 2007b) achieved increased grain yield, and improved surface soil structure when organic amendments were applied to the surface of a Sodosol, there was nevertheless minimal change in the subsoil. The approach of our study was to incorporate a large amount of organic amendments into the subsurface at 40 cm in 2005. This showed impressive increased grain yield in the first year of crop production (Gill *et al.* 2008) in addition to improved macroporosity in the organic treatments (Gill *et al.* 2009). This study investigated the residual effects, after 3 seasons, on grain yield, soil water-use and soil structure from the deep incorporation of organic amendments. It was postulated that improved soil structure was likely linked to the presence of plant roots, as opposed to the presence of the organic amendment.

Materials and methods
The trial site was located at Yaloak estate near Ballan, Victoria (longitude 144.23 E, latitude 37.86 S, 508.7 m elevation). Two paddocks, both with permanent raised beds (1.7 m wide) for 8 years, were selected to apply the treatments. One paddock had 4 years of lucerne history (*Medicago sativa* cv. Cimaron) followed by canola and two years of wheat. The other paddock adjacent to the lucerne paddock was under continuous cropping. The soil of both paddocks was a Sodosol (Isbell 2002) or Solonetz (FAO) with dense sodic subsoil. Basic soil properties are listed for the non-lucerne site (lucerne site similar) in Table 6. Long-term average rainfall at the site is 576 mm with the most effective rainfall (rainfall exceeds evaporation) from June to August.
Experimental design and treatments
The field trials, established in April 2005, were a randomized block design with nine treatments (Table 2) in four blocked replicates. The size of each plot was a 5 m long and 1.7 m wide raised bed. The amendments were applied manually (Table 2) at 30–40 cm deep with the help of a pipe (15 cm diameter) attached to a deep ripper. Dynamic lifter® had 4% N, 2.2% P and 1.9% K, and lucerne pellet had 2.8% N, 0.9% P and 1.4% K. Amendments were applied in two rip lines on each 1.7-m bed (centre to centre) 1 week before sowing (Gill *et al.* 2008).
Crop
Canola crop (Brassica napus var. Thunder) was sown at a rate of 5 kg /ha on 1 June 2007. Mono-ammonium phosphate was applied at 70 kg/ha at the time of sowing and then urea was applied at the rate of 90 kg /ha 106 DAS. The crop was windrowed 186 days after sowing (DAS) and 10 days later was harvested for grain. Rainfall was below average for much of the year, with the 5 month period, prior to the sowing of the canola, 50 mm below average, and around half of the average for August to October, which resulted in around 50 mm below the annual average.

Soil water
Soil water was measured, in a limited number of treatments, T1, T3 T5 and T9, with a neutron moisture probe using access tubes located in the middle of the plot.
Water-stable aggregates
Soil samples were collected 128-129 DAS from the T2, T5 and T9 treatments. Soil was sampled at three locations across the bed; R1 was the outermost location, directly under the second outside row of canola plants, R2 was under the third outside row, while S was between R1 and R2. The R1 and R2 sampling locations were positioned directly over an actively growing canola plant. Water-stable aggregates were determined on field moist soils (mean θg 0.19 g /g soil) of 8-10 mm in diameter.

Table 6. Soil properties of experimental sites before treatments applied in 2005.

Site	Depth (cm)	pH[1]	EC[2] (dS/m)	Clay (g/kg)	ESP[3] (%)	BD[4] (g/cm^3)	θv (cm^3/cm^3) 0.3 MPa	1.5 MPa
Non-lucerne	0–10	5.2	0.10	550	12.9	1.07	0.40	0.19
	10–20	7.2	0.24	580	14.7	1.38	0.42	0.21
	20–40	5.7	0.08	610	17.1	1.46	0.48	0.29
	40–60	5.7	0.07	640	20.3	1.70	0.52	0.34

[1] 1:5 soil: 0.1M Ca Cl_2 , [2] Electrical conductivity 1:5 soil:water, [3] Exchangeable sodium percentage, [4] Bulk density

Results
Crop growth
The highest mass of shoots at 107 DAS (rosette stage), was found with the deep incorporated organic treatments (data not shown). T9 (lucerne site) showed and additional 1 t /ha DM while at the non-lucerne site T5 and T6 treatments produced 1 t /ha greater (p<0.05) shoot yield than T1-control and T2-deep ripping treatments. After a further 19 days of crop growth all treatments showed a similar yield of dry matter. The exception was T9, which produced approximately 1 t /ha more than the control (data not shown).
Shoot nitrogen
Nitrogen concentration (g N /kg DM) in the canola shoots 107 days after sowing, were generally higher in the treatments where organic amendments had been incorporated in the subsoil (Table 7). However, the N concentrations were only significantly greater (p<0.05) in T9 compared to the control.
Grain yield
All the organic treatments significantly (p<0.05) increased the grain yield in comparison to the control (Table 7). The organic-amendments contributed to a 50 to 80% increase, compared to the control, in grain yield at both sites while the inorganic treatments had a similar yield to the control and deep ripped treatment.

Table 7. Description of the treatments established in 2005, and nitrogen concentration in shoots and grain yield of canola in 2007.

Treatment	Description	Rate of addition (t /ha)	Nitrogen (g N /kg DM) L[3]	NL[4]	Grain yield (t /ha) L	NL
T1	Control	Direct sowing	44.4	44.5	1.61	1.56
T2	Deep ripping 30-40 cm	None	45.3	46.1	1.62	1.47
T3	Gypsum (DR40[1])	10	43.2	46.3	1.52	1.79
T4	MAP[2] (DR40)	0.1	44.7	46.7	1.53	1.49
T5	Lucerne pellets (DR40)	20	43.3	42.7	2.90	2.52
T6	Dynamic lifter (DR40)	20	47.4	42.8	2.45	2.34
T7	Sand (DR40)	20	48.5	49.4	1.79	1.39
T8	Gypsum+MAP (DR40)	10+0.1	49.9	50.5	1.66	1.31
T9	Lucerne pellets+gypsum+MAP (DR40)	20+10+0.1	53.8	51.5	2.94	2.76
		LSD (p=0.05)	5.0	6.4	0.47	0.76

[1] Deep ripping to 30-40 cm, [2] Mono-ammonium phosphate, [3] L-the site with Lucerne history, [4] NL-non-lucerne site

Water use from soil profiles and water use efficiency
The improvement in crop water use in 2007 was clearly demonstrated in the deep incorporated organic treatments at the non-lucerne site. Approximately 23 mm more soil water was depleted below the 40 cm layer, in the organic treatments, T5 and T9, compared to the control (**Error! Reference source not found.**). The most efficient conversion of soil water to grain was shown by the organic-amended treatments; showing an additional 2.5 to 3.2 kg/ha/mm, equating to a >50% increase in water use efficiency (Table 6).

Table 8. Loss of soil water (mm) from soil profiles, and the apparent water use and water use efficiency (WUE) (June-November) for canola plants grown in selected treatments at the non-lucerne experimental site in 2007.

Treatment	Depth of soil layer (cm)				Total	WU[2]	WUE[3]
	0-20	20-40	40-60	60-80	0-80	(mm)	(kg/ha/mm)
T1-Control	2.7	5.3	0.1	7.3	15.4	317	4.9
T3-Gypsum	2.4	5.7	2.5	11.1	21.6	324	5.5
T5-Lucerne	3.3	4.9	12.1	18.7	39.0	341	7.4
T9-G+L+MAP	2.3	8.3	13.1	16.0	39.7	342	8.1
LSD[1]	n.s.	n.s.	6.6	10.2	13.4	13.4	2.2

[1] p=0.05, n.s. not significant at p=0.05, - not applicable, [2] Apparent water use = total profile loss + growing season rainfall, [3] Apparent water-use efficiency = grain yield (kg /ha) / water use (mm)

Soil aggregate stability

The formation of water–stable macroaggregates in soil sampled in October 2007 was increased significantly (p<0.01) by the deep incorporation of organic amendments in 2005. An additional 15% of the soil sample had formed macroaggregates >0.25 mm with the two organic amendment treatments (T5 and T9), compared to soil from the control (T1) treatment (Table 9). This represented an almost 1/3 increase in macroaggregation with the organic amendment treatments. The amendment treatment × sample position interaction for macro-aggregation was significant at p=0.06. The basis for this interaction was the increased percentage of macroaggregates in the soil sampled beneath a canola plant, compared to between the plant rows, when organic amendments had been incorporated in the subsurface 30-40 cm layers 2 years earlier (Table 4). In contrast, there was no difference in soil macroaggregation between positions of samples within the control treatment. The macroaggregation data were subject to the variation that occurs in the field, with a coefficient of variation that exceeded 28%. Thus, increases in macroaggregation, due to the presence of an actively growing canola plant (R location) were only significant (p<0.05) at the R1 location with treatment T5 and at the R2 location with the T9 treatment.

Table 9. for the effect of organic amendments on the formation of macroaggregates (%>0.25 mm) in soil samples from the amendment and location treatments.

	Aggregation (% >0.25 mm)			
		Position		
Amendment treatment	Mean (position)	S	R1	R2
Control (T1)	48.0	50.5	47.5	45.9
Lucerne (T5)	54.2	54.2	75.4	58.9
Lucerne+MAP+gypsum (T9)	62.7	51.5	64.8	71.7
LSD (p=0.05)	9.1		15.8	

Discussion

Crop growth and use of subsoil water

This field study has demonstrated the residual effects of subsoil-incorporated organic amendments on the growth and yield of canola after three seasons of crop production on this Sodosol with high clay, sodic subsoil. The increased grain yield of up to 80% has been achieved nearly three years after the initial deep incorporation of organic amendments (Table 7). The increased use of subsoil water by canola plants grown on the organic treatments, as shown at the non-lucerne site (Table 8), and the increased accumulation of nitrogen in the canola shoots (data not shown) appeared to be the factors that contributed to the increased grain yield. This was shown by the two organic-amendment treatments, lucerne (T5) and lucerne plus gypsum and MAP (T9), at the non-lucerne site. After 107 DAS the canola shoots from T5 and T9 had accumulated on average around 50 kg more nitrogen per hectare than the control and deep ripped treatments in addition to the 50 kg of fertilizer nitrogen applied during crop growth. In addition, these organic treatments used three times more water below the 40 cm layer than the control, resulting in a 50% improvement in apparent water-use efficiency (Table 8).

Soil structure

The improved crop yield and water-use efficiency in the organic-amended treatments could in part be attributed to the improved soil structure. In the 2007 season, two and half years after the incorporation of organic amendments, there was a one-third increase (p<0.01) in soil macroaggregation, in comparison to the non-amended control soil (Table 9). However, the treatment × soil sample location interaction at the 10% level (p=0.07) suggests that the presence of canola crop roots had a crucial role in stabilizing soil macroaggregates. Furthermore, the increased macroporosity of the subsurface in 2005 was attributed to the

presence of crop roots (Gill *et al.* 2009). Thus it is not surprising that after 2.5 years had lapsed since the incorporation of the organic amendments into the subsurface, that crop root growth played a prominent role in the maintenance of the improved soil structure. The importance of root growth was previously shown to be more important than total carbon input in rehabilitation of degraded prairie grasslands (Jastrow 1996). The use of gypsum with deep ripping is often used to minimize structural degradation that may occur when deep ripping sodic soils. In this field study, there was no evidence of any increased extraction of water from the profile (The improvement in crop water use in 2007 was clearly demonstrated in the deep incorporated organic treatments at the non-lucerne site. Approximately 23 mm more soil water was depleted below the 40 cm layer, in the organic treatments, T5 and T9, compared to the control (Error! Reference source not found.). The most efficient conversion of soil water to grain was shown by the organic-amended treatments; showing an additional 2.5 to 3.2 kg/ha/mm, equating to a >50% increase in water use efficiency (Table 6).
Table 8) and subsequently no difference to the control in dry matter yield or grain yield (Table 7) which has previously been reported (Hamza and Anderson 2002). In fact, gypsum can have a detrimental effect on root growth (Clark 2004) due to the high soil electrical conductivity (Clark *et al.* 2007) in the gypsum-amended soil. leading to reduced root density (Clark 2004) and lack of yield improvement (Hamza and Anderson 2002).

Conclusion

This study demonstrates that the use of subsoil ‘manuring’ improves production on soils with sodic subsoil on a long-term basis than with current methods of intervention, such as deep ripping. Importantly, the greatest improvement is probably due to the incorporation of subsoil nutrients, thus providing a stimulus to plant root growth. The presence of root growth in the subsoil is likely to be the most important vector for change of subsoil structure.

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The effects of over cultivation on some soil properties, nutrients response and yields of major crops grown on acid sand soils of Calabar South-Southern part of Nigeria

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Abstract

Most of the arable land in Nigeria is characterized by fragile soils, having undergone intensive weathering, leaching and they are dominated by low activity clay, are infertile, have low nutrient response and are either acid or posses tendencies to become acid due to continuous or over cultivation. Soils especially around the cities in Nigeria are used for growing vegetables, cereals like maize, legumes like melon, soybean and cowpea which have been cultivated continuously for a period upward of 20 years due to the lack of arable land and the good market for the crops. Studies were conducted on the soil properties, soil reaction (pH); total nitrogen, organic carbon, base saturation, microbial populations (fungi and bacteria) and the determination of crop response to nutrient applications. The results obtained showed that the pH is acidic ranging from 4.1 to 5.1 and values of total nitrogen, organic carbon, base saturation, microbial populations and the identified nitrogen fixers are low. There is about a 60% yield reduction for the cultivated crops. The uptake of the applied nutrients by the crops is low consequently the soil is generally of low productivity.

Key Words

Over-cultivation, soil properties, fragile soils, microbial populations, response to nutrients, yield

Introduction

Agricultural practice around the densely populated areas of the world is characterized by overcultivation and continuous cultivation of land (Nair 1979). In this situation, there is continual loss and removal of soil nutrients by the harvested produce. The cultural practices adopted cause the nutrient cycle to deteriorate and affect the sustainability of the system (Kang 1990). Crop production in these areas in Nigeria is very far from being sustainable and yields are far below their potentials (SSSN 2008). This is due mainly to fragile soils, lack of nutrients, soil degradation destroying soil structure and soil erosion (Bello and Iyapo 2008).

Materials and methods

Soil samples were collected randomly from a well managed control site and seven farms that had been planted to crops under continuous cultivation for about 10 years, located around the city of Calabar, Nigeria. Soil was taken from a depth of 0-20cm using a soil auger. The composite representative samples were analyzed for their physical, chemical and biological properties using the standard soil analytical methods of Odu *et al.* (1986). The soil, are characterized with high acidity (Table 1) with the major nutrients like organic carbon, total nitrogen, potassium very low, this could be attributed to the continual removal of nutrients from the soils year in year out (Kang 1990).

Results and discussion

Table 1. Physical and chemical properties of the soil.

Location	pH	OC %	Total N %	AVP mg/kg	K	ECEC (cmol kg^{-1})	Clay	Silt %	Sand	Texture cla
Control	4.7	1.20	0.09	65.0	0.08	4.28	10.7	8.6	30.70	Sandy loan
Ask-Atu	4.3	0.90	0.07	50.00	0.05	3.33	10.8	2.7	86.60	Sandy loan
Atimbo	4.4	0.30	0.02	9.75	0.09	3.00	14.8	3.7	81.60	Sand loam
Anantigha	4.9	0.83	0.07	43.25	0.07	4.00	3.7	7.7	88.60	Sandy
Calabar south	5.1	0.68	0.05	100.00	0.08	3.48	4.7	8.7	86.60	Loamy san
Uncial Quarter	4.6	0.86	0.09	70.75	0.08	4.12	6.6	6.8	86.60	Loamy san
Unicla farm	4.7	0.90	0.06	66.00	0.08	3.62	10.7	8.9	84.6	Sandy loan
Mean value	4.6	0.81	0.06	56.40	0.08	3.69	8.86	6.43	85.04	Sandy loan
Range	43-5.1	0.30-1.20	0.02-0.09	9.75-100	0.05-0.0	3.00-4.28	3.7-10.8	2.7-8.9	80.6-88.60	
SD	0.33	0.34	0.03	10.02	0.02	0.47	4.07	2.68	4.14	
CV %	7.6	4.0	42.86	19.1	28.6	11.80	42.8	38.8	4.9	

The micro-organisms (Table 2) are generally scanty and have low populations which could be attributed to the continuous tampering with the soil ecology and application of chemicals and fertilizers that eliminate the microbial populations. High available P is due to continuous application of phosphorus based fertilizer. The yields (Table 3) of the cultivated crops are generally low showing that the soils no longer support good crop yields. There is need for proper land use planning around the cities to enable the availability of a large expanse of land for agricultural production since the demand for food is always higher around cities. In addition, organic farming should be encouraged.

Table 2. Microbial isolates and population distribution in the samples.

Location	Bacteria isolates	Bacteria count	Fungi isolate	Fungi count
Control	Micrococcus	$18x10^6$	Rhizopus	$5x10^3$
	Bacillus subtillis	$17x10^6$		
Asok Atu	Micrococcus	$10x10^6$	Rhizopus	$3x10^3$
	Bacillus subtillis	$7x10^6$	Mucor	$2xw^3$
		$9x10^6$		
Atimbo	Micrococcus	$4x10^6$	Rhzopus	$2x10^3$
	Bacillus subtillis	$8x10^6$	Mucor	$3x10_3$
Anantigha	Bacillus subtillus	$10x10^6$	Rhizopus	$2x10^3$
	Klebsiella	$12x10^6$	Mucor	$2x10^2$
Calabar south	Baarllis subtillis	$7x10^6$	Rhizopus	$2x10^3$
	Klebrela	$12x10^6$	Mucor	$2x10^3$
Unical quarters	Baallus klebbela	$9x10^6$	Rhizopus	$2x10^3$
		$4x10^6$	Mucor	$2x10^3$
Unical farm	Bacillus substillia	$5x0^6$	Mucor	$4x10^3$
	klebsIella	$8x10^6$		
	Micrococcus	$4x10^6$		

Table 3. Yield of arable crop planted on the plots.

Location	Maize (shelled grain yield) t/ha	Pumpkin (biomass yield) t/ha	Cassava (tuber yield) t/ha	Green (Amananthus) (biomass yield) t/ha	Water hot (biomass) t/ha
Control	2.3	6.8	13.9	7.5	6.5
Asok-Atu	0.4	2.3	6.2	3.1	2.2
Atimbo	0.3	2.3	5.8	3.0	2.3
Anantigha	0.6	2.1	5.2	2.8	2.4
Calabar south	0.8	2.0	5.0	2.6	3.5
Uncial quarters	0.7	2.3	4.7	2.7	2.8
Unicla farm	0.9	2.7	5.5	3.2	3.6

Conclusion

There is need for proper land use planning around the cities to enable the availability of large expanse of land for agricultural production since the demand for food is always higher around the cities. In addition, organic farming should be encouraged.

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The influence of Natural Sequence Farming stream rehabilitation on upper catchment floodplain soil properties, Hunter Valley, NSW, Australia

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Abstract

Upper catchment floodplain soils under long-term (30 years) Natural Sequence Farming (NSF) management are compared with soils managed under conventional farming to determine whether any significant changes occur in soil physical, chemical and biological properties. The results show significant changes in total and available phosphorus concentrations, effective cation exchange capacity and soil macro-biota abundance and diversity. The electrical conductivity results showed a relatively neutral response while the total nitrogen, organic carbon and bulk density values suggest a negative response to NSF. However the higher grazing pressure and hay cutting occurring on the NSF sites confounds the soil organic carbon and bulk density results. This suggests that NSF has potential for soil improvement in an agricultural floodplain setting, however suitable pasture management systems must also be applied otherwise they appear to be an over-riding management factor for some soil properties.

Key Words

Soil fertility, stream-floodplain connectivity, soil fertility.

Introduction

Natural Sequence Farming (NSF) seeks to re-instate stream-floodplain connectivity in incised stream channels through the placement of 'leaky weir' structures within the incised channel (CSIRO 2002). This is in an attempt to slow stream velocity and increase stream base level and stage height to enable lateral transfers of water into the floodplain sediments (Keene *et al.* 2007). The ultimate aim is to restore the alluvial aquifer watertable to a height where it interacts with the soil profile. This interaction is thought to have occurred in the chain of ponds and swampy meadow floodplain morphologies that typified upper catchments prior to land degradation and resultant stream channel incision (Eyles 1977; Prosser 1991). This study investigated the effects of long-term (approximately 30 years since initiation) NSF management on upper catchment floodplain soils located on a grazing property along the Bylong Creek in the upper Hunter Valley, NSW. The NSF managed soils were compared with conventionally managed soils to determine whether any significant changes occur in soil physical, chemical and biological properties in relation to agricultural productivity.

Methods

The sample sites selected included three sites on both NSF managed paddocks and paddocks situated upstream and adjacent to the NSF managed paddocks which were selected as the conventional farming control (Non-NSF). The sample sites were paired based on the floodplain position, surface soil type, and adjacent channel morphology on the NSF and Non-NSF managed land. An attempt was made to position sites just behind the levee and use average floodplain soils (essentially loams and neither levee nor true backplain nor palaeo versions). These paired sites were:

- downstream of NSF structure/downstream of narrow incision;
- NSF structure/narrow channel incision; and
- NSF created channel pool/incised channel scour pool (Figure 1).

In order to pair the sites based on these hydrogeomorphic features concessions were made regarding the land use. The NSF sites were subjected to a relatively higher grazing pressure and to some hay cutting compared to the Non-NSF sites which formed part of a recently set up stock-excluded riparian reserve (approx. 3 years of exclusion). Thus measured changes in soil properties on the NSF sites should be emphasised as these are despite the differential in land use. The paired sites were aggregated for each treatment (NSF and Non-NSF) to compare any effects of management type across all sites. Thirty-one soil samples were collected per site along bisecting transects during April 2008 (Figure 2). Subsequent laboratory analyses carried out according to standard analytical methods (Table 1). Statistical significance was determined by t-tests.

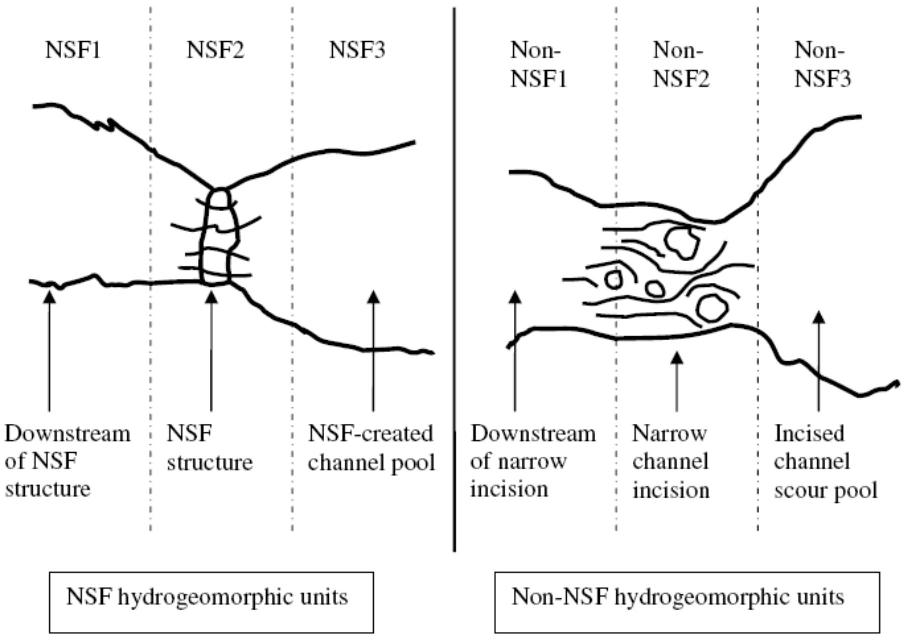

Figure 9. Schematic layout of sample site pairing to effectively compare hydrogeomorphic influences on the floodplain soil (water flow from right to left).

Table 10. Soil property and the laboratory analyses conducted.

Soil property	Laboratory analysis
Total P (ppm)	Acid digestion and Technicon Autoanalyser
Available P (cmol/kg)	Water extraction and ICPAES
ECEC (cmol/kg)	Water extraction and ICPAES
Macro-biota abundance (indiv/core)	Temperature gradient extraction and microscope counts
Macro-biota diversity (func. grps/core)	Temperature gradient extraction and microscope counts
ECe (dS/m)	1:5 soil:water suspension and conductivity probe
Total N (ppm)	Acid digestion and Technicon Autoanalyser
Bulk density (g/cm^3)	Oven dried weight of uniform soil cores
SOC (%)	Walkley & Black (1934)

Results

From the comparison of the paired sites it was found that significant differences (*P<0.05*) do exist between the soils sampled under the different management regimes and this suggests that NSF management practices influence at least some of these differences. The effects of current land use (i.e., hay cutting and grazing pressure differences) also seem to counteract NSF treatment effects. The soil properties found to support NSF practices were (Table 2): total and available soil phosphorus, effective cation exchange capacity (ECEC), and soil macro-biota abundance (individuals/core) and diversity (functional groups/core). However, other analyses show either a relatively neutral (ECe) or negative (total nitrogen) effect on soil properties and potential productivity. Other soil analyses including bulk density and soil organic carbon (SOC) percentages suggest that the current grazing pressure (i.e., around 3 years) on the land is an over-riding control that obscures any effects that NSF may have on these properties.

Table 11. The measured values for a range of soil properties on NSF and Non-NSF sites. Standard error is in parentheses and P<0.05 for all values.

Soil property	NSF managed sites	Non-NSF managed sites
Total P (ppm)	938.59 (24.25)	827.19 (19.34)
Available P (cmol/kg)	0.12 (0.01)	0.05 (0.01)
ECEC (cmol/kg)	34.54 (2.30)	29.58 (2.13)
Macro-biota abundance (indv/core)	9.81 (1.21)	6.76 (1.07)
Macro-biota diversity (func. grps/core)	2.67 (0.34)	1.67 (0.26)
ECe (dS/m)	1.32 (0.08)	1.03 (0.07)
Total N (ppm)	3547.13 (135.56)	4560.71 (155.47)
Bulk density (g/cm^3)	1.02 (0.03)	0.85 (0.06)
SOC (%)	4.99 (0.16)	6.08 (0.20)

Discussion

The influence of NSF management on soil properties is relatively unknown, thus the results of this study cannot be assessed in the context of similar studies, as none exist. Therefore, the results are assessed in the context of the possible explanations for the changes in soil properties as identified in the literature. The NSF predictions of an increased height in the alluvial aquifer watertable and consequent increases in the soil moisture content are used as the basis for this assessment. The inferred soil processes occurring as a result of NSF management include:

- Increased soil moisture as a result of higher soil watertables and capillary rise and consequent increased biomass growth, nutrient cycling and organic turnover (Guobin and Kemp, 1992; Jobbagy and Jackson 2001);
- changes in redox potentials in the bulk soil and microsites altering biogeochemical cycling and availability (increased soil phosphorus and decreased nitrogen) (Baldwin and Mitchell, 2000; Sleutel *et al.* 2008); and
- increased soil moisture levels and persistence (increased soil macro-biota abundance and diversity) (Spain and Hutson, 1983; King and Hutchinson, 2007).

It must be noted that the alluvial sediments of floodplains in the upper Hunter Valley are composed of sandy textures (Kovac and Lawrie, 1991), thus allowing for potentially high transmissivity and infiltration of rainfall and stream water. Therefore it is debateable whether NSF techniques have the same potential for soil improvement in clay dominated floodplain systems where movement of water into and through the alluvial aquifer is more restricted due to the confining pore space.

This study highlighted the changes in soil properties a higher watertable can have in an upper catchment floodplain. The follow up study to these results is investigating remnant chain of ponds to compare with downstream incised floodplain soils to characterise any loss of soil quality following channel incision. This characterisation will be used as a basis for assessing the ability of NSF techniques to improve soil conditions from those of incised floodplains to high alluvial watertable floodplains, as is found in chain of ponds systems.

Conclusion

Based on the potential increases in the watertable and soil moisture as predicted by NSF concepts and the broader literature, NSF management appears to have major influences on the soil chemical and biological properties. Furthermore, the only definitive result that shows NSF is having adverse effects on floodplains soils is the reduction in total nitrogen. Despite the fact that the grazing pressure and hay cutting appears to confound the organic carbon and bulk density results, the remaining results are still positive. Finally, this study highlighted several areas where current research seeks to improve the understanding and quantification of the potential and actual effects NSF management has on floodplain soils. In particular, quantifying any changes resulting from stream channel incision

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Time-controlled grazing and soil erosion control under a catchment scale experiment in South-east Queensland, Australia

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Abstract
Grazing systems affect pasture production and hence surface cover which is the protective layer of soil against water erosion. Time-controlled (TC) grazing as an alternative to conventional grazing systems has become popular in some parts of Australia and rest of the world for its relatively higher pasture productivity. It involves short periods of intensive grazing which is of concern for environmental impacts and sustainability. To address some aspects of the issue, a runoff catchment experiment was established to investigate the effect of the newly adopted grazing system (TC grazing) on runoff and sediment loss from 2001 to 2006. The results show that sediment loss was reduced significantly over the study period as the surface cover increased. The reduction in soil erosion was achieved despite the fact that the increase in ground cover under TC grazing had little effect on runoff. Decrease in runoff and soil loss is mostly attributed to the higher level of surface cover (90%) achieved during the second period of the study (2004-2006) compared with 65% for the first (2001-2003). Long rest periods in TC grazing was seen to be the major contributor to soil and pasture recovery after the intensive defoliations and subsequent increase in above ground organic material providing soil erosion control.

Key Words
Runoff, soil loss, ground cover, pasture, Time-controlled grazing, Queensland, Traprock.

Introduction
Traditional practices including continuous grazing in rangelands usually lead to soil compaction with associated loss of pore structure and connectivity which reduce infiltration capacity (Greenwood and McKenzie 2001). For this reason under continual utilization of pasture species by grazing animals, as the stocking rate increases, runoff and soil loss increase (Rauzi and Hanson 1966). Introduction of rotational grazing system in the 1960s, that includes some periods of grazing exclusion, resulted in some improvement in soil and surface hydrology, through the increase in above and below ground organic materials. In south-east Queensland, time-controlled (TC) grazing, as a variant of rotational grazing is the main alternative to traditional grazing practices. This paper briefly provides information on the effects of TC grazing on runoff and soil loss based on the data collected from a small catchment practiced by TC grazing for 6 years.

Methods and materials
Study area
The research was conducted at "Currajong", a grazing property in the semi-arid region of south-east Queensland, Australia (28º 33' S, 151º 33' E, altitude 675 m). The area, known locally as Traprock, is located in the catchment of the MacIntyre Brook at the northern headwaters of the Murray Darling basin. The annual rainfall for the study area is 645 mm, with summer dominant of around 70% characterized by relatively high frequency of medium to large events of short (thunderstorms), and long (cyclonic depressions) durations. In the dry season (April to September), there are smaller events, both in magnitude and intensity associated with frontal depressions.
The soil is shallow to moderately deep with a hard setting brown to dark clay loam underlined by a bleached A2 horizon. Vegetation is open Eucalypt woodland with an understorey of native and naturalized perennial grass species dominated by a desirable species known as Queensland blue grass [*Dichanthium sericem* (R. Br.) A. Camus].

Treatments
The runoff catchment with area of 8 hectares; 8% slope and 40 cm average soil depth was instrumented by a San Dimas flume, automatic water sampler, two pluviometers and associated loggers. The height of the runoff flowing through the flumes was recorded in mm using a Greenspan pressure transducer positioned in

the stilling wells. The surface runoff, passing through the flume, was sampled using automatic pumping samplers capable of holding up to 50 water bottles. A bilge pump, submerged in a mixing pond at the outlet of the flumes, was triggered to facilitate this action. The catchment was located in a research paddock with a long history of continuous grazing but converted to TC grazing from 2001 onward. The paddock including the runoff catchment was grazed with high stocking rates of 12.6 ± 6 DSE (Dry Sheep Equivalent)/ha in differing short durations (14 ± 9 days) and long rest periods (101 ± 60 days) depending on feed availability and rate of grass growth.

Results

The results showed a number of 27 runoff events were recorded in the catchment from 2001 to 2006. Total rainfall generating runoff was 1383 mm with overall runoff coefficient of 19.5% and the sediment loss of 439 kg/ha. The mass curves of runoff and soil loss using all runoff events (Figure 1a) illustrate decreasing trends in runoff depth and sediment loss with time despite the linear increase in rainfall. Regression analysis (Table 1) verified such decreasing trends in runoff and sediment which were best described by negative second order polynomial equations (p< 0.01). These results indicate a lower proportion of rain being converted to runoff towards the end of the study period and sediment loss reduced at a greater rate than runoff depth.

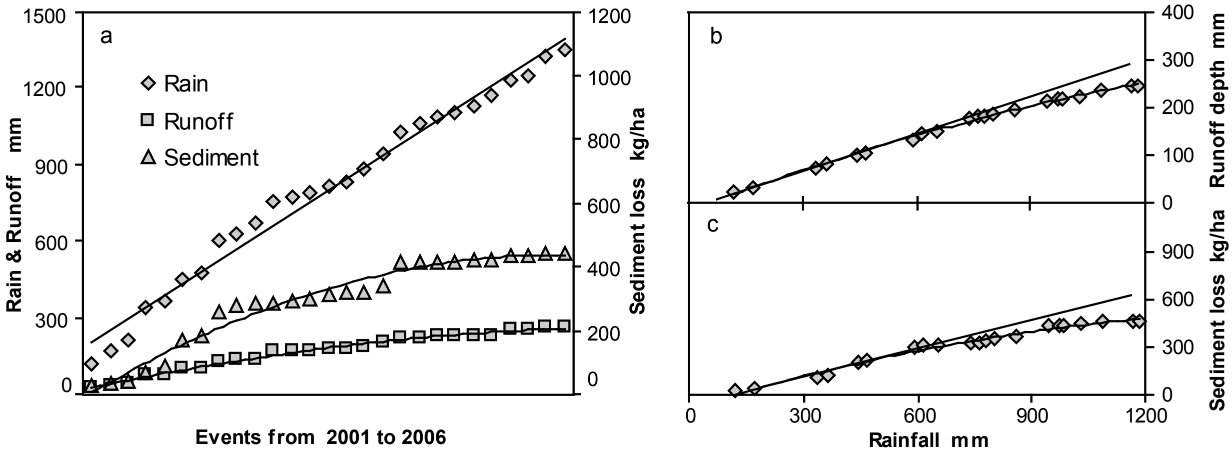

Figure 1. Mass curves of rainfall, runoff and sediment with time (a); double mass curves of rainfall-runoff (b) and rainfall-sediment loss (c) from 2001 to 2006

Under a selection of 21 runoff events, double mass curves of rainfall-runoff (Figure 1b) and rainfall-sediment (Figure 1c) also present the decreasing trends of runoff and soil loss through time (p< 0.01). It's again indicated a lower rate of rainfall converted to runoff with the same situation for sediment loss, being more noticeable over the second half of the study period. The results of the polynomial regression analysis (Motulsky and Christopoulos, 2004) employed in this study (Table 1) verified such significant declining trends of runoff and sediment through time under TC grazing. This analysis determines the extent to which the newly added second order term in the curvilinear model significantly increased R^2 or decreased SSE of the residuals.

Table 1. Polynomial regression analysis for runoff and soil loss.

Curve's name	Equations of best fit	R^2	df	F
Mass curves of rainfall depth with time	$Y= 45.46X + 160.14$	0.98		
Mass curves of runoff depth with time	$Y= -0.233X^2 + 15.48X + 9.64$	0.99	2:24	96***
Mass curves of sediment loss with time	$Y= -0.646X^2 + 34.7X - 29.41$	0.97	2:24	56***
Double mass curves of rainfall-runoff	$Y= -0.0007X^2 + 0.3X - 17.5$	0.99	2:18	108***
Double mass curves of rainfall-sediment	$Y= -0.0002X^2 + 0.71X - 80.4$	0.98	2:18	21.5***

*** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$

The decline in runoff and soil loss is pronounced over the latter years of the study where the grass cover reached and sustained its highest level. The records of ground cover corresponding to the time of the runoff events (Figure 2a) show two distinct periods of low and high surface cover achieved under TC grazing during the course of the study. It suggests a mean ground cover of 65% for the first period of the study (2001-2003) and 90% for the second (2004-2006) which is higher than the minimum safe threshold of 70% recommended for the region (Sanjari *et al.* 2009). The gross values on runoff and sediment over the two periods of the study (Figure 2b) illustrate a significant decrease in sediment loss and to some extend in runoff from the first period to the second, despite 5% increase in total rain and 1% increase in rainfall erosivity (6962 to 7048 MJ/ha*mm/hr) in the second period.

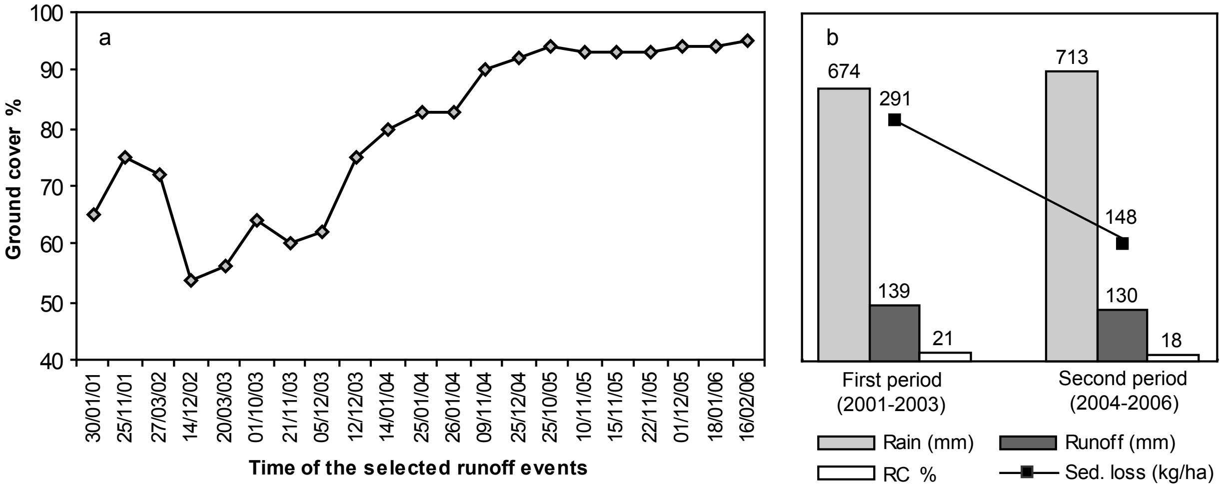

Figure 2. Ground cover changes over the study period (a); total rainfall, runoff, runoff coefficient (RC) and sediment loss over the first (2001-2003) and second (2004-2006) periods (b).

A decrease in runoff and soil loss could be a result of an increase in infiltration and interception facilitated by the higher level of both ground and foliar covers which protect the soil surface against raindrop impact and surface runoff (entrainment and re-entrainment). An increase in soil organic matter and ground litter in this area reported earlier by the authors (Sanjari *et al.* 2008) are also the factors that may have increased infiltration and reduced runoff and soil loss.

Inclusion of long rest periods in TC grazing is an important factor for soil and pasture recovery. In the study area, there are high chances of having some consecutive favorable wet conditions over the rest periods, entering the main inputs into the process of pasture recovery which triggers a mass regrowth. For instance, over the growth season of 2003-2004, the catchment was rested for 156 days, during which a total of 480 mm rainfall occurred. Such a coincidence produced large amounts of organic matter that has been a major resource for ground cover.

Some studies under rotational grazing (McGinty *et al.* 1979; Wood and Blackburn 1981) have emphasized on the significant effect of rest duration on runoff and soil loss compared with continuous grazing and even non-grazed areas. In Texas, USA, Warren *et al.* (1986a) found some soil recovery during a 30 days rest period. This was evident from the higher infiltration rates and lower sediment loss recorded at the end of the rest periods compared with the beginning of them.

Conclusion

The grazing system of Time-controlled, showed that under prevailing conditions of the study area, has potential to increase ground cover from 65% in the first period of the study (2001-2003) to 90% during the second, only three years after conversion from continuous grazing. This amount of surface cover provided the soil surface with adequate protection, resulted in significant decrease in soil loss over the second period of the study. This capability is attributed to the provision of sufficient rest periods, allowing a great accumulation of above and below-ground organic matter and surface residue. Runoff also decreased over the second period but not as much as sediment did. Time-controlled grazing appears to be efficient in reducing runoff over a longer period of time with a favorable soil and climatic conditions, where a larger increase in soil organic material is expected to occur.

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Transport and deposition of *Escherichia coli* O157:H7 and *Enterococcus faecalis* in three Italian soils

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Abstract
A series of column experiments was conducted under saturated flow conditions to investigate the factors affecting *Escherichia coli* O157:H7 and *Enterococcus faecalis* transport in three Italian soils. Breakthrough curves (BTC) differed according to the bacteria species and soils. *E. coli* moved faster through the columns, most likely due to size exclusion phenomena, which constrained the cells to more conductive flow domains and large pore networks. Macroporosity seems to be a key factor for identifying the vulnerability of groundwater resources to microbiological contamination.

Key Words
Bacterial transport, soil columns, saturated flow, macroporosity.

Introduction
Increasing livestock densities have compounded the environmental contamination problems associated with disposal of the resulting manure. A lot of effort has been made in Italy to control nitrate water pollution, but little is known about the potential microbiological contamination risks coming from manure distribution. Indeed manure and biosolids contain many pathogenic microorganisms, such as *Cryptosporidium*, *Giardia*, *Escherichia coli* O157:H7, *Enterococcus faecalis*, *Salmonella*, and some viruses (e.g., rotavirus). Microbial contamination of groundwater is a serious problem that can result in major outbreaks of waterborne diseases. Predicting the transport and fate of pathogenic microorganisms is therefore required to delineate areas vulnerable to microbiological contamination and protect groundwater resources. The objective of this work was to investigate the transport and deposition behavior of *E. coli* O157:H7 and *Enterococcus faecalis* in three Italian soils.

Methods
Breakthrough (BTC) experiments were carried out on nine undisturbed soil cores (internal diameter 6 cm, length 15 cm) collected in three soils (three replicates per soil) located in NE Italy within two densely populated livestock areas. Soils were clay loam (S1), sandy clay loam with 30% of gravel (diameter of 2-10 mm) (S2) and sandy loam (S3). Prior to BTC experiments, cores were sterilized by tyndallization (10 min at 75 °C for 3 days) and then subjected to capillary saturation with sterilized deionized water. A mixed bacterial suspension was prepared at concentrations of approximately 10^7 CFU /mL of *E. coli* O157:H7 and 10^8 CFU/mL of *Enterococcus faecalis*. Br^- (500 mg/L) was added to the suspension as conservative tracer. BTC experiments were conducted under saturated flow conditions pumping 3 pore volumes (PVs) of suspension and then 2 PVs of sterilized water. Bacteria effluent concentrations were measured by membrane filtration, serial dilution and plate counting in mFC agar. Deposition of the bacteria at five depths along the columns was measured at the end of the experiments. Adsorption of bacteria cells to the soils and inactivation rate in the liquid were measured in batch experiments. To evaluate the potential effect of soil structure on bacteria transport, soil porosity distribution (0.007 μm-3 mm) and specific surface were measured by mercury intrusion and N2 adsorption at 77 K, applying the BET equation, respectively.

Results
BTCs differed according to bacteria species and soils. *E. coli* relative concentration in the effluent was higher than *E. faecalis* (Figures1-2): on average a peak of 0.72 was observed at 3 PVs in S1 while in S2 a first peak of 0.94 at 0.7 PVs was followed by a second one at 2.3 PVs (Figure 1). *E. coli* breakthrough was slightly accelerated relative to Br^-, most likely due to size exclusion phenomena which constrained the cells to more conductive flow domains and large pore networks, which were physically accessible (Bradford *et al.* 2006). Slower mobility was observed for *E. faecalis*, especially in S1 where the relative concentration increased steadily and slowly up to 0.063 at 4.3 PV (Figure 2), suggesting the blocking of favorable

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attachment sites (Tong *et al.* 2005) and/or filling of straining sites (Bradford *et al.* 2006). No cell breakthrough was instead observed in S3 for either bacteria species, which were transported in the soil column only up to a depth of 7.5 cm from the top surface. Bacteria recovery in the leachate was higher for *E. coli*, with more than 30% and 70% in S1 and S2, respectively, while recoveries of *E. faecalis* were 5% and 40%. The higher transport in S2 could be associated to the presence of a relevant macropore system (diameter range 200-3000 μm), that according to intrusion analysis represented 13% of the overall porosity.

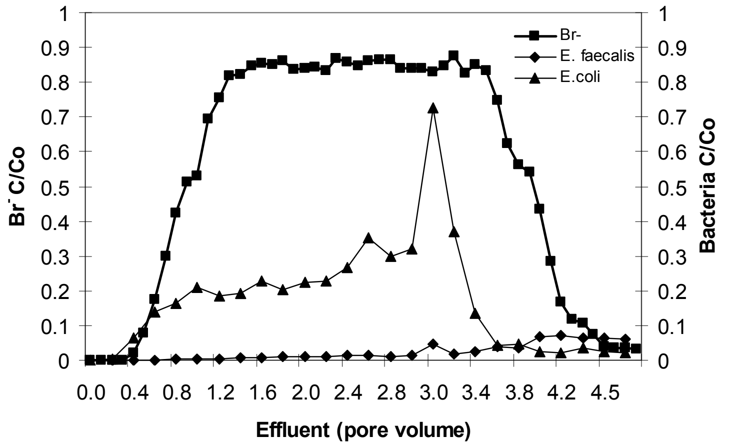

Figure 1. Effluent concentration curves for Br-, *E.coli* and *E. faecalis* in the clay loam soil (S1).

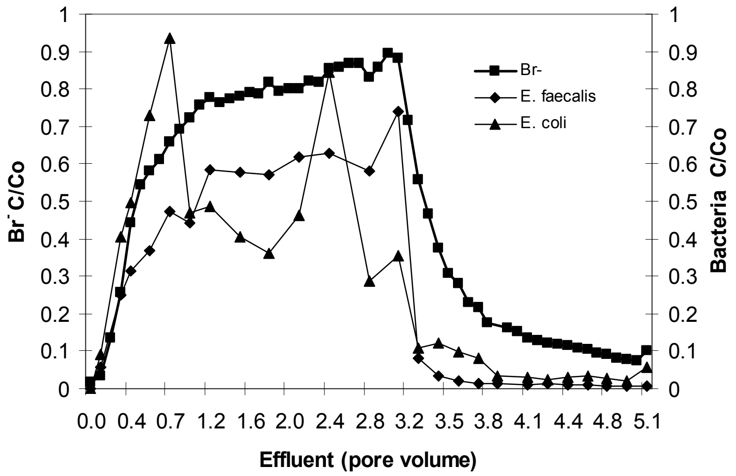

Figure 2. Effluent concentration curves for Br-, *E.coli* and *E. faecalis* in the sandy clay loam (S2).

Conclusion

Column experiments have demonstrated that the interaction between bacteria species and soil type can affect microbiological transport. Macroporosity appears to be a key factor for identifying the vulnerability of groundwater resources to microbiological contamination. Further experiments are needed to confirm this evidence at larger scales.

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Urine patch area coverage of an intensively stocked dairy pasture

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Abstract
The urine patch of the grazing cow has been identified as the key source of N loss from pasture-based dairy systems. Although critical to N modelling, quantitative data on the annual area coverage of urine patches in pastures is scarce. A new technique using survey-grade global positioning system (GPS) technology was developed to measure the paddock area coverage of dairy cattle urine and dung patches. A four year study was conducted on an intensively stocked (4.3 cows/ha) dairy farm in Canterbury, New Zealand. Twelve field plots on typical grazed pasture were monitored over a four year period, sampling at 12 week intervals. Urine and dung deposits within the plots were visually identified, the pasture response area (radius) measured and position marked with survey-grade GPS. Spatial geographic information system (GIS) software was used to analyse the data. The mean urine patch pasture response area was 0.35 m^2. It was calculated that the mean area covered by urine patches on an annual basis was 23.1 ± 2.2 % for the given stocking density and grazing management regime.

Key Words
Nitrogen, urine, area coverage, dairy, grazed pasture, GPS.

Introduction
Urine and dung deposited by grazing animals causes high nutrient loading to a relatively small proportion of the total grazed area (Haynes and Williams 1993). The high N loading rate (1000 kg N ha^{-1}) of the dairy cow urine patch exceeds pasture N demand (Moir *et al.* 2007), and hence represents the major source of N loss from intensively grazed pasture systems (Di and Cameron 2002*a*). Much valuable research has been conducted to quantify (Silva *et al.* 1999, Ledgard *et al.* 1999, Di and Cameron 2002*a*) and mitigate (Di and Cameron 2002*b*, 2007) N loss from temperate grazed grassland in New Zealand. However, in order to effectively model and manage N losses from grazed pastures, information on the spatial nature of urine depositions is required. Quantitative research data on the area coverage of urine depositions to grazed pasture is scarce internationally.

The measurement of annual urine patch coverage in grazed pastures is difficult. Short-term observations of grazing dairy heifers were made by Petersen *et al.* (1956), mostly focusing on dung depositions and distribution. These workers concluded that a negative binomial function was in close agreement with measurements of the distribution of dung patches, and probably also urine patches. MacLusky (1960) estimated that the surface area affected by cow urinations was 0.68 m^2/cow/d, which equates to a low annual coverage value of < 10% of the paddock area. Estimates of total urine patch area coverage, are however, unclear in this study. Richards and Wolton (1976) conducted more detailed calculations, based in part on the work of Petersen *et al.* (1956). Assuming that overlapping occurs, they used the negative binomial function and calculated that 23 % of a paddock might be covered by urine patches annually. However, this study did not have the ability to distinguish between old and fresh urine patch response areas, which are a critical aspect of the calculations. Based on values from literature, Williams (1988) calculated that 23% of a pasture would be covered in excreta (dung and urine) in one year. Again using a theoretical calculation, Whitehead (2000) estimated an annual urine coverage area of 21% for grazing dairy cattle. In a more detailed recent study, White *et al.* (2001) measured the frequency and location of urinations and defecations of dairy cows for 5 x 24 hr grazing periods. Taking an average area coverage for urine and faeces based on literature values, they calculated an area coverage of excreta of about 10% of the total paddock area for a stocking density of 2.48 cows/ha. Although the most comprehensive study to date in this field of research, the annual urine patch coverage area value of 10% by White *et al.* (2001) seems low when compared to New Zealand grazing systems.

In a preliminary study, Moir *et al.* (2006) presented a new methodology to overcome these measurement issues. A Real-Time Kinematic Global Positioning System (RTK-GPS) was used to record the temporal and spatial location and radius of animal urine and dung patches in the field. In this paper we present the full results of this study examining field urine depositions by dairy cattle, using the method of Moir *et al.* (2006). The objective of this study is to quantify the annual area coverage and spatial distribution of dairy cow urine depositions to an intensively stocked grazed pasture system.

Methods

The research was conducted on the Lincoln University Dairy Farm (LUDF), near Christchurch, New Zealand. The trial was four years in duration, commencing in May 2003. The farm is 161 ha (effective) in area with a stocking density of 4.3 cows/ha, and is spray irrigated from November to March. Milk production is 1800 kg milk solids (MS)/ha/yr with cows grazed outdoors year round on a pasture only diet. Most of the dairy herd graze off-farm for 4 weeks during the winter months of June and July. Twelve 10 m x 10 m (100 m^2) plots were established on 'typical' grazing areas of the farm, and sampled at twelve week intervals. Plots were grazed as part of the normal grazing rotation of the farm.

Urine patches were visually identified as being areas of lush, dense pasture growth, typical of a large pasture nitrogen growth response. The location of all animal urine and dung patches deposited on the plots were recorded using a GPS. Survey grade Trimble™ RTK GPS (TNL 5700 rover, plus base unit) was used, giving a position accuracy of ± 0.01 m. Patch positions were marked by placing the GPS pole in the centre of the dung or urine patch and the location recorded in the data logger. In addition, the mean radius of the urine or dung patch was measured by clamping a ruler horizontally to the base of the GPS pole. All measurements were taken at least 14 days after the paddock was last grazed meaning that urine patches were easily observed due to the high pasture mass of the urine patch compared with other areas of the sward.

The field GPS data was ground-truth corrected and geographic information system (GIS) data analysis was performed using *ArcGIS 8.0* (ESRI 2002). Location coordinates were established for urine and dung patches, including patch radius. During data analysis it was assumed that if the centre of a urine patch was within ± 10 cm of another patch, it was deemed as having resulted from the same urination event. Dung patch data was removed from the data set. The data output was then summarised in terms of: (i) number of urine patch observations in each plot per sampling event; (ii) area of the plot (%) affected by urine deposition at each sampling event; and (iii) the mean radius of urine patches.

Results

The average observed urine patch radius and size (area) were very consistent. Mean urine patch radius ranged from 27 cm in the winter of Year 2, up to 40 cm in the summer of Year 3 (Table 1). Urine patch area ranged from 0.31 to 0.50 m^2 (Table 1). Overall, the mean urine patch observed in the field can be described as having a radius of 33 cm and an area of 0.35 ± 0.001 m^2.

Table 1. Mean urine patch radius (cm) and area (m^2) across all years.

Season of Deposition:	Year 1		Year 2		Year 3		Year 4	
	Patch Radius	Patch Area	Patch Radius	Patch Area	Patch Radius	Patch Area	Patch Radius	Patch Area
Winter	33.1	0.34	27.5	0.24	30.6	0.29	38.3	0.46
Spring	35.0	0.38	32.5	0.33	38.3	0.46	29.4	0.27
Summer	30.4	0.29	39.5	0.49	39.7	0.50	30.9	0.30
Autumn	27.6	0.24	30.6	0.29	31.2	0.31	37.8	0.45
Annual Means	31.5	0.31	32.5	0.34	34.9	0.39	34.1	0.37
4 Year Mean		0.35						
SEM		0.001						

The average number of urine patches measured per plot is presented in Figure 1. Mean values ranged from 11.0 to 20.0 urine patches/plot. The number of patches varied between seasons, but no trend in seasonal variation between years was apparent (Figure 1). Mean urine patch numbers across all samplings and all years was 15.2 patches /plot/sampling. This value equates to 1520 urine patches/ha at any one time. On a spatial basis, urine patch area coverage varied from season to season, and between years. Annual area coverage by urine patches varied from 21.6 (Year 2) to 24.4 % (Year 4), with an average value of 23.1 % ± 2.2 % (Figure 2A). Area coverage appeared to be lowest for winter and autumn deposition periods, except in year 4, where the trend was reversed. Spatially, urine depositions were of a random nature (Figure 2B).

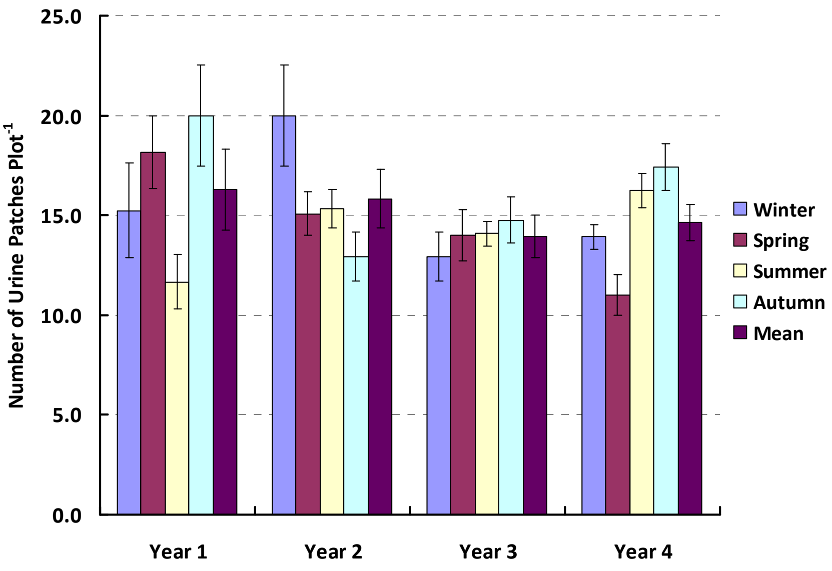

Figure 1. Mean numbers of urine patches observed per plot on a seasonal basis for all years. Error bars represent ± 1 SEM.

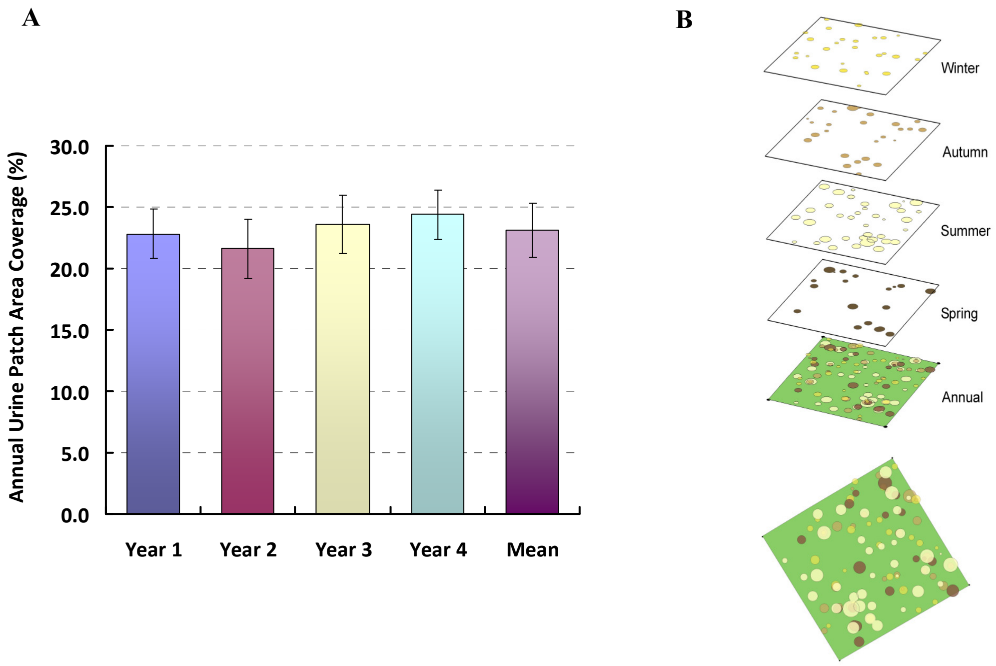

Figure 2. (A) Mean annual area coverage of urine patches from GIS data analysis. Error bars represent ± 1 SEM.; and (B) A graphical example of a GIS data analysis output for cow urine depositions on one field plot for one year. These outputs were used to calculate and map the spatial area coverage of urine patches in the field on a temporal basis.

Discussion

Urine patch radius and area values measured using this new GPS method agree well with values reported by other workers. Petersen *et al.* (1956) reported a mean urine patch area as 0.28 m^2, Richards and Wolton (1976) reported 0.49 m^2, while Haynes and Williams (1993) summarised the range as being 0.2 to 0.4 m^2, with a likely mean value of 0.3 m^2. The data from our study suggest that in the field environment, the value is likely to be in the region of 0.35 m^2. Annual urine patch area coverage data presented here provide valuable new information on spatial urine coverage under an intensively stocked dairy system. The mean area coverage value presented here is 23.1 ± 2.2 % of the paddock area covered in urine patches annually. This value agrees strongly with the theoretical calculations of Peterson *et al.* (1956) (23%), Williams (1988) (23%) and Whitehead (2000) (21%). In contrast, the estimates of around 10% coverage by MacLusky (1960) and White *et al.* (2001) are not in agreement with results from our study. However, the random nature of urine and dung depositions reported here (Figure 2B) do compare well with the results of White *et al.* (2001), and demonstrate the even grazing of pasture, and therefore even urine and dung deposition, that occurs under a high stocking rate.

Conclusions

A new method of accurately measuring and recording the position and area coverage of urine and dung depositions by grazing cattle in the field has been successfully developed in this study. Our detailed results indicate that for dairy pastures with a high stocking density of 4.3 cow ha^{-1}, the average urine coverage of paddocks on an annual basis was 23.1 ± 2.2 %, with a mean urine patch area of 0.35 m^2. It was estimated that on average 1520 urine patches ha^{-1} were present at any time through the year. This is valuable information for those measuring, modeling and mitigating N loss from grazed dairy pasture systems.

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Use of the BOs-1EP for the low-sample estimation of the spatial distribution of grain sizes

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Abstract
The soil sensor system BOs-1EP, developed by the University of Applied Sciences Osnabrück, is presented here. The measuring principle is based on recording complex electrical conductance using just one pair of electrodes. The BOs-1EP is principally used to perform geoelectrical measurements in the topsoil. The measurement readings constitute a basis for the low-sample estimation of the spatial distribution of grain sizes. In addition, the readings taken using the BOs-1EP are compared to those determined using the commercial measuring systems ARP03 and EM38. The correlations between the EC values and grain sizes determined by the BOs-1EP are equally good, and sometimes even better, than the ARP03 measurement readings. While there is only weak correlation between the EC values of the EM38 and the grain sizes in the topsoil.

Key Words
BOs-1EP, digital soil mapping, soil particle size, estimation, precision farming, electrical conductivity.

Introduction
Small-scale soil information is of vital importance to economically (Kielhorn und Trautz 2007) and ecologically (Trautz *et al.* 2007) successful plant production. There is often a correlation between an unsteady level of yield and the characteristics of the soil (Scheffer & Schachtschabel 2002). If small-scale soil information, such as the type of soil, is available to agriculturists, applications (Brozio 2004; Gebbers 2004; Roth 2004) and cultivations measures (Voßhenrich 2003) can be aligned to the respective types of soil, and optimised. The small-scale soil mapping required for such information can be performed using innovative mapping methods, e.g. using soil sensors. A new soil sensor system (BOs-1EP) with the measuring principle "recording complex electrical conductance" was developed within the research projekt PIROL at the University of Applied Sciences Osnabrück. The BOs-1EP is specifically designed for taking geoelectrical measurements in the topsoil. A precise measuring depth and a defined measuring volume can be assigned to the measurement reading (HINCK 2009). Using the measurement readings, an area can be divided into subareas. For instance, a field can be divided into subareas using the cluster method (Hinck *et al.* 2006) or by dividing electrical conductance (EC) into classes (Hinck *et al.* 2008). These subareas can then be singled out for soil analysis and sampling (Hinck *et al.* 2009).

Methods
Measuring principle of the BOs-1EP
The measuring principle of the BOs-1EP is based on recording complex electrical conductance. The values measured are the magnitude, the phase shift and the noise of the electrical signal. The electrical conductance and electrical capacity of the plate assembly can be computed from the magnitude and the phase shift. Electrical noise describes the contact quality between the measurement plates and the soil. In addition, the soil temperature is taken using an infrared thermometer. Two 180 cm^2 metal plates act as electrodes. The BOs-1EP is attached to the tail hydraulics of a tractor (Figure 1) and the metal plates are dragged through the soil (galvanic coupling). The measuring depth and measuring volume are defined by the measuring set-up and the depth control of the BOs-1EP. The electrical field between the two blades in the soil is sketched in Figure 2. It can clearly be seen that the electrical field is located between the pair of electrodes, which enables us to determine the depth and measuring volume from which the measurement reading was taken. The measurements described here were carried out with an electrode space of 26 cm and a measuring depth of 25 cm. Five individual measurements are taken within half a second, whereby the five individual values are captured within a period of approximately 50 milliseconds. The mean of the five individual values is calculated. In this way two measurement readings per second are gained. The technical data of the BOs-1EP

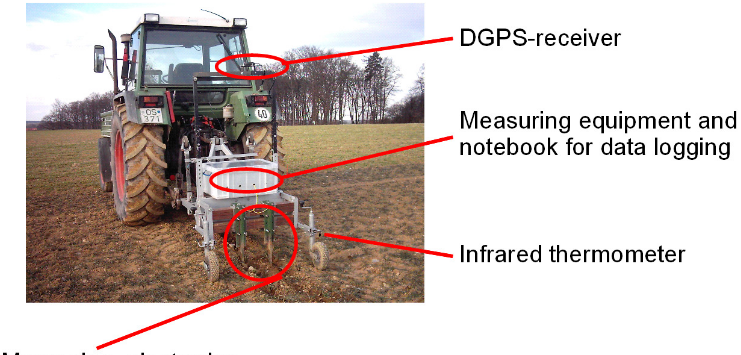

Figure 1. The BOs-1EP measurement system attached to the tractor.

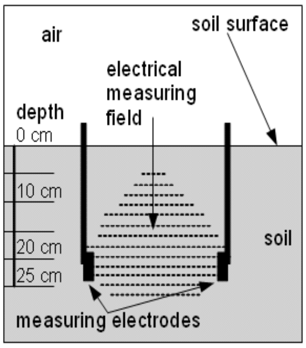

Figure 2. Behaviour of the electrical field in the soil between the pair of electrodes, BOs-1EP measurement system.

measurement system are given in Table1. We also used the commercial measurement systems EM38 and APR03 to evaluate the correlation between the grain size and electrical conductance (Table1). Thus a comparison of the results from the three measurement systems could be made.

Table1. Technical data of the three measurement systems used.

	BOs-1EP	ARP03	EM38
Measurement method	Detection of complex electrical conductance	Direct current, four-terminal electrode arrays	Electromagnetic
Electrical contact (sensor <> soil)	Galvanic (direct contact measurement)	Galvanic (direct contact measurement)	Induction (contactless)
Frequency	125,000 Hz	150 Hz	14,600 Hz
Measurement depth	Electrode depth: 25 cm	Electrode arrangement 1 (EC1) Measured depth: 0 – 50 cm	Horizontal dipole mode: 63% of the signal response describes a depth down to 60 cm
Measurement property	Defined measured volume at a defined depth	Measurement is the integral over the measured depth	Measurement is the integral over the measured depth
Date of measurement	14 March 2007	Autumn 2004	14 March 2007

"Im Berge" test field

The measuring systems were tested and evaluated on test fields of the University of Applied Sciences Osnabrück. The results are presented on the basis of the "Im Berge" test field. This field, with an area of 2.4 ha, has a very heterogeneous geological and pedogenic development (Hinck 2009). Thorough soil investigations have been carried out regarding this field. The field was subdivided into 224 10 m x 10 m grid cells (Figure 3). Mixed soil samples were taken from each grid cell, and the types of soil were identified in the laboratory. In the topsoil (at a depth from 0 to 30 cm), clay contents of 9% to 40% (Figure 4), silt contents of 21% to 40% and sand contents of 24% to 69% were determined.

Results

Correlation between grain sizes and EC

The correlations determined by the BOs-1EP are equally good as those of the ARP03. The EM38 reveals considerably weaker correlation for geoelectrical measurements in the topsoil (Table3). In the case of the EM38, the considerably larger measuring volumes and the difficulty of determining depth must be taken into account. Since there is a correlation between the EC and the grain sizes, it is possible to estimate the distribution of grain sizes using the EC readings. (Hinck 2009)

Estimation of the grain sizes using the EC

To this end, the field map containing electrical conductance was employed. It was used to select seven (virtual) sampling locations. Two grid cells with high EC readings, as well as two grid cells with low and three with moderate EC measurements were selected. The distribution of grain sizes was estimated for the 224 grid cells using the available data, the EC and the respective result of the analysis for the investigated grain size (sand, silt or clay). The accuracy of estimate is verified using the difference between the true value (laboratory value) and the estimated value (Table3). The spatial distribution of the electrical conductance and the estimated clay contents for the respective measuring system are presented in Figures 5 to 7.

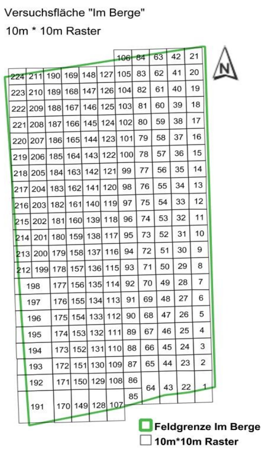

Figure 3. Sampling and evaluation grid for the "Im Berge" test field

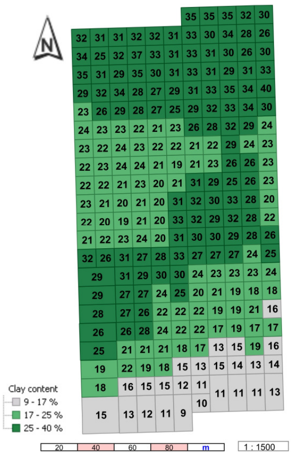

Figure 4. Spatial distribution of the clay content (in %) at a depth of 0 - 30 cm for the "Im Berge" test field

Table 2. Coefficiencies of determination between the grain size and the EC of the respective measuring system (Hinck *et al.* 2007)

Measuring System	Sand	Silt	Clay
BOs-1EP (EC25)	0.6 - 0.7	0.4 - 0.6	0.6 - 0.8
ARP03 (EC1)	0.6	0.6	0.7
EM38 (EChor)	0.2 - 0.5	0.3 - 0.6	0.2 - 0.5

Table 3. Comparison of the difference between the true and estimated sand and clay content in the topsoil of the three measuring systems used; number of grid cells with an acceptable deviation.

	BOs-1EP				ARP03				EM38			
	sand		clay		sand		clay		sand		clay	
Difference in percentage points	hits count	hits %	hits count	hits %	hits count	hits %	hits count	hits %	hits count	hits %	hits count	hits %
0	13	6	20	9	16	7	20	9	9	4	12	5
±1	42	19	69	31	39	17	67	30	32	14	57	25
±2	82	37	114	51	69	31	106	47	57	25	98	44
±3	107	48	161	72	95	42	135	60	78	35	126	56
±4	130	58	183	82	112	50	160	71	107	48	145	65
±5	153	68	201	90	130	58	177	79	132	59	161	72
±6	174	78	211	94	148	66	194	87	152	68	178	79

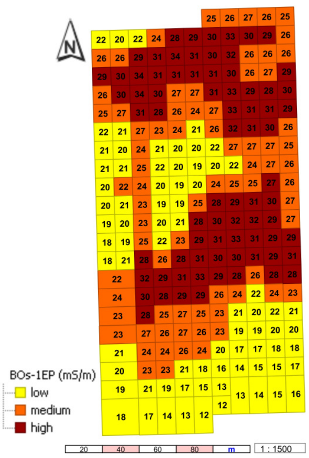

Figure 5. BOs-1EP; estimated clay content (see value in grid cell); yellow-orange-red colouring shows the spatial distribution of the electrical conductivity.

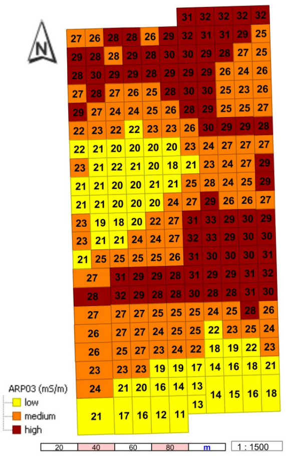

Figure 6. ARP03; estimated clay content (see value in grid cell); yellow-orange-red colouring shows the spatial distribution of the electrical conductivity.

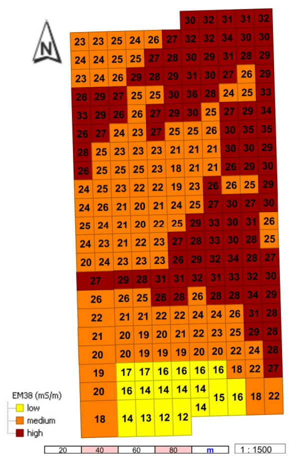

Figure 7. EM38; estimated clay content (see value in grid cell); yellow-orange-red colouring shows the spatial distribution of the electrical conductivity.

Conclusion

It is possible to take reliable geoelectrical measurements using the presented measuring principle "recording complex electrical conductance" with just one pair of electrodes. The measurement readings and the resulting correlations between the EC and the grain size demonstrate correlations that are equally good, or sometimes even better, than those of the ARP03. The estimation of the distribution of grain sizes using the EC values is accordingly accurate. The correlation between the grain size in the topsoil and the EC values of the EM38 is weaker, hence the less accurate estimation of the grain sizes. A field map with the estimated distribution of grain sizes forms the basis of precision soil sampling, which avoids inaccurate mixed soil samples, e.g. from sandy and silty parcels. Misinterpretations of the soil analysis results are therefore minimised. Such field maps can be used to support further management decisions (e.g. determining lime requirements).

Acknowledgement

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Vertical and horizontal distribution of soil properties influenced by individual trees in grazing landscapes of NSW Australia

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Abstract
Scattered paddock trees play an important role in the Australian environment and influence their immediate environment both above- and below-ground. These trees are rapidly being lost from the landscape and there is a need to understand their functions more fully in order to optimise landscape management. This investigation aimed to quantify how single trees influence the soil resource with depth and to investigate the spatial extent of their influence. Three isolated trees were comprehensively examined for their influence on soil chemistry to a depth of 75 cm and to a radial distance of more than 3.5 canopy radii. Modification of soil condition was strongly dependent on the soil property examined, although typically values were higher under the tree at the surface and diminished with distance. We conclude that single trees significantly improve soil condition and that a distance of 2.5 canopy radii is sufficient to explain the spatial influence of scattered trees.

Key Words
Keystone structures, organic matter, competition.

Introduction
In the past decade there has been growing international interest in the influence of trees on their surrounding environment (e.g. Belsky *et al.* 1989; Eldridge and Wong 2005; Gibbons *et al.* 2008; Graham *et al.* 2004; Jackson and Ash 1998; McElhinny *et al.* 2009; Obrador and Moreno 2006; Wilson 2002). Scattered trees can either occur naturally, such as savannas, or in modified environments, such as the remnant paddock trees that exist throughout production landscapes in Australia. These trees are a valuable natural resource for both above- and below-ground ecological services and act as 'keystone structures' in the grazing landscape (Manning *et al.* 2006). However, it has been estimated that within 40 to 185 years, these trees could be lost from the Australian landscape (Gibbons *et al.* 2008).

It has been demonstrated, in a range of environments, that individual trees have the capacity to modify soil condition, organic matter content, nutrient status etc., and therefore they would appear to have value in the production landscape in ameliorating land and soil degradation effects (Yates and Hobbs 1997). In northern NSW, where approximately 60% of agricultural businesses have reported land and soil degradation problems (ABS 2008), these trees might have particular value.
Here we sought to clarify the effects of trees on the surrounding soil, and posed two specific research questions:
1. How does an individual tree influence the soil at different depths?, and
2. How do these vertical changes alter with distance from the tree?
These questions will form the basis for subsequent investigation of tree: soil: pasture interactions.

Methods
The study was conducted on the University of New England's property "Tullimba" 325625E 6626834N near Armidale NSW, Australia. Soils across the property consist predominantly of shallow Yellow Chromosols (Isbell 2002). These soils are characterised by a sandy A horizon 0-20 cm deep and a sandy clay B horizon 20-80 cm deep. The site was historically set stocked with cattle at a rate of 0.4 cows / ha and has single superphosphate applied (rates 100-156 kg/ha) every 1-2 years.

Three isolated (no other trees within a 50m radius) Grey Box (*Eucalyptus moluccana* Roxb) trees were examined. Trees studied were 20-24 m high and had canopy radii from 5-6.2 m. Soils were sampled from four concentric zones around each tree determined by the individual tree canopy radius (cr); a) *inner canopy*: 0-0.5 cr, b) *outer canopy*: 0.5-1 cr, c) *intermediate*: 1-2.5 cr, and d) *open*: 2.5 + 10 m. Each of these *zones* was divided into eight equal *segments* aligned along principal compass bearings, totalling 32 *segments* across all *zones*. In each segment, 1 sample location was located randomly and a soil core collected at depth increments of 0-5, 5-10, 10-20, 20-30, 30-50 and 50-75 cm (totalling 192 samples / tree). Soils were dried at 40°C for 48 hours or until weight stable and analysed for soil moisture, total C, N and S, extractable P, pH (1:5 $CaCl_2$ & H_2O) and EC at the NSW Natural Resources Laboratory, Yanco.

Results and discussion

There were clear differences in both vertical and horizontal distribution of soil properties in relation to the individual trees studied (Figure 1). However, these patterns differed depending upon the soil property being considered. The results indicate four types of pattern occurring with depth and distance from the tree,

Soil moisture at 0-5 and 50-75 cm moisture content was slightly but significantly higher under the tree canopy compared with the intermediate and open zones. For the other soil depths however, soil moisture was significantly higher in intermediate and open zones.

EC was clearly separated by the presence of the tree's canopy, and was significantly higher than either the intermediate or open zone throughout the soil mass

pH typically increased with increasing soil depth. At the soil surface, pH was consistently higher under the tree canopy compared with open pasture. However, this pattern was reversed in the deeper soil layers (50-75cm).

Total C/N/S and extractable P were significantly higher under the tree canopy and in the intermediate zone compared with the open pasture. However, this increase is restricted to the top 20 cm of soil. As this pattern was similar across these soil properties only the total C has been presented here. These results suggest that individual trees significantly influence soil condition in their immediate vicinity both horizontally and vertically albeit that the intensity and magnitude of these effects varies between soil properties. Our results suggest that there is,

a) Potentially an area of competition between the tree and the pasture understory within the 5-50 cm region for available soil moisture,

b) A sufficient litterfall, cation and anion addition from a single tree to significantly elevate soil pH and to increase the nutritional status of the surface soil,

c) Incorporation of organic matter at the soil surface rapidly diminished with soil depth

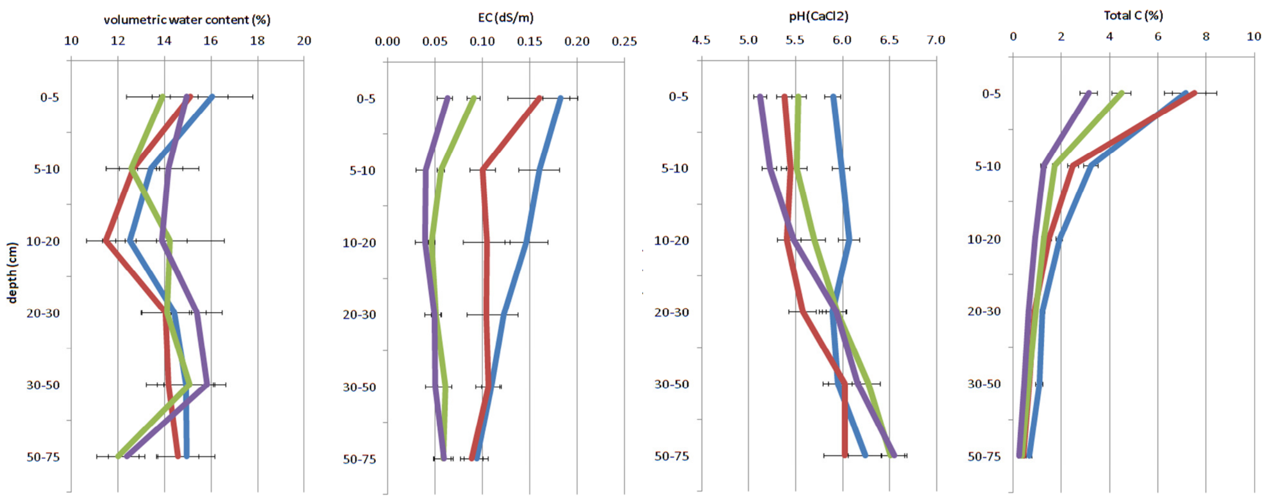

Figure 1. Examples of the changes in some of the selected soil property distribution with depth and distance from the tree. Blue = inner canopy, red = outer canopy, green = intermediate, and purple = open zone. Only 4 of the 7 soil results are shown here as these represent the general trends the other soil properties display. Those with similar trends are indicated in the text above.

Conclusion

This study indicates that trees have a substantial horizontal and vertical influence through the 0-75cm soil mass but that the magnitude, intensity and pattern of these effects differs according to the soil property in question. We further conclude that area distance of 2.5 canopy radius is probably approaching the outer extent of an individual trees horizontal influence on soil properties in this environment. Further work is now underway to elucidate the processes influencing soils around these trees and to link pasture productivity and quality to these soil patterns.

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Water contamination by nitrate and pesticide in a small watershed under tobacco cultivation

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Abstract
Tobacco is usually seen as a “dirty crop” due to its risk to human health, both for producers and for smokers. Nevertheless, in many countries the crop has important social and economical impacts. Watershed is the unit where conservation strategies should be planned to favour soil and water conservation and amelioration. Thus, herein we present results on nitrate and pesticide contamination of surface and shallow well waters, in a small watershed under tobacco production. In the watershed with shallow soil and steep slopes, high potential for water resources contamination cropped to tobacco and rapid decline in soil productive capacity and in water quality were observed. The following elements lead to soil and water degradation: improper agricultural practices, utilization of high doses of fertilizers and pesticides, absence of riparian forest, and intense soil use. A shift in agricultural practices is needed in the short term, by including soil, water and wildlife conservation strategies; whereas a change in cash crop, in the long term, is necessary to replace tobacco cultivation.

Key Words
Rural catchment; watershed hydrology; environmental contamination; steep lands.

Introduction
Tobacco cultivation is an activity with a high potential for contamination of water resources in watersheds and it leads to a rapid decline in the productive capacity of the soil and water quality in these locations. This is largely due to the improper agricultural practices of these lands and the utilization of high doses of fertilizers and pesticides.

Runoff and leaching are the two main ways pesticides may reach surface and ground water. Runoff is the physical transport of pollutants over the soil surface by overland flow, whereas by leaching the pollutants are transported through the soil with infiltrating, ascending or laterally draining water.

The hydrologic cycle of water influences the complex partitioning of molecules and ions within and between the environmental components soil, water and air. Pesticides and other agrichemicals are applied at field scale and react in the soil at molecular scale, but the impact might be at watershed (sum of soil-water interactions). The amount of pesticide runoff depends on slope, soil texture, moisture content, rainfall characteristics, and pesticide characteristics. In watershed scale, the cropped areas distribution in the landscape affects sediment and pesticides concentration. The natural buffer zones (such as riparian zones) may act as pesticide trap along agricultural fields.

Leaching is increased for water-soluble pesticide, sandy texture, rainfall right after pesticide application, low-adsorbing pesticide, and existence of preferential flow through macropores and other large voids. Groundwater contamination is favoured by weakly-sorbed but persistent pesticides, since they are readily leached through the soil. Several pesticides commonly used in tobacco crops, such as chlorpyriphos, imidacloprid, flumetralin, and clomazone, are applied in southern Brazil, as well as non-recommended pesticides for tobacco crops as iprodione, atrazine and simazine. These chemicals pose risk to humans and wildlife.

Intensive farming significantly changes the natural ecosystem and the impacts may be assessed by analysis of surface water. The sediment and runoff leaving crop fields may transport several environmental pollutants used for crop protection against pests and diseases. Thus, water becomes unfit for human consumption bringing negative impact of major significance to rural communities, with repercussions also in urban communities. Surveys demonstrated that sediment discharge in the watershed is high and that phosphate ions are released to solution, on average, twice as rapidly as sediments collected from sub-watersheds with low anthropic activity than those from sub-watersheds with high anthropic activity.

Although tobacco might be seen as a "dirty crop" due its risk to human health, both for producers and for smokers, the crop an important social and economical impact in many countries. Brazil is the second largest producer of tobacco, where thousand families make their living. About 50% of those families live in the state of Rio Grande do Sul (RS), located in southern Brazil, where the studies presented herein were done.

Watershed is the unit where conservation strategies should be planned to favour soil and water conservation and amelioration. Thus, herein we present results on nitrate and pesticide contamination of surface and shallow well waters, in a small watershed under tobacco production.

Methods
A small watershed in Agudo-RS, southern Brazil, with an area of 480ha was studied (Figure 1). Lino Creek and its tributaries constitute the drainage system of the watershed located in a basaltic mountain side, between the Central Depression and Mid Plateau. The region is characterized by the presence of native forest and also of tobacco crop, which uses pesticides without proper control. The watershed is characterized by (i) a low anthropic activity site with steep slopes and stream borders protected with permanent vegetation (riparian zone) and few agricultural fields and (ii) a high anthropic activity site also with steep slopes, but there are agricultural fields close to the stream and less riparian vegetation.


Figure 1. Lino Creek watershed, Agudo-RS, Brazil.

In the pesticide study, water samples were collected in five water sources used for human consumption and in the Lino Creek. Besides tobacco grown as main cash crop, other crops are cultivated after tobacco harvesting, while cultivated forest is used for wood production for tobacco drying after harvest. The water samplings were taken at three times during and after the cultivation of tobacco, namely: after the transplantation of the seedlings, during trimming, and after harvesting the tobacco. The quantification of the active ingredients chlorpyrifos, iprodione and flumetralin was made by gas chromatography with electron-capture detection, whereas imidalcloprid, atrazine, simazine and clomazone were quantified by high performance liquid chromatography with ultraviolet detection.

We also evaluated the nitrate concentration in soil solution in tobacco crop fields, native forest, grasslands and in water from two wells used for domestic supply, and monitored the concentrations of nitrate and ammonium in the soil solution in the region of the root system and below it in a shallow soil planted to tobacco under conventional tillage (CT), minimum tillage (MT) and no-till planting (NT), in a small, hilly watershed in southern Brazil. Monitoring of nitrate concentration in the soil solution was performed in and below the root zone (Kaiser *et al*. 2006), using tension lysimeters with porous ceramic cup for solution collection, and distillation and titration for nitrate analysis.

Results and discussion
In the tobacco production system in South Brazilian many types of pesticides are used. Some properties of these pesticides are: imidacloprid is a systemic insecticide that presents a high residual effect and mobility in the soil and has a half-life in soil from 48 to 190 days. Atrazine is a highly persistent herbicide in the soil, has a high potential for groundwater contamination despite its moderate solubility in water and has a half-life from 60 to more than 100 days. Clomazone is a highly effective herbicide but causes groundwater contamination due to its water solubility (1100 mg/L) and long half-life that averages from 28 to 84 days. Chlorpyrifos is an organophosphate insecticide that is classified as moderately hazardous. In soil,

chlorpyrifos is degraded at a moderate rate; due to the low solubility (1.4 mg/L) and hydrophobic nature (log K_{ow} 3.31–5.27); chlorpyrifos rapidly partitions from the water and adsorbs to sediment particles. Simazine is a persistent herbicide and does not adsorb strongly to soil particles. As it has a high half-life (36–234 days) in soil and low solubility (6.2 mg/mL) in water, it is likely to contaminate groundwater (Becker *et al*. 2009).

Six pesticides (imidacloprid, atrazine, clomazone, iprodione and chlorpyrifos) of the seven active ingredients tested were found both in the water from the creek and from wells used for human consumption. Only flumetralin was not detected in any of the water samples. In samples taken after transplantation of the tobacco, chlorpyrifos was detected in water in all nine collecting points in the watershed and showed to be persistent over time. The water could be consumed if the Brazilian standards would be considered, but could not when considering the European standards of water quality, since the standards are higher and thus more restrictive to human consumption. This poses both a scientific and a political issue.

The indiscriminate use of prophylactic treatments for the cultivation of tobacco along with the lack of landscape planning and environmental protection explain the widespread occurrence of pesticides in water from the creek and from wells for human consumption. This result called for immediate and intensive effort to reduce pesticide use in crop production, protection of wells for human consumption, and integrated watershed planning.

Results from the nitrate study show that nitrate reached depths below the tobacco root zone and represents a source of water contamination. The levels of nitrate were higher in crops fields compared to the grassland and native forest, reaching 80 mg/L in areas with tobacco. The well located below the tobacco crops had higher concentrations of nitrate, surpassing the critical limit of 10 mg/L in some periods.

Ranging from 8 to 226 mg/L, the nitrate content was greater after initial fertilization and decreased throughout the cycle. The average nitrate content in the rooting zone was 75 in the NT, 95 in the MT and 49 mg/L in the CT. Below the rooting zone, the average nitrate content was 58 in the NT, 108 in the MT and 36 mg/L in the CT. Minimum tillage presented the greatest nitrate concentration in the soil solution during the tobacco cycle, but was not statistically significant in relation to conventional tillage and no-till planting. The reduction in the nitrate concentration in the soil solution over time may be attributed to uptake of the nitrogen from the soil solution by the growing crop, microbial immobilization and also to the losses through runoff, denitrification and leaching.

A potential risk for contamination of groundwater sources of the watershed by nitrate is evident. In spite of the great variation in the nitrate concentration observed both among treatments through time and in space, the concentrations of nitrate found below the tobacco rooting zone were high when compared with other results in the literature.

Conclusions
High potential for water resources contamination in watersheds cropped to tobacco and rapid decline in soil productive capacity and in water quality were observed in the watershed with shallow soil and steep slopes. Improper agricultural practices, utilization of high doses of fertilizers and pesticides, absence of riparian forest, and intense soil use are elements leading to soil and water degradation. A shift in agricultural practices is needed in the short term, by including soil, water and wildlife conservation strategies, whereas a change in cash crop, in the long term, is necessary to move away from cultivating tobacco.

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What is the impact on farmer nitrogen fertilizer use of incorporating the effects of nitrous oxide emissions?

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Abstract
The use of nitrogen (N) fertilizer continues to be important for crop production, but the increased recent focus on nitrous oxide (N_2O) as a potent greenhouse gas has added new considerations to fertilizer decisions. We present an economic decision framework which includes agricultural and environmental dimensions and provides policy information for the proposed Carbon Pollution Reduction Scheme (CPRS) in Australia. The economic framework indicates the 'best' fertilizer decision from both agricultural and environmental viewpoints. The former focuses on profit, based on likely crop responses to added fertilizer and prices, and marginal revenues and marginal costs. Marginal revenue is the willingness to pay for fertilizer by the crop producer, or the input demand. The price elasticity of demand for fertilizer is relatively unresponsive, meaning that an increase in fertilizer price will have a proportionally-lower decrease in amount demanded. In this study we also examine wheat grower N fertilizer decisions by incorporating the effects of greenhouse gas (N_2O) emissions, based on a carbon price of \$25/t of carbon (C) dioxide equivalent (CO_2e). Because of the inelastic demand and the relatively low N_2O emissions for Australian wheat cropping the reduction in farm-level demand for fertilizer is relatively small. We illustrate our findings with a case study of wheat production in Western Australia.

Key Words
Fertilizer decisions, economics, agriculture, greenhouse gas, nitrous oxide.

Introduction
We present an economic decision framework for N fertilizer applied to crops. Recent price fluctuations have emphasised the importance of economic considerations in making these fertilizer decisions. Also important is the emerging focus on the agriculture-induced greenhouse N_2O emitted to the earth's atmosphere and proposals to mitigate emissions and initiate emissions trading (Australian Government 2008). What is the impact of imposing a price for C on fertilizer in terms of likely farm-level responses?

These questions can be investigated by presenting an appropriate fertilizer decision framework. Standard micro-economic theory for the firm based on a production function, relative prices and the premise that profits are important to farmers leads to the marginal economic framework which can be applied to fertilizer decision making. We use a case study of wheat production in the central wheat belt of Western Australia as an illustration. This marginal economic framework is not new, it has been outlined by Heady (1952) and many others. But it has not been widely used in applied agricultural decision making.

The Australian Government (2008) has proposed the introduction of a CPRS, but carriage of this legislation is politically uncertain. In the meantime a number of issues for agriculture and the CPRS can to be investigated, including how such a scheme would operate in an industry with many small producers whose emissions are difficult to measure and monitor. Considerations of effectiveness, compliance costs, administration costs and avoidance of distortions among producers are important.

An issue that does not seem to have been flagged is the likely response by farmers in their crop management decisions if the price of C is reflected in prices paid by farmers for inputs and prices received for outputs. We investigate the former issue for wheat production and N fertilizer in Australia. By how much is N fertilizer usage likely to fall if the price of fertilizer rises?

Economic framework

The conventional production economics framework addresses the question of 'how much' of an input to be used to maximize crop profits. It has been developed based on a hypothesized production response to added inputs, a set of (fixed) prices for inputs and outputs, and an assumption that farmers want to make a profit from these decisions. The mathematical solution procedure solves for the necessary and sufficient conditions of the constrained optimization problem when the production function is substituted into the profit function (e.g. see Silberberg 1990). Applications in a farm production economics framework were presented by Heady (1952). The condition necessary for the profit-maximizing level of input is that the input should continue to be added until the declining marginal revenue just equals the marginal cost, provided that the sufficient condition, of production concavity, holds. The production function is assumed to be continuous, smooth, (twice) differentiable and concave. According to Thornley and France (2007), many biophysical responses exhibit diminishing returns which characterize concavity. The general mathematical approach presented by Silberberg (1990) has been set out for the crop/fertilizer decision by Farquharson (2006). However, the mathematical solution approach which relies on differentiability is not necessary for the single-input/single-output problem (CIMMYT 1988), and a more intuitive approach is presented here. This involves predicting agricultural and environmental production responses to added N fertilizer and investigating how the environmental effects influence the optimal agricultural decisions.

Methods

The response of wheat yield to increased levels of soil available N was predicted using the Water and Nitrogen Management Model (WNMM) (Li *et al*. 2007; Li *et al*. 2008). WNMM was calibrated and validated for a wheat-cropped soil at Cunderdin in the central wheat belt of Western Australia (Barton *et al.* 2008). Thirty-seven years of climate data (1970 to 2006) were used for the analysis. Using these inputs WNMM was run with a base level of 30 kg units of soil mineral N plus additional 25 kg units from zero to 150. Predictions of wheat yield (cv. Carnamah) were developed and mean yield responses were used as a basis for the economic analysis.

N_2O emissions were estimated using two calculations of the global warming potential (in units of CO_2e) of alternative fertilizer decisions. The calculations were based on WNMM results and an IPCC default value (IPCC 2009):

CO_2e = annual N_2O emissions (kg N/ha from WNMM) * ratio of molecular weights (N_2O/N) * 310 (1)

CO_2e = N applied (kg/ha) * 0.01 (IPCC default value of 1%) * ratio of molecular weights * 310. (2)

The fertilizer price used was $1.24/kg of N contained in urea, based on a price of $570/t bulk fertilizer in Australia (Incitec/Pivot Company personal communication, September 2009). Wheat price information was obtained from Australian Wheat Board (AWB) Western Pool No. 1 for 2009-10 (AWB Limited, 2009). A (port delivered) price of $248/t FOB and GST exclusive was translated into a farm-gate price of $218/t by deducting typical freight, levy and receival costs. The Carnamah variety is AUH2 grade wheat which does not receive premiums for protein increments.

The economic analysis was conducted by assuming that the different levels of soil N represent different N fertilizer decisions for a single crop year. Starting from the lowest level of fertilizer, the change in yield is multiplied by the wheat price to develop the marginal revenue for each additional kg of soil nitrate N. The marginal cost for each additional kg of N is the N purchase price. The comparison of marginal revenue and cost starts from an initially-low level of soil N fertility and evaluates decisions to sequentially apply extra amounts of N. In the analysis this marginal approach is applied to both the agricultural and environmental responses to added soil N.

The marginal revenue schedule represents the willingness to pay for fertilizer by the wheat grower based on an expected production response, or the demand for the input by the wheat grower. As for any demand function the elasticity can be calculated to provide additional policy information. The price elasticity of demand is the expected change in fertilizer quantity used for a small percentage change in the fertilizer price.

Results

The yield response for different levels of soil N is shown in Figure 1. The mean yield shows the concave characteristic of increasing at a decreasing rate up to a maximum. The marginal revenue and marginal agricultural cost for the mean yield response using the above prices are shown in Figure 2. The purchase price of urea fertilizer was $1.24/kg N (marginal cost), and crop harvest was assumed to be by contractor and charged at a constant rate per ha. The best soil N level agriculturally (N^{*a}) to satisfy the profit objective is around 80 kg N per ha (Figure 2). Arc elasticities were calculated for increasing prices along the input demand (marginal revenue) schedule. The elasticities varied from -0.1 to -0.3, a relatively inelastic response.

The estimated N_2O emissions (from equations (1) and (2)) are shown in Table 1 and plotted in Figure 1. There is a substantial difference in predicted emissions from these two approaches. Perhaps the level of N_2O emissions from Australian wheat is much less than the predictions using the IPCC default value? The N_2O emissions in Table 1 were converted to units of t CO_2e and expressed per unit of soil available N, so that the environmental costs could be directly compared to the agricultural costs.

The marginal costs of N_2O were calculated based on a price of \$25/t CO_2e. These marginal costs are \$0.12/kg N/ha using the IPCC estimates, but only \$0.01-0.02/kg N/ha using the WNMM predictions. The combined marginal agricultural and environmental costs of applying nitrogen fertilizer for agricultural purposes using the IPCC calculation are shown in Figure 2. The marginal cost using WNMM results is very close to the agricultural cost, and has not been plotted separately.

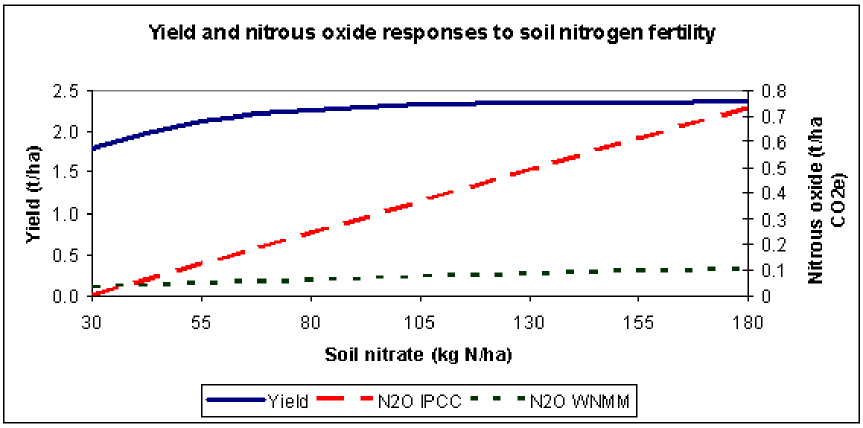

Figure 1. Wheat yield and nitrous oxide responses to increased nitrogen fertilization predicted at Cunderdin, Western Australia.

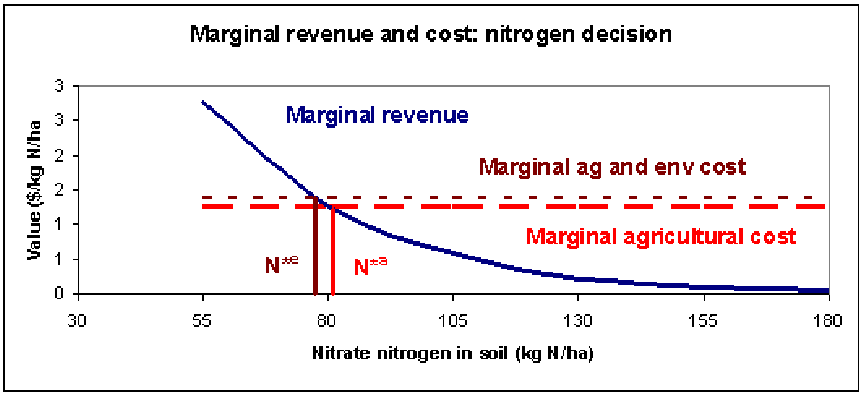

Figure 2. Marginal revenues and costs for the agricultural and environmental decision.

Table 1. Predicted CO_2e of N_2O emissions from N fertilizer applied to wheat in Western Australia.

N_2O emissions	Level of N fertilizer (kg N/ha) applied to base of 30 kg/ha in soil						
(kg/ha CO_2e)	0	25	50	75	100	125	150
WNMM (1)	31	46	58	72	83	93	100
IPCC formula (2)	0	122	244	365	487	609	731

When the IPCC-based environmental cost of N fertilizer is included the best fertilizer decision (N^{*e}) is reduced by about 4 kg N per ha (i.e. by about 5%) from the agricultural decision (N^{*a}). Marginal costs based on the WNMM results do not change the agricultural decision.

Discussion

The N fertilizer decision for wheat growers involves economic considerations, not least because of the costs and benefits involved and the alternative uses for scarce and costly funds. There have been substantial price fluctuations for N fertilizer in recent years. The traditional marginal economic framework shows the 'best' level of fertilizer for profit purposes. As well, the input demand function gives other information for policymakers. The inelasticity of demand for fertilizer means that a policy objective of substantially reducing agricultural N_2O emissions by increasing the N price is unlikely to have a large effect on farm-level usage of fertilizer. An increase in price will reduce the quantity used but not by very much, because soil fertility is such a necessary part of the crop production process. But we can say more than this if we predict the N_2O emissions associated with each N fertilizer decision. Using a C price of $25/t CO_2e we calculated the marginal costs associated with N_2O emissions using two different methods. Using the IPCC default value, the N_2O costs rise as more fertilizer is applied. However, the indicated impact on optimum fertilizer use is small, a reduction of around 5% for the average response. Using the WNMM results there appear to be much lower levels of N_2O emissions and the cost implications are trivial.

Conclusion

The economic decision framework presented here can provide important information for decision makers at both the farm and policy level. By using a crop simulator we have shown the likely size of farm-level response if an emissions trading scheme is introduced resulting in an increased price for N fertilizer. Imposing a price on C may have less of an impact on agricultural fertilizer usage than perhaps otherwise thought. This result adds to other calls (e.g. Matson *et al.* 1998) to develop improved N fertilizer formulations that emit less N_2O into the atmosphere.

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