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Active layer thermal monitoring at two ice-free areas of King George Island, Maritime Antarctica

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Abstract
The present work focuses on soil temperature and moisture data for one year (2008/ 2009) for two sites at King George Island, Maritime Antarctica. The sites were installed in February 2008 and consist of precision thermistors with probes at different depths down to the permafrost table, and one soil moisture probe placed at the bottommost layer at each site, recording data at hourly intervals. The active layer thermal regime in Fildes and Potter Peninsula is dynamic, with extreme variation at the surface during summer resulting in frequent daily freeze and thaw cycles. The soil thermal regime is essentially periglacial with poor thermal conductivity, which in some way reduces thermal degradation of the permafrost. The coarse nature of the active layer, especially at Potter Peninsula, results in large pores occupied by air and water, enhancing nonconductive heat transfer processes. Thermal diffusivity is extremely variable throughout the summer.

Key Words
Soil thermal regime, permafrost, climate change, Maritime Antarctica

Introduction
The active layer and permafrost are key components of the terrestrial cryosphere and are highly sensitive to climate changes. The thermal regime and depth of the active layer, as well as the nature and continuity of the permafrost, are very useful for long-term studies regarding the impacts of global warming on ecosystem functioning. Soil temperature regime at high latitudes is an important indicator of the nature of the permafrost, which strongly influences geomorphologic, hydrologic, and other related phenomena, manifested in the active layer. The depth of frost penetration depends mainly on the intensity and duration of the cold snow cover, precipitation and cloud cover (Guglielmin *et al.* 2008).

Periglacial regions are highly sensitive systems for climate change studies due to their transitional situation. In this respect Maritime Antarctica has been increasingly recognized as a key region for monitoring climate change. The largest and most rapid changes are expected to occur in the periglacial environment and evidences of permafrost degradation are already being observed. Despite the recent interest, few investigations of thermal conditions of the active layer and permafrost have been made based on year round measurements (Leszkiewicz & Caputa 2004, Cannone *et al.* 2006).

During the austral summer of 2008/2009, twelve active layer monitoring sites were installed, distributed in ice-free areas of King George and Livingstone Islands, and at the northernmost portion of the Antarctic Peninsula (Hope Bay). The objective of the present paper is to present and discuss soil temperature and moisture data from the summer of 2008 to the summer of 2009 for two sites installed at King George Island.

Methods
The study sites are located at Potter and Fildes Peninsulas, King George Island, Maritime Antarctica. The region experiments a cold moist maritime climate characterized by mean annual air temperatures of -2°C (Olech 1994) and mean air temperatures above 0°C for up to four months, during the summer period. Precipitation ranges between 350 and 500 mm per year, with rainfall occurring in the summer period, (Øvstedal & Smith 2001).

The active layer monitoring sites were installed in February 2008, and consist of precision thermistors arranged as a vertical array with probes at different depths down to the permafrost table. Soil moisture probes were placed at the bottommost layer at each site. All probes were connected to a Campbell Scientific CR 10 data logger recording data at hourly intervals.

Soil characteristics of the monitored sites and the exact depth of the probes are presented in Tables 1 and 2. Meteorological data for Potter and Fildes were obtained from the Teniente Jubany and Eduardo Frei stations,

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respectively. Daily estimations of soils apparent thermal diffusivity (ATD) were made, according to McGaw *et al.* (1978), using the following equation: α'=[ΔZ2/2Δt]x[(Tij+1- Tij-1)/(Tji-1- 2Tji+ Tji+1)]
Where α'= apparent thermal diffusivity (m^2/s), Δt=time increments (s), ΔZ=space increments (m), T= temperature, j= temporal position and i=depth position. Other authors (Nelson *et al.* 1985; Outcalt and Hinkel 1989) have used this estimative in their works.

Table 1. General characteristics of the monitored sites.

Site	Altitude	Soil Class	Vegetation	Depth of the active layer	Thermistors depth (cm)*
Potter	70 m	Umbric Leptic Cryosol	Lichens (*Usnea sp.* and *Himantormia sp.*)	95 cm	8(P1), 36(P2), 56(P3), 90(P4)
Fildes	65 m	Turbic Eutric Cryosol	Mosses and Lichens (*Usnea sp.* and *Himantormia sp.*)	90 cm	10.5(F1), 32.5(F2), 67.5(F3), 83.5(F4)

* the moisture probes were installed at the bottommost part of the trench.

Table 2. Granulometric fractions of the studied profiles.

Depth	cs	Fs	sil	clay	Class
			g/kg		
Potter - Umbric-Leptic Cryosol					
0 – 10	67	9	10	14	Loamy-Sand
10 – 20	68	11	12	9	Loamy-Sand
20 – 40	67	9	14	10	Loamy-Sand
40 – 60	52	19	21	8	Loamy-Sand
60 – 80	47	24	21	8	Loamy-Sand
Fildes - Turbic Eutric Cryosol					
0 – 20	28	18	34	20	Loamy
20 – 50	29	17	36	18	Loamy
50 – 100	14	30	47	9	Loamy

cs – coarse sand; fs – fine sand, sil – silt

Results

The highest soil temperature at Fildes Peninsula was 4.44 °C, registered for the top soil layer in January 08th 2009, while the highest mean daily air temperature was 3.7 °C, on January14th. During the summer period, soil temperature at the upper layers presented high positive correlation with air temperature, (0.80 to 0.93). Soil water content, ranged from 60% in the summer to 30% in winter. Mean annual temperatures of -0.33°C, -0.42°C, -0.67°C and -0.54°C were found for the increasing depths. The temperatures for the bottommost layer indicate that the permafrost occurs deeper than 83.5 cm. At this depth, maximum temperature was 0.38 °C, minimum -3.10 °C, with mean annual value of -0.60 °C. This temperature oscillation close to 0^oC suggests that the permafrost table is situated close to this depth.

Thermal diffusivity was estimated for two intermediate depths for each day. Since it was calculated from the observed temperatures, and includes the thermal impact of nonconductive heat transfer, it is more properly referred to as the apparent thermal diffusivity (ATD), considered always as an average value. In some cases, the ATD may be negative, indicating that nonconductive effects oppose and overwhelm the conductive tendency (Outcalt and Hinkel, 1989). ATD varied widely during the studied period (Figure 1). Seasonal fluctuation is common due to contributions of conductive and nonconductive soil heat transfer mechanisms. Addition of soil water, for example, increases the conductivity, but also increases soil heat capacity (Hinkel *et al.* 2001). Mean ATD for the studied period were $6.78x10^{-08}$ m^2/s and $-6.26x10^{-08}$ m^2/s at 32.5 and 67.5 cm respectively. These values are consistent with those reported by Hinkel *et al.* (2001) for thawed, saturated mixed silty soils (2–$3x10^{-7}$ m^2/s). The difference between the ATDs tends to be greater in early summer, with drastic fluctuations of soil temperature and moist content. Cooler autumn temperatures result in a near-isothermal soil condition with little heat transfer and almost no variation of ATD. Mean ATD during winter (21/06 to 23/09) was positive, except for the deepest horizon (-8.46 $x10^{-09}$ m^2/s); which shows a notable temperature buffering capacity. ATD showed considerable temporal variation and no clear correlation between inflections and periods of significant precipitation.

The highest soil temperature at Potter Peninsula was 6.0°C and occurred in January 15^{th} 2009, while the highest mean daily air temperature was 5.0°C, also in January. During the summer period, soil temperature depended on air temperature in surface showing low correlation in subsurface. Correlation within layers was strong only between surface horizons (0.62 to 0.97), indicating a considerable resistance in temperature changes at permafrost level. The influence of air temperature on the profile thermal regime is greatly reduced from 56 cm depth downwards, where the highest temperature did not exceed 1.0°C. The coarse nature of the profile seems to have a considerable influence over its thermal conductivity, contributing for the permafrost preservation, as shown by the low correlation between air temperature and soil temperature at 90 cm depth. The water content showed a fairly variable behaviour ranging from values around 5.5 % in the winter to 34.4 % in the summer. Mean annual temperatures of -0.60°C, -0.53°C, -0.86°C and -0.84°C were obtained for the increasing depths, suggesting that the permafrost table lies below 90 cm.

As observed in Fildes, ATD varied widely during the studied period (Figure 2), but at Potter it was more affected by variations of the water content. Mean ATD for the studied period was -5.39×10^{-08} m^2/s and 7.59×10^{-09} m^2/s for the 36.0 cm and 56.0 cm layers. Differences were greater in summer, with drastic fluctuations of soil temperature and moisture content. Colder conditions resulted in low variability of ATD. Winter mean ATD (21/06 to 23/09) was positive 8.37×10^{-08} m^2/s, 3.52×10^{-08} m^2/s, respectively for the 36.0 cm and 56.0 cm layers. The coarse nature of the profile results in high macroporosity. Nonconductive heat transfer processes occur, causing variation of the thermal diffusivity.

Fildes presented higher ATD in surface, revealing an opposite trend in depth when compared to Potter. The finer texture and consequent greater water retention capacity at Fildes appears to work in both directions in relation to ATD. The energy flux is higher thought out the profile but, at the same time, higher water content means greater soil heat capacity. As a consequence, soil temperature rises evenly buffering sudden changes, and contributing to permafrost preservation. At Potter, the coarser nature of the profile reduces the water retention capacity leaving empty pores thought out the soil. Soil air works well as an isolator, preventing temperature changes. However when summer rain or a rapid thaw of snow occur the energy transfer in the profile is rapid.

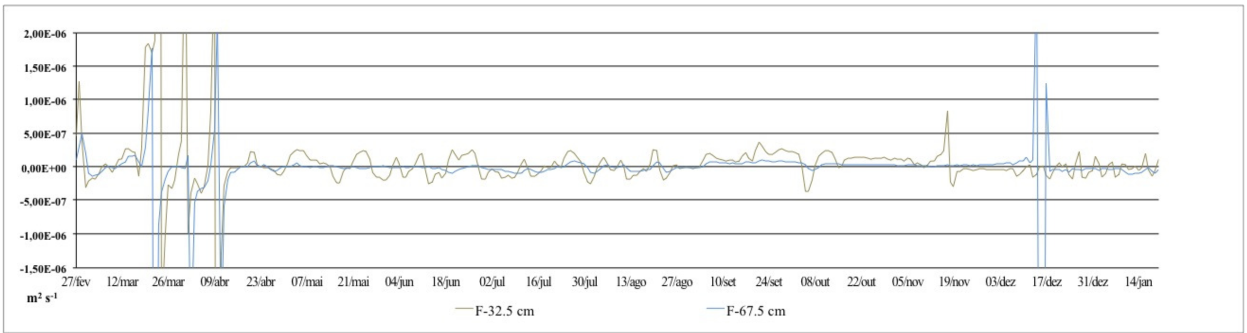

Figure 1. ATD variation during the monitored period for two depths at Fildes Peninsula.

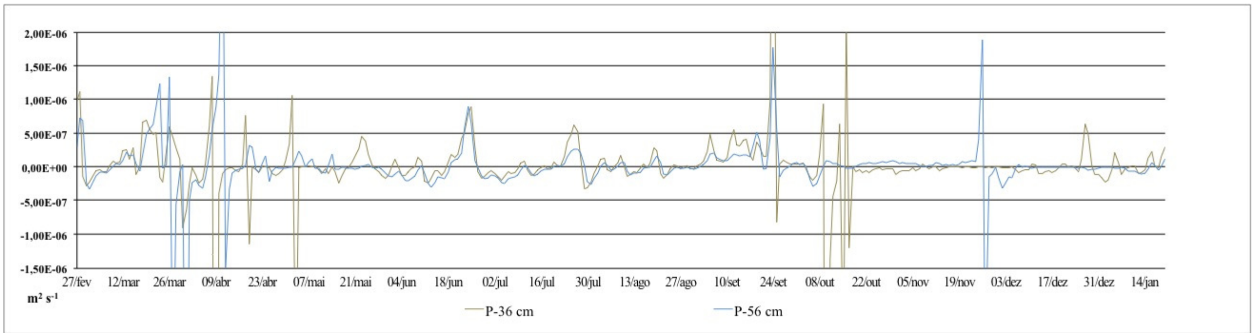

Figure 2. ATD variation during the monitored period for two depths at Potter Peninsula.

Conclusion

The active layer thermal regime in Fildes and Potter Peninsula is dynamic, with extreme variation in surface during summer resulting in frequent daily freeze and thaw cycles. This has implications to soil genesis, favouring cryoturbation and cryoclastic weathering. This annual dataset of 2008-09 indicates that the permafrost table lies below 90 cm for both sites, which is close to the limit established for classifying these soils as Cryosols or Gelisols, according to the WRB and Soil Taxonomy systems, respectively. The profiles thermal regime is essentially periglacial with poor thermal conductivity, which in some way reduces the thermal degradation of the permafrost. The coarse nature of the Potter site results in high macroporosity, favouring nonconductive heat transfer processes.

Acknowledgements
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References

Guglielmin M, Evans CJE, Cannone N (2008) Active layer thermal regime under different vegetation conditions in permafrost areas. A case study at Signy Island (Maritime Antarctica). *Geoderma* **144**(1-2), 73-85.
Leszkiewicz J, Caputa Z (2004) The thermal condition of the active layer in the permafrost at Hornsund, Spitsbergen. *Polish Polar Reserch* **25**, 223–239.
Cannone N, Ellis Evans JC, Strachan R, Guglielmin M (2006) Interactions between climate, vegetation and the active layer in soils at two Maritime Antarctic sites. *Antarctic Science* **18**, 323-333.
Olech M (2004) Lichens of King George Island, Antarctica, Krakow. The institute of botany of the Jagiellonian University.
Øvstedal DO, Lewis-Smith RI (2001) Lichens of Antarctica and South Georgia: guide to their identification and ecology. Cambridge. Cambridge University Press, 411.
McGaw RW, Outcalt SI, Ng E (1978) Thermal properties and regime of wet tundra soils at Barrow, Alaska. In 'Third International Conference on Permafrost' (Ed National Research Council of Canada'. pp. 47–53. (Ottawa, Canada).
Nelson FE, Outcalt SI, Goodwin CW, Hinkel KM (1985) Diurnal thermal regime in a peat-covered palsa, Toolik Lake, Alaska. *Arctic* **38**, 310–315.
Outcalt SI, Hinkel KM (1989) Night frost modulation of near-surface soil–water ion concentration and thermal fields. *Physical Geography* **10**, 336–346.

Application of distillery effluents to agricultural land: Is it a win-win option for soils and environment

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Abstract
Molasses based distilleries in India generate approximately 40 billion litres of effluents annually characterised by high organic load and salts posing a major disposal problem. The post methanation distillery effluent (PME) also being rich in plant nutrients (K, N), its use as ferti-irrigation source in agriculture is an attractive disposal option. The paper discusses the experimental results of effects of PME application (treatments: 0, 10, 20, 30 and 40 per cent of PME (5000 mg/l)) in agricultural field on the soil microbial population and chloride levels; thereby know whether soil is a good sink for recycling this nutrient rich effluent. Microbial enumeration studies revealed a beneficial effect of PME irrigation up to 30 per cent concentration due to the presence of carbon and nutrients that enhanced the soil microbial activity. Soil chloride levels and effluent colour were highest in the 0-30 cm soil depth, and beyond 45 cm their concentration decreased significantly suggesting soil acted as a good medium. Crop growth and soil health were negatively affected at higher PME concentrations or when applied without dilution. Therefore, monitoring and integrated approaches are needed to effectively utilize PME as valuable resource in agriculture and reduce its negative effects on the environment.

Key Words
PME, wastewater, recycling, plant nutrients, ferti-irrigation, microbial population

Introduction
Alcohol production from sugarcane molasses is an important distillery industry in India. For every litre of alcohol produced, 12 to15 litres of distillery effluent are generated. There are 290 distilleries in India generating about 40 billion litres of effluent annually and their disposal is a serious problem. The treatment of this wastewater before disposal is regulatory; however, owing to the high effluent treatment costs and due to elaborate physico-chemical methods, partial treatment is carried out and huge quantities of the effluent is either stored in lagoons, unlined tanks or let out into the surface water bodies or streams, thereby adversely affecting the good quality water resources and environment.

As the distillery effluents have high potential to produce methane, they are subjected to anaerobic digestion for methane recovery (Joshi 1999). The post methanation distillery effluent (PME) produced from the treatment is characterised by high biological oxygen demand (BOD) and chemical oxygen demand (COD), intense brown colour and high salt levels apart from being rich in plant nutrients. Though the bio-methanation of distillery effluent under anaerobic conditions brings down its BOD load from around 50,000 mg /l to 8,000-5,000 mg/l, due to their high organic load and salts, further treatment is still needed. If these effluents are discharged to water streams, the suspended solids present in the effluent would impart turbidity in water, reduce light penetration and impair biological activity of aquatic life. Hence an economically viable and environmentally safe means of disposal is needed to handle such large volumes of PME.

The only feasible alternative for disposal of PME seems to be land. As the effluent is mainly a plant extract, rich in organic matter and plant nutrients like potassium, nitrogen, sulphur and calcium, there is a scope for using it advantageously as a source of ferti-irrigation to agricultural crops (Joshi *et al.* 1996). Though the beneficial effect of distillery effluent on agricultural crops is known, little information is available on PME ferti-irrigation effects on residual salt levels in the soil profile, its degradation and soil microbial health. Therefore, this paper explores the potential advantages or negative effects of PME application in an agricultural field in dryland conditions.

Methods
Laboratory and field experimental methods to assess the effluent characteristics and its application effects in an agricultural field are presented.

Field experiment and soil

Field experiments in maize crop were conducted during rainy season on a sandy loam Ustochrept soil type, at experimental farm site of Indian Agricultural Research Institute, New Delhi, having subtropical, semi-arid type of climate. Surface soil samples (0-15 cm) were collected from selected control points (no fertilizer or effluent applied) and analysed for its initial physico-chemical properties by standard methods (Page *et al. 1982*). The soil was sandy loam in texture, with 0.38% organic carbon, 0.05% total N, ammonium actetate extractable K 159 mg/kg, EC 0.38 dS/m and pH 8.2.

Treatments

BOD of PME was taken as the main factor for the treatments to study the application effects on agricultural land. The treatments consisted of 0, 10, 20, 30 and 40 per cent PME (5000 mg/l) irrigation levels that were tested in a randomized complete block design with three replications in a plot size of 5m x 4m; four PME irrigations were given during the crop period in a maize field.

Soil sampling and analytical methods

To study the effect of PME irrigations on soil microbial health, soil samples were collected in triplicates from the treatment plots after every irrigation during the crop growth period and processed for enumeration of microbial population (total viable and culturable fungi, bacteria, and actinomycetes) using serial dilution and spread plate method (Page *et al*. 1982). To study the effect of PME treatments on chloride levels in the soil profile, after the 4th irrigation, soil samples were collected from the plots at 15 cm depth interval upto 90 cm and analysed for water soluble chlorides. Subsequent soil samples were collected at weekly intervals for 75 days and the water soluble soil extracts were measured for their colour intensity as per the APHA standard methods (APHA 1994).

Results

Review and survey around distilleries revealed that the practice of the use of PME by farmers in India basically emanates from the scarcity of water to meet their irrigation requirements, especially during water shortage periods in the dry regions. With increasing demand of good quality water for industry, potable water supplies and other sectors, there has been use of PME for crop irrigation around the distilleries. As the PME has high amounts of plant nutrients (K>N >P) (Table 1), its application improved crop growth in the maize field study (Karanam 2001). Considering the high cost of plant fertilizers and recognizing the nutrient value in this agro-industrial effluent, use of PME as ferti-irrigation source to agricultural crops is considered a viable option.

Table 1. Chemical composition of the post-methanation effluent (PME).

Parameters	Values*	Parameters	Values*
Organic C	148	Mg	0.61
N	2.0	BOD (mg/l)	5130
P	0.07	TDS (mg/l)	5530
K	3.98	Chloride	2.0
Sulphate	0.6	pH	8.5
Ca	1.1	EC (d S/m)	13.8

*All values except pH or otherwise stated are in g/l

Soil microbial population was studied, as they are an important entity of soil ecosystem helping in nutrient recycling processes and regulating the soil productivity. PME treatments at lower and up to 30 per cent concentrations increased the soil microbial population over control (Figure 1), that may be attributed to the carbon and nutrients present in the PME. An increase in bacterial population over control was found and the highest count was recorded with 20 per cent PME treatment at third irrigation which was significant among different PME treatments. However, 30 per cent PME treatment at third irrigation had higher fungi and actinomycetes (0.425 x 106 and 6.6 x 106 cfu/g of soil respectively) population in soil. The fungal population were in lesser number compared to bacteria or actinomycetes population. This study indicated that higher PME concentrations had a negative impact on soil microflora.

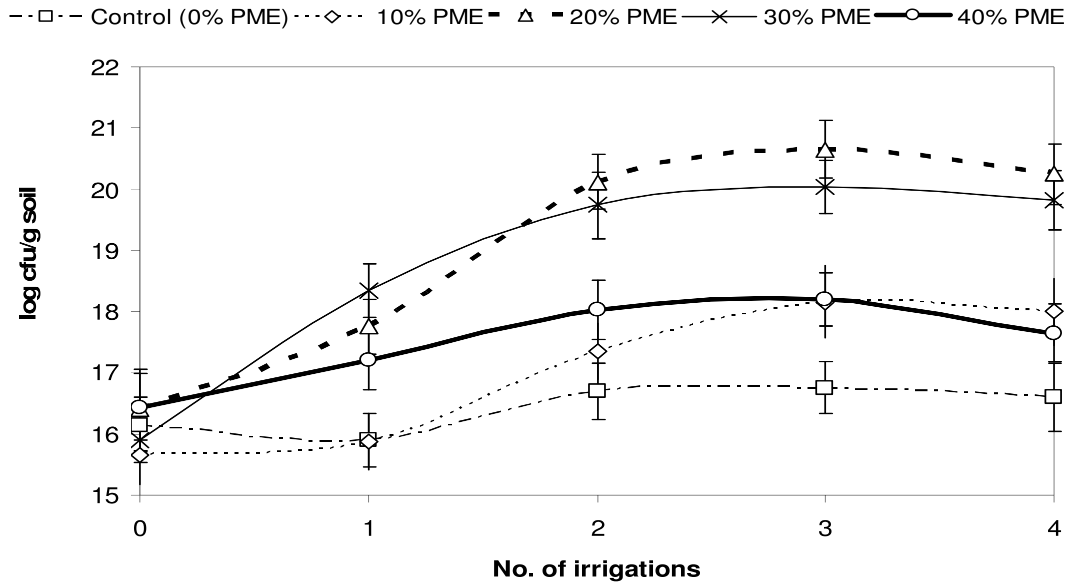

Figure 1. Effect of post methanation distillery effluent (PME) irrigations on the soil microbial population in an agricultural field. Figure adapted from Karanam (2001).

Study of chloride concentration at different soil depths, which get added to the soil through PME irrigation helped in understanding the effect of PME application in the soil profile. Results showed that chloride content in the soil profile increased with PME concentration, highest at 40 per cent PME treatment. Maximum chloride levels were observed in the 0-30 cm soil depth in all the PME treatments and the values were significantly higher in PME irrigated plots over control (Figure 2). Beyond 30-45 cm soil depth, the chloride concentration decreased significantly indicating less possibilities of PME affecting the groundwater.

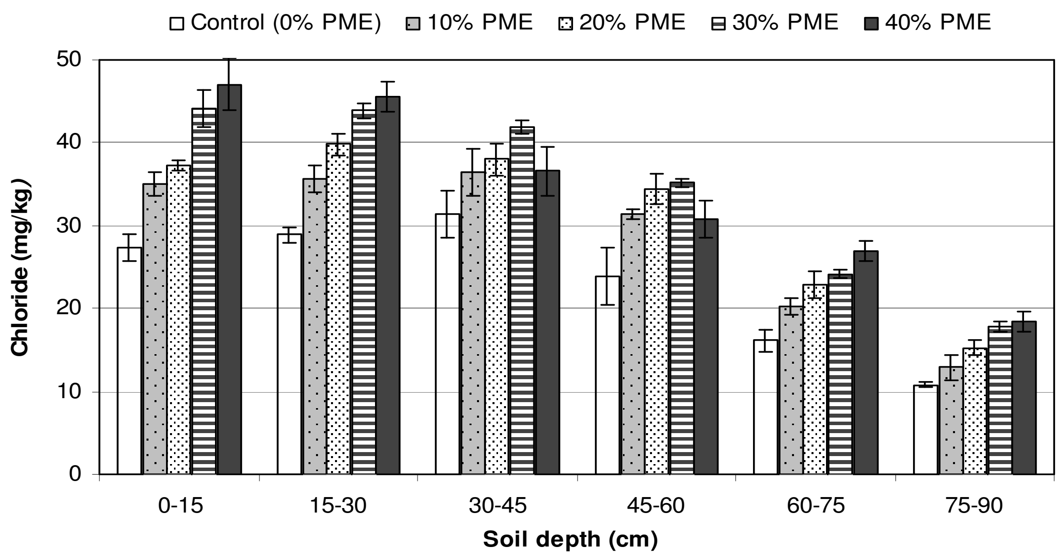

Figure 2. Changes in soil chloride levels at different soil depths with post methanation distillery effluent (PME) irrigations. Figure adapted from Karanam (2001).

In PME irrigated plots, most of the effluent colour remained in the 0-30 cm of soil depth. When irrigated with higher concentrations of PME (40%) treatment, the colour intensity in soil extracts was observed to a soil depth of 60 cm. However with progression of time there was a significant reduction in the residual colour (Karanam 2001). The PME applied to the soil being mostly organic (melanoidins) and interactive in nature, its movement down in the soil profile would be lesser in comparison to chloride ion. When the PME is spread over larger areas as in agricultural land, with processes such as solar radiation effect, crop rhizosphere and biodegradation due to soil microbial activity, and adsorbent nature of the soil, there are less chances of ground water contamination.

Conclusion

The use of PME in agricultural fields with appropriate dilution (upto 1500 mg/l i.e., 30 per cent PME concentration) provides a plausible solution for on-land disposal of the effluents as they have potential to provide major and micro nutrients to crops and save on cost of fertilizers apart from primarily acting as a source of irrigation water in agriculture. This would thereby prevent pollution and improve availability of other good quality water resources, and the approach would prove beneficial for soils and environment. Hence application of nutrient rich PME to agriculture can provide an economic and environmental friendly method of disposal, while at the same time help to improve soil fertility and crop yields. However, monitoring is needed to understand the long term effects of PME use. Also, factors such as organic load of PME, soil type and its properties, water availability, crops grown, rainfall pattern, depth of water table, groundwater quality and environment of the region need to be considered. For adoption success of the research findings, participation of all the stakeholders such as regulatory bodies, industry, farmers, land managers and environmental researchers is very important for appropriate PME disposal or its use in agriculture The way forward is to adopt integrated approaches to manage and effectively utilize this valuable resource in agriculture without posing any problem to groundwater bodies and environment.

References

APHA (1994) 'Standard methods for the examination of water and wastewater. 18th edition'. (APHA, AWWA, WPCF Publishing: New York)

Joshi HC (1999) Bioenergy potential of distillery effluent. *Bioenergy News* **3**(**3**), 10-15.

Joshi HC, Pathak H, Choudhary A, Kalra N (1996) Distillery effluent as a source of plant nutrients: Prospects and problems. *Fertilizer News* **41**, 41-47.

Padmaja Karanam V (2001) 'Degradation of post methanation distillery effluent in an agricultural soil'. (PhD Thesis, Division of Environmental Sciences, IARI Publishing: New Delhi, India)

Page AL, Miller RH, Keeney DR (1982) 'Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd edition, Agronomy No. 9'. (ASA-SSSA Publishing: Madison, WI)

Carbon sequestration under different physiographic and climatic conditions in north Karaj river basin

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Abstract

Some of the most important local factors on soil carbon sequestration are climatic conditions (such as precipitation, temperature and sun radiation) and physiographic properties (such as elevation, slope shape, slope degree and slope aspect). We investigated the effects of climate and physiographic properties on soil carbon distribution and sequestration. Four elevation and five precipitation classes were considered, by compilation of a topographic map (1:50000) and DEM of the studied region. The results show that except for the lowest elevation class organic carbon contents decrease with increasing elevation. In other words the maximum organic carbon content belongs to elevation class no. 2 (2250- 2500 m), which corresponds to precipitation class no. 3. The highest carbon content was observed in middle precipitation class and elevation class no. 2 which is significantly far from grazing and human activities and also receives more suitable climatic conditions (precipitation and temperature) without a vegetation period limitation. The results indicate that the physiographic and climatic conditions play important roles in land management in order to achieve soil carbon sequestration. Considering the physiographic and climatic conditions different management schedules including replanting species, grazing and soil protection should be considered.

Key Word

Physiography, climate, carbon sequestration, organic carbon

Introduction

Physiographic properties (such as elevation, slope shape, slope degree and aspect) and climatic conditions (such as precipitation, temperature and radiation) are among the most important factors affecting soil carbon sequestration for each region. In this study we have investigated the effects of climatic and physiographic properties on soil carbon distribution and sequestration at the northern region of Karaj, Iran. Effects of climate change on soil organic carbon storage and its distribution differ between different regions, and temperature and rainfall levels are among the main influencing factors causing the differences. Temperature and humidity are important factors affecting the rate of organic material decomposition. Decomposition doubles with every 10 °C increase in temperature, while the increase in soil moisture increases the amount of organic matter. Landscape attributes including slope, aspect, elevation, and landuse are the dominant factors influencing SOC in areas with the same parent material and climate regime. Landscape attributes affect organic activities, run-off and run-on processes, condition of natural drainage, and exposure of soil to wind and precipitation (Dianwei *et al.* 2006). Comparison between SOC contents of different slope shapes showed that concave slopes have higher SOC and less soil loss than convex slopes. These patterns are the same as have been shown in other studies. The slope gradients were less for the concave slopes indicating a convergence and potential slowing of run off which would allow water to slow and eroded soil particles to be deposited thus SOC decreases as slope gradient increases (Jerry *et al.* 2007).

Methods

Four elevation classes (class1=2000-2250 m, class2=2250-2500 m, class3=2500-2750 m, class4=2750-3000 m) and 5 precipitation classes (class1=350-400 mm, class2=400-450 mm, class3=450-500 mm, class4=500-550 mm, class5=550-600 mm) were defined. ETM^+ satellite images of 2002 were analyzed and classified, using PCA software. A digital elevation model (DEM) of the studied region was obtained from the topographic map (1:50000 scale) in Arc-GIS environment, and different physiographic characteristics including (slope, altitude, aspect) were extracted. Landform units were determined by intersecting the slope, hypsometric and aspect maps. Climatic information also was obtained from the regression models, which exist between precipitation and temperature with elevation (eqs. no. 1 and 2) respectively at the studied region.

$$P(mm) = (0.2055 \times elevation) - 30.039 \quad (1)$$

$$T(°C) = (-0.0073 \times elevation) + 24.435 \quad (2)$$

Physicochemical characteristics of 24 surface samples (Table 1) were analyzed. Sampling design carried out according to joint sampling from opposing aspects at different altitudes and climatic conditions (precipitation and temperature). Figure 1 shows the schematic position of the studied area.

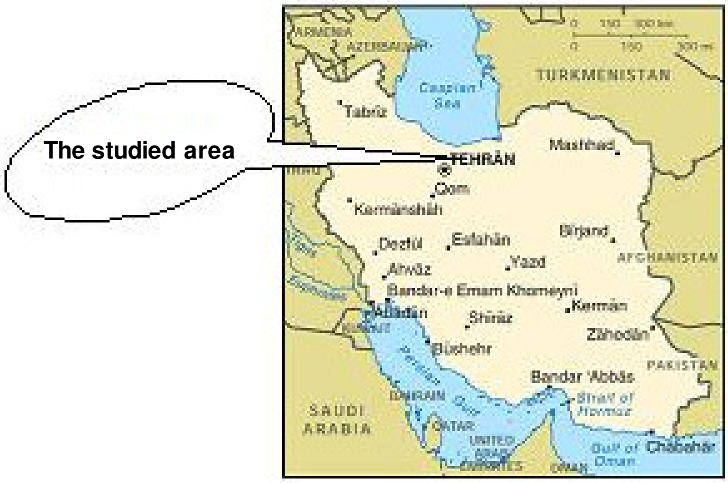

Figure 1. Schematic location of the studied area.

Results

The results showed that the two lowest organic carbon contents belong to the lowest and highest elevation classes (Figure 2b), although not for the same reasons. In the case of the lowest elevation class, due to lower precipitation, its accessibility for intensive grazing, and soil and vegetation disturbances, organic carbon content is low. While in the case of the highest elevation class, low organic carbon content is the result of shorter vegetation period due to the colder temperature regime, which restricts organic matter input. The highest OC content was observed in the elevation class no. 2 (2250-2500 m) and class no. 3 and 4 were the next steps accordingly. The middle elevation and precipitation class temperature regimes have rather suitable conditions due to longer vegetation periods. Also with increasing the elevation till 3000 m precipitation increases, but decreasing temperature below the biological zero point restricts the yield of vegetation cover and thus the soil organic carbon content.

Table 1. Selected chemical and physical properties of samples.

No	EC	pH	%Clay	%Silt	%Sand	CEC	%$CaCO_3$	OM	%N	C/N
1	2.52	7.77	19.6	46	34	12.8	5.58	0.85	0.066	7.5
2	1.00	8.13	9.6	28	62	1.0	2.12	0.85	0.074	6.6
3	1.23	8.09	6.3	34	60	11.2	2.08	1.35	0.068	11.5
4	1.35	7.95	8.3	30	62	17.0	3.56	0.81	0.085	5.5
5	0.72	8.09	17.6	18	64	4.1	2.77	0.89	0.077	6.7
6	0.92	7.57	8.3	26	66	6.7	2.85	2.62	0.162	9.4
7	2.35	8.03	10.3	28	62	2.0	0.65	2.55	0.173	8.5
8	1.73	8.19	22.8	15	62	5.1	2.33	1.04	0.093	6.5
9	2.64	7.97	11.7	24	64	16.1	1.94	0.04	0.121	0.19
10	1.16	7.89	9.6	32	58	2.4	1.90	4.09	0.264	9.0
11	1.16	8.05	12.3	24	64	4.2	0.98	0.81	0.062	7.6
12	2.58	7.96	19.6	34	46	14.7	1.94	0.93	0.116	4.6
13	2.37	8.31	9.7	38	52	16.3	1.97	2.47	0.156	9.2
14	1.30	7.99	9.7	32	58	17.2	2.91	1.42	0.118	7.0
15	0.74	7.95	7.6	16	76	12.7	3.38	2.59	0.223	6.7
16	2.21	8.11	7.6	16	76	9.3	0.00	1.58	0.127	7.2
17	1.12	8.04	15.7	40	44	10.5	1.03	0.19	0.110	1.0
18	0.69	8.01	13.6	24	62	15.2	2.62	0.93	0.132	4.1
19	2.72	7.98	17.7	32	50	15.2	1.12	1.12	0.163	4.0
20	1.26	7.39	15.6	46	38	18.7	1.27	7.72	0.493	9.1
21	1.01	7.43	4.3	19	77	10.7	3.13	4.09	0.180	13.2
22	1.53	7.46	5.7	14	80	13.5	0.26	0.62	0.067	5.3
23	1.80	6.61	2.3	14	84	16.3	0.00	1.04	0.103	5.8
24	1.09	7.95	1.6	12	86	12.5	0.98	0.81	0.104	4.5

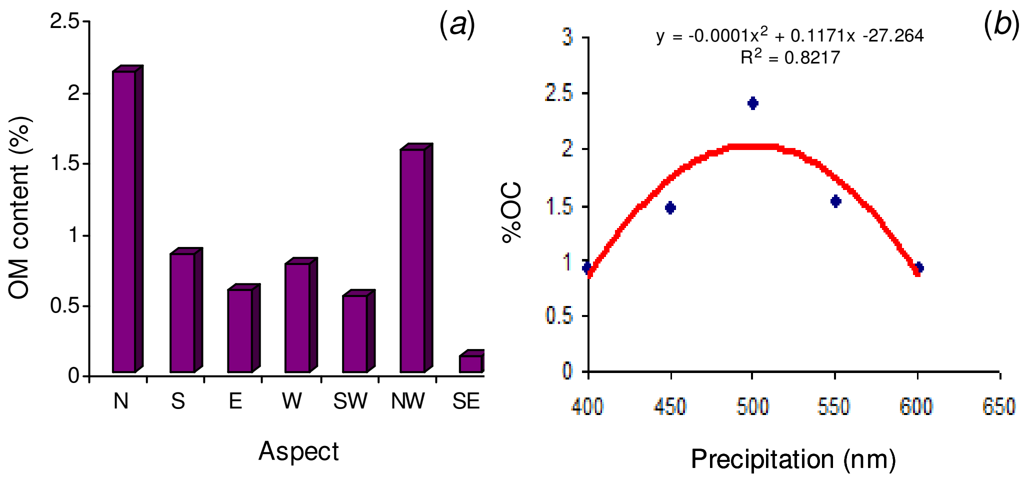

Figure 2. Relationship between soil OM and aspect (a left) and relationship between soil OC and precipitation (b right).

Conclusion

Comparison of soil OC contents for different geographical aspects showed that the highest OC contents belong to the northern and north-western aspects in all elevation and precipitation classes (Figure 2a). These results show that an overall conservation and management program must consider specific bio-eco-physical conditions of each site to be comprehensive. For a successful soil carbon sequestration program we should pay attention to all environmental aspects involved in increasing biomass yield, site specific programming and soil carbon sequestration.

References

Dianwei L, Zongming W, Bai Z, Kaishan S, Xiaoyan L,Jianping L, Fang L, Hongtao D (2006) Spatial distribution of soil organic carbon and analysis of related factors in croplands of the black soil region, Northeast China. *Agriculture, Ecosystems and Environment* **113**, 73-81.

Jerry C, Ritchie G, McCarty W, Venteris ER, Kaspar TC (2007) Soil and organic carbon redistribution on the landscape. *Geomorphology* **89**, 163-171.

Changes in micromorphological features of semidesert soils in the southeast of European Russia upon the recent increase in climate moistening

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Abstract

In the past 30 years, a definite trend towards an increase in climatic humidity and a rise in the groundwater table has been observed in the southeast of European Russia. Stationary studies at the Dzhanybek Research Station in the north of the Caspian Lowland prove that these climatic changes have been reflected in soil microfeatures. A comparison of soil thin sections taken in different times: in the 1950s, 1960s, 1970s, 1982, and 2002 from the same soils has been performed. No considerable changes in the soil properties took place in 1950s through 1970s, when the climatic parameters were relatively stable. From 1982 to 2002, when a significant rise in the climatic moistening and in the depth of the groundwater took place, certain changes in the soil microfeatures took place. These include the activation of humus accumulation and biogenic structuring, the eluviation of the silty clay-humus matter, the development of solodic features, gleyization of the soil mass, and the accumulation of coal-like particles. In the case of salt-affected soils, the development of hydrogenic accumulations of gypsum and carbonates took place.

Key Words

Climate change, soil forming processes, hydromorphic features, biological activity, decalcification

Introduction

In the European part of Russia, the driest landscapes are found in its southeastern part. Geomorphologically, this area is delineated as the Caspian Lowland, an ancient accumulative plain of marine genesis. Geobotanically, it belongs to the subboreal desert steppes and northern deserts (Safronova 2002). Since the end of the 1970s, an increase in the degree of climatic moistening has been observed in the southeast of European Russia (Sotneva 2004; Sapanov 2007). In absolute values, these changes are not very considerable: annual precipitation has increased by 50 mm, and the potential evaporation during the summer season has decreased by 70 mm. However, arid and semiarid ecosystems are very sensitive to such changes. Under conditions of a generally low natural drainage, the increase in climatic moistening leads to a simultaneous rise in the groundwater level (Sokolova *et al.* 2000; Sapanov 2007) (Figure 1). These changes have already been reflected in the character of vegetation in the northern part of the Caspian Lowland. The results of geobotanical research at several key plots demonstrate an increase in the portion of mesophytic species (Novikova *et al.* 2004). What are the effects of the increased moistening of the climate and the rise in the groundwater level on the soils? In this paper, we try to estimate them on the basis of micromorphological data obtained at the Dzhanybek Research Station of the Russian Academy of Sciences in different years.

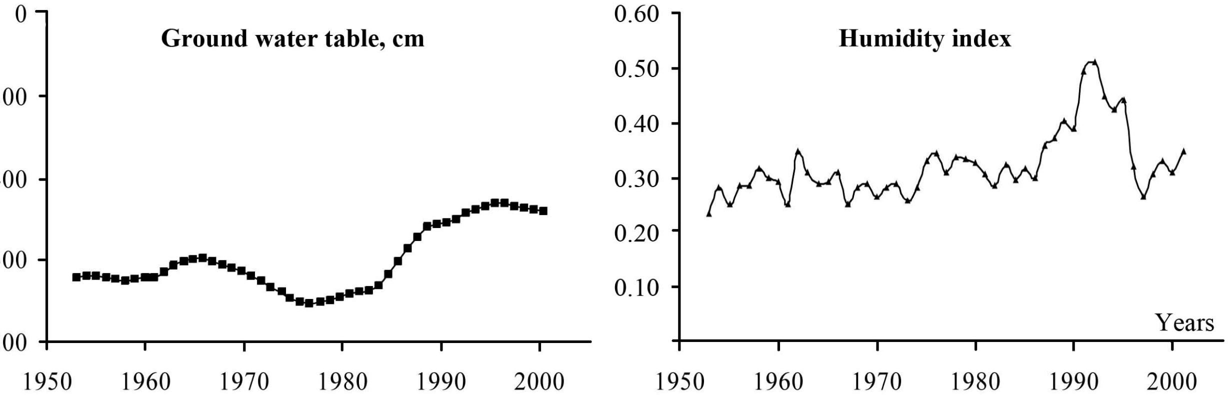

Figure 1. Dynamics of the groundwater table and humidity index in the northern part of the Caspian Lowland. The values have been smoothed by the moving 5-year averages (Sapanov 2007).

Materials and methods

The Dzhanybek Research Station is found in the northern part of the Caspian Lowland on the Volga–Ural interfluve with absolute heights about 26–28 m a.s.l. This is the area with the semiarid subboreal climate. Annual precipitation is about 250--350 mm, and potential evaporation reaches 1000 mm. The entire territory is a virtually nondrained flat composed of homogenous heavy loams of the Khvalyn (Late Pleistocene) transgression of the Caspian Sea. The groundwater table at the beginning of the 21st century is found at the depth of 4–5 m (Figure 1). The soils are developed from the brown loesslike calcareous loams underlain by clays with interlayers of sands at the depth of more than 15 m.

Local soils and vegetation have complex patterns related to the redistribution of precipitation (mainly, snowmelt runoff) by the elements of the well-pronounced microtopography (Rode and Pol'skii 1963). The microhighs with a relative elevation of up to several decimeters receive only atmospheric precipitation; the soil thickness under them contains a considerable amount of salts. These elements are occupied by solonchakous solonetzes under sparse semidesert vegetation (Figure 2). The presence of the solonetzic (natric) horizon with a very low water permeability specifies the nonpercolative soil water regime and the absence of salt leaching. Salts precipitate from the soil solutions in the subsurface horizons. At the depth of 20–30 cm, the content of soluble salts reaches 1.5–2.5%. The accumulation of calcium carbonates is observed below the solonetzic horizon, in the layer of 30–50 cm (6% $CaCO_3$). The gypsum content in the layer below 30 cm reaches 3–6%. The humus content is low (<2%). Saucer-like local microlows receive additional water owing to the surface redistribution of precipitation. Dark-colored chernozem-like soils with a periodically percolative water regime are developed in the microlows under forb–grassy steppe communities. These soils are free from soluble salts and gypsum; the accumulation of carbonates is seen from the depth of 50–70 cm (up to 5–6% $CaCO_3$). The humus content reaches 4–6%. On the microslopes between microhighs and microlows, light chestnut soils with different degrees of solonetzicity are developed under Agropyron–fescue dry-steppe associations.

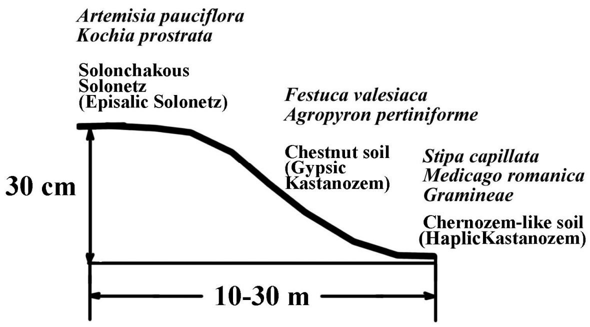

Figure 2. Soils and vegetation along a typical microcatena in the Dzhanybek area. Soil names according to the WRB system (2006) are given in parentheses.

A comparative study of the microfabrics of solonetzes and chernozem-like soils was performed on the basis of thin sections prepared from undisturbed micromonoliths of the main genetic horizons (Gerasimova *et al*. 1992; Stoops 2003). Samples taken in 1982 and 2002 were obtained from the same soils in the pits located at very close distances (<30 m) from one another. Micromorphological descriptions of soils of the station for the earlier periods were taken from the works of Pol'skii (1958), Yarilova (1966), and Tursina (Bazykina 1978).

Results

Soil micromorphological features in the period of the relatively stable climate (1950s-1970s)

This period was characterized by the stability of micromorphology of solonetzes and dark-colored chernozem-like soils. The latter soils had the high content of clayey-humus plasma in the upper horizon, the high compactness of angular blocky aggregates, the high interaggregate porosity in the middle-profile horizons, and the even distribution of micrograined calcite and high compactness of the silty-plasmic material in the lower-lying calcareous horizons.

In the solonetzes, the uppermost horizons had the low content of peptized humus-clayey plasma and plant debris; their platy peds had no intraped differentiation of plasma. The solonetzic horizons had a typical angular-blocky structure with an increased content of clayey plasma and a relatively small amount of thin clay stress cutans on ped faces. The subsolonetzic horizons had the high inter- and intraggregate porosity and the specific rounded aggregates. The pores in the lower-lying gypsiferous horizons contained dense infillings composed of very fine (0.02 mm) lens-shaped and irregular-shaped gypsum crystals. These infillings were also preserved during the next period.

Soil micromorphological features in the period of changing climate (1982-2002)
In the **dark-colored chernozem-like soil,** a general increase in the degree of biogenic aggregation and in the amount of plant tissues of different degrees of decomposition took place. This attests to the enhancement of humus accumulation processes and is related to a greater phytomass production and a higher activity of the soil biota in the comminution and transformation of plant residues and the soil structuring. An increase in the density of forb–grassy vegetation specifies the rise in the soil porosity and some loosening of the middle-profile horizons with the development of specific pedogenic structure. The increasing porosity of the middle-profile horizons favors the leaching of carbonates under conditions of a more pronounced percolative water regime of the soil. The processes of decalcification are diagnosed by the appearance of carbonate-free zones around intraped pores in the middle-profile horizons. The high degree of optical orientation of clayey plasma in the middle-profile horizons of the chernozem-like soil should be noted. It may be due to the recent physicomechanical processes, or be inherited from the former stage of the enhanced salinization. A common micromorphological feature typical of both the dark-colored chernozem-like soil and the solonchakous solonetz is the abundance of fine-dispersed charred plant tissues (coal-like particles). Their formation takes place upon incomplete mineralization of plant tissues under conditions of the increased surface hydromorphism related to the recent rise in precipitation.

In the **solonetzes**, the following changes took place in the recent past (1982–2002). In the above-solonetzic horizons: (1) the content of clay particles somewhat decreased; (2) the amounts of plant tissues of various sizes, flocculated humus particles, and iron concentrations increased; (3) an indistinct platy structure was transformed into a clearly pronounced lens-shaped structure with a definite differentiation of particles within the lens-shaped aggregates (with the accumulation of clay particles at their lower sides at the expense of clay depletion from the upper parts of the aggregates); and (4) recent gypsum concentrations appeared around the roots. In the solonetzic horizons: (1) the content of clayey plasma somewhat increased, (2) the angular blocky structure became more pronounced, and (3) the degree of optical orientation of the clayey plasma in the intraped mass increased. At the same time, no fresh illuviation clayey coatings appeared on pore walls. In the saline subsolonetzic horizons: (1) the degree of compaction of the pseudosandy salt-bearing material increased, (2) the degree of the soil impregnation with fine-grained calcite (micrite) increased, and (3) the amount of gypsiferous infillings in the pores also increased, and the gypsum crystals became larger (Figure 3).

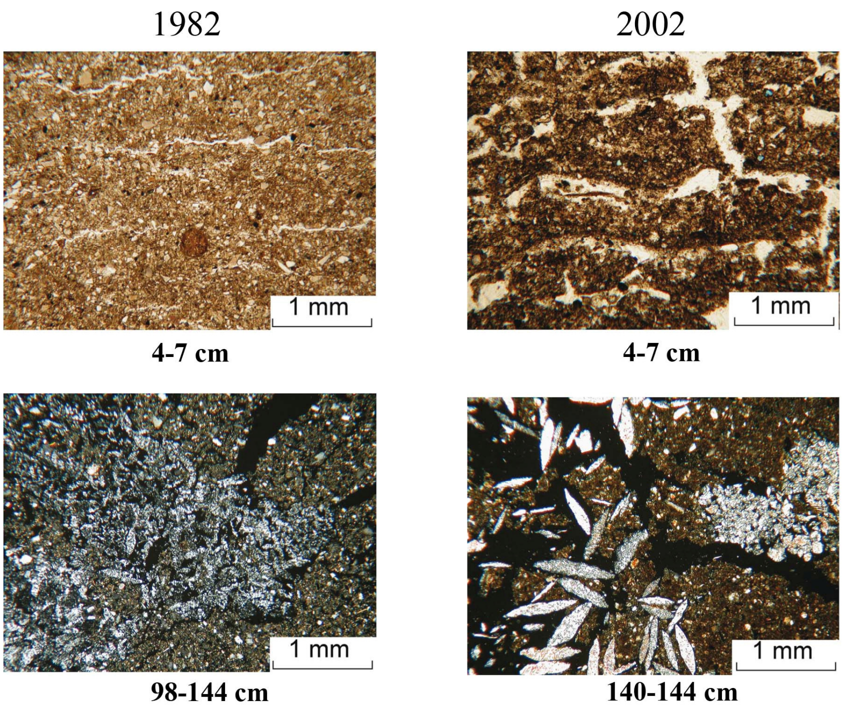

Figure 3. Enhancement of the accumulation of humus and biogenic aggregation in the surface horizons (upper line, N II) and of the hydrogenic accumulation of gypsum (the appearance of large gypsum crystals) in the lower horizons (lower line, N X) in the solonetzes during the 20-year-long period (1982–2002).

Conclusion

The revealed changes in the microfabrics of studied soils make it possible to assess the trends of pedogenic processes related to the recent rise in the atmospheric precipitation and in the groundwater table. In 1982-2002, the activation of humus formation, biogenic structuring, eluviation of silty-clay-humus matter, solodic process, gleyization, and accumulation of coal-like particles (charred plant detritus) took place. In the solonetzic horizons of solonetzes, some re-organization of the clayey coatings with their inclusion in the intraped mass was observed. In the subsolonetzic horizons, the compaction of the pseudosandy salt-bearing mass, the accumulation of fine-grained calcite (micrite), and large gypsum crystals took place. The identified micromorphological changes are concordant with changes in the factors of soil formation observed in the last decades.

Acknowledgments
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References

Bazykina GS (1978) The change in agrophysical properties of solonchakous solonetzes of northern Caspian Lowland due to amelioration. In ‘Issues of Soil Hydrology and Genesis’ pp. 5-31. (Nauka: Moscow).

Gerasimova MI, Gubin SV, Shoba SA (1992) ‘Micromorphology of Soils in the Main Natural Zones of the USSR’. (ONTI: Pushchino).

Novikova NM, Volkova NA, Khitrov NB (2004) The vegetation of the solonetiz complex in the protected steppe plot of the northern Caspian Lowland. *Arid Ecosystems* **10,** 9-18.

Pol’skii MN (1958) Agrophysical properties of solonchakous solonetzes as the target of amelioration. In ‘Scientific Bases for Land Improvement in Semideserts of Northwestern Caspian Lowland’. pp. 58-73. (Izd. Akad. Nauk SSSR: Moscow).

Rode AA, Pol’skii MN (1963) The water regime and balance in the virgin soils of semidesert complex. In ‘The Water Regime of Semidesert Soils’. pp. 5-83. (Izd. Akad. Nauk SSSR: Moscow).

Safronova IN (2002) Phytoecological mapping of the northern Caspian Lowland. In “Geobotanical Mapping’. pp. 44-65. (BIN RAN: Saint-Petersburg).

Sapanov MK (2007) The synchronism in the changes of the Caspian Sea level and ground water table in the northern Caspian Lowland in the second half of the XXth century. *Izvestiya RAN. Geographical Series* **5**, 82-87.

Sokolova TA, Sizemskaya ML, Sapanov MK, Tolpeshta II (2000) Variations in the content and composition of salts in the soils of the solonetzic complex at the Dzhanybek Research Station during the last 40-50 years. *Eurasian Soil Science* **33,** 1166-1177.

Sotneva NI (2004) The dynamics of climatic conditions at the Dzhanybek Research Station in the northern Caspian Lowland in the second half of the XXth century. *Izvestiya RAN. Geographical Series* **5,** 74-83.

Stoops G (2003) Guidelines for Analysis and Description of Soil and Regolith Thin Section, 184 p. (Soil Science Society of America: Madison, Wisconsin, USA).

Yarilova YeA (1966) The peculiarities of micromorphological features of solonetzes in the chernozemic and chestnut zones. In ‘The Micromorphological Method in the Research into Soil Genesis’, pp. 58-75. (Nauka: Moscow).

Ferruginous paleosols around the K/T boundary in Central-Southern Sardinia (Italy): Their potential as pedostratigraphic marker

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Abstract
This paper focuses on the main morphological, chemical and mineralogical features of ferruginous paleosols around the K/T boundary in central-southern Sardinia (Italy), on their relationships with the coeval ones in south-western France, and on their potential role in stratigraphy. The main features of the Sardinian ferruginous paleosols indicate the presence of petroplinthic and pisoplinthic horizons. Pisoplinthic horizons are also present in the two considered French outcrops. Their genesis may be related to the warm and humid tropical climatic conditions occurring during Latest Maastrichtian-Lower Paleocene (Danian), which favored the formation of plinthic horizons, followed by the increasing dry conditions occurring during the Paleocene, which favored the irreversible drying of the plinthic horizons in petroplinthic and pisoplinthic horizons. On the basis of the consistent stratigraphic position, large extent and lateral continuity, these paleosols can be considered a good pedostratigraphic marker in the region and can be defined as a geosol, being helpful in the framework of extensive chronostratigraphic correlations and allowing further regional-scale morphostratigraphic correlations.

Key Words
Geosol, paleosols, Upper Cretaceous-Lower Paleocene, Sardinia, France

Introduction
Seven small outcrops of Upper Cretaceous-Lower Paleocene ferruginous paleoalterites were recently recognised and described in central-southern Sardinia (Italy) (Murru *et al*., 2007b). These paleoalterites were considered similar to those of the same age described in south-western France (Saurel *et al*., 1976; Gourdon-Platel, 1980). On these basis, Murru *et al*. (2007b) conclude that the pre-rotation position of the Sardinian-Corsican block along the south-eastern margin of the European paleocontinent allows to presume a similar climatic and environmental regional history. This paper focuses on the paleosols present within all the seven Sardinian outcrops, on their relationships with those in south-western France, and on their potential to represent a good pedostratigraphic marker for a larger area.

Materials and methods
The seven outcrops are scattered in various localities of central-southern Sardinia (Figure 1a). For each outcrop, described in detail in the field a main vertical profile was sampled, together with numerous other lateral levels. All the deposits lie on a Paleozoic substrate and are covered (except one) by Paleocene-Lowermost Eocene transitional to shallow-water marine sediments, sometimes with interposed lacustrine carbonate levels (Murru *et al*., 2007a). Their sedimentological characters are typical for an alluvial continental environment, with different depositional energy and varied paleomorphology. Within all the seven deposits ferruginous paleosols are present.

On the collected samples, physical, chemical, and mineralogical analyses were carried out. Bulk rock chemical composition was determined by X-ray fluorescence spectroscopy (XRF) using a Panalytical Magix Pro instrument. Al and Fe were chemically analyzed by means of optical ICP. The mineralogical composition was determined by X-ray diffraction (XRD) using a Panalytical X'pert Pro diffractometer, with Cu-Kα radiation generated at 40 kW and 20 mA. Microscopic and submicroscopic observations were made using a SEM FEI Quanta 200. Scanning electron microscopic analyses, coupled with energy dispersive spectroscopy (SEM-EDS), were performed on thin sections.

Results and discussion

The eastern outcrops are located at Monte Maraconis, at Ballao, and at Sant'Andrea Frius (Figure 1a). At Monte Maraconis the substrate is made up of Ordovician metavulcanites and the ferruginous paleosol shows a weak red (10R 4/4) cemented horizon, about 60 cm thick, with light gray (5Y 6/1) bleached tongues, covered by Lower Eocene conglomerates (Figure 1b) containing fragments of the cemented horizon, which testify its partial erosion. Quartz, hematite and clay minerals (illite 39%, mixed layers 24%, kaolinite 37%) are present in the cemented horizon. Al content is 3.5% and Fe content is 22.2%. The bleached areas contain quartz and clay minerals (illite 57 %, mixed layers 16%, kaolinite 27%). Al content is 7.6% and Fe content is 2%. At Ballao, on the same substrate, the ferruginous paleosol shows a dusky red (10R 3/4) cemented horizon, about 2 m thick, with light gray (2.5Y 7/2) bleached tongues (Figure 1c), covered by transitional and marine Lower Eocene sediments. Quartz, hematite, and kaolinite are the main components in the cemented horizon. At Sant'Andrea Frius, where the substrate is made up of Paleozoic metasandstones, the ferruginous paleosol shows a weak red (10R 5/2) cemented horizon with diffuse light olive gray (5Y 6/2) mottles (Figure 1d), covered by Uppermost Paleocene transitional to shallow-water marine sediments. Mineralogical analyses show the presence of quartz, hematite and illite, with traces of kaolinite. Al content is 6.3% and Fe content is 5.6%. The western outcrops are located at Villamassargia, Piolanas, Nuxis, and Guardia Pisano (Figure 1a). At Villamassargia, where the substrate is made up of Lower Paleozoic metasandstones, the ferruginous paleosol resembles very much those of south-eastern Sardinia (Figure 1e). The dusky red (10R 3/4) cemented horizon, about 4 m thick, is formed by quartz, hematite and kaolinite. Al content is 5.0% and Fe content is 12.7%. The bleached areas contain quartz and clay minerals (illite 2 % and kaolinite 98%). Al content is 4.1% and Fe content is 0.2%. The paleosol is covered by Paleocene palustrine carbonate sediments and continental deposits of the Cixerri Formation (Middle-Upper Eocene). At Nuxis the Cambrian basement is made up of dolomitic metalimestones mineralized with barite and highly karstified. The karstic cavities are filled by dark brown (7.5YR 3/3) ferruginous horizons, about 8 m thick, which are overlain by continental deposits of the Middle-Upper Eocene Cixerri Formation (Figure 1f). Three main horizons are recognizable in the ferruginous sequence preserved in the karstic cavities: a well lithified ferruginous dark brown horizon, a caothic well lithified ferruginous dark brown horizon, and a pisolithic horizon. The mineralogical analysis shows the presence of abundant hematite, kaolinite, and barite, with some goethite and quartz.

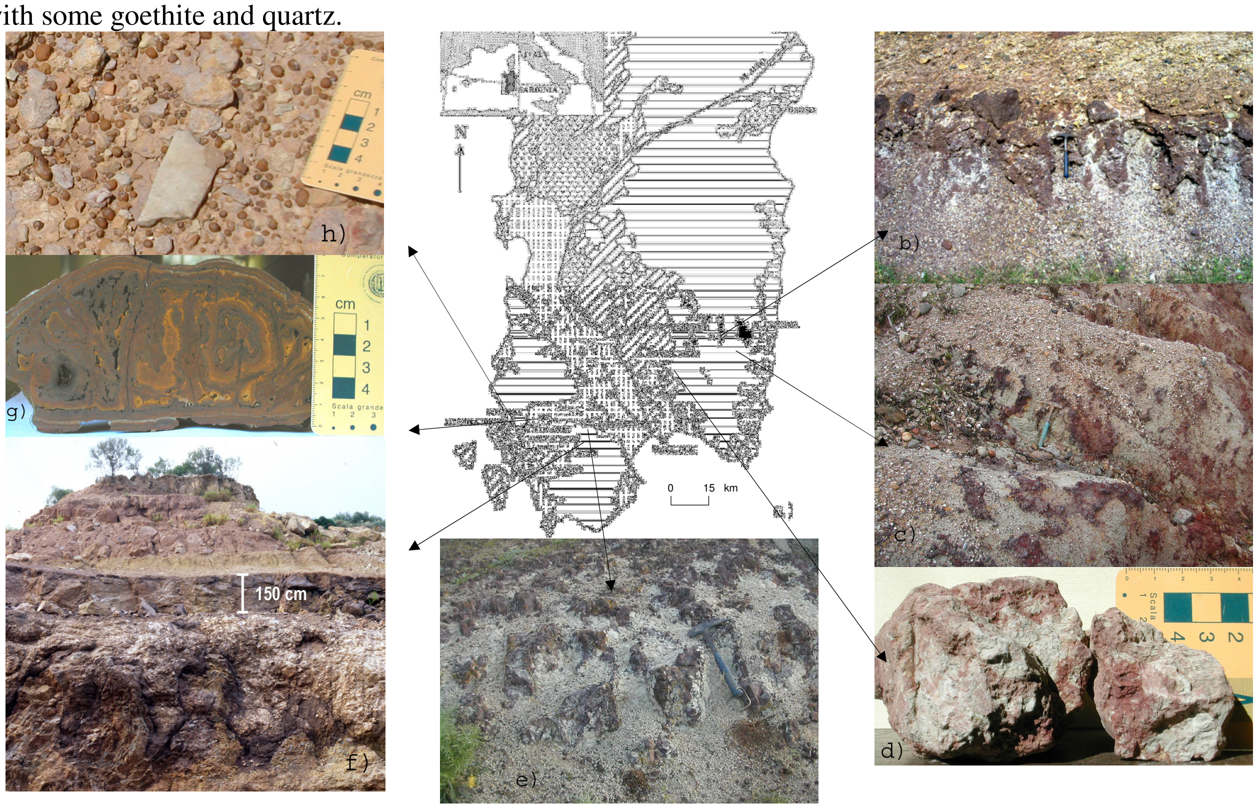

Figure 1. a) Spatial distribution of the seven outcrops of Upper Cretaceous-Lower Paleocene ferruginous paleoalterites in Sardinia; b) Monte Maraconis outcrop; c) Ballao outcrop; d) fragments from the Sant'Andrea Frius outcrop; e) Villamassargia outcrop; f) Nuxis outcrop; g) large concentric ferruginous nodule from the Piolanas outcrop; h) pisolithic nodules from the Guardia Pisano outcrop.

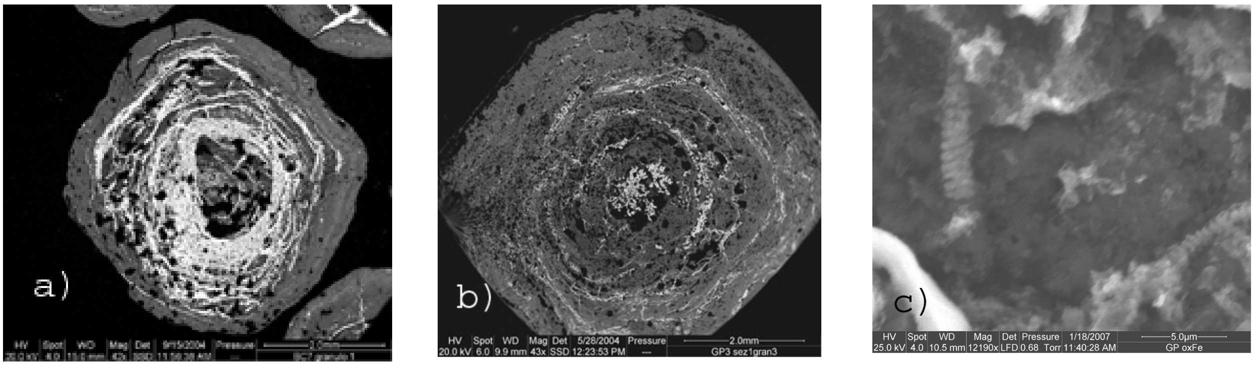

Figure 2. SEM/EDS images of Nuxis (a) and Guardia Pisano (b) concretions showing the concentric distribution of their mineralogical components; c) SEM/EDS image of a Guardia Pisano concretion showing twisted stalks similar to the *Gallionella* ones.

Traces of calcite are also present. The chemical composition is the following: Fe_2O_3 27-24%, Al_2O_3 21-19%, BaO 32-14%, and CaO 2.9-0.07%. At Piolanas, where the substrate is formed by Cambrian dolomitic metalimestones, large concentric ferruginous masses, which are made up of nodules soldered each others with growth, are found at the surface of a plowed soil, probably testifying for a former ironstone in the area (Figure 1g). The mineralogical analysis shows the presence of goethite and, subordinately, quartz and magnetite. At Guardia Pisano the basement is made up of Permian metaclaystones. The paleosol is represented by pisolithic levels in marly clays (Figure 1h), covered by Upper Paleocene-Lowermost Eocene shallow water marine sediments. The mineralogical analysis shows the presence of very abundant goethite in the pisoliths and very abundant calcite in the sediments. The chemical analyses show the same trend, with Fe_2O_3 contents of about 49% in the pisoliths and from 1 to 5% in the sediments and CaO content ranging from 32 to 43% in the sediments and from 1 to 4% in the pisoliths. SEM/EDS observations on the pisolithic concretions of Nuxis show the concentric distribution of their main mineralogical components (Figure 2a). The nucleus is made up by kaolinite and hematite. The cortex of the pisoliths is often thick and is made up of layers of hematite and kaolinite, alternating with the concentric planes of a complex system of craze planes filled by microcristalline barite precipitates. SEM/EDS observations on the pisolithic concretions of Guardia Pisano show a concentric primary structure starting from a kaolinitic nucleus (Figure 2b). The nucleus is covered by concentric layers of goethite, alternating with the concentric craze planes filled by microcristalline barite and calcite precipitates. The SEM images of the pisoliths support the hypothesis of bacterial contribution in the precipitation of iron hydroxides (Figure 2c).

The Maastrichtian ironstone outcropping near Marseille (southern France), studied by Saurel *et al*. (1976), is formed by pisolithic concretions, consisting of several concentric layers enveloped around quartz grains, mainly composed by Fe_2O_3 (56.2-33.8%), Al_2O_3 (11.5-8.5%), and CaO (12.3-0.8%). Kaolinite is the only clay mineral; among the Fe oxides, goethite prevails on hematite. In northern Aquitaine (south-western France) there are numerous outcrops of a pisolithic ironstone, lying on a Jurassic-Cretaceous karstified carbonate substrate and covered by Lower Eocene marine deposits. In the Montchoix outcrop, pisoliths, representing more than the 56% of the volume, are contained in clays lying on Campanian limestones and are covered by Cuisian marine clays (Gourdon-Platel 1980). The pisolithic concretions, formed around the K/T boundary, show a concentric distribution of their mineralogical components and contain large amounts of iron oxides (more than 60%), with goethite (70-80%) strongly prevailing on hematite, and low Al_2O_3 content (10-15%).

The main features of the ferruginous paleosols located at Monte Maraconis, Ballao, Sant'Andrea Frius and Villamassargia, as well as those of the two lowest horizons at Nuxis, indicate the presence of petroplinthic horizons (IUSS Working Group WRB, 2006). The large concentric ferruginous nodules soldered with growth found at the surface of a plowed soil at Piolanas may also be considered as part of a former petroplinthic horizon. The upper horizon at Nuxis fits the requirements for the pisoplinthic horizon (IUSS Working Group WRB, 2006) while the pisolithic levels at Guardia Pisano can be referred to a former pisoplinthite in the area. Pisoplinthic horizons are also present in the two considered French outcrops.
The genesis of these petroplinthic and pisoplinthic horizons may be related to the warm and humid tropical climatic conditions occurring during Latest Maastrichtian-Lower Paleocene (Danian), which favored the formation of plinthic horizons, followed by the increasing dry conditions occurring during the Paleocene, which favored the irreversible drying of the plinthic horizons in petroplinthic and pisoplinthic horizons. The formation of the pisoliths at Nuxis can be related to the presence of a ferruginous plasma, derived from the leaching of the

underlying ferruginous deposits during more humid periods, that reorganized itself in concentric bands around nucleus of kaolinite and hematite. At Guardia Pisano, on a clayey substratum characterized by very slow drainage, the pisoliths could have formed similarly, but with goethite in state of hematite. In both cases, their regular structure tends to be obliterated during the repeated phases of hardening, drying and cracking as testified by the many craze planes. The precipitation of microcrystalline barite, leached from the barite-rich Paleozoic substrate, in the tensional planes opened in the pisoliths could have happened during and after their formation. Both in Sardinia and France (Gourdon-Platel, 1980), the bacterial contribution in the precipitation of iron hydroxides has been pointed out.

The constant stratigraphic position (around the K/T boundary), the large extent, and the supposed lateral continuity of the discussed ferruginous paleosols, of which the Sardinian and French outcrops are scattered remnants, are all important requirements to consider them as a pedostratigraphic unit (NACSN, 2005). According to the latest revision of NACSN (2005) the fundamental and only unit in pedostratigraphic classification is the geosol, which consists of a traceable, mappable three-dimensional body of soil material comprising one or more differentiated pedologic horizons (petroplinthic and pisoplinthic horizons, in the study area) (INQUA Working Group, 1995; Catt, 1998). As the physical and chemical properties of a specific pedostratigraphic unit may vary greatly, both vertically and laterally, from place to place (NACSN, 2005), a geosol is not a soil or paleosol, but rather a whole soilscape that can be recognised as a laterally extensive stratigraphic horizon (Morrison, 1978). The considered ferruginous paleosols clearly separates different sedimentary cycles and point to a period of relative geomorphic stability. For all these reasons, the paleosols at issue can be defined as a geosol.

Conclusions

The numerous small outcrops, found in Sardinia and southern France, containing remnants of petro- and pisoplinthic horizons, have important implications for understanding climate regimes in the south-eastern margin of the European paleocontinent in the Late Cretaceous-Early Paleocene. The evidence they provide can be helpful in establishing extensive chronostratigraphic correlations as well as regional-scale morphostratigraphic correlations. Consequently, these outcrops represent a pedostratigraphic unit worthy of consideration in future regional geological mapping.

References

Catt JA (1998) Report from working group on definitions used in paleopedology. *Quaternary International* **84**, 51-52.

Gourdon-Platel N (1980) Les cuirasses de fer pisolithique du tertiaire continental de la bordure Nord-Aquitaine: typologie des pisolithes et hypothèses sur leur formation. *Revue de Géomorphologie Dynamique* **4**, 129-142.

INQUA Working Group (1995) Definitions used in paleopedology. Paleopedology Glossary. 2nd Draft, July 1994. *INQUA/ISSS Paleopedology Commission, Newsletter* **11**(2), 35–37.

IUSS Working Group WRB (2006) World reference base for soil resources 2006. 2nd edition. World Soil Resources Reports n. 103. FAO, Rome.

Morrison RB (1978) Quaternary soil stratigraphy concepts, methods and problems. In 'Quaternary Soils' (Ed. WC Mahaney), pp. 77-108. (Geoabstracts, Norwich).

Murru M, Ferrara C, Matteucci R, Da Pelo S (2007a) I depositi carbonatici palustrini paleocenici della Sardegna centro-meridionale (Italia). *Geologica Romana* **40**, 201-213.

Murru M, Ferrara C, Matteucci R, Da Pelo S, Vacca A (2007b) I depositi continentali ferruginosi del Maastrichtiano sommitale-Paleocene della Sardegna meridionale (Italia). *Geologica Romana* **40**, 175-186.

NACSN (North American Commission on Stratigraphic Nomenclature) (2005) North American Stratigraphic Code. *American Association of Petroleum Geologists Bulletin* **89**(11), 1547-1591.

Saurel P, Arlhac P, Gouvernet C, Redondo C, Rousset C (1976) Présence d'une cuirasse gravillonaire ferrugineuse dans le Rognacien de Sénas (Bouches-du-Rhône, France). *Paléogéographie. Bulletin de la Société Géologique de France* **18**, 59-67.

Global estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 IPCC guidelines

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Abstract

While there have been many estimates of global CH_4 emissions from rice fields, none of them have been obtained using the IPCC guidelines. In this study, we used the Tier 1 method described in the 2006 IPCC guidelines to estimate the global CH_4 emissions from rice fields. To accomplish this, we used country-specific statistical data regarding rice harvest areas and expert estimates of relevant agricultural activities. The estimated global emission for 2000 was 25.4 Tg/yr, which is at the lower end of earlier estimates and close to the total emission summarized by individual national communications. Monte Carlo simulation revealed a 95% uncertainty range of 14.8 to 41.5 Tg/yr. We estimated that, if all of the continuously flooded rice fields were drained at least once during the growing season, the CH_4 emissions would be reduced by 4.1 Tg/yr. Furthermore, we estimated that applying rice straw off-season wherever and whenever possible would result in a further reduction in emissions of 4.1 Tg/yr globally. Finally, if both of these mitigation options were adopted, the global CH_4 emission from rice paddies could be reduced by 7.6 Tg/yr.

Key Words

Methane, rice field, IPCC guidelines, emission inventory, mitigation potential

Introduction

Although the total source strength of global atmospheric CH_4 is relatively certain, the strength of individual sources remains uncertain (Lelieveld *et al.* 1998). Using the global source strength and assuming that 80 Tg CH_4 /yr are emitted from rice fields, Houweling *et al.* (2000) modeled the global distribution of atmospheric CH_4. Frankenberg *et al.* (2005) subsequently compared these modeled results to satellite observations and found discrepancies over India and the tropics, indicating that the rice emissions used in the model were probably overestimated. Keppler *et al.* (2006) recently reported that CH_4 is emitted from terrestrial plants under oxic conditions, which resulted in the addition of 62-236 Tg CH_4 /yr to the CH_4 budget. Although later recalculations and modeling studies reduced the plant contribution to 52.7-85 Tg CH_4 /yr (Parson *et al.* 2006; Houweling *et al.* 2006), these findings still indicate that it is necessary to re-evaluate the CH_4 emissions from other sources. The United Nations Framework Convention on Climate Change requires all signatories to develop and periodically update national inventories of anthropogenic emissions by source. Most signatories have submitted their national communications using 1994 as the base year, and annex I countries have submitted their national inventory reports on annual basis. Although most countries used the 1996 guidelines to estimate the CH_4 emission from rice cultivation, some major rice-producing countries developed their own emission factors based on local measurements or used models. The purpose of this study is to provide an updated estimate of CH_4 emission from global rice fields using the tier 1 method described in the 2006 IPCC guidelines with the default emission factors and country- or region-specific agricultural activity data for individual rice producing countries.

Methods

2006 IPCC Guidelines

We used the Tier 1 method in the IPCC guidelines (IPCC, 2007), in which the emission from a country is the sum of emissions from fields under each specific condition, as shown in Equation 1.

$$CH_{4Rice} = \sum_{i,j,k} EF_{i,j,k} \times T_{i,j,k} \times A_{i,j,k} \times 10^{-6} \quad (1)$$

where CH_4Rice is the annual CH_4 emission from rice cultivation in a country or region in Gg CH_4 /yr, $EF_{i,j,k}$ is a daily emission factor specific for *i, j,* and *k* conditions in kg CH_4 /ha day-1, $T_{i,j,k}$ is the cultivation period of rice for *i, j,* and *k* conditions in days, $A_{i,j,k}$ is the annual harvested area of rice for i, j, and k conditions in ha /yr, and i, j, and k represent different ecosystems, water regimes, types and amounts of organic amendments, and other conditions under which CH_4 emissions from rice may vary.

As shown in Equation 2, the daily specific emission factor is estimated from a baseline EF and various SFs to account for the water status during and before the rice season, as well as the types and amounts of organic fertilizers used.

$$EF_i = EF_c \times SF_w \times SF_p \times SF_o \times SF_{s,r} \qquad (2)$$

where *EFi* is the adjusted daily emission factor for a particular harvested area, *EFc* is the baseline emission factor for continuously flooded fields without organic amendments, *SFw* is the scaling factor for differences in the water regime during the cultivation period, *SFp* is the scaling factor for differences in the water regime in the pre-season prior to the cultivation period, *SFo* is the scaling factor for both the type and amount of organic amendment applied, and *SFs,r* is the scaling factor for soil type, rice cultivar, etc., if available.

Source of activity data

Data for the lowland rice area for the year 2000 were collected at the sub-national level for monsoon Asian countries and the United States using country-specific statistics. Data for other countries were collected from the Food and Agriculture Organization's statistical database (http://faostat.fao.org/). The areas of rice fields that were irrigated and rainfed were scaled according to Huke and Huke (1997). Other information on water status and the use of organic fertilizer were obtained from various literatures and expert estimation.

Sensitivity analysis

The sensitivity of the estimated emission to variation in the input parameters was evaluated using the Risk Analysis Add-in for Microsoft Excel version 4.5 (Palisade Corporation). Input parameters included a baseline emission factor, various scaling factors, the amount of organic amendment, and the proportions of rice fields under different water regimes during the rice-growing season and preseason. The baseline emission factor and all of the scaling factors have a lognormal distribution (Yan *et al.* 2005) with a mean and range that is provided in the 2006 IPCC guidelines. The amount of organic amendment is country-specific as estimated above; however, we assumed it was normally distributed with a coefficient variation (CV) of 30%. We have estimated the ratios of the water regimes of irrigated rice fields under continuous flooding, single drainage, and multiple drainage for each country on an individual basis, as described above. In addition, we assumed that the proportion of fields under continuous flooding had a CV of 30%, and that when this value varied it had a trade-off relationship with the ratio of irrigated rice fields under single and multiple drainage. The ratio of rice fields with different preseason water statuses defined in the previous section were all assumed to have an exponential distribution.

Results

We estimated a global emission of 25.4 Tg CH_4 /yr, of which 18.9 Tg was from irrigated rice fields and 6.4 Tg was from rainfed and deepwater rice fields. As shown in Table 3, which presents the emission by individual countries, more than half of the global emission from rice fields occurred in China and India, while more than 90% of the global emission from rice fields was from monsoon Asian countries. Our estimate is at the lower end of the early estimates. A major reason for the discrepancy between our estimate and previously published global totals may be that we distinguished rice ecologies and water management practices (i.e., continuously flooded, intermittently irrigated, rainfed, or deepwater rice fields).

Table 1. Estimated emissions from global rice fields, Tg CH_4 /yr.

Region/country	Irrigated rice	Rainfed and deepwater rice	Total
China	7.41	0.00	7.41
India	3.99	2.09	6.08
Bangladesh	0.47	1.19	1.66
Indonesia	1.28	0.38	1.65
Vietnam	1.26	0.39	1.65
Myanmar	0.80	0.36	1.17
Thailand	0.18	0.91	1.09
Other monsoon Asian countries	2.32	0.67	2.99
Rest of the world	1.20	0.49	1.70
Total	18.90	6.49	25.39

The areas with the greatest emissions were the delta regions of large rivers in Bangladesh, Myanmar, and Vietnam. In addition, the generated map revealed that other areas with high emissions were found on the island of Java in Indonesia, central Thailand, southern China and the southwestern portion of the Korean peninsula (Figure 1).

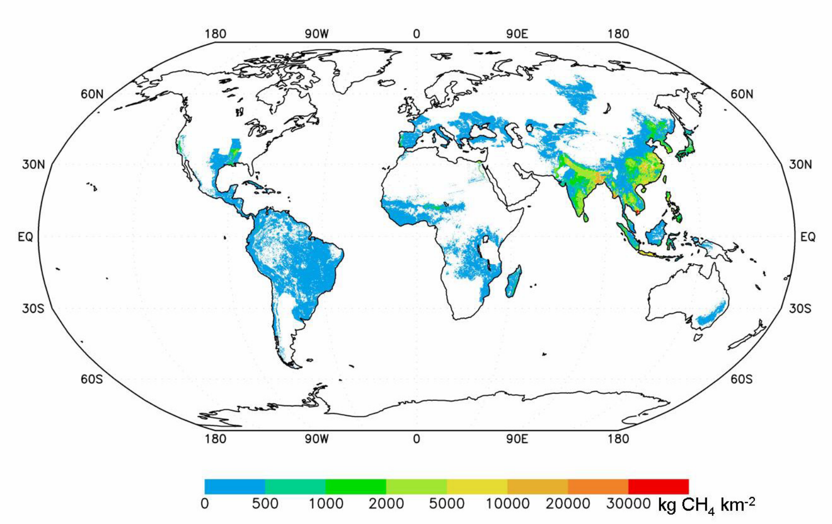

Figure 1. Estimated annual methane emission from global rice paddies at a spatial resolution of 5 minutes.

We ran 10,000 Monte Carlo simulations using the error ranges of the baseline emission factor and scaling factors provided in the 2006 IPCC guidelines and the assumed error ranges of the activity data to test the sensitivity of the estimated emissions to the controlling factors. The 95% variation range for the estimated emissions was 14.8 to 41.5 Tg/yr and the estimated emissions were most sensitive to variation in the baseline EF (Figure 2). This is primarily due to the large variability in the baseline EF, which includes the contribution of many influencing factors that are not considered in the guidelines. The estimated emissions were also highly sensitive to the amount of organic amendment and the fraction of rice fields under continuous flooding (Figure 2), indicating that reliable information regarding agricultural activities is crucial to improving the accuracy of emission inventories.

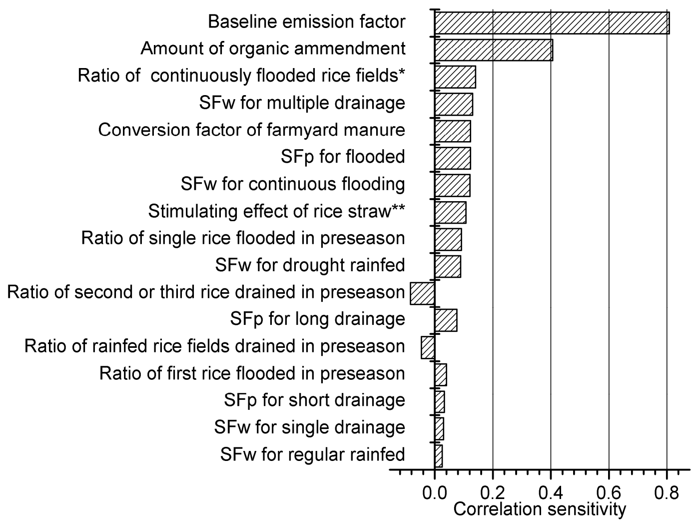

Figure 2. Correlation sensitivity of the estimated methane emission to input parameters calculated using the Risk Analysis Add-in for Microsoft Excel version 4.5 (Palisade Corporation). * Fraction of irrigated rice fields continuously flooded during the rice growing season.

Because continuous flooding increases the amount of CH_4 emitted from rice fields, another mitigation option is to drain continuously flooded fields once or more during the rice-growing season. Indeed, adoption of this practice would result in a reduction of 4.1 Tg/yr. It is well known that the water regime exerts a trade-off effect on CH_4 and nitrous oxide (N_2O) emissions from rice fields. Even though the global warming potential of 1 kg of N_2O is approximately 12 times higher that of 1 kg of CH_4, the increased global warming potential resulting from this amount of N_2O emission is only approximately 2.7% of the reduced global warming potential that would result from the 4.1 Tg reduction in CH_4 emission. Therefore, it is favourable to reduce CH_4 emissions from rice fields by draining the fields.

Conclusion

Using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and country-specific activity data, we estimated that the emission of CH_4 from global rice fields is 25.4 Tg/yr, with a 95% certainty range of 14.1-41.5 Tg/yr. Although the estimated emissions for individual countries do not always agree well with the national communications, the estimated global emissions are very close to the sum of the individual national communications. These results indicate that the emission of CH_4 from rice paddies was overstated in most earlier atmospheric models, which allows for a new CH_4 source or higher estimated CH_4 emissions for other sources. Draining the continuously flooded rice paddies once or more during the rice-growing season would also reduce global emissions by 4.1 Tg CH_4 /yr. Furthermore, the increased global warming potential resulting from increased N2O emission due to draining the fields would be negligible when compared to the reduction in global warming potential that would occur as a result of the reduced CH_4 emissions.

References

Frankenberg C, Meirink JF, van Weele M, Platt U, Wagner T (2005) Assessing methane emissions from global space-borne observations. *Science* **308,** 1010-1014.

Houweling S, RockmanT, Aben I, Keppler F, Krol M, Meirink JF, Dlugokencky EJ, Frankenberg C (2006) Atmospheric constraints on global emissions of methane from plants. Geophysical Research Letter **33,** L15821, doi:10.1029/2006GL026162

Huke RE, Huke EH (1997) 'Rice area by type of culture: South, Southeast, and East Asia. A revised and updated data base'. (International Rice Research Institute: Manila, Philippines).

Intergovernmental Panel on Climate Change (IPCC) (2007a), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, (Eds HS Eggleston, L Buendia, K Miwa, T Ngara, K Tanabe). (Published: IGES, Japan).

Keppler F, Hamilton JTG, Brass M, Rockmann T (2006) Methane emissions from terrestrial plants under aerobic conditions. *Nature* **439,** 187–191.

Lelieveld J, Crutzen PJ, Dentener FJ (1998) Changing concentration, lifetime and climate forcing of atmospheric methane, Tellus, B, 50, 128– 150. Houweling, S., F. Dentener, J. Lelieveld, B. Walter, and E. Dlugokencky (2000), The modeling of tropospheric methane: How well can point measurements be reproduced by a global model? *Journal of Geophysical Research* **105,** 8981-9002.

Parsons AJ, Newton PCD, Clark H, Kelliher FM (2006) Scaling methane emissions from vegetation, *Trends Eco. Evolution* **21,** 423-424.

Yan XY, Yagi K, Akiyama H, Akimoto H (2005) Statistical analysis of the major variables controlling methane emission from rice fields. *Global Change Biology* **11,** 1131-1141.

Greywacke weathering under tropical climate: Chemical and mineralogical changes (example from central-Brazil)

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Abstract

Greywackes are matrix-rich sandstone, in general, containing chemically unstable minerals, which under tropical weathering conditions give origin to thick weathering profiles, depleted in base cations and rich in metals hydroxides. This work deals with a thin weathering profile developed on a proterozoic greywacke, under tropical conditions in central-Brazil. The rock presents a fine-grained texture and is mainly composed of quartz, feldspars and phyllosilicates. Initial weathering yields expandable clay minerals and opaque minerals (Fe-oxihydroxides), which replace phyllosilicates and form euhedral crystals. From fresh rock to the most altered level, K_2O and Na_2O decrease, Fe_2O_3 increases, but Mg remains almost constant. The fine-grained texture of the rock, and expandable clay minerals produced in the first stage of alteration inhibit water infill in the rock, explaining the narrow level of weathering. This study reinforces the role of the parent rock in the weathering, even under tropical conditions.

Key Words

Greyawcke, Fe-oxide, interstratified clay minerals, smectite, electron microprobe, X-ray diffraction

Introduction

In tropical and equatorial climates, soils are very thick and mainly formed of kaolinite combined with Al and Fe-oxihydroxides, even where the composition of parent rocks is different. However, the composition of parent materials is of decisive importance for the beginning of weathering, when mineral composition and water flow control the products of alteration (Meunier, 2005). The mainly chemical and mineralogical transformations lead leaching of base cations and Si, result in formation of kaolinite and oxidation of iron and manganese. Weathering of chlorite is characterized by both Fe oxidation and leaching of Mg yielding vermiculites and smectites (Newman, 1982). On landscape modeled by differential erosion, hills are sustained by resistant rocks. In central Brazil, the tropical climate is characterised by annual precipitation of approximately 1600 mm with a wet season from October to March and a mean temperature ranging from 18 to 22°C. Erosional processes produce plateaus sustained mainly by granites, quartzites, sandstones and lateritic crusts, but some are maintained by greywackes from the proterozoic Três Marias Formation (Bambuí Group). Despite the chloritic matrix and plagioclase content, the alteration profiles on these greywackes are only a few centimeters in depth and the plateau surfaces are covered by sand among boulders, cobbles and pebbles produced by spheroidal weathering. On boulders and cobbles, alteration occurs from the surface to the core, in which parental rock is preserved. In this paper we present the initial mineralogical change on the greywacke and the possible mechanism that limits the weathering on the surface. Indeed, mineralogical studies allow a better understanding of the processes of soils formation and better determine the rate of soil processes (Cornu *et al*., 2009).

Methods

The study was carried out on a representative greywacke cobble (15 cm) from Três Marias Formation collected on a plateau near Cabeceiras town, Goiás, Brazil (S 15° 46’ - W 48°23’). Three samples were selected: a fresh parent rock, an incipient altered rock and an altered level (Figure 1).

Sample	Macroscopic characteristics
EGC 37 II a	Medium yellowish brittle level (2 cm thickness) at surface of the cobble, with strong alteration.
EGC 37 II b	Medium grey brownish level (3 cm thickness with incipient alteration, surrounding the core.
EGC 37 II c	Dark grey greenish hard rock in the 6 cm core without alteration features.

Figure 1. Macroscopic characteristics of greywacke samples.

Polished thin sections of samples were studied by both conventional petrographic microscopy and microprobe.

Bulk chemical analyses of major elements were determined after acid digestion (hot, conc. HF, $HClO_4$, HNO_3 and HCl) of finely ground samples. Analyses were performed using ICP-AES for Si, Ti, Fe, Ca and Mg determination and ICP-MS for Na and K. X-ray diffraction (XRD) analyses were performed using a Rigaku D/Max diffratometer with Cu radiation, under 35 kV and 13 mA, on fine earth (< 0,1mm) powders from whole samples and clay-sized fraction isolated by centrifuge and prepared by conventional technics: air-dried, and later solvation by ethylene-glycol for 12 hours. Elemental analysis of the minerals was made on polished thin sections, using a CAMECA/Camebax electron microprobe with operating conditions of 15kV, beam current of 5 to 10 mA and counting time of 10-15 sec. per element with a spot size of about 2 µm. Analyzed phyllosilicates are chlorite and interstratified clay minerals. Structural formulae for chlorite are calculated on the basis of 56 negative charges and assuming all iron as ferrous. Analyses with high Na, Ca and K contents and low octahedral occupancy have been interpreted as intimate intergrowths of mica and chlorite, or even mixed-layer clay minerals.

Results

Mineralogical composition is quite different in three samples (Figure 2). Fresh rock (EGC 37 II c) consists of more than 15% matrix constituted of an intimate intergrowth of illite and chlorite beside opaque minerals. The grains are 35% quartz, 30% feldspar mainly plagioclase, 12% of phyllosilicates (muscovite, biotite, chlorite) and the rest are opaque minerals, tourmaline and zircon. Micas and chlorite occur as clear laminae or are small lamella in lithic grains, with typical pleochroism. Biotite and muscovite are brown and white, respectively and chlorite is green or grey. Opaque minerals are euhedral crystals inside detrital grains, or micro-crystals along cleavage planes in phyllosilicates and somewhere replace partially other minerals.

In the level surrounding the core (EGC 37 II b) the composition is similar to fresh rock, feldspar being preserved, but phyllosilicates present changes: most of them become brownish and some are completely replaced by opaque minerals. In the most altered level (EGC 37 II a), some K-feldspars are still preserved, while all the phyllosilicate have lost their original colour or have been completely replaced by opaque minerals.

X-ray diffratograms from whole samples show typical reflections for quartz, illite and feldspar (Figure 3). The 14 reflection from chlorite is low, the 7 and reflections are high (coincident with kaolinite), while, 4.7 is present in both fresh rock and incipiently altered rock, but do not appear in most altered sample.

In clay fraction, quartz and feldspar reflections are low or missing, while phyllosilicates have high peaks. Fresh rock (EGC 37 II c) presents a distinct 14 Å reflection that does not expand under solvation by ethylene-glycol, characteristic of chlorite. This same reflection in EGC 37 II b displaces to 16 Å, indicating a smectite and it appears a 30 reflection under solvation by glycerol. These reflections indicate both the presence of smectite and an interstratified clay mineral. The most altered sample (EGC 37II a) presents kaolinite peaks and a high background.

Table 1 shows the chemical composition of the whole rock is quite different from one sample to another. Si, Al and Mg contents in the whole rock are almost constant in three samples. From fresh rock to the most altered, Fe_2O_3 increases, while Na_2O and K_2O decrease.

Table 1. Chemical composition of greywacke (whole rock).

Samples	SiO_2	Ti O_2	Al_2O3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
ECG-37IIa	73.94	1.06	10.23	5.99	1.32	0.31	0.33	0.62	0.12	6.10	99.83
ECG-37IIb	78.52	0.65	10.07	2.86	1.22	0.46	1.19	1.21	0.12	2.61	98.92
ECG-37IIc	72.91	0.70	10.88	3.36	1.56	0.54	2.34	1.89	0.11	2.73	97.02

Elemental analyses (Table 2) show Fe-chlorite in fresh rock wich low vacance in octahedral site. In incipient altered rock, chlorites like lamelaes have more high octahedral vacance, that is atributed to oxidation state of iron and seems to indicate presence of smectite, or vermiculite, where Mg is high. In the most altered sample, the phyllosilicates like lameleas presents highest vacance in octahedral site (Figure 4) calculated as chlorite and high Fe content, that may be correspond to mixture or interestratified Fe-Kaolin (Ryan & Huerta, 2009).

Table 2. Elemental composition (%) of phyllisilicates calculated as chlorite.

SAMPLES	Si	Al(t)	Al(o)	Fe	Mg	Ti	Oct	Ca	Na	K	Alc
ECG-37IIa	6.2-7.8	1.8-0.2	3.5-4.8	2.1-4.3	1.8-4.0	0.0-0.02	9-10.6	0-0.1	0.1-0.2	0.1-0.5	0.2-0.3
ECG-37IIb	6.0-6.8	2.0-1.2	2.7-3.1	3.4-4.4	3.0-4.8	0.0-0.1	10.7-11.7	0-0.1	0-0.2	0.1-0.3	0.1-0.2
ECG-37IIc	5.8-6.2	2.2-1.8	2.4-2.6	4.2-6.5	3.2-4.2	0-0.1	10.8-11.9	0-0.01	0-0.1	0-0.2	0.07-0.2

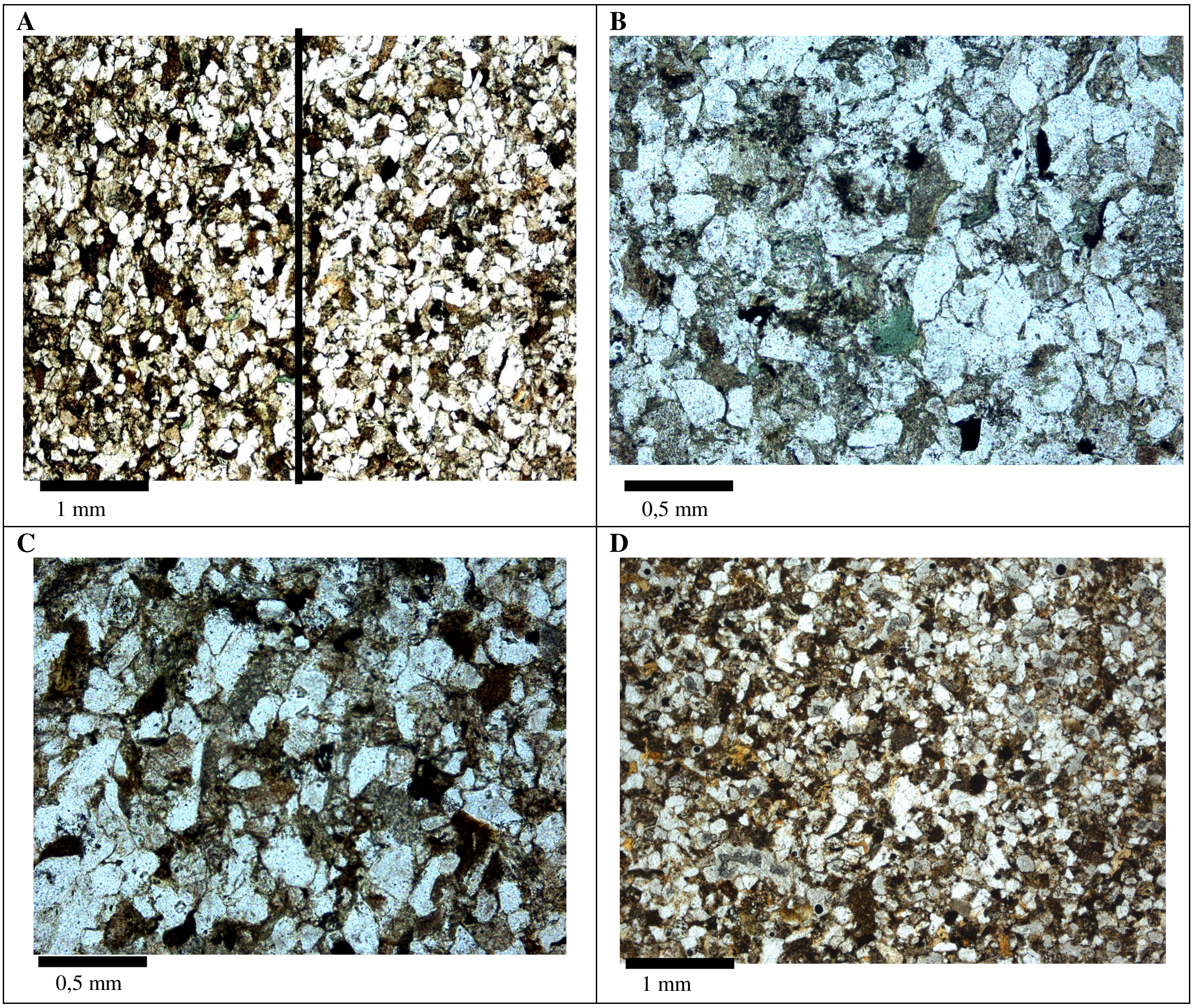

Figure 2. Greywacke under microscope: A) line indicates the contact between EGC 37 II c (fresh rock) and EGC 37 II b (incipient altered rock; B) detail on fresh rock, with green chlorite; C) detail on incipient altered rock: phyllosilicates are brown and some are replaced by opaque minerals; D) most altered rock: opaque minerals replace almost all phyllosilicates.

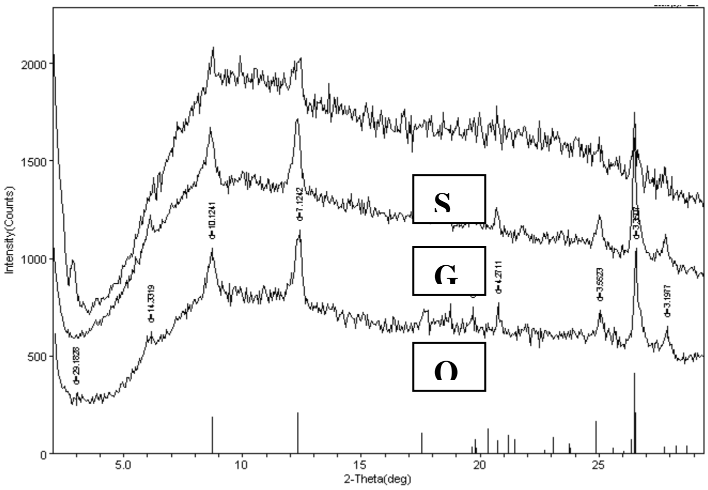

Figure 3. Diffractogram of clay fraction of EGC 37 IIb: O - oriented powder air-dried; G – solvated in ethylene-glycol; S – solvated in glycerol.

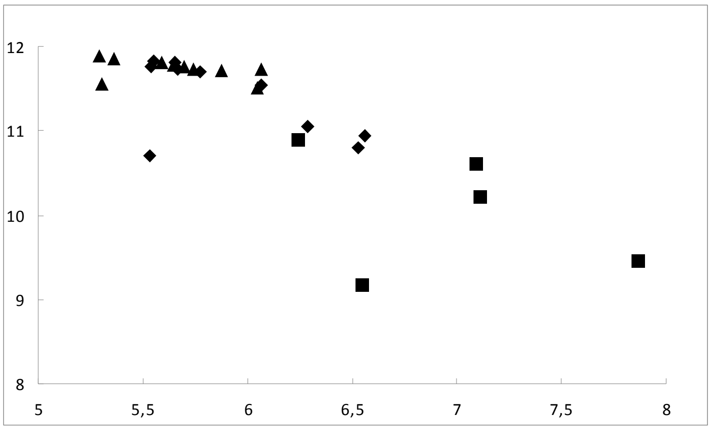

Figure 4. Octahedral occupation (Y axis) and Si content (X axis) in phyllosilicates calculate as chlorites: ▲– fresh rock; ♦– incipient altered rock; ■ – most altered sample.

Conclusion

From the fresh rock to altered one, the studied greywacke behaves as expected in some aspects and is different in others. Smectite and vermiculite are produced in the first stage of alteration and disappear in the surface, where kaolinite remains; Fe_2O_3 increases, while Na_2O and K_2O decrease. However, Mg and Al_2O_3 contents remain almost constant in all samples. Mg content corresponds to vermiculite and interstratified clay minerals calculated by microprobe analyses and identified by XRD. The high background in XRD of most altered sample indicates high content in iron. The thin weathering profile is attributed to fine grained rock and the expansive clay minerals in the first stage of alteration, inhibiting the water infill in the fresh rock. This work shows that the parent rock plays a decisive role in the beginning of weathering and can determines the path of the soil formation.

References

Cornu S, Montagne D, Vasconcelos PM (2009) Dating constituent formation in soils to determine rates of processes: A review. *Geoderma* **153**, 293-303.

Meunier A (2005) Clays. Spring, Berlin. 472 pp.

Newman ACD (1987) Chemistry of clays and clay minerals. Mineralogical Society Monograph 6, Mineralogical Society, 480 pp.

Ryan PC, Huertas (2009) The temporal evolution of pedogenic Fe-smectite to Fe-kaolin via interstratified kaolin-smectite in a moist tropical soil chronosequence. *Geoderma* **151**, 1-15.

How the different tree species composition can alter throughfall, chemical properties of subsurface runoff and soil chemistry

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Abstract
This study deals with the evaluation of chemical changes of throughfall, subsurface runoff and soil chemistry in forest stands with different tree species composition. The research plots were placed in spruce (*Picea abies (L.) Karst.*) and beech (*Fagus sylvatica (L.)*) forest stands of the second generation aged 34 and 40 years in the central part of the Drahanská vrchovina Upland in the Czech Republic on acid Cambisol of the silver fir-beech forest vegetation zone. Considerably lower pH values of throughfall (as effect of tree crowns) and seepage waters (as effect of crown and soil) were found in spruce forest stands in comparison with beech stands. In subsurface lysimetric waters, higher concentrations of Na were detected in beech stands (statistically significant differences). Unlike the low soil pH value in H layer of the surface humus under spruce stands any indication of washing basic cations in seepage waters was observed recently. A remarkable improving character of beech for soil pH and base saturation was found. Our results prove the importance of the increased proportion of beech (*Fagus sylvatica*) in the species composition of forest stands at sites of autochthonous mixed forest stands in Central Europe.

Key Words
Forest, tree species composition, subsurface runoff, soil chemistry, Czech Republic

Introduction
Effects of forest stands (canopy density) become evident at the creation of the amount of runoff and chemical composition of throughfall (Berger *et al.* 2008). The forest floor is a connecting link between stand and soil and its condition and form are one of the key factors relating to the nutrients cycle and dynamics of decomposition as well as to the problem termed acidification (Waring and Running 1998; Emmer 1999; Sparks 2003). The importance of the tree species composition and character of soil organic matter (the complex of all non-living organic components of the soil) is increased in air-polluted areas in mountain and upland regions predominated by coniferous forests (Kulhavy *et al.* 2004).

Material and methods
Sites studied: The study is based on research carried out at permanent field plots in the Drahanská vrchovina Upland, Czech Republic. In the region, acid granodiorite of the Brno massif creates a parent rock and modal oligotrophic Cambisol (Nemecek *et al.* 2001) is the main soil type. Forest type is Abieto-Fagetum mesotrophicum with *Oxalis acetosella* (Pliva 1987). A more comprehensive description of the two experimental stands composed of (1) Norway spruce (*Picea abies (L.) Karst*.) and (2) European beech (*Fagus sylvatica (L)*.) is given in Table 1.

Sampling: The sampling was carried out in 2004, 2006 and 2008 always at the end of the growing season (in November). Samples of the forest floor were taken at 10 repetitions in each of the horizons and years, and in the organomineral horizon (A) in 5 repetitions in each year. Water samplings were carried out in the period 2006-2008 once every 14 days in the growing season. In the winter season, water was sampled once a month only from undercrown collectors. Seepage waters were sampled using zero-tension lysimetres under A_o horizon.

Analyses of soil, throughfall and seepage water: The values of pH were determined using potentiometry (CSN ISO 10390) by means of a digital pH meter OP-208/1 (Radelkis Budapest, Hungary). Carbon and nitrogen were determined from samples devoid of coarse particles after fine grinding or comminution on a LECO TruSpec analyser (MI USA) (Zbiral *et al.* 1997). Available values were determined after extraction via an acid solution of ammonium nitrate and ammonium fluoride (Mehlich 1984; Zbiral 1995) using the method of flame atomic absorption spectrometry (Ca and Mg) and the method of atomic emission spectrometry (Na and K). Cation exchange capacity (CEC) was determined using the summation method (Zbiral *et al.* 1997). The determination of the soil adsorption complex by hydrogen was carried out using the method of double measurement (Zbíral *et al.* 1997). Dissolved organic carbon (DOC) was determined by an adapted method according to Robertson *et al.* (1999). Then, the content of DOC was determined using Shimadzu TOC-VCSH/CSN analyser (Shimadzu

Corporation, Japan). The pH value of the water samples was determined by potentiometry according to the CSN ISO 10523 standard, and the conductivity of precipitation and seepage waters was determined by conductometry according to the CSN EN 27888 stansdard. The sub-samples of water for the determination of metals (Na, K, Mg, and Ca) were acidified by adding 0.5 ml of reagent-grade nitric acid per 100 cm^3 and analyzed using the flame atomic absorption spectrophotometry for Ca and Mg determination, and flame atomic emission spectrophotometry in case of Na and K (spectrometer AA 30 F4 VARIAN, air-acetylene flame

Statistical analysis: Statistical analyses were carried out in the Statistics Program (Stat-Soft Inc., Tulsa USA). Data were transformed by a decimal logarithm for further statistical processing. Potential differences in precipitation and soil water of the spruce and beech stands were tested by a two-sample t-test. Significance was assessed at the level $\alpha = 0.05$.

Table 1. Basic characteristics of the forest stands.

	Age	Stand structure [%]	Humus form†	Surface humus [t/ha dry weight]†††††	Soil type	A.S.L. [m]	Rainfall [mm]	Temp. [°C]	Forest type
Spruce stand	34	spruce 100	moder	35.9	Modal oligotrophic Cambisol†	632	717††††	6.5††††	5S1 - *Abieto-Fagetum mesotrophicum* with *Oxalis acetosella*†††
Beech stand	40	beech 100	mull-moder	18.8	Cambisols (CM)††				

†soil taxonomy by Nemecek *et al.* 2001; ††WRB; †††taxonomy by CFMI (Czech Forest Management Institute); ††††Hadas 2002; †††††Mensik *et al.* 2009

Results

Table 2. Results of the throughfall and seepage water analysis in the spruce and beech stands (T-test, mean - arithmetic mean; t - t-value; P- probability).

	Throughfall				Seepage water			
	Spruce stand	Beech stand	T- test		Spruce stand	Beech stand	T- test	
	mean	mean	T	P	mean	mean	t	P
pH	5.423	5.913	-3.81	<0.001**	5.070	5.627	-3.66	<0.001**
DOC [mg/l]	9.506	6.935	-7.39	<0.001**	23.679	27.582	1.83	0.07
Ca [mmol/l]	0.028	0.018	1.89	0.06	0.018	0.021	-0.22	0.83
Mg [mmol/l]	0.012	0.008	2.55	0.01*	0.013	0.012	0.97	0.33
Na [mmol/l]	0.018	0.017	0.86	0.39	0.043	0.077	-3.52	<0.001**
K [mmol/l]	0.079	0.101	0.55	0.54	0.132	0.167	-1.19	0.24
Conductivity [µS/cm]	42.42	40.40	1.18	0.23	46.80	54.03	-1.01	0.32

Table 3. Results of soil analysis (mean - arithmetic mean; H - layer of humus; Ah - layer of organomineral horizon; pH - soil acidity; C/N - total carbon to total nitrogen ratio; DOC - dissolved organic carbon; CEC - cation exchange capacity; BS - base saturation).

Stand	H layers of forest floor						Ah layer of soil horizon					
	pH (H_2O)	pH (KCl)	C/N	DOC (mg/g)	CEC [mmol/ 0.1 kg]	BS [%]	pH (H_2O)	pH (KCl)	C/N	DOC (mg/g)	CEC [mmol/ 0.1 kg]	BS [%]
Spruce stand	3.5*	2.7*	24.0NS	1.2NS	360.7NS	20.3*	3.7	2.7	27.0	1.2	173.9	13.8
Beech stand	4.7*	4.1*	19.0NS	0.8NS	285.7NS	38.7*	4.3	3.2	18.0	0.8	173.0	32.9

* Statistically significant differences ($\alpha < 0.05$; 0.01); NS not significant

Throughfall water: Mean pH values of the throughfall waters in the spruce stand were 5.42, and in the beech stand 5.91 during the period of monitoring. pH values of the throughfall were lower in the spruce stand ($t = -3.8$; $P < 0.001$). The mean concentrations of individual cations in throughfall of the spruce stand and in the beech stand are given in Table 2. Statistically significant differences were determined only in the magnesium and DOC concentration ($t = 2.6$; $P = 0.006$ and $t = -7.39$, $P < 0.001$) with higher concentrations always in the spruce stand.

Soil: The highest pH values in H horizon were found in a beech stand, soil reaction (in H_2O) is moderately up to heavily acid. In pH (H_2O, KCl) at the level of significance ($\alpha < 0.01$), statistically significant differences occurred between the beech stand and spruce stand (Table 3). The lowest C/N ratio occurs in forest floor in H horizon in a pure beech stand (19), the highest C/N ratio is in the spruce stand (24). Statistically significant differences were not detected in the C/N ratio, the content of DOC and CEC in forest floor (H) and the organomineral horizon (Ah) between spruce and beech at the level of significance $\alpha = 0.05$. Statistically significant differences were detected in the BS in forest floor (H) between spruce and beech stands and mixed stands at the level of significance $\alpha = 0.05$.

Seepage water underneath the forest floor: The mean pH values of seepage waters underneath the forest floor during the period monitored in the spruce stand were 5.1 and in the beech stand 5.6 this difference is highly significant (Table 2). The mean conductivity of seepage waters underneath the forest floor for the period monitored in the spruce stand and in the beech stand was 46.8 (54.0) µS/cm. The Al concentrations in the spruce stand were 0.02 mmol/l and in the beech stand 0.03 mmol/l. The concentration of sodium was statistically lower in the spruce stand ($t = -3.5$; $P < 0.001$).

Conclusion

Based on the results, it is possible to notice that forest canopy can alter the chemical composition of precipitation as well as properties of the surface humus and upper layers of a mineral soil. Soil reactions (pH) and the saturation of a sorption complex by bases (BS) were affected most. These affects were worse in case of the 34-year old spruce stand than in case of the 40-year old beech stand. Slight positive soil-improving effect of beech could be noticed. Our results demonstrated favourable reclamation effects of beech in the species composition of forest stands of upland areas of Central-Europe and the suitability of increasing the proportion of beech at sites where allochthonous spruce monocultures predominate at present.

Acknowledgement

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References

Berger TW, Untersteiner H, Schume H, Jost G (2008) Throughfall fluxes in a secondary spruce (*Picea abies*), a beech (*Fagus sylvatica*) and a mixed spruce-beech stand. *Forest Ecology and Management* **255**, 605-618.

CSN EN ISO 27888 (75 7344) (1985) Water quality: Determination of electrical conductivity.

CSN ISO 10523 (75 7365) (1995) Water quality: Determination of pH.

Emmer IM (1999) Methodology of humus form research. *Lesnictvi-Forestry* **44,** 16-22.

Hadas P (2002) Temperature and precipitation conditions in the high elevation spruce stands of the Drahanska vrchovina upland. Ekologia-Bratislava **21,** 69-87.

Juma NG (1999) The pedosphere and its dynamics: a systems approach to soil science. Alberta (Canada), Edmonton. 355.

Kulhavy J (2004) Ecological Consequences of Conversion. In ‘Norway spruce Conversion: Options and Consequences’. (Eds H Spiecker, J Hansen, E Klimo, JP Skovsgaard, H Sterba, K von Teuffel) pp. 165-195. (European Forest Institute Research Report 18. S. Brill Academic Publishers, Leiden, Boston, Köln: 269).

Mehlich A (1984) Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Communications in Soil Science and Plant Analysis* **15,** 1409-1416.

Mensik L, Fabianek T, Tesar V, Kulhavy J (2009) Humus conditions and stand characteristics of artificially established young stands in the process of the transformation of spruce monocultures. *Journal of Forest Science* **55,** 215-223.

Nemecek J, Macku J, Vokoun J, Vavricek D, Novak P (2001) Taxonomy classification system of soil in the Czech Republic (in Czech). Taxonomicky klasifikacni system pud Ceske republiky. Praha, CZU: 79.

Pliva K (1987) Typological classification system of the Czech Forest Management Institute (in Czech). Typologicky klasifikacni system UHUL. Brandys nad Labem. 52.
Robertson GP, Bledsoe CS, Coleman DC, Sollins P (1999) Standard soil methods for long-term ecological research. New York, Oxford University Press. 462.
Sparks DJ (2003) Environmental soil chemistry. Academic Press, London. 267.
Waring RH and Running SW (1998) Forest ecosystems: Analysis at multiple scales. London (UK): Academic Press, San Diego (California). 370.
Zbiral J (1995) Soil Analysis. I. Unified Working Procedures [Manuscript] (in Czech). Analyza pud I, Jednotne pracovni postupy. UKZUZ Brno, 197.
Zbiral J, Honsa I, Maly S (1997) Soil Analysis. III. Unified Working Procedures (in Czech). Analyza pud III. Jednotne pracovni postupy. UKZUZ Brno, 150.

Managing soil fertility to sustain crop production in the watersheds in Senegal

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Abstract
Crop production has been decreasing in the past decades, due to some extent to the rapid population growth, coupled with the increase population of livestock on the rangelands. As a result, there has been pressure on land and cultivation on marginal lands to maintain food production at minimum levels. Land mismanagement, inappropriate soil management and farming practices among others have accentuated soil erosion, nutrient depletion as well as environment degradation. In the fight against land degradation, emphasis needs to be shifted away from the erection of physical structures to a better understanding of the role of watershed as a provider of nutrients for soil quality improvement. This study relates the chemical composition of the geomorphologic units, within the watershed, to the soil fertility and crop production. A ultimate goal of watershed management is to achieve and maintain a balance between resource development to increase the welfare of the population - and resource conservation to safeguard resources for future exploitation and to maintain ecological diversity - both for ethical reasons and as an assumed prerequisite for the survival of mankind, then the objective of this study is to increase/stabilize production of crops and forage.

Key Words
Soil fertility, watershed management, soil degradation, soil chemical properties, farming practices, crop production

Introduction
The rapid population growth which, in the past decade, exceeded growth in agricultural production has resulted in pressure on land and cultivation on marginal lands to maintain food production at minimum level. Coupled with this situation, is the increased population of livestock on the rangelands which are minimally managed and, in most cases, over-stocked, causing serious soil erosion and land degradation. Deforestation, land mismanagement, bush fires and inappropriate soil management and farming practices among others have accentuated land as well as environment degradation (Chopart *et al.* 1979). Nutrient depletion is the most important element in the land degradation equation (Pieri 1989; Ndiaye 1979). Many areas in Senegal have predominant inherently low fertility soils; degraded soils, soils cropped over long periods and removal of nutrients through crops and residues both for domestic and export crops-without replenishing the nutrients lost and use of marginal areas unsuitable for agricultural activities (Diack *et al.* 2000). In addition, non-adoption of improved management practices by the majority of farmers has resulted in accelerated erosion, one of the major causes of land degradation. As a result, arable lands have decreased from 3.8 10^6 to 2.4 10^6 ha with a drastic decrease in the use of upland soils for crop production. As an alternative, the watershed is an area which catches the water from precipitation and is then drained by a river and its tributaries. It is a "resource region" where the eco-system is closely interconnected around a basic resource - water. The watershed or river basin is therefore an ideal management unit (Michel 1973). Micro-watershed planning has been conceived and adopted for holistic development of rainfed farming in recent years. Watershed management is fast becoming a blueprint for agricultural development in most parts of the country today, by introduction of improved soil and moisture conservation measures, better crop and rangeland management practices. The objective of this study is (1) to determine the key-soil chemical properties within two morphological units; (2) to provide guidance for future studies on management strategies of watersheds to improve crop production.

Methods
Watershed site
The watershed is located in the Koutango village, Kaolack, a semiarid agrecological zone in the southern part of the peanut basin. It covers 173.3 km^2 between 13^O 66' and 13^O 82' and 15^O 91' and 16^O 09'. The region is characterized by a north Sudanian climate with an average annual rainfall of 700 mm. Rainfall events (June-October) are quite aggressive with a degradation index of 1730 t/km^2/an. Temperatures vary between 20^{O}C in December-January and 35^{O}C in April-June. Vegetation is relatively dense and represented by *Cordyla pinnata*

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associated with *Combretum glutinosa* and *Piliostigma reticulaum*. From its toposequence, the watershed presents four geomorphologic sequences: an upland unit which is 40 m high, naturally established colluvium on a slight slope, a flat terrace and a lowland unit. For the purpose of this study, the last three units were evaluated in terms of soil fertility within the watershed, by analyzing soil chemical properties.

Soil analysis

Soil sampling was done from soil profile, according to the distinct number of layers and soil horizons, in each of the two morphological soil units. Each soil sample was analyzed for total carbon (C) by the Walkley-Black method, total nitrogen (N) by the Kjeldalh method, total phosphorus (P) by the Duval method and cation exchange capacity (CEC) by the Cobaltihexamine Chloride method.

Results and discussion

Total carbon content varies between 3.14 and 25.20 g/kg under lowland condition. In the colluvium, total C varies between 1.29 and 3.14 g/kg whereas under terrace condition, it varies between 1.21 and 3.00 g/kg (Figure 1). Compared to the colluvium and terrace soils, the lowland soil presents the highest values for total C content, at the soil surface, within the watershed. With high soil moisture content from rainfall and the presence of diverse vegetation, the soil carbon content tends to accumulate over time, which contributes to an establishment of a good soil fertility level.

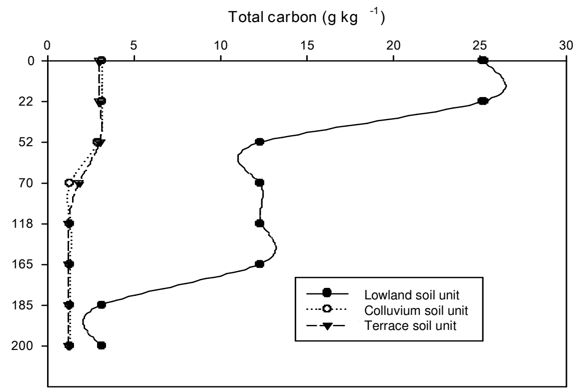

Figure 1. Total soil carbon for soils in the different geomorphologic units within the watershed.

Total soil N content varies between 0.32 and 1.50 g/kg. For the colluvium varies between 0.18 and 0.32 g/kg while under terrace conditions, total N varies between 0.18 and 0.22 g/kg (Figure 2). Similar to the soil carbon, total nitrogen has the highest content under lowland conditions as compared to colluvium and terrace.

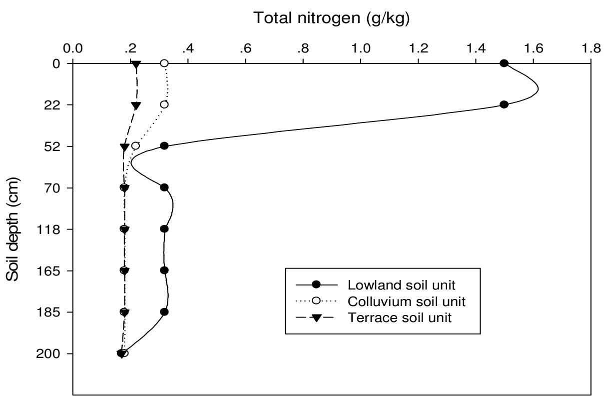

Figure 2. Total soil nitrogen for soils in the different geomorphologic units within the watershed.

Under lowland conditions, the total P content varies between 0.18 and 0.42 g/kg whereas in the colluviums, it varies between 0.21 and 0.41 g/kg and between 0.16 and 19 g/kg for the terrace (Figure 3). It has been noted that total P contents are not different between the lowland and colluviums units in the shallow layers. This could be due to the presence of Fe as Fe is linked to P in general for most tropical soils (Cissé 1981)

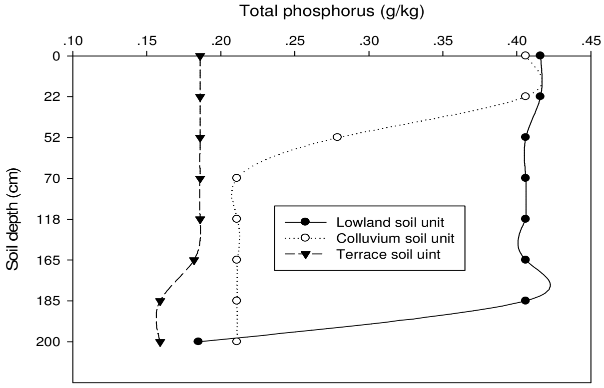

Figure 3. Total soil phosphorus for soils in the different geomorphologic units within the watershed.

Soils from the lowland have CEC contents varying between 1.10 and 11.6 me/100g. In the colluviums CEC content varies from 2.30 to 5.70 me/100 g whereas in the terrace, it varies between 1.50 and 2.10 me/100 g. The highest contents are noted for soils under lowland conditions, particularly in the horizons high in clay and/or organic matter (Figure 4).

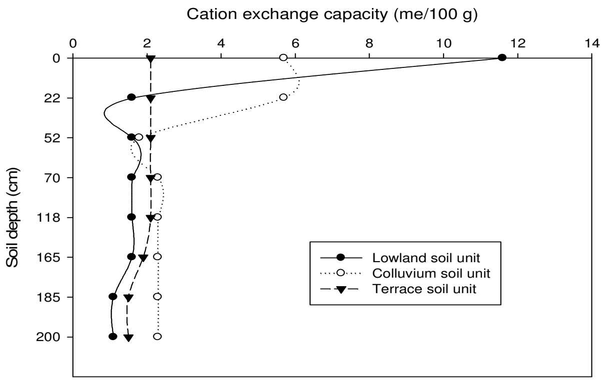

Figure 4. Cation exchange capacity for soils in the different geomorphologic units within the watershed.

Conclusion

Based on an evaluation of the chemical soil properties, through comparison, of the different components of the watershed, soils under lowland conditions seem to be more suitable for sustainable crop productivity.
Upland soils are known for not having high enough levels of nutrients for crop production in an environment where pressure on land and cultivation on marginal lands to maintain food production is an issue. Therefore, the management of watersheds throughout the region needs to be undertaken.

References

Chopart JL, Nicou R, Vachaud G (1979) Le travail du sol et le mulch pailleux. Influences comparees sur l'eau dans le système arachide mil au Sénégal. In 'Isotopes and radiation in research on soil-plant relationships'. (Ed Intenational Atomic Energy Agency) pp. 199-221. (AIEA-SM.235/22:Vienna, Austria).

Cissé L (1981) Note succincte sur l'acidification des sols exondes au Sénégal : processus de correction.

Diack M, Sene M, Badiane, AN, Diatta M, Dick RP (2000) Decomposition of a Native Shrub, Piliostigma reticulatum, Litter in Soils of Semiarid Senegal. *Journal of Arid Soil Research and Rehabilitation* **14**, 205-218.

Pieri C (1989) 'Fertilité des terres de savanes'. Bilan de 30 ans de recherché et de développement agricoles au sud du Sahara. (CIRAD)

Michel P (1973) 'Les bassins versants des fleuves Senegal et Gambie'. Etude geomorphologique. (ORSTOM : Paris).

Ndiaye JP (1979) 'Evaluation en chaux de quelques sols du Sine-Saloum'. Rapport d'activités.

On local changes of temperature regime of the soil-atmosphere system around the Caspian Sea in the 20th century

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Abstract
In this paper the results of investigations of changes of temperature and water regimes for a long time period for a medium-size area are presented. The location of the experiments is in different soil-climatic zones of Azerbaijan: in a humid subtropical zone, in a middle moist subtropical zone and in a dry subtropical zone. We used the data of temperature changes over a period of more than one hundred years (1889-2008), thus we could compare the change of temperature on a long-term basis. The most important results are those of the second half of the 20th century, especially between 1970 and 2008. The comparison of three locations regarding climatic changes shows different characteristics. For example, in the humid subtropics according to the decadal data during fifty years, the average annual temperature is characterized by its increasing and decreasing. It is reflected in the thermo-physical characteristics of soils (Gerayzade 1989). During these periods according to temperature of a surface soil heat exchange in soil periodically changes its direction, playing a part in soil formation processes. Heating of different layers of earth creates certain streams of heat in the soil profile, and naturally also promotes moisture redistribution. The special changes on temperature here can be observed on the decadal data for 1970-1979, 1980-1989, 1990-1999 and 2000-2009. Though, specific trends in air and soil temperature are not observed.

Key Words
Global warming, soil temperature regimes

Introduction
The forecasting of the process of global warming is one of the difficult problems of the present day. First, because natural processes depend on many various factors, secondly, because it is difficult to predict volumes of green house gases in the last decades. According to the Japanese Meteorological Agency and the World Meteorological Organization relative to 1891 the average index of temperature of 2008 compared to 1891 has exceeded on 0.2^{0}C and has taken the tenth place among the warmest years (http://www.jma.go.jp/jma/indexe.html). Considering the average temperature of the atmosphere between 1971 and 2000 there have been 5 an abnormal warm years: 1998 (0.37^{0}C), 2002, 2003, 2006 (0.31^{0}C), 2005 (0.32^{0}C). Therefore we decided to check up on changes in values of temperature using long-term data for different part of Azerbaijan, particularly in regions next to the Caspian Sea. The intervention of man accelerates desertification processes. Unsystematic cutting down of woods (Amirov 1997) , building the megacities and the corresponding communications are the reasons of releasing superfluous quantities of carbonic gas to the atmosphere, increasing the greenhouse effect which is the principal cause of climate warming (Mammadov and Khalilov 2005).

Methods
In order to study the dynamics of temperature change in the soil-atmosphere system in the period 1970-2008, data about dynamics of temperature on the hydrometeorological stations, located in the research area have been collected. On the basis of the received data the average values of temperature for months and years from 1970 to 2000 are calculated (Safarov 2000). Further generalization is conducted concerning to the calculated average values. On the basis of the collected data adequate tables and diagrams are made. The temperature and humidity changes in soil-atmosphere system have been established. The created temperature gradient also generates the humidity gradient both in air and soil. The evaporation increases negative influences on environment water balance as a whole, thus the balance established by centuries is disturbed. The major factors defining the thermal condition of environment are also the vegetative cover, the water-air regimes, the nutrients, the biological properties of soils (Ulanova and Sirotenko 1968).

At the same time, on the formation of temperature fields in the soil influences its thermo-physical properties: the thermal capacity, the thermal conductivity and the temperature conductivity which in their turn are functions of soil-physical properties, such as humidity, granulometric structure, density, porosity, the maintenance of organic substance, temperature, etc. All of them cause the heterogeneity of thermo-physical parameters of soils (Gerayzade 1989). Therefore the knowledge of thermo-physical properties of soils in interrelation with their genetic features, character and degree of natural humidifying, consolidation and aeration of a soil profile is essential for analyses of the genetic characteristic of soils, as well as for and the forecast of changes of hydrothermal properties of soil horizons under influence of anthropogenous factors (Masimov 1999).

The last decades were characterized by mass cutting down of woods in a number of areas of Azerbaijan, and also growth of forest parks around cities. All of these have cardinally changed the heat and moisture regimes in their vicinities (Imanov, etc 2002). Therefore the experimental definition of the thermo-physical characteristics of soils and finding-out the features of their changes in the soil profile depends on soil-physical factors; the establishment of laws of hydrothermal modes and dynamics of thermo-physical factors of investigated soils, finding out the influence of area of woods on hydrothermal modes and thermal properties of soils becomes a requirement.

Results

In Table 1 decadal averaged sizes of air temperature of a year and months are given (1970-79, 1980-89, 1990-99, 2000-09). Analyzing the given table, one can see increasing or decreasing temperature from 1970 to 2008. For example, the temperature in January, February and March in Khachmaz district gradually increases with regard to their average long-term values (1.9^{0}C, 2.03^{0}C, 5.0^{0}C). The special increase of temperature is observed during the period from 2000 to 2008, their relation to corresponding values of base temperatures are 1,5263; 1,6256 and 1,26. In April and May the temperature of air according to their average long-term values has also changed: in April has slightly decreased, in May, on the contrary, has increased, so indexed parities have made 0,9036 and 1,0080. The average temperature in June and August has slightly increased, in August, on the contrary, has decreased. The average temperature in September, October and November have increased and indexed parities have made 1,095238; 1,097015; 1,077561. In December temperature reduction is observed, accordingly indexed ratio has made 0, 860465.

Analyzing local changes of long-term monthly average temperatures on decades, it is possible to show changes of monthly average and annual temperatures for the concrete period. For drier Khachmaz area average long-term temperature in January from 1970 to 2008 has increased more than 2 ^{0}C. In February this increase was decreased according to the absolute size - approximately 1,6; in March - 1,4; in April and May reduction of monthly average temperatures is accordingly 1,3 and 0,5 ^{0}C. Further again we see the increase of temperature concerning their average long-term values. In June - 0,7^{0}C, in July – 0.2; August - 1,9; September - 3,2; October - 1,7; November - 0,7^{0}C and in December there is again a temperature recession - 1,1^{0}C. As we see it is not a standard course of temperature change according to the months. In whole mid-annual temperature according to

Table 1. The average monthly and annual temperature of air in the experimental areas, ^{0}C

Months	1	2	3	4	5	6	7	8	9	10	11	12	Average
Khachmas district													
1970-1979	0.5	1.7	4.9	11.3	17.3	21.2	24.5	23.5	17.5	13.0	8.1	4.8	12.3
1980-1989	2.7	1.8	4,7	11.0	16.3	21.7	24.8	23.5	19.6	13.1	8.1	3.8	12.6
1990-1999	2.5	2.6	5.4	10.9	16.4	22.0	24.8	24.2	19.6	14.1	8.3	4.3	12.9
2000-2008	2.9	3.3	6.3	10.0	16.8	21.9	24.6	25.4	20.7	14.7	8.8	3.7	13.3
Lenkoran district													
1970-1979	2.5	4.0	7.3	12.9	18.4	22.0	25.0	24.4	21.1	15.6	10.2	5.5	14.1
1980-1989	4.6	4.3	7.1	12.6	17.6	22.7	25.5	24.6	21.2	15.1	10.4	5.7	14.3
1990-1999	4.0	4.3	7.5	12.3	17.8	22.3	25.1	25.1	21.0	16.0	10.3	5.8	14.2
2000-2008	0.4	4.0	9.4	13.2	18.4	22.7	26.0	26.1	21.7	17.0	11.1	5.3	14.6
Astara district													
1970-1979	3.9	5.0	7.5	12.9	18.3	22.2	24.6	24.6	21.5	16.3	11.2	6.9	14.0
1980-1989	4.0	4.1	6.7	12.7	17.7	22.6	25.5	24.6	21.0	15.0	10.5	5.9	14.2
1990-1999	3.0	4.3	6.6	12.5	17.6	22.3	24.6	23.6	20.9	15.1	10.4	5.7	13.9
2000-2008	0.8	5.6	7.9	12.7	17.9	22.8	25.2	25.1	22.3	16.4	11.9	7.2	14.7

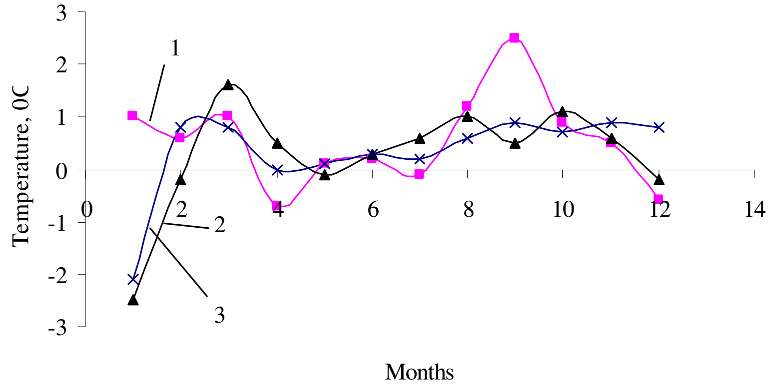

Figure 1. Average changes of month temperature for period from 1970 to 2008. 1 – Khachmaz district; 2 – Lenkoran district; 3 – Astara district

meteorological stations for the last 40 years has increased approximately on 1^{0}C. The similar analysis can be spent for Lenkoran and Astara areas. Mid-annual temperature made on decades (1970-79; 1980-89; 1990-99; 2000-08) since 1970 were consistently increasing by 2008, it reached a difference in 1^{0}C, in Khachmas, in Lenkoran this difference makes 0.5, in Astara - 0.7.

The annual dynamics of deviations of decadal monthly average values of temperatures from 1970 to 2008 concerning their average values (Table 2) are presented in Figure 1. Considering Figure 1 we see that the long-term temperature average in January in Khachmaz is increased for 1 ^{0}C, at the same time in Lenkoran and Astara this indicator has decreased for more than 2 0C. Similar comparisons can be spent for the other months. As for example, in March in all objects of research the temperature increase within 1 ^{0}C is observed, in April in Lenkoran the insignificant increase of temperature is marked, in Astara average statistical the temperature is approximately equal and in Khachmaz it is reduced approximately on 1 ^{0}C. The temperature from May till July slightly increases. Temperature substantial growth is observed from August till December

Table 2. Annual dynamics of monthly average temperatures on their long-term average values, ^{0}C

Month Districts	1	2	3	4	5	6	7	8	9	10	11	12
Khachmaz	1,9	2,7	5,3	10,7	16,7	21,7	24,7	24,1	19,3	13,8	8,3	4,1
Lenkoran	2,9	4,2	7,8	12,7	18,5	22,4	25,4	25,1	21,2	15,9	10,5	5,5
Astara	2,9	4,8	7,1	12,7	17,8	22,5	25	24,5	21,4	15,7	11	6,4

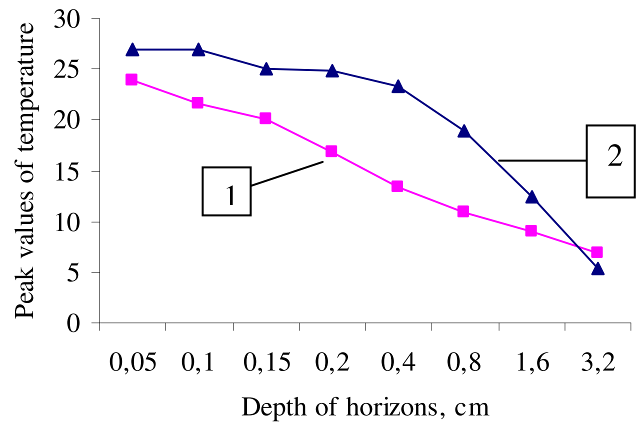

Figure 2. Temperature field of soils Hachmaza. 1 averages for 1885-1935; 2 averages for 1970-2000.

Considering data of Figure 1, it is possible to notice that basically temperature changes occur from January till March and from July till September. From May till June the changes are insignificant. It is possible to notice that in January-February temperature gradients for Lenkoran and Astara are negative, but at the same time in Khachmas during this period temperature change has a positive sign. Vibrating of temperature changes between positive and negative values occurs rather often. As a whole the temperature rising within last 40 years is observed the changes of the temperature field of soils in Hachmaz according data from 1885 to 1935 and from

1970 to 2000 are presented on fig. 2. Data of this drawing evidencely shows the differences in peak values in temperature field between horizons of soils at the expense of temperature change of the soil surface. However it is necessary to notice that the temperature field of the soil profile depends on humidity, density, granulometrical and mineralogical structures, organic substances, etc. as well.

Conclusion

In spite of the fact that research objects are within 500 km along Caspian Sea, they sharply differ in soil covering and according to the climatic indicators. Research objects cover dry, average and damp subtropical zones of Azerbaijan. In the separate years the soil-atmosphere systems are observed both increase and reduction of soil-atmosphere system temperature. However as a whole the increase of temperature of investigated soil-climatic zones is observed. It is especially characteristic for the period from 1990 to 2008. This gives grounds to consider that the global warming of the earth atmosphere is a complex process; it is difficult to predict with what regularity it occurs in the concrete region. In this case the value of Caspian Sea which is the thermal accumulator directly influencing on the temperature conditions of regions should be considered.

References

Amirov F(1997) 'Forest and forestry of Azerbaijan'. (Baku: Elm).
Gerayzade AP (1989) 'Transformations of energy in soil-plant-air systems'. (Baku: Elm).
Imanov F, Safarov S, Khalilov S (2002) 'Drought of 2000 year and its influence on agroecological situation and river flowing in Azerbaijan'. (Baku University News).
Mammadov GSh, Khalilov MYu (2005) 'Ecology and environmental protection'. (Baku: Elm).
Masimov MP (1999) Global anthropogenic changes of climate and its regional aspects. Energy, Ecology, Economy, No 5.'
Safarov S (2000) 'Modern tendency of air temperature changes and quantity of atmospheric precipitations in Azerbaijan'. Baku: Elm).
Ulanova E, Sirotenko O (1986) 'Statistical analysis methods in agricultural meteorology'.
www.jma.go.jp/jma/indexe.html

Ornithogenic Cryosols from Ardley Island, Maritime Antarctica

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Abstract

This study presents the chemical, morphological and physical characterization of a soil transect under the strong influence of abandoned penguin rookery ecosystems at Ardley Island. Soil surveying and sampling were performed during the austral summer, enabling detailed soil and geomorphology mapping. Most profiles expressed advanced pedological evolution despite their shallowness in some cases. Most soils have low pH values at the surface due to oxidation and mineralization of guano. Calcium amounts were high in all profiles even those under weak faunal influence, with high magnesium concentration and moderate potassium concentration for Antarctic standards, with little variation between sites. High exchangeable sodium indicates sea sprays provenance. The soils of Ardley Island are well developed in comparison to other soils from Antarctica, which can be attributed to the chemical weathering promoted by guano deposition and mineralization. Phosphatization of the mineral substrate is one of the most important soil forming processes at this part of Antarctica.

Key Words

Soil thermal regime, Climate change, Maritime Antarctica

Introduction

Ardley Island is one of the oldest ice-free areas of Maritime Antarctica. Home of breeding penguins since the early ice retraction, it supports approximately 10,218 individuals during the summer (Trivelpiece *et al*., 1987). With 2.0 km length and 1.5 km width, it is completely colonized by cushions of moss vegetation and lichens, and is defined as an area of Special Scientific Interest by the Scientific Committee of Antarctic Research (SCAR). Wang *et al*. (2007), found a temporal relationship between penguin population and vegetation abundance as long as 2400 BP, with Penguins playing a dominant role in this delicate ecosystem. Liguang *et al*. (2004) reported relic ornithogenic soils morphologically described as alternating layers of relict plant-rich tundra and sediments enriched with nutrients due to penguin droppings. Ornithogenic Cryosols have been recognized as ecosystems of special interest, because of their narrow C/N ratios, high nutrient levels and diversity of habitats for microorganisms. (Ugolini, 1972; Blume *et al*., 2002; Simas *et al*., 2007; 2008).The aim of this study is to report the chemical and morphological characteristics of a soil transect under the influence of penguins on abandoned rookery ecosystems at Ardley Island, emphasizing the biogeochemical cycling of nutrients.

Materials and Methods

The studied soils are located at Ardley Island (62°13'S, 58°56'W) (Figure 1). The parent material is composed of weathered volcanic rocks, mainly andesitic basalts. Ardley Island has a cold moist maritime climate characterized by mean annual air temperatures of -2°C and mean air temperatures above 0°C up to four months during summer. The temperature stays above freezing point throughout the summer, so that plant communities, mainly mosses, lichens, and algae, can establish and grow vigorously during this period.

Soil surveying and sampling were performed during the austral summer, enabling detailed soil and geomorphology mapping. Sampling pits were dug to the depth of permafrost. Samples of soil horizons were collected down to permafrost level, kept refrigerated and submitted to chemical analysis. Soil pH, exchangeable nutrients and texture were determined for <2 mm air-dried samples according to EMBRAPA (1997). Soil texture was obtained through dispersion of <2 mm samples in distilled water, sieving of coarse and fine sand, sedimentation of silt+clay followed by siphoning of the <2-µm fraction. Exchangeable Ca^{2+}, Mg^{2+} and Al^{3+} were extracted with 1 mol/l KCl and P, Na and K with Mehlich-1 extractant (dilute double 0.05 mol/l HCl in 0.0125 mol/l H_2SO_4). Nutrient levels were determined by atomic absorption (Ca, Mg and Al), flame emission (K and Na) and photocolorimetry (P). H+Al was extracted with 0.5 mol/l calcium acetate buffered at pH 7.0 and determined by titration with 0.0025 mol/l HCl (EMBRAPA,1997). Total organic C (TOC) was determined by wet combustion (Yeomans and Bremner, 1988). Soil samples were also subjected to X-ray difractometry, the difractograms were obtained at regular temperatures using a Rigaku Geigerfle, with graphite monochromators and cobalt tube.

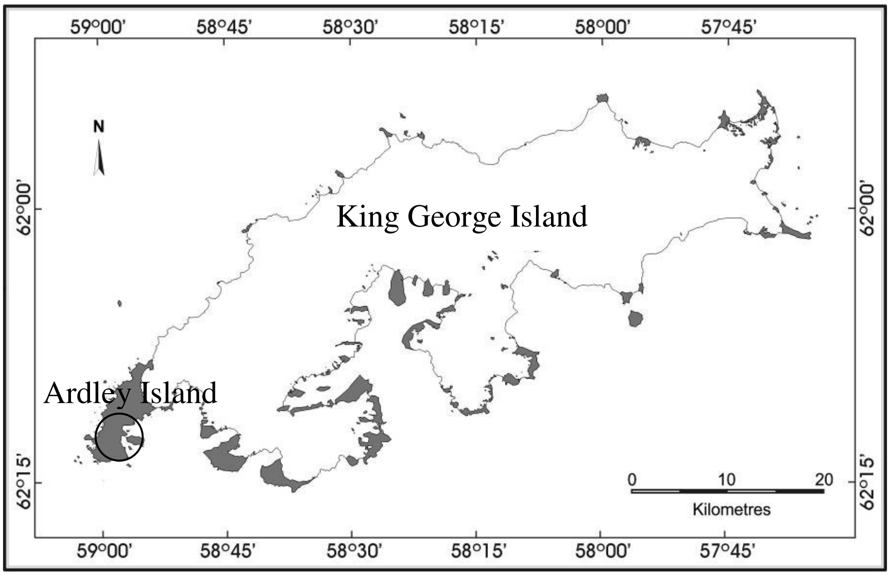

Figure 1. Study site.

Table 1. General characteristics of the studied sites.

Site	Altitude	Soil Class	Vegetation	Depth of the active layer
Ardley 1	77 m	Histic Ornithic Cryosol	Mosses and Lichens (*Usnea sp.* and *Himantormia sp.*)	10 cm
Ardley 2	50 m	Folic Eutric Cryosol	Lichens (*Usnea sp.* and *Himantormia sp.*)	25 cm
Ardley 3	45 m	Cambic Drainic Cryosol	Not vegetated	20 cm
Ardley 4	42 m	Histic Ornithic Cryosol	Mosses	80 cm
Ardley 5	31 m	Leptic Arenic Cryosol	Mosses	40 cm

Results

Most of the studied soils have advanced pedological evolution. Soil A1 (Figure 2) is located at one of the highest portions of the island and is only 10 cm deep. Nevertheless, it has strong structural development, ornithogenic influence and luxuriant vegetation cover. Fine sand (FS) and silt are the main granulometric fractions of the fine earth, while plagioclase, magnetite and quartz are the main minerals. Soil A2 in located near the penguin colony, at an intermediate position, with weaker ornithogenic influence and vegetation cover dominated by lichens. Despite the low primary productivity at this site, it has a 3 cm thick, dark A horizon. High content of coarse sand (CS) and uniform contents of FS, silt and clay were determined. Plagioclase, magnetite, olivine, chlorite, and quartz are the main minerals in the fine earth. Soil A3 is located at the centre of the island with no ornithogenic influence and no vegetation cover. CS and silt are the main granulometric fractions in the fine earth, which has 20 % of clay (Table 2). Plagioclase, pyroxene, chlorite, magnetite, olivine and quartz are the main minerals.

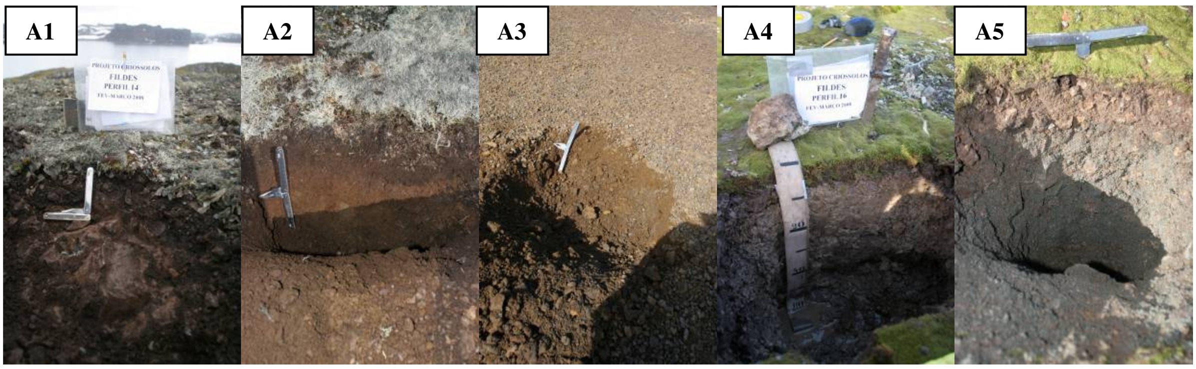

Figure 2. Soil profiles (A1-A5) studied at Ardley Island, Maritime Antarctica.

Profile A4 is located on the top of a gentle slope near the coast, under strong past and present ornithogenic influence, showing a grayish color and exuberant moss cover. It has up to 20 % of CS, 45% of silt and up to 30% of clay. Plagioclase, pyroxene, chlorite, magnetite, olivine, quartz and phosphate minerals are present. Profile A5 is located at the marine terrace expressing not only present ornithogenic influence but also occasional inputs of marine mammals droppings. CS content reaches up to 55 % in surface and 77 % in sub-surface. Plagioclase, pyroxene, chlorite, magnetite and quartz are the main minerals. Most soils have acidic reaction at the surface due to oxidation and mineralization of guano. Only A3 has pH values higher than 7.0, reflecting the nature of the mineral substrate with no ornithogenic influence. Calcium and magnesium levels values are high in all profiles. Potassium did not vary much between sites. High exchangeable sodium indicates sea sprays, with higher values at the topmost position indicating a dryer soil condition upland, as verified for the western coast of Admiralty Bay by Simas et al. (2007). Aluminum values were low, if not null, for the majority of the samples, except for sites A2 and A4, which have lower pH values.

Table 2. Chemical characteristics of the studied profiles.

Hor.	depth (cm)	CS	FS	Silt	Clay
		A1 Histic Ornithic Cryosol			
O	0-5	25	34	32	9
A	5-10	16	38	33	13
		A2 Folic Eutric Cryosol			
A	0-10	43	21	20	16
Bi	15-25	54	19	16	11
		A3 Cambic Drainic Cryosol			
Bi	0-20	32	12	36	20
		A4 Histic Ornithic Cryosol			
A	0-10	19	7	45	29
B1	10-30	20	8	44	28
B2	30-60	24	15	37	24
BC	60-70	23	12	43	22
		A5 Leptic Arenic Cryosol			
A	0-10	55	12	15	18
C	10-30	77	8	8	7

Total organic carbon (TOC) is closely related to ornithogenic influence (Table 3), with soil A3 presenting the lowest values (0.3 % of TOC). Soil A1 has the highest TOC values, reaching 21.2 % in surface. Soil A5 has high values only at the surface. On the other hand, at soil A4 the TOC values increase with depth, suggesting podzolization. The values of available P were extremely high for samples under penguin guano influence. Soils A1, A4 and A5 present values close to 2500 mg dm^{-3}. Soil A5 showed greater values in surface which is consistent with the present day colonization at this site. Soil A2 presents moderate values and A3 very low P, illustrating a low background for P in the parent material at Ardley.

Table 3. Chemical characteristics of the studied profiles.

Horizon	Depth (cm)	pH H_2O	pH KCl	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H+Al	T	V %	TOC %	P mg dm^{-3}
				-----	-----	-----	cmol$_c$ dm^{-3}	-----	-----	-----			
					A1 Histic Ornithic Cryosol (77 m)								
O	0-5	5.09	3.77	3.36	2.22	174	498.0	1.45	24.3	32.50	25.2	21.2	2218.9
A	5-10	5.41	3.97	4.97	2.36	239	628.1	0.96	26.6	37.27	28.6	18.5	2748.9
					A2 Folic Eutric Cryosol (50 m)								
A	0-10	6.19	4.33	3.92	7.68	139	235.7	0.58	13.8	26.78	48.5	5.42	195.4
Bi	15-25	5.64	3.42	6.15	12.23	182	239.7	5.69	19.2	39.09	50.9	0.6	253.8
					A3 Cambic Drainic Cryosol (45 m)								
Bi	0-20	7.69	6.66	6.55	3.42	25	44.8	0.00	0.3	10.52	97.1	0.3	0.2
					A4 Histic Ornithic Cryosol (42 m)								
A	0-10	5.68	4.10	5.53	4.51	149	285.7	0.77	12.2	23.86	48.9	5.7	2469.1
B1	10-30	6.32	4.70	7.26	4.51	147	319.8	0.10	8.6	22.14	61.2	2.6	3181.9
B2	30-60	5.84	4.19	4.51	2.58	148	265.7	0.67	14.9	23.53	36.7	9.4	1125.7
BC	60-70	4.01	3.64	0.18	0.16	65	69.8	3.37	26.4	27.21	3.0	10.5	564.5
					A5 Leptic Arenic Cryosol (31 m)								
A	0-10	5.49	4.33	7.92	3.76	134	217.9	0.00	7.6	20.57	93.1	3.9	2284.5
C	10-30	6.32	3.42	5.85	2.90	145	197.9	0.00	2.1	12.08	82.6	0.4	448.5

Conclusion
The soils of Ardley Island are well developed for Antarctic standards due to chemical weathering favoured by guano deposition and mineralization, similarly to soils from the western coast of Admiralty Bay. The phosphatization of the mineral substrate is one of the major soil forming processes, influencing soils chemical, mineralogical and morphological characteristics.

Acknowledgements
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References
Blume HP, Beyer L, Kalk E, Kuhn D (2002) Weathering and soil formation. In 'Geoecology of Antarctic Ice Free Coastal Landscapes' (Eds. Beyer L, Bölter EM), pp. 114-138. Spinger-Verlag, Berlin.
EMBRAPA — Centro Nacional de Pesquisa de Solos (1997) Manual de métodos de análise de solo. Centro Nacional de Pesquisa de Solos, Rio de Janeiro, p. 212.
Liguang S, Renbin Z, Xuebin Y, Xiadong L, Zhouqing X, Yuhong W (2004) A geochemical method for the reconstruction of the occupation history of a penguin colony in the maritime Antarctic. *Polar Biol* **27**, 670-678.
Simas FNB, Schaefer CEGR, Melo VF, Albuquerque-Filho MR, Michel RFM, Pereira VV, Gomes MRM, Costa LM (2007) Ornithogenic cryosols from Maritime Antarctica: Phosphatization as a soil forming process. *Geoderma* **138**, 191-203.
Simas FNB, Schaefer CEGR, Albuquerque Filho MR, Francelino MR, Fernandes Filho EI, Gilkes RJ, Costa LM (2008) Genesis, properties and classification of cryosols from Admiralty Bay, maritime Antarctica. *Geoderma* **144**, 116-122.
Trivelpiece WZ, Trivelpiece SG, Volkman NJ (1987) Ecological segregation of Ade´ lie, Gentoo, and Chinstrap penguins at King George Island, Antarctica. *Ecology* **68**, 351-361
Ugolini FC (1972). Orthinogenic soils of Antarctica. In (Ed. Llano GA), Antarctic Terrestrial Biology Am. Geophys. Uion Antarct. Res. Ser, pp. 181-193.
Yeomans JC, Bremner JM (1988) A rapid and precise method for routine determination of organic carbon in soil. *Communications in Soil Science and Plant Analysis* **19**, 1467-1476.

Response of pedogenesis to Holocene climate change in Southern Arabia

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Abstract
Pedostratigraphic and soil morphological data show a well-preserved and wide spread palaeosol at the southwestern margin of the Ar-Rub' al-Khali, Ma'rib, Yemen. The marker horizon of the buried soils is considered as a new proxy of Holocene climate change that is characterised by alternation of e.g. low and high precipitation. The humic palaeosol mainly represented by Ahb and ABb horizons indicates soil development in a more humid climate during the Early Holocene in Southern Arabia as compared to overlying sediments (cover sediments). These cover sediments are obviously a result of increasing aridity from 5800 to 5950 yrs BP on. The early Holocene palaeosol is characterised by AMS ^{14}C, soil chemical and geochemical data. The pedogenic status quo of this palaeosol is a very important proxy for the interpretation of regional palaeoclimate fluctuations and of the southward shift of the ITCZ in Southern Arabia.

Key Words
Holocene palaeosol, pedogenesis, ITCZ, AMS radiocarbon data, Yemen

Introduction
Holocene climate change on the Arabian Peninsula is characterised by well-known fluctuations of both moisture and aridity (Mayewski *et al.,* 2004). Particularly the variability of the monsoonal climate and the shift of the Intertropical Convergence Zone (ITCZ) were in focus of recent research on dune activities (Bray and Stokes, 2004), playa like sediments (Fuchs and Buerkert, 2008), faunal assemblages of interdunal deposits (Radies *et al.,* 2005) and the geochemistry of lacustrine sediments (Parker *et al*., 2006) in southeastern Arabia. High resolution palaeoclimate information is available from speleothem records in Oman (Fleitmann *et al*., 2007) and from Socotra (Shakun *et al*., 2007) as well as from marine sediment records in the Northern Arabian Sea (Sirocko *et al*., 1993). In southwestern Arabia data of lacustrine response to a period of increased precipitation between 12 ka and 7.5 ka BP come from sediments of palaeolakes in the Ramlat al-Saba'tayn (Lezine *et al.,* 2007) and from Lake Mundafan situated more northerly in the Ar-Rub' al-Khali (McClure, 1976). Longer lasting lacustrine phases may correlate with geomorphodynamic stable phases and, therefore, with phases of soil development.
Early to Mid Holocene palaeosols in the central Yemen Highlands, Yemen (see Figure 1) were dated to the period from 7300 to 4290 cal yrs BP (Wilkinson, 1997; Davies, 2002).

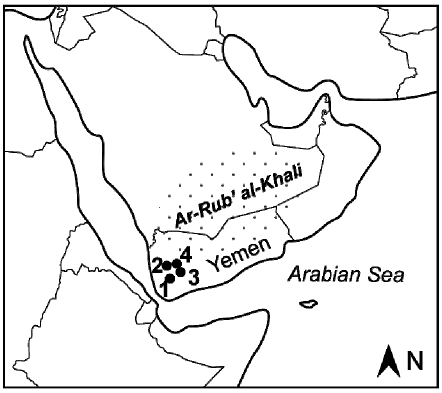

Figure 1. Location of soil investigation sites in Yemen (1 Wilkinson, 1997, Davies, 2002; 2 De Maigret *et al*., 1989; Brinkmann, 1996; 4 this paper).

A palaeosol in Wadi At-Thaylah (Khawlan), dated at 5700 to 5500 cal yrs BC (De Maigret *et al*., 1989), indicates pedogenesis in the eastern Yemen highlands during the moist Early Holocene. Palaeosols with comparable ages were found in Wadi Al-Jubah area, southeast of Ma'rib, dated at 6400 to 5500 cal yrs BC (e.g. Brinkmann, 1996).

In the context of archaeopedological research buried palaeosols dated to the Early Holocene were recently found around Ma'rib at the southwestern margin of the Ar'Rub al-Khali (Pietsch *et al*., 2010; Kühn *et al*., 2010).

Methods

Soil description followed the FAO Guidelines (FAO, 2006). Soils were classified after WRB (IUSS-Working Group WRB 2007). Layer identification followed Ollier and Pain (1996) and substrate classification Pietsch and Lucke (2008). Soil analysis was carried out after Blume *et al*. (2000). Major and trace elements were measured by XRF (Zschornack, 2007). Existence of allophane was proved by NaF method (Fieldes and Perrott, 1966). Colours have been classified by Munsell colour charts (2000). For selected soil physical and chemical data refer to Table 1. Radiocarbon data were obtained by AMS from humic acid and minute gastropods. Little carbon-reservoir effects of those molluscs yield reliable ^{14}C ages and are therefore suitable for constraining the ages of sediments in which they occur (Pigati *et al*., 2004).

Results

In the surrounding of Ma'rib Oasis a buried palaeosol with Ahb (sometimes ABb) horizon is widely spread. The palaeosol - visible as a humic marker horizon - represents an old land surface and is covered by a stratified cover sand with an average thickness of 40 cm and no sign of soil formation. At most sites a desert pavement is developed and embedded in a vesicular Av horizon on top of the cover sediment (cf. McFadden *et al.,* 1998). The Av horizon is 5 to 10 cm thick and occurs on many sites around the oasis of Ma'rib. The stones of the desert pavement have a blackish desert varnish on the upper side and are lighter coloured at the lower side. In the Ahb or ABb horizon below the cover sediment rhizolithes occur, which are described as former root channels, often calcified and holding organic remnants (Klappa, 1980). Yet they do not have visible signs of secondary calcifications and fall apart by soft pressure in our study areas. Some of the soil horizons reveal even a structure after these root pseudomorphs implying a dense vegetation cover or a long period of vegetation. Similar root pseudomorphs were described so far only within irrigation sediments of the Sabaean time (Brunner, 1982).

AMS ^{14}C- data

Buried soils have been dated at 8000 to 4500 cal yrs BC (ERL, Hv). Radiocarbon ages of humic acid correlate well with ^{14}C-ages of mollusc shells, mainly of *Pupoides coenopticus* and *Zootecus insularis*. The potential for incorporation of old carbon from ground water during shell formation in these minute molluscs (i.e. carbon-reservoir effects, Pigati *et al*., 2004) can be regarded as little in the Ma'rib region, since substrates of soils are aeolian sediments with low carbonate content. They do not occur in direct contact to Jabal Balaq, a ridge of Jurassic limestone.

Soil physical and chemical data

The layering can be easily noticed in the vertical grain size distribution of single profiles (Table 1). Sandy cover sediments can clearly be distinguished from more silty-clayey sediments wherein the palaeosol is formed. Grain size quotient Q (sum 630–63 µm sand fraction/sum silt fraction) clearly marks the boundaries between soil layers. Organic carbon contents of the buried soils reach 0.6 %, plant available phosphate contents 200 mg/kg in some soils.

Table 1. Grain size distribution and soil chemistry of a buried soil (Mat03, ND not determined).

Horizon	Depth (cm)	2000-630 µm (%)	630-200 µm (%)	200-125 µm (%)	125-63 µm (%)	63-20 µm (%)	20-6.3 µm (%)	6.3-2 µm (%)	<2 µm (%)	Q	C_{org} (%)	PO_4 (mg/kg)	TiO_2/Zr
C	0-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2Cw	10-25	5.4	5.4	10.4	44.0	19.4	5.6	3.5	6.3	2.1	ND	126	23
3Cw	25-43	4.0	4.6	10.1	40.5	20.3	7.3	3.7	9.5	1.8	0.21	125	24
4Ahb1	43-60	3.3	6.1	7.2	32.4	20.0	10.2	5.3	13.4	1.3	0.58	135	28
4Ahb2	60-85	4.9	3.2	6.8	34.8	22.6	9.1	4.9	13.7	1.2	0.42	102	29
4Ck1	80-100	0.4	2.0	6.5	40.6	29.3	7.4	4.8	9.0	1.2	0.40	64	25
4Ck2	100-125	0.9	1.7	4.1	33.3	36.2	9.3	5.1	9.3	0.8	ND	ND	25
5Ckm	125+	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Geochemistry
Minor and major elements have been taken into consideration to detect soil layering. TiO_2/Zr quotients show significant changes of contents of rather immobile heavy minerals from fluvial loams (3Cw) to those of mixed aeolian and aquatic sediments and volcanic ashes (4Ahb).

Conclusions
Pedostratigraphic position and properties of the marker horizon imply *in situ*-soil formation at all sites. It may serve therefore as a tool to refine the over-regional interpretation of the proxy climate data (marine and speleothem) on a regional or even local scale.
The Early Holocene palaeosol in Ma'rib region was formed until around 7500 yr BP representing an Early Holocene moister period. Between 5800 and 7500 yrs BP the soil was covered by sandy-gravelly sediments. Desert varnish developed on stones on top of cover-sediments formed a desert pavement over time. The cover sediments show no signs of pedogenesis corroborating arid and dry climate conditions after its formation. Pedogenic processes would have destroyed sedimentary layering. Events with intense precipitation may have caused the development of cover sediments most probably formed as a result from sheet wash.
Based on the fact of an abrupt discontinuity between the cover sediment and the buried palaeosol as well as lacking signs of pedogenesis we infer an arid climate after the formation of the cover sediment, i.e. after around 5800 yr BP. Therefore we assume a southward retreat of the ITCZ and the associated zone of rainfall to the Yemen highlands at 15°N at that time. Only single outriders of the ITCZ to the north may have caused rainfall in the southwestern desert margin of the Ar'Rub al-Khali.
On the other hand, fluctuating climate conditions, evident at the southwestern margin of the Ar-Rub' al-Khali, contribute better understanding to the timing of pedogenic response to Holocene moisture changes at the desert margin in Southern Arabia.

References
Blume HP, Deller B, Leschber R, Paetz A, Schmidt S, Wilke BM, Eds (2000) Handbuch der Bodenuntersuchungen. Terminologie, Verfahrensvorschriften und Datenblätter. Physikalische, chemische, biologische Untersuchungsverfahren. Gesetzliches Regelwerk – Grundwerk. (Berlin, Wien, Zürich).

Bray HE, Stokes S (2004) Temporal patterns of arid–humid transitions in the south-eastern Arabian Peninsula based on optical dating. *Geomorphology* **59**, 271-280.

Brinkmann R (1996) Pedological characteristics of Anthrosols in the al-Jadidah basin of Wadi al-Jubah, and native sediments in Wadi al-Ajwirah, Y.A.R. In 'Environmental research in support of archaeological investigations in the Yemen Arab Republic 1982–1987' (Eds. Grolier MJ, Brinkmann R, Blakely JA), pp.145-211. (AFSM V. Washington).

Brunner U (1983) Die Erforschung der antiken Oase Ma'rib mit Hilfe geomorphologischer Untersuchungsmethoden. Archäologische Berichte aus dem Yemen II. (Mainz, Sana'a).

Davies CP (2006) Holocene paleoclimates of southern Arabia from lacustrine deposits of the Dhamar highlands, Yemen. *Quaternary Research* **66**, 454.464.

De Maigret A, Azzi C, Marcolongo B, Palmieri AM (1989) Recent pedogenesis and neotectonics affecting archaeological sites in North Yemen. *Paléoorient* **15**, 239-243.

FAO (2006) Guidelines for soil description (Rome).

Fieldes M, Perrott KW (1966) The nature of allophane in soils. Part 3. Rapid field and laboratory test for allophane. *New Zealand Journal of Science* **9**, 623-629.

Fleitmann, D, Burns SJ, Mangini A., Mudelsee M, Kramers J, Villa I, Neff U, Al-Subbary AA, Buettner A. Hippler D, Matter A. (2007) Holocene ITCZ and Indian monsoon dynamics recorded in stalagmites from Oman and Yemen (Socotra). *Quaternary Science Reviews* **26**, 170-188.

Fuchs M, Buerkert A (2008) A 20 ka sediment record from the Hajar Mountain range in N-Oman, and its implication for detecting arid–humid periods on the southeastern Arabian Peninsula. *Earth and Planetary Science Letters* **265**, 546-558.

IUSS-Working Group WRB (2007) World Reference Base for Soil Resources (WRB). World Soil Resources Reports 103 (Rome).

Klappa CF (1980) Rhizoliths in terrestrial carbonates: classification, recognition, genesis and significance. *Sedimentology* **27**, 613-629.

Kühn P, Pietsch D, Gerlach I (2010) Archaeopedological analyses around a Neolithic hearth and the beginning of Sabaean irrigation in the oasis of Ma'rib (Ramlat as-Sab'atayn, Yemen). *Journal of Archaeological Sciences* doi:10.1016/j.jas.2009.12.033

Lézine AM, Tiercelin JJ, Robert C, Saliège JF, Cleuziou S, Inizan ML, Braemer F (2007) Centennial to millennial-scale variability of the Indian monsoon during the early Holocene from a sediment, pollen and isotope record from the desert of Yemen. *Palaeogeography, Palaeoclimatology, Palaeoecology* **243**, 235-249.

Mayewski PA, Rohling EE, Stager JC, Karlen W, Maasch KA, Meeker LD, Meyerson EA, Gasse F, van Kreveld S, Holmgren K, Lee-Thorp J, Rosqvist G, Rack F, Staubwasser M, Schneider RR, Steig EJ (2004) Holocene climate variability. *Quaternary Research* **62**, 243-255.

McClure HA (1976) Radiocarbon chronology of late Quaternary lakes in the Arabian Desert. *Nature* **263**, 755-756.

McFadden LD, McDonald EV, Wells SG, Anderson K, Quade J, Forman SL (1998) The vesicular layer and carbonate collars of desert soils and pavements: formation, age and relation to climate change. *Geomorphology* **24**, 101-145.

Ollier C, Pain C (1996) Regolith, soils and landforms. (Chichester).

Parker AG, Goudie AS, Stokes S, White K, Hodson MJ, Manning M, Derek K (2006) A record of Holocene climate change from lake geochemical analyses in southeastern Arabia. *Quaternary Research* **66**, 465-476.

Pietsch D, Kühn P, Scholten T, Brunner U, Hitgen H, Gerlach I (2010) Holocene soils and sediments around Ma'rib Oasis, Yemen: further Sabaean treasures? *The Holocene* doi:10.1177/0959683610362814

Pietsch D, Lucke B (2008) Soil substrate classification and the FAO and World Reference Base (WRB) systems: examples from Yemen and Jordan. *European Journal of Soil Science* **59**, 824-834.

Pigati JS, Quade J, Shahanan TM, Haynes CV Jr. (2004) Radiocarbon dating of minute gastropods and new constraints on the timing of late Quaternary spring-discharge deposits in southern Arizona, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* **204**, 33-45.

Radies D, Hasiotis ST, Preusser F, Neubert E, Matter A (2005) Paleoclimatic significance of Early Holocene faunal assemblages in wet interdune deposits of the Wahiba Sand Sea, Sultanate of Oman. *Journal of Arid Environments* **62**, 109-125.

Shakun JD, Burns SJ, Fleitmann D, Kramers J, Matter A, Al-Subbary A (2007) A high-resolution, absolute-dated deglacial speleothem record of Indian Ocean climate from Socotra Island, Yemen. *Earth and Planetary Science Letters* **259**, 442-456.

Sirocko F, Sarnthein M, Erlenkeuser H, Lange H, Arnold M, Duplessy JC (1993) Century-scale events in monsoonal climate over the past 24,000 years. *Nature* **364**, 322-324.

Wilkinson TJ (1997) Holocene environments of the high plateau, Yemen, recent geoarchaeological investigations. *Geoarchaeology* **12**, 833-864.

Zschornack GH (2007) Handbook of X-Ray Data. (Berlin).

Simulation of Br concentration in soil columns by HYDRUS-ID model

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Abstract
Water and contaminants moving through the vadose zone are often subject to a large number of simultaneous physical and chemical nonequilibrium processes. Modification of the transport of one component is difficult, time consuming and expensive, therefore it is important to develop methods to simulate this movement. In the present study our purpose was to investigate bromide concentrations in soil columns, Br simulations by the HYDRUS-ID model and study the efficiency of this model in estimating concentrations of Br. For this, we used sandy loam and loamy sand textures, 3 Br doses (10, 20 and 30 mg/kg soil) were added to columns under saturated conditions. After leaching, samples were taken at every 2 cm from 0-12 cm depth; at every 4 cm from 12-20 cm depth; and at every 5 cm from 20-25 cm depth. Br concentration was measured using a Br selective electrode. The result showed that this model proved a suitable estimation of Br concentration with depth and thus can be use for prediction of Br diffusion in these soils.

Key Words
Nonequilibrium, concentration profile, model, bromide, simulation

Introduction
Amount of leaching is related to the velocity of water movement at soil and conservation potential of solutes by soil. The most important things that affect solute movement include: texture, structure and capillary conductivity that are influenced by management and tillage (Agus *et al.* 1992; Cary *et al.* 1967). Soil anions have a particular importance and this is because of their importance for salinity, productivity and groundwater pollution. Most anions are inactive and do not adsorb at adsorption sites, thus they can be leached from the soil profile and pollute groundwater. Often, Br is used as a tracer because of its low concentration in most soils, and its low chemical activity in adsorption reactions. This ion does not react chemically with with the kinds of compounds normally found in soil solution and is not attracted to clay or organic matter surfaces. Thus, it may act as a tracer of the water flow pathways.

Material and methods
Soil columns 10.17 cm in diameters and 25cm in were filled with soils having sandy loam and loamy sand textures. We kept the bulk density of the soil in the column similar to that in the field. The ends of the columns were closed with 5cm of sand washed with acid to inhibit soil loss and closed by aluminum nets. Experiments were laid out in by 18 columns with 3 replications to each texture. Three different doses of Br (10, 20 and 30 mg/kg soil) were dissolved in 250 ml distilled water, after solute pulse treatments applied to columns, leaching them in saturated conditions with 5cm constant head. After leaching, samples were taken at every 2 cm from 0-12 cm depths; at every 4 cm from 12-20 cm depths; and at every 5cm from 20-25 cm depths. Then we measured the Br concentration with a Br selective electrode. Bulk density was determined by the core method (Klute 1986), saturated hydraulic conductivity determination was made by a constant head method (Klute 1986), texture with a pipette method (Klute 1986). Electric conductivity was determined from soil extracts and cation exchangeable capacity ammonium acetate extraction.

Results
After measurements of Br concentration, all necessary data for modeling were collected from columns and were compared with leachate concentrations predicted by the model. In all level of treatments Br concentration was less measured less than detection of ion selective electrode. As we can see in the diagram below,the ion selective electrode is too sensitive to measure the estimated concentrations and can be concluded that the model has good prediction of the concentration. According to estimated concentrations, Br concentrations in all 3 levels of treatments for the sandy loam were more than for loamy sand textures, because the finer-textured soil contains smaller pores, thus increasing the portion of immobile water and thus decreasing leaching of Br. For both textures maximum concentration within the profile occurred at 23-25 cm depth because Br is an anion that is not well adsorbed by the soil, and is thus easily leached and transmitted to of the bottom of the soil columns.

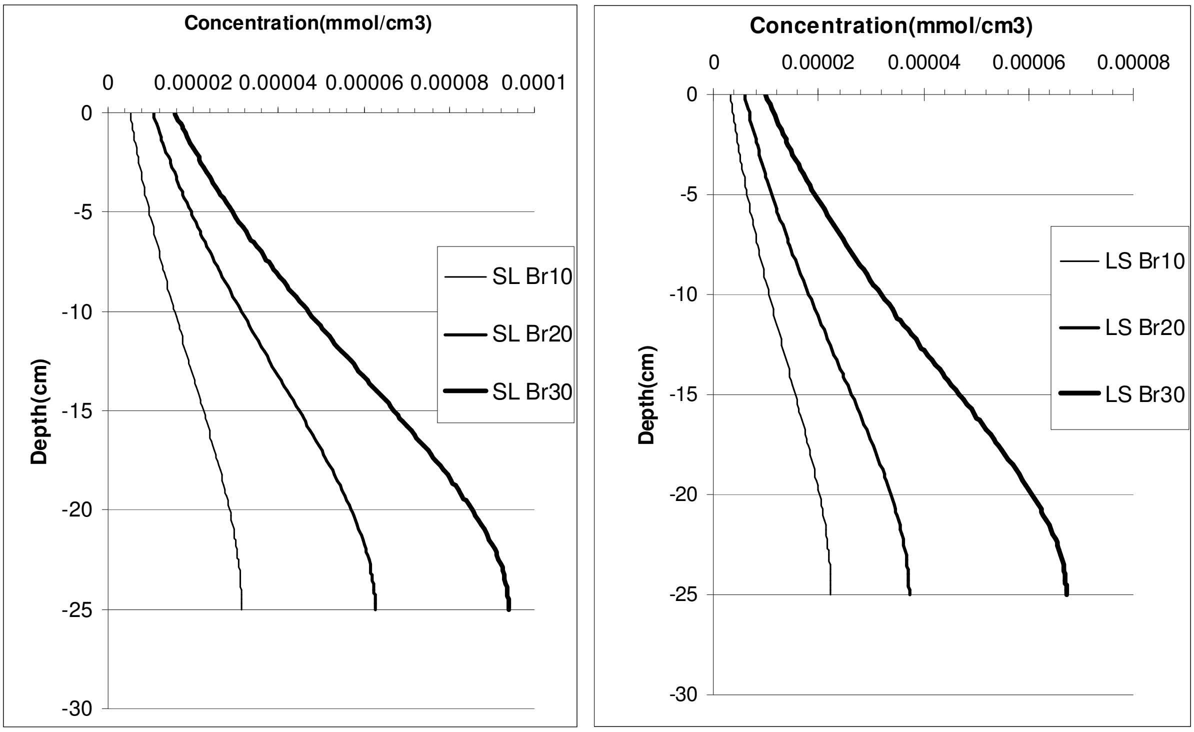

Figure 1. Chart of Br Concentration profile for sandy loam and loamy sand soils.

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References

Abdalla NA, Lear BN (1975) Determination of inorganic bromide in soil and plant tissues with bromide selective-ion electrode. *Commun in Soil Sci. and Plant Analysis* **6**, 489-494.

Agus F, Cassel DK (1992) Field scale bromide transport as affected by tillage. *Soil Sci. Soc. Am. J.* **56,** 254-260.

Bowmas RS (1984) Evaluation of some new tracers for soil water studies. *Soil Sci. Soc. Am. J.* **48**, 987-993.

Cary EE, Wieczorek GA, Alloway, WH (1967) Reaction of selenite-selenium added to soils that produce low-selenium Forage. *Soil Sci. Soc. Am. J.* **31**, 21-26.

Klute A (1986) 'Method of soil Analysis. Part 1- physical and mineralogical methods. 2nd edition'. (Ed A Klute) (American Society of Agronomy Inc.: Madison, WI).

Klute A (1986) 'Method of soil Analysis. Part 2- Chemical and Biochemical methods. 2nd edition'. (Ed A Klute) (American Society of Agronomy Inc.: Madison, WI).

Soil carbon depth functions under different land uses in Tasmania

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Abstract
Agricultural soils play an important role in the global carbon cycle and can act as a significant carbon sink if managed appropriately. Thirty soil cores were sampled from five different land uses across a consistently mapped Brown Dermosol in the Midlands region of Tasmania. Each core was separated at three depths (0 – 10, 10 – 20, 20 – 30 cm) to generate 90 samples. Each of these samples was analysed for total organic carbon (TOC) to assess the effect of the different land uses on soil carbon dynamics with depth. As expected, TOC levels in the topsoil were depleted under intensive land management practices, however the carbon levels in the subsoils suggested that increases in land use intensity resulted in higher TOC levels below 10 cm. This emphasises the importance of sampling at depth when assessing soil carbon dynamics in relation to land use. After 12 years of intensive cultivation however, some fields showed little change in TOC levels, which is likely a function of the protective nature of the high clay and silt content (~70%) of the soil and the associated use of minimum tillage. If Australia enters into a CPRS and agriculture is included, recognition of the role of subsoils as a carbon sink will be necessary in ensuring carbon taxes are appropriately administered.

Key Words
SOC dynamics, land use intensity, sampling depth, CPRS

Introduction
As a result of Australia's ratification of the Kyoto protocol, and the intent by Australia to introduce a carbon pollution reduction scheme (CPRS), a need exists to properly define realistic carbon sequestration options with sound scientific evidence that could eventually underpin policy changes in the future. Having defensible knowledge as to the potential of Australian soils to sequester carbon will be crucial in ensuring that soils are included as a potential sink for atmospheric CO_2 in any future developing carbon pollution reduction scheme. For soils to be included in a potential CPRS, scientific evidence must consistently demonstrate the effect of different land uses on soil carbon levels, and these changes must be shown to be easily quantifiable. The majority of previous studies quantifying the effect of land use on soil carbon have mostly just measured changes in the topsoil (~15cm). The aim of this research was to assess changes in soil carbon at depth in response to increasing levels of land use intensity.

Materials and Methods
The data used in this research was collected from the property "Lowes Park" in the Midlands of Tasmania. The property has five centre pivot irrigators that overlap with an area of consistently mapped soil type (Leamy 1961). From these five overlapping fields, four were selected and used as sample sites. At each sample site, five soil cores were extracted with a truck mounted hydraulic push-tube apparatus, and from each core five sub-samples were taken at the following depths: 0 - 10, 10 - 20, 20 – 30 cm.

Five randomly sampled soil cores from six separate sampling sites provided in the extraction of 30 total soil cores. From these soil cores, 150 individual samples were generated, air-dried for a week and weighed for calculation of bulk density.

The 90 samples were sieved at 2 mm to remove any stones, or large organic material. Post sieving, each individual sample was sub-sampled and a portion of that sub-sample was milled for 20 seconds in a Retch MM200 ball mill to allow for complete disaggregation of all solid clay particles and soil aggregates. This allowed for complete combustion of material during the analysis process. Analysis total organic carbon (TOC) was performed on 20 - 30 mg of milled soil, on a Perkin-Elmer CNH dry combustion analyser.

For analysis of mineral associated carbon, a 20 g oven dry sample of each soil was dispersed in 100 ml of water containing 2.5 g of the dissolved chemical dispersant calgon (sodiumhexametaphosphate). The samples were put into 250 ml centrifuge tubes, and placed on their side on a horizontal shaker at 175 rpm for 16 hours. The suspended soil was then washed over a 53 µm sieve, taking care to account for the entire initial sample. The material was washed gently on the sieve with distilled water until the water running through the sieve appeared clear. Both fractions were recovered and the samples dried at 60°C until the water used in the separation process had evaporated. Each fraction was weighed, and the dried <53 µm fraction was milled, and analysed again for the carbon content. The calculation for the carbon content of the >53 µm fraction was calculated by difference from the TOC data set after accounting for the bulk density.

Relative land use intensity was calculated by assigning numerical values to particular land management practices, the sum of which was calculated for the period of cultivation and divided by the calculated intensity of the control site.

Results

From the 90 data points collected, the mean TOC values for each field can be compared. The experimental design aimed to have two key land uses. However when specific land use histories were collected a distinct difference between Field 1 and the remaining fields became apparent. Figure 1 below reveals the general trend in TOC content with depth, information about the variation in the results obtained, and specific differences and trends between individually sampled fields.

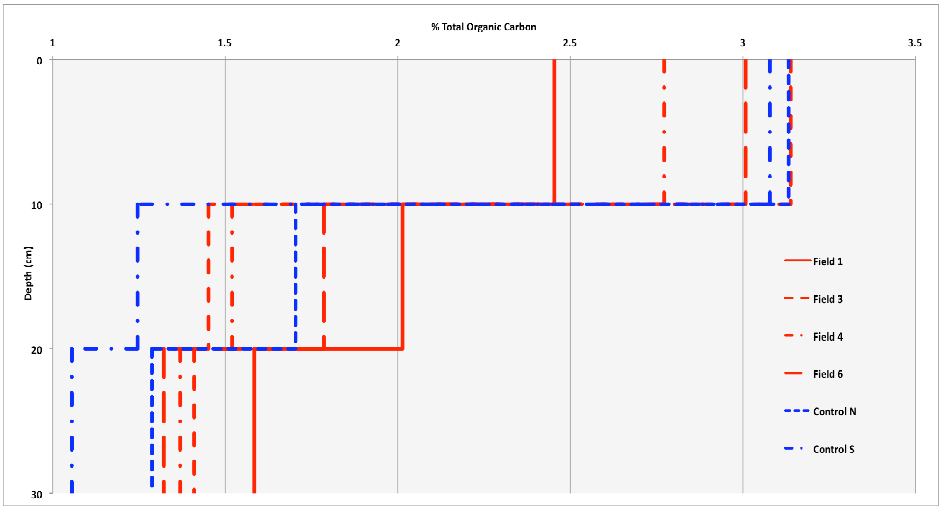

Figure 1. Graph showing TOC dynamics at depth for each sampled field. Each value is the mean TOC content of the 5 cores taken at that site. In the 0 – 10 cm section both control sites, Field 6 and Field 3 have relatively high carbon levels. The values of the 10 – 20 cm section are particularly variable, however Control South has low levels of carbon compared to all other sampled fields. Both values for the control sites are lower than all the sampled field sites for the 20 – 30 cm section suggesting the cropping is increasing carbon levels deeper in the soil profiles. Field 1 has significantly less carbon in the topsoil, relative to all other sampled sites, but has relatively high TOC levels in the soil deeper than 10 cm.

The calculation of relative land use intensity allows for the comparison of TOC content at depth for different fields whilst accounting for the different land use histories.

Discussion

Sampling sites of particular interest from Figure 1 are Control South and Field 1. Control South showed the greatest difference between the TOC value for the 0 – 10 cm soil section, and the TOC value of the 10 – 30 cm soil section. Conversely, Field 1 had an almost linear decline in TOC content with depth, a feature possibly attributable to a deep tillage event in 1998 (Figure 2). In the topsoil, Field 1 had 20% less TOC than Control South, a figure consistent with other land use studies into agricultural practices of high intensity performed in Tasmania (Sparrow 1999). The values for Control South and Field 1 are statistically different at every depth.

The two control sites had very similar amounts of carbon in the 0 – 10 cm soil section, however in the 10 – 20 cm section, Control North was not statistically different to any other field site except Control South. The difference between the controls decreased in the 20 – 30 cm soil section, however the value for Control North was more similar to the intermittent cropping sites. Sampling control sites was necessary to assess variability of carbon levels across the landscape. It should be noted that at the time of sampling, these pastoral soils had been subjected to an extended drought, which may have been responsible for a degree of soil degradation. This result is suggestive of the difficult nature of soil carbon measurement, and the difficulty in assessing whether differences in carbon measurements are a function of natural variation or of different land management practices.

Figure 2. Table of relative land use intensity. Green represents established pasture or lucerne (1). Yellow represents the cultivation of annual cereals using direct drilling (2). Orange represents the cultivation of annual cereals or poppies with conventional tillage (disc and harrow) (4). Red represents a deep tillage event following the production of potatoes (8). The sum of these assigned values gives a score, which is divided by the value for the control to give a value for relative land use intensity.

Relative land use intensity can then be plotted against the TOC values at all depths for the associated fields.

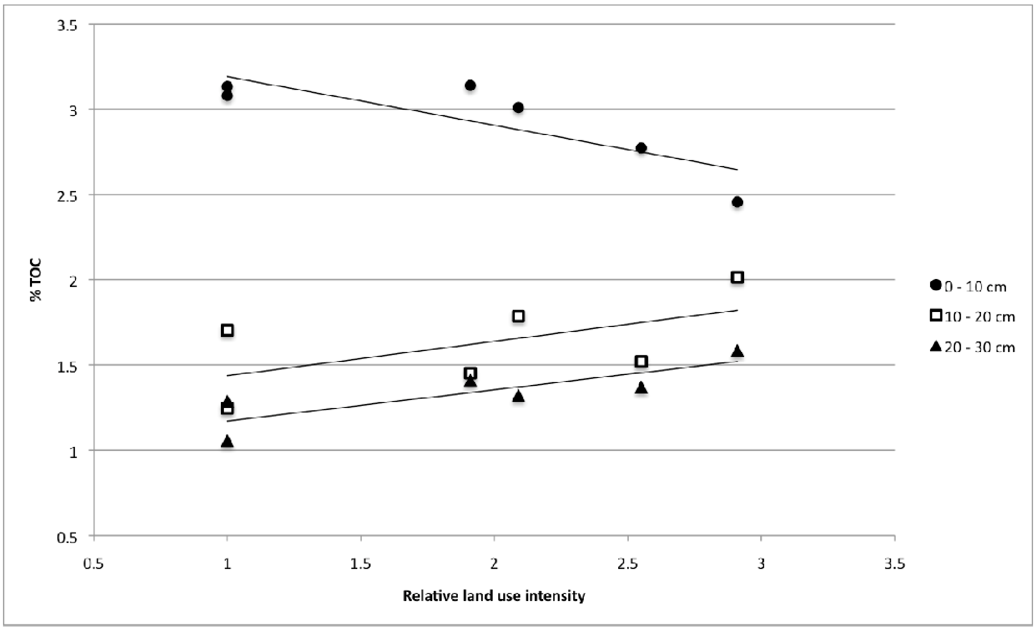

Figure 3. Graph showing relationship between TOC percentage and relative land use intensity for the three sampled depths. Note the inverse relationship in the 10 – 30 cm soil section under increasing land use intensity. This suggests either carbon burial, increased root growth and subsequent carbon deposition, or the accumulation of soluble organic carbon in the more intesive land management practices. Topsoils show the expected decline in soil carbon with increased intensity of use.

In general, the establishment of perennial systems such as lucerne or improved pasture results in increases in soil carbon content (Contant 2001). Since lucerne is a deep-rooted perennial, the high level of carbon in the 10 – 30 cm section could be a function of the long term deposition of carbon to those depths, or mixing by deep tillage.

These interactions discussed above are summarised in Figure 3. Figure 3 shows the trend of TOC content for increasing land use intensity for each depth, regardless of field. As expected and suggested in the relevant literature, the carbon content of the topsoil decreases with increasing land use intensity (Lal 1997). However what is of most importance in this graph is the dynamics of the carbon associated with the soil deeper than 10 cm. This graph shows that an increase in land use intensity, and thus presumably productivity, results in an increase in carbon associated with that soil. This indicates the crucial importance of sampling at depth when assessing carbon stocks or the dynamics of soil carbon associated with changes in land use.

The lack of significant change in TOC content for various land management practices suggests the resilience of these soils to carbon loss. Despite heavy usage over a 10 – 12 year period, TOC levels in soils have changed very little. This is complementary to other studies assessing the effects of agricultural management on Dermosols in Tasmania, which suggest that despite their intense use, these soils are still in good health (Cotching 2002). The resilience of these soils to carbon loss is likely a function of the high clay and silt content of the sampled soils (~70% clay and silt content). Published evidence indicates that one of the principle factors in physical protection of organic matter in soils is its ability to associate with clay and silt particles (Hassink 1997). Therefore, soils with a higher clay and silt content will show a greater resistance to the degradation of organic matter.

Conclusion

The major finding of this research was that the process of intermittent cropping, and the associated increases in the productivity of the soil, resulted in the accumulation of carbon at depths below 10 cm. Although in this research the TOC deficit incurred in the topsoil was not exceeded by the gains made in the mean subsoil levels, this work is suggestive of the potential of subsoils as a strong carbon sink. More research into carbon dynamics at depths below 10 cm could confirm the use of subsoils as a significant carbon sink. If a CPRS is established and agriculture included, this will be a vital avenue of soils research. The challenge for soils scientists is to reliably predict the quantity of carbon that could be sequestered by the implementation of certain agricultural practices. For soils to be included in a CPRS, the action of sequestration and the dynamics of carbon in soils must be defensible and backed up with significant data of relative consistency. This appears to be the major challenge facing the potential of soils to become part of a CPRS.

References

Contant T, Paustian K, Elliot E (2001) Grassland management and conversion into grassland: effects on soil carbon. *Ecological Applications* **11,** 343-355.

Cotching W, Cooper J, Sparrow L, Mccorkell B, Rowley W (2002) Effects of Agricultural management on Dermosols in northern Tasmania. *Australian Journal of Soil Research* **40,** 65-79.

Hassink J (1997) The capacity of soils to preserve organic C and N by their association with clay and silt particles. *Plant and Soil* **191,** 77-87.

Lal R, Kimble J (1997) Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecosystems,* **49,** 243-253.

Leamy ML (1961) Reconnaissance soil map - Interlaken. IN Soils, C.D.O. (Ed. *Division Report.* Adelaide.)

Sparrow L, Cotching W, Cooper J, Rowley W (1999) Attributes of Tasmanian Ferrosols under different agricultural management. *Australian Journal of Soil Research* **37,** 603-22.

Soil morphology adaptations to global warming in arid and semiarid ecosystems

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Abstract

As the aboveground goes, so goes the belowground. Or stated differently, as climate and vegetation change, soil morphology adapts to those changes. Two general categories of soil morphology adaptations are (1) vertical movement of horizons and (2) presence of constituents. Vertical movement of horizons most prominently includes the upward shift of argillic and calcic horizons as climates become drier (increased aridity) and their downward shift when climates become wetter. Presence of constituents includes the accumulation of organic carbon in A horizons during wetter climates and its loss during drier climates, in contrast to soluble salts that accumulate during arid periods but are flushed from the soil during wetter climates. Based on pedological observations during the last century and paleorecords, some soil morphology features are many times more labile than other features, ranging from diurnal soil gas and water dynamics to millennial-scale mineralogical transformations. Soils in arid and semiarid ecosystems cover approximately 46 % of the total ice-free land area and have received much attention because of their vulnerability to desertification. Change in climate, including warming temperatures, can set into motion changes to soil moisture that not only impact soil morphology, but also biotic processes, such as shrub invasion that has feedback loops to root structure, microbial activity, CO_2 fluctuations, and carbonate chemistry. Replacement of grass cover with woody shrubs also increases bare ground that sets into motion positive feedback loops that amplify erosion and favour further shrub advances. Such lateral migrations are, in turn, linked back to soil because the velocity of these migrations is dependent on the nature of soil-geomorphic templates. Because of their vast area and their sensitivity to increased warming, morphological change of arid and semiarid soils may be vast, only exceeded by changes in soils of tundra and boreal forests that experience warming.

Key Words

Arid and semiarid soil change, global warming, desertification, biotic change, pedogenic carbonates

Introduction

Vertical movement and the thickening or thinning of soil horizons is affected by the lateral movement of biomes across the soil surface driven by climate change. The rates at which these changes occur vary widely depending on properties of the soil and properties of the landscape. Soil properties like temperature and the chemistry of the soil atmosphere can vary hourly. Soil organic matter and soluble salt content may vary over a period of decades. Clay mineralogy and dissolution of framework minerals may vary on a time scale of thousands to millions of years (Birkeland 1999). Properties of the landscape that can affect the velocity of lateral biome migration include the physical and chemical properties of the soils as a substrate, as well as the influence of topography. The term *soil-geomorphic template*, has been used to account for the combined influences of soil, topography, and soil parent material on vegetation patterns and biome migration (Monger and Bestelmeyer 2006). Soil is a factor in biotic change because it is the substrate that provides water, nutrients, anchorage for plants, and habitat for burrowing animals. Topography is a factor in biotic change because it influences local microclimate by means of elevation, lateral redistribution of water, and slope orientation. Soil parent material is a factor in biotic change because it provides the lithic inheritance from the geologic landscape that gives rise to soils with different particle size distribution (i.e., available water holding capacity) and nutrient status. Numerous linkages and feedback-loops occur between the soil-geomorphic template, microclimate, vegetation, and animals. A perturbation in any of these factors can steer an ecosystem from one state to another. The integral relationship between the soil-geomorphic template and biotic change is an example of how biological and geological systems are coupled and co-evolve on the long-term (Quaternary landscape evolution) and short-term (human-induced desertification) time scales.

Methods

To quantify lateral movements of arid and semiarid ecosystems and understand the resulting soil changes, various remote sensing, GIS, soil morphology, carbon dioxide fluxes, and isotopes methods are required (Gile *et al.* 1966; Serna *et al.* 2006; Chopping *et al.* 2008; Monger *et al.* 2009).

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Results

Soil organic carbon is a morphology feature that responds to climate change more quickly than other features (Figure 1). Pedogenic carbonate responds less rapidly, but like organic carbon, may have labile and recalcitrant end members not accounted for by measurements of carbonate using standard techniques (Philips *et al.* 1987; Monger *et al.* 1991). Clay content is least affected by climate and has a more gradual increase with time being generated by neoformation during wetter periods and dust accumulation during drier periods.

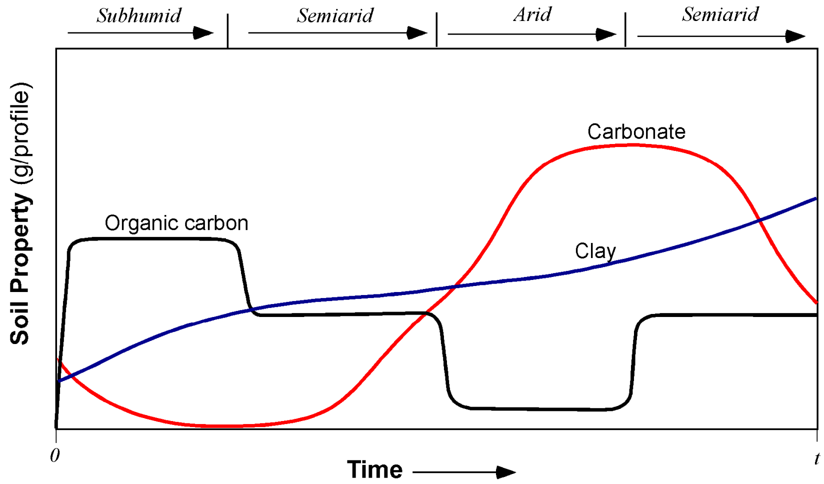

Figure 1. Hypothetical variations of three soil properties with time and climate change. Modified from Birkeland (1999).

Soil morphology changes are also affected by erosion. In many arid and semiarid soils erosion has stripped away the A and B horizons of the soils and exposed underlying calcic horizons. Since the calcic horizons are brought into the shallow, more intense weathering zone of increased biologic activity above the depth where pedogenic carbonate normally forms, the possibility arises that such exhumed carbonates are active sources of CO_2 emissions (Serna *et al.* 2006). To address this possibility, the hypothesis was tested that soils with exhumed calcic horizons will emit more CO_2 than neighboring non-eroded soils by (1) comparing the amount of CO_2 released from the soil types and (2) by measuring the isotopic composition ($\delta^{13}C$) of CO_2. Two years of data revealed that the amount of CO_2 was not statistical different at the $\alpha = 0.05$ level. Moreover, the isotopic analysis of CO_2 did not match the isotopic values of pedogenic carbonate, nor were there any statistical differences ($\alpha = 0.05$) in $\delta^{13}C$ of CO_2 between the eroded versus non-eroded soil types. It was conclude, therefore, that exhumed calcic horizons are not actively emitting CO_2 at a rate significantly greater than adjacent soils, and thus carbon stored in calcic horizons can be considered a recalcitrant reservoir within the decadal timeframe pertinent to carbon sequestration policies.

Deeper wetting fronts in the Pleistocene also affect soil morphology and are probably responsible for vertical, karst-like pipes that cross-cut petrocalcic and calcic horizons. Similarly, carbonate filaments in B horizons overlying petrocalcic and calcic horizons in soils of Pleistocene age are probably the result of an upward shift in the depth of wetting during subsequent drier climates based on depths of carbonates in soils of Holocene age and radiocarbon dates of the carbonate crystals themselves. Other evidence for climatically driven shifts in carbonate depth includes engulfment of argillic horizons by calcic horizons as the depth of wetting shifts upward with increasing aridiy, and micromorphologic evidence of episodic deposition of carbonates, opal, and clay in argillic horizons and duripans.

Lateral movement of biomes can be determined by historical records and paleoenvironmental evidence. Carbon isotopes are particularly useful for understanding biome migration in arid and semiarid climates having C_4 grasslands and C_3 shrublands at multiple scales. (1) At the broadest scale, the *biome scale (hundreds to millions of* km^2*)*, an isotopic record interpreted as C_3 vegetation replacing C_4 grasslands may indicate invading C_3 woody shrubs instead of expanding C_3 forests (a common interpretation). (2) At the *landscape scale (several tens of* m^2 *to hundreds of* km^2*)*, the accuracy of scaling up paleoclimatic interpretations to a regional level is a function of the landform containing the isotopic record. (3) At the *soil profile scale (*cm^2 *to* m^2*)*, soil profiles with multiple generations of carbonate mixed together have a lower-resolution paleoecologic record than stacked soil profiles separated by C horizons. (4) At the *rhizosphere scale (*μm^2 *to* cm^2*)*, carbonate formed on roots lack the 14-17‰ enrichment observed at broader scales, revealing different fractionation processes at different scales. Carbon isotopes also help explain recent bioclimatic migrations. For example, modern studies based on survey records and vegetation reveal that shrub invasion has been greater on the rocky piedmont slopes (bajadas) than in adjacent alluvial flat zones that receive runon water, similar to the patterns in the stratigraphic record. Lateral movement of biomes driven by climate change can also be accelerated by land management. In managed ecosystems, over-grazing, for example, can perturb this system by selective herbivory and seed dispersal, thus reducing ground cover and increasing erosion (Figure 2).

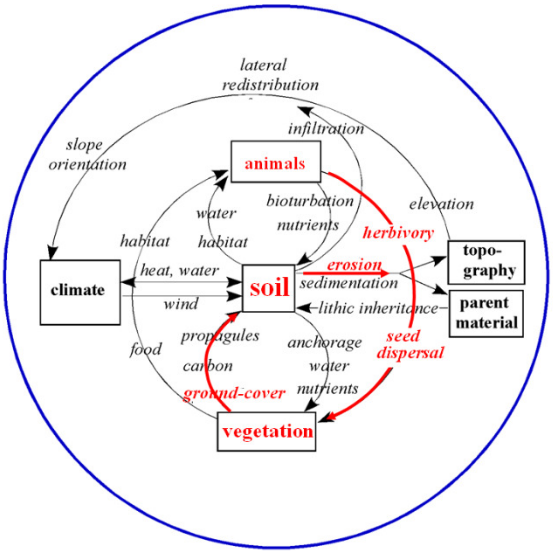

Figure 2. Model showing the links in the soil-geomorphic-biotic change system. Red text and arrows illustrate the paths involved when the system adapts to a perturbation caused by overgrazing. Figure modified from Monger and Bestelmeyer (2006).

Conclusion

Soil morphology, being the product of the five soil forming factors, responds to climatic and ecological changes. As such, it serves as a record of past changes. Some morphological features, however, are more sensitive to aboveground changes than other features. Because soils in arid and semiarid climates are vulnerable to desertification, it is important to understand the feedback loops of these dryland soils to aboveground ecosystems. Of particular importance is how soil-geomorphic templates influence the encroachment of woody shrubs into grasslands because this is the major biome migration occurring across vast areas of the World's arid and semiarid landscapes. These migrations are driven by increased aridity caused by warming, lower amounts of rainfall, and land management. Soil morphology is an integral part of this larger system.

References

Birkeland PW (1999) 'Soils and geomorphology'. 3rd ed. (Oxford University Press: New York).

Chopping M, Su L, Rango A, Martonchik JV, Peters DPC, Laliberte A (2008) Remote sensing of woody shrub cover in desert grasslands using MISR with a geometric-optical canopy reflectance model. *Remote Sensing of Environment* **112**, 19-34.

Gile LH, Hawley JW (1966) Periodic sedimentation and soil formation on an alluvial-fan piedmont in southern New Mexico. *Soil Science Society of America Proceedings* **30**, 261-268.

Monger HC, Bestelmeyer, BT (2006) The soil-geomorphic template and biotic change in arid and semiarid ecosystems. *Journal of Arid Environments* **65**, 207-218.

Monger HC, Daugherty LA, Lindemann WC, Liddell CM (1991) Microbial precipitation of pedogenic calcite. *Geology* **19**,997-1000.

Monger HC, Cole DR, Buck BJ, Gallegos RA (2009) Scale and the isotopic record of C_4 plants in pedogenic carbonate: from the biome to the rhizosphere. *Ecology* **90,** 1498-1511.

Philips SE, Milnes AR, Forster RC (1987) Calcified filaments: An example of biological influences in the formation of calcrete in South Australia. *Australian Journal of Soil Science* **25**,405-428.

Serna-Perez A, Monger HC, Herrick JE, and Murray L (2006) Carbon dioxide emissions from exhumed petrocalcic horizons. *Soil Science Society of America Journal* **70,**795-805.

Sustainable production of grains in Amazonian floodplain

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Abstract
The Amazonian floodplains present high natural fertility and can be used for sustainable production of grains by the local populations of Amazonas. With the objective to evaluate the potential productivity of the floodplain ecosystem, two experiments with maize and cowpea were carried out at the district of Iranduba-AM, Brazil, in a soil classified as Gley Humic. The experimental design of cowpea experiment was a randomized block with twenty treatments consisted by twenty cowpea genotypes. The variables evaluated were flowering, 100 grain weight and yield. The experimental design of the maize experiment was a randomized block with twenty five treatments and two replications. The variables evaluated were plant height, stand, ear length and grain yield at 13% moisture. The data of both experiments were subjected to analysis of variance and treatment means were compared by the Scott Knott test at 5% probability. The genotypes MNC05-832B-234-5, California Black Eye, Vaina Blanca, MNC99-541F-5, MNC99-537-4, MNC99-542F-5 and MNC99-537F-1 can be a good option for the floodplain conditions in the State of Amazonas. In the case of corn, the yield did not show significative differences between the genotypes, but some treatments reached more than 5000 kg/ha.

Key Words
Maize, cowpea, Amazonas, food security

Introduction
The central Amazonian floodplain is composed of an extensive mosaic of wetlands including lakes and seasonally flooded grasslands and forests. These habitats are highly productive and contain a diverse biota (Palha *et al.* 2003). The Amazonian River floodplain (várzeas) belongs to the few areas in central Amazonia with relatively high natural fertility and productivity, because of annual flooding with sediment-rich water add nutrients to the system. Many development planners consider the area to be of high agricultural production potential and of great importance for regional and national economy and development. Inland fishery provides an important part of the animal protein supply of the local population. However, agricultural production is low and does not satisfy the demand of large cities like Manaus, because of the specific ecological conditions of the *várzea*. (Junk 2001). Despite the difficulties of predicting the frequency of flooding, a large portion of food crops are produced in these areas (Smyth 1996). Maize is an essential crop for food security around the world. In Brazil, maize is the second most important grain crop, both in cultivated area and production just after soybean (Stork *et al.* 2009). The cowpea (*Vigna unguiculata* L.) is the main grain legume in the Amazon, where it is grown under subsistence crop rotation or intercropped with cereals. Studies in humid conditions with incorporation of cowpea residue have shown that that legume can be an important source of N for subsequent crops (Smyth *et al.* 1987). Representing nearly 100% of the dry grain yield of all crops grown in the state of Amazonas, the cowpea is cultivated in the floodplains and uplands. Yields vary considerably in both ecosystems, while in the floodplain area the average is around 1000 kg/ha, on upland, the yield rarely exceeds the 300 kg/ha. Due to the high fertility of floodplains and the optimal availability of water, light and heat, it is believed that the yield can be easily (Nogueira 1980). Although several authors have reported on the high fertility of the floodplain, few studies with data from cultures have been reported. This study aimed to evaluate the productivity of maize and cowpea for Amazonas River floodplain conditions in the district of Iranduba, Amazonas State, Brazil.

Methods
Local characteristics
Two experiments were carried out at the Caldeirão Experimental Station of Embrapa Western Amazon, in the district of Iranduba - AM, Brazil, located at coordinates 03°15' S 60°13' W. The altitude is 30 m and the soil is a Gley Humic, considered to have high fertility (Table 1). The climate according Köppen classification is Ami with average annual temperature of 27° C, average annual rainfall of 2015 mm and relative humidity around 88%. The experiments aim to evaluate two species with potential use by local populations: cowpea and maize.

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Cowpea

The experimental design of cowpea experiment was a randomized block with twenty treatments and four replications. The treatments consisted of twenty cowpea genotypes: MNC99-537F-1, MNC99-537F-4, MNC99-541F-5, MNC99-541F-8, MNC99-542F-5, MNC00-553D-8-1 -2-2 (BRS Novaera), MNC00-553D-8-1-2-3, MNC99-557F-2, MNC01-627F-14-2, MNC01-627F-14-5, MNC03-720C-20, MNC03 -720C-31, MNC03-731C-21, MNC03-732C-5, CTX-5058-09C, MNC05-784B-32-2, MNC05-832B-234-5, Vaina Blanca, California Black Eye and BRS Guariba. The soil was tillage mechanically with one plowing and two harrowing. The sowing was done manually on 26/08/2008, leaving two plants per hole after thinning. The variables evaluated were flowering, 100 grain weight and yield. The data were subjected to analysis of variance and treatment means were compared by Scott Knott test at 5% probability. Considering that the state average yield is low, it is estimated that at around 350 kg/ha, the genotypes MNC05-832B-234-5, California Black Eye, Vaina Blanca, MNC99-541F-5, MNC99-537-4, MNC99-542F-5 and MNC99-537F-1 can be a good option for the floodplain conditions in the State of Amazonas.

Maize

The experimental design of maize experiment was a randomized block with twenty five treatments and two replications. The treatments consisted of twenty five maize genotypes: Sintetic 256 L, VSL FB 33, VSL BS 42 C 60, BRS 2020, BRS Caimbé, Sintetic 1 X, BRS 4103, Sintetic RxS Spod, BRS Eldorado, Sol da Manhã, MC 20, BR 473, BR 106, Sint Pro VA, BR 106 Q, BRS 2022, AL BDE/40, AL 30/40, H25ALTA, AL Piratininga, UFV 8, BIO 4, AEO 2008, UFV 7 e Sint. Multipla TL. The sowing was done manually on 19/11/2008, at 0,8m of spacing and leaving five plants per meter after thinning. The variables evaluated were plant height, stand, ear length and grain yield at 13% moisture. The data were subjected to analysis of variance and treatment means were compared by Scott Knott test at 5% probability. Considering that the state average yield of cowpea is low, it is estimated that at around 350 kg/ha, the genotypes can be a good option for the floodplain conditions in the State of Amazonas.

Results

Soil

The chemical results of soil analysis are in the Table 1. The soil chemical analysis indicates high levels of phosphorus, calcium and magnesium, as well as high base saturation and low levels of exchangeable aluminium. According to these results, it can be inferred that the soil has the ability, at least chemically, support crops such as maize and cowpea.

Table 1. results of chemical analysis of soil taken at depth 0-20cm.

Depth	pH	O.M.	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}	Al	H+Al	SB	t	T	V	m
(cm)		g /kg	(--- mg/dm^3 ---)		(---------------------- cmol$_c$/dm^3 -----------------------)							------- % -----	
0-20	5,39	13,47	67	75	9,27	2,25	0,44	2,05	11,83	12,27	13,88	85,26	3,58

O.M.=organic matter; SB=sum of basis; t= effective cation exchange capacity; T= cation exchange capacity at 7,0 pH; V=basis saturation; m=Aluminiun saturation.

Cowpea

In Table 2 are the data for the cowpea genotypes evaluated. All treatment results are significant by F test and Scott Knott at 5% probability. The yield of the test ranged from 538 to 1447 kg/ha and the genotypes with higher yields were MNC05-832B-234-5, California Black Eye, Vaina Blanca, MNC99-541F-5, MNC99-537-4, MNC99-542F-5 and MNC99-537F-1 with yield of 1447, 1.406, 1229, 1212, 1211, 1207 and 1205 kg/ha, respectively. The genotypes MNC 01-627F-14-2, MNC05-784B-38-2, MNC01-627-14-5, CTX-5058-09C and MNC03-732C-5 presented the lowest yields with 801, 774, 757 and 538 kg/ha, respectively. The genotype MNC05-832B-234-5 showed good productivity, relative precocity, average of 45.25 days to flowering and good 100 grains weight (19.92 g). These attributes are of great importance for the choice of variety to be sown early in the meadow ecosystem, the growing season is short and the earlier the variety, the greater the possibility of growing another culture and enjoy better availability of the area and the residual effect promoted by the cultivation of legumes. BRS Guariba e BRS Novaera produced 1103 and 954 kg/ha, respectively, with flowering period of 49 days and 100 grain weight of 17.20 and 16.57 g. Thus, considering that the state average yield is low, it is estimated that at around 350 kg/ha, the genotypes MNC05-832B-234-5, California Black Eye, Vaina Blanca, MNC99-541F-5, MNC99-537-4, MNC99-542F-5 and MNC99-537F-1 can be a good option for the floodplain conditions in the State of Amazonas.

Table 2. Data of commercial subclass, yield, 100 grains weight and flowering of cowpea genotypes evaluated in the Amazon River floodplain at Iranduba, AM, Brazil (2008).

Cowpea Genotype	Comercial Subclass	Yield* (kg/ha)		100 grain weight* (g)		Flowering* (days)	
MNC05-832B-234-5	White	1.447	a	19,92	a	45,25	c
California Black Eye	Black Eye	1.406	a	15,68	b	45,25	c
VAINA BLANCA	Black Eye	1.229	a	16,24	b	45,25	c
MNC99-541F-5	White	1.212	a	15,10	c	49,00	b
MNC99-537F-4	White	1.211	a	17,58	b	49,00	b
MNC99-542F-5	White	1.207	a	17,87	b	49,00	b
MNC99-537F-1	White	1.205	a	17,64	b	49,00	b
BRS NOVAERA	White	1.103	b	17,20	b	49,00	b
MNC 03-720C-20	White	1.091	b	16,86	b	49,00	b
MNC99-541F-8	White	1.073	b	14,93	c	51,75	a
MNC03-731C-21	White	999	b	18,80	b	51,25	a
BRS GUARIBA	White	954	b	16,57	b	49,00	b
MNC00-553D-8-1-2-3	White	930	b	19,22	a	49,50	b
MNC99-557F-2	White	882	b	17,31	b	46,50	c
MNC03-720C-31	White	871	b	18,39	a	47,75	c
MNC01-627F-14-2	White	840	b	15,61	b	47,75	c
MNC05-784B-38-2	White	801	c	18,88	a	50,00	b
MNC01-627-14-5	White	774	c	15,04	c	49,00	b
TVx-5058-09C	White	757	c	12,66	c	52,25	a
MNC03-732C-5	White	538	c	17,54	b	51,25	a
** V.C. (%)		21,61		17,08		4,15	

* Values followed of the same letter did not differ by the Scott Knott test at 5% of probability.
** V.C. = variation coefficient.

Table 3. Data of yield, stand, height and ear length of maize genotypes evaluated in the Amazon River floodplain at Iranduba, AM, Brazil -2008.

Genotype	Yield* (kg/ ha)	Stand** (plants/ ha)		Height** (cm)		Ear Length* (cm)
BRS 2020	5612	59375	a	2,03	a	11,51
H25ALTA	5105	61718	a	1,95	a	13,97
Sintetic RxS Spod	4957	33593	c	1,81	b	16,86
BRS Eldorado	4805	54687	a	2,27	a	14,75
VSL FB 33	4803	59375	a	2,04	a	13,98
Sintetic MULTIPLA TL	4780	55468	a	2,04	a	13,87
VSL BS 42 C 60	4647	55468	a	1,80	b	14,91
Sol da Manhã	4640	47656	b	2,24	a	13,87
BRS 2022	4536	56250	a	1,76	b	13,20
UFV 7	4501	60937	a	2,02	a	15,59
Sintetic 1 X	4495	57812	a	2,04	a	14,94
BRS 4103	4451	53906	a	1,85	b	15,62
AL Piratininga	4256	58593	a	2,15	a	14,83
BRS Caimbé	4199	53906	a	2,15	a	15,64
AL BDE/40	4155	59375	a	1,98	a	14,39
BIO 4	3978	52343	a	2,04	a	16,56
Sintetic 256 L	3899	60937	a	1,99	a	15,09
BR 106 Q	3809	47656	b	2,18	a	15,93
AL 30/40	3699	56250	a	1,98	a	12,68
BR 106	3667	53125	a	2,18	a	13,31
Sint Pro VA	3421	55468	a	1,65	b	13,64
BR 473	3394	53906	a	2,25	a	14,76
UFV 8	3213	54687	a	1,57	b	10,59
MC 20	3140	59375	a	2,02	a	15,34
AEO 2008	2851	39062	c	2,13	a	14,46
Variation Coefficient (%)	24,73	6,89		7,84		14,58

* No significance in the F test (P>0,01).
** Values followed by the same letter did not differ by the Scott Knott test at 5% of probability.

Maize

There was significance effects for the F test for height and stand, however, for the variables yield and ear corn length, there was no significance for this test (Table 3). The number of plants/ha ranged from 61,718 to 33,593, indicating that some genotypes and some plants died before completing the cycle, and are not adapted well to the climate. The genotypes AEO 2008, Sint RXS Sprode had the lowest numbers of plants per ha, with 39,062 and 33,593 plants/ha, respectively. Plant height ranged from 1.57 m to 2.27 m with an average of 2.01 cm indicating good development based on the overall mean. The shorter plants were UFV 8, Sint Pro VA, BRS 4103, BRS 2022, VSL BS 42 C 60 and Synthetic RXS Sprode. Yield ranged from 2851 to 5612 kg/ha, values higher than the regional average. Although there was no difference in the F test, these figures indicate that there are genotypes with good yield that can be recommended for cultivation in the floodplains areas.

Conclusion

Cowpea and maize represent a good alternative for food production and can be cultivated in a sustainable way in the Amazonian Floodplains. The cowpea can be cultivated in the Amazonian Floodplains without use of liming or fertilizer to achieve high yields and maize needs low amounts of nitrogen to achieve good yields in this ecosystem.

References

Junk WJ (1989) Sustainable use of the Amazon River floodplain: problems and possibilities. *Aquatic Ecosystem Health & Management* **4**, 225-233.

Nogueira OL (1981). ‘Cultura do feijão-caupi no Estado do Amazonas’. (EMBRAPA-UEPAE: Manaus).

Palha WSN, Novo EMLM, Barbosa CCF, Carvalho AS, Forsberg BR, Melack J (2003). Mapeamento e estimativa de cobertura da terra e de habitats aquáticos de várzea, na região da amazônia central utilizando imagens TM/LANDSAT-5 E SAR/JERS-1. In ‘Proceedings of the 11th Simpósio Brasileiro de Sensoriamento Remoto, Belo Horizonte, Minas Gerais’. (Eds Epiphanio JCN, Banon GJF). pp. 2853-2860 (INPE: São José dos Campos).

Smyth JT, Cravo MS, Bastos JB (1987) Soil nutrient dynamics and fertility management for sustained crop production on Oxisols in the Brazilian Amazon. In ‘Tropsoils Technical Report 1985-1986’. pp. 88-94.

Smyth TJ (1996). Manejo da fertilidade do solo para produção sustentada de cultivos na Amazônia. In ‘O solo nos grandes domínios morfoclimáticos do Brasil e o desenvolvimento sustentado’. (Soc. Bras. Ci. Solo/ UFV: Viçosa).

Storck L, Cargnelutti Filho A, Lopes SJ, Toebe M, Silveira TR. (2009) Duração do subperíodo semeadura-florescimento, crescimento e produtividade de grãos de milho em condições climáticas contrastantes. *Revista Brasileira de Milho e Sorgo* **8**, 27-399.

The impact of free-air CO_2 enrichment (FACE) on N leaching from paddy soil

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Abstract
China FACE (Free-air Carbon Dioxide Enrichment) system was used to study the effects of elevated CO_2 on N leaching from paddy soil in the rice season. The results showed that elevated CO_2 had different effects on NH_4^+-N concentration in the till-layer soil solution at different stages. FACE condition increased NO_3^--N concentration in soil solution at 5 cm, 15 cm, 30 cm, 60 cm and 90 cm depth, by 46.5%, 36.8%, 23.3%, 103.7% (P<0.01) and 42.7% (P<0.05), respectively. Elevated atmospheric CO_2 can increase N loss via leaching from paddy soil. It is indicated that the amount of N in paddy soil will decrease faster under elevated atmospheric CO_2 due to larger N loss via leaching and uptake by rice plant, and there will need to be higher N inputs to maintain N balance in paddy soils in the future.

Key Words
Elevated CO_2; nitrogen; leaching; rice season; paddy soil

Introduction
Atmospheric [CO_2] has risen from approximately 280 mmol/mol in pre-industrial times to 387 mmol/mol in 2009 (IPCC 2001; IPCC 2009). CO_2 enrichment usually stimulates crop growth and yield (Rogers 1993). Elevated [CO_2] can reduce carbon mineralization in soil, and increase the amount of DIC (dissolved inorganic carbon) in the leachate while it has no significant effect on the amount of DOC (dissolved organic carbon) in the leachate (Marhan 2008). Elevated CO_2 increases nitrogen fixation and decreases soil nitrogen mineralization in Florida scrub oak (Hungate 1999). So the responses of different ecosystems to elevated [CO_2] in atmosphere are different. Rice (Oryza sativa L.) is one of the most important plants in the world and the first staple food in Asia, providing nutrition to a large proportion of the world's population. The response of rice ecosystem to atmospheric [CO_2] enrichment in China is a research hotspot. There have been many studies involving rice yield, elements in plant, soil respiration and soil microflora under elevated [CO_2](Xu 2006; Yang 2008; Liu 2008). The research about nitrogen dynamics in paddy soils under elevated [CO_2] is relatively lacking. It is very important to know the response of nitrogen dynamics to elevated [CO_2]. On the one hand, nitrogen is one of the most important elements to rice plant growth, yield as well as quality. On the other hand, nitrogen via runoff and leaching can enter into the water bodies, and increase the water eutrophication and groundwater pollution. Using FACE (Free-air Carbon Dioxide Enrichment) experiment, we studied nitrogen leaching loss from paddy soil under atmospheric [CO_2] enrichment by determining the concentrations of NH_4^+-N and NO_3^--N at different soil depth. Our objective is to understand nitrogen geochemical behaviour under future climates and provide theoretical support to nitrogen fertilizer application conditions in paddy fields.

Materials and methods
Experiment site description and meteorology
The FACE experimental system of rice-wheat rotation was established in Xiaoji town, Yangzhou city, Jiangsu Province, China (119°42'0''E, 32°35'5''N). The soil is Shajiang Aquic Cambosols with a sandy-loamy texture. Relevant soil properties are as follows: soil organic C (SOC) 18.4 g/kg, total N 1.45 g/kg, total P 0.63 g/kg, total K 14.0 g/kg, available P 10.1 mg/kg, available K 70.5 mg/kg, and pH(H_2O) 7.2. The station, 5 m above sea level in elevation, sits in the subtropical marine climatic zone with mean annual precipitation being 980 mm, annual evaporation 1100 mm, annual mean temperature 14.9 ^oC, annual sunshine hours 2100 h and frost free period 220 days.

Face system
The FACE system has six octagonal plots located in different paddies having similar soils and agronomic histories. Three plots were randomly allocated for the elevated CO_2 treatments (hereinafter called FACE plots) and the other three for the ambient treatments (hereinafter referred to as ambient plots). In the FACE plots, the plants were grown within 14-m-diameter 'rings' which sprayed pure CO_2 both day and night throughout the growing season except for a few days during transplantation towards the plot centre from eight peripheral

emission tubes (5mlong) located about 0.5m above the canopy (Okada, 2001). The ambient plots had no ring structures, and plants were grown under ambient [CO_2] without ring structures. The target [CO_2] in the FACE plots throughout the rice growth season was controlled to 200 mmol/mol above that of ambient by computer system platform. Adjacent plots were buffered to avoid treatment cross-over. Details of the design, rationale, operation, and performance of the CO_2 exposure system used in this study can be found in Okada (2001) and Liu (2002).

Crop cultivation
A japonica cv. Wuxiangging 14 was tested in the experiment. Standard cultivation practices as commonly performed in the area were followed in all experimental plots. Rice seeds were sown under ambient [CO_2] conditions on 18 May. On 14 June 2007, the seedlings were manually transplanted at a density of three seedlings per hill into the FACE and ambient plots. Spacing of the hills was 16.7 cm × 25 cm (equivalent to 24 hills/m^2). The amount of nitrogen (N) was 25 g N/m^2, which was supplied as urea (N, 46%) and compound chemical fertilizer (N:P_2O_5:K_2O = 15:15:15,%). Phosphorous (P) and potassium (K) fertilizers were applied as compound fertilizer at rates of 7 g P_2O_5/m^2 and 7 g K_2O/m^2, respectively. N was applied as a basal dressing 1 day prior to transplanting and as side dressing at early-tillering on 21 June (60% of the total) and at panicle initiation (PI) on 28 July (40%),while P or K was both applied as basal dressing 1 day prior to transplanting.

Soil solution sampling and measurements
On 18 June 2007, soil solution samplers (RHIZON SMS-MOM, Netherlands Eijkelkamp Agrisearch Equipment) were inserted at 5cm, 15cm, 30 cm, 60 cm and 90 cm depths. There are 2 replicates at same soil depth in each plot. The soil solution at different soil depths was sampled on 30 June, 22 July, 15 August and 10 September. NH_4^+-N and NO_3^--N in soil solution samples were measured colorimetrically by the indophenol blue method and ultraviolet spectrophotometry (Lu 2000), respectively.

Statistical analysis
Data were analyzed with the statistical package SPSS15.0 and EXCEL2007 for Windows.

Results

NH_4^+-N concentration in soil solution
Due to NH_4^+ -N concentrations in soil solution at 30 cm, 60 cm and 90 cm depths on 30 June were very low (data not shown), the NH_4^+ -N concentrations in soil solution at 30cm, 60cm and 90cm depths on 22 July, 15 August and 10 September were not determined. Figure 1 show dynamics of NH_4^+ -N concentrations in soil solution at 5cm and 15cm depths during the rice season. With rice growing, change of NH_4^+-N concentration in soil solution at 5cm depth in FACE treatment had the same trend with that in ambient treatment (Figure 1a). There was significant difference (P<0.01) between different stages (Table 1). The NH_4^+-N concentration in soil solution at 5cm depth in FACE treatment on 30 June was 105.7% (P>0.05) higher than that of ambient treatment, while 43.8% (P<0.05) lower than that of ambient treatment on 15 August.

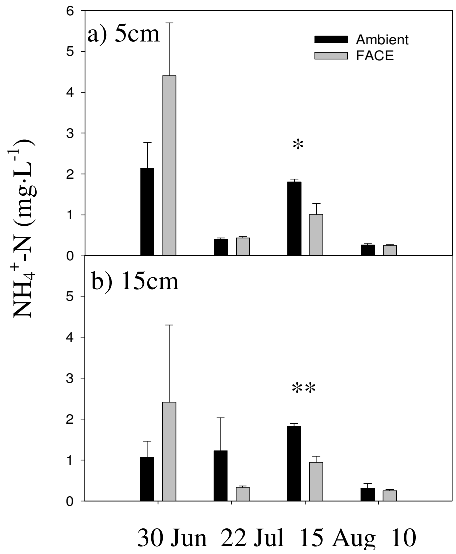

Figure 1. Effect of elevated CO_2 on NH_4^+-N concentration in soil solution at different tillaged-layer soil depths.

Table 1. F-values of a two-way factorial ANOVA on NH_4^+-N concentration in soil solution at different depths.

	5 cm	15 cm
CO_2	0.840(0.376)	0.051(0.824)
Stage	11.297(0.001)	1.298(0.312)
CO_2* Stage	2.469(0.108)	0.948(0.442)

Note: P values are in the parentheses.

The change of NH_4^+-N concentration in soil solution at 15cm depth in FACE treatment had the same trend with that at 5cm depth (Figure 1a, b). The trend of NH_4^+-N concentration in soil solution at 15cm depth in ambient treatment was different. In ambient treatment, the NH_4^+-N concentration in soil solution at 15cm depth on 22 July was slightly higher than that on 30 June, while in FACE treatment, that on 22 July was lower than that on 30 June. Unlike 5cm depth, there was no significant difference at 15cm depth between different stages. The NH_4^+-N concentration in soil solution at 15cm depth in FACE treatment on 30 June was 125.4% (P>0.05) higher than that of ambient treatment, while 48.5% (P<0.01) lower than that of ambient treatment on 15 August (Table 1). Although the effects of elevated [CO_2] on NH_4^+-N concentration in soil solution at 5 cm and 15cm depth were not significant, from the whole growth period, elevated [CO_2] had the trend of increasing NH_4^+-N concentration in soil solution at 5 cm and 15cm depth at early stage (on 30 June), while decreased that at later stage (especially on 15 August).

NO_3^--N concentration in soil solution

NO_3^--N concentration in soil solution at 5cm depth in both FACE and ambient treatment decreased with rice growing, while that at 15cm depth increased (Figure 2 a, b). There was no significant difference between different stages due to large variation between replicates (Table 2). The NO_3^--N concentration in soil solution in FACE treatment was 39.1%, 61.0%, 68.8% and 18.9% (5cm) and 6.4%, 24.0%, 34.9% and 68.3% (15cm) higher than that of ambient treatment on 30 June, 22 July, 15 August and 10 September, respectively. NO_3^--N concentration in soil solution at same stage was decreased with higher depth (Table 2). NO_3^--N concentration in soil solution at different depths during different stages in FACE treatment was higher than that in ambient treatment except at 30cm depth on 30 June and 15 August. NO_3^--N concentrations in soil solution in FACE treatment were almost same with ambient treatment at 60 cm and 90 cm depths on 30 June.

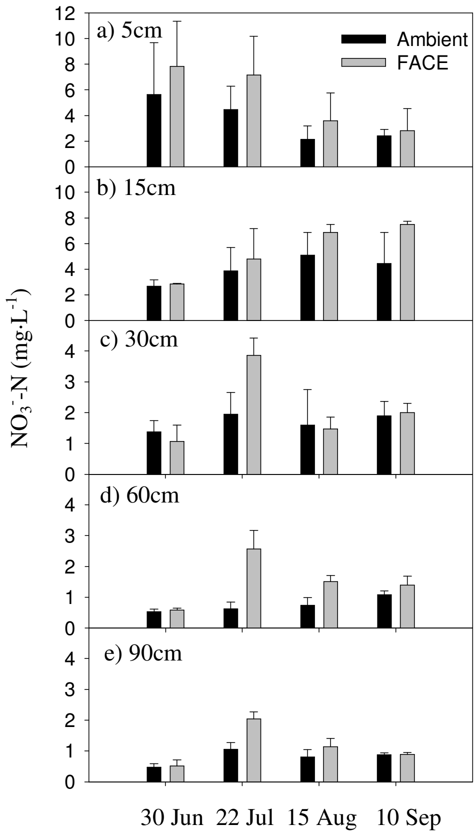

Figure 2. Effect of elevated CO_2 on NH_4^+-N concentration in soil solution at different depths.

Table 2. F-values of a two-way factorial ANOVA on NO_3^--N concentration in soil solution at different depths.

	5 cm	15 cm	30 cm	60 cm	90 cm
CO_2	0.220(0.646)	0.209(0.654)	0.785(0.391)	16.006(0.001)	6.569(0.021)
Stage	0.788(0.519)	1.870(0.175)	3.356(0.050)	5.056(0.012)	10.870(0.000)
CO_2* Stage	0.253(0.858)	1.057(0.395)	1.560(0.243)	4.798(0.014)	2.894(0.068)

Note: P values are in the parentheses.

NO_3^--N concentrations in soil solution in FACE treatment were 98%, 311.1% (P<0.05) and 93.4% (P<0.05) higher than ambient treatment at 30 cm, 60 cm and 90 cm depths on 22 July. From the view of the whole rice growth period, NO_3^--N concentrations in soil solution in FACE treatment were 23.3%, 103.7% (P<0.01) and 42.7% (P<0.05) higher than ambient treatment at 30 cm, 60 cm and 90 cm depths.

Conclusion

Elevated CO_2 had different effects on NH_4^+-N concentration in tillaged-layer soil solution at different stages. FACE condition increased NO_3^--N concentration in soil solution at 5cm, 15cm, 30cm, 60cm and 90cm depth, with 46.5%, 36.8%, 23.3%, 103.7% (P<0.01) and 42.7% (P<0.05), respectively. The results indicate that N loss via leaching from paddy soil could be larger, and there will need more N inputs to maintain N balance in paddy soil in the future.

References

Hungate BA, Dijkstra P, Johnson DW *et al.* (1999) Elevated CO_2 increases nitrogen fixation and decreases soil nitrogen mineralization in Florida scrub oak. *Global Change Biology* **5**, 781-789.

Intergovernmental Panel on Climate Change (IPCC) (2001) IPCC Third Assessment Report-Climate Change The Scientific Basis Technical Summary, Geneva.

Intergovernmental Panel on Climate Change (IPCC) (2009) IPCC Report in Climate Conference in Copenhagen. 6-18 December 2009.

Liu G, Han Y, Zhu J G *et al*. (2002) Rice-wheat rotational FACE platform. I. System construct and control. *Chinese Journal of Applied Ecology* **13**, 1253–1258 (in Chinese).

Liu HJ, Yang LX, Wang YL *et al.* (2008) Yield formation of CO_2-enriched hybrid rice cultivar Shanyou 63 under fully open-air field conditions. *Field Crops Research* **108**, 93–100

Lu RK (2000) 'Analysis Method of Soil Agricultural Chemistry'. (China Agricultural Science and Technology Press: Beijing) (in Chinese)

Marhan S, Derain D, Erbs M *et al.* (2008) Soil organic matter mineralization and residue decomposition of spring wheat grown under elevated CO_2 atmosphere. *Agriculture Ecosystems & Environment* **123**, 63-68.

Okada M, Liffering M, Nakamura H *et al.* (2001) Free air CO_2 enrichment (FACE) with pure CO_2 injection: rice FACE system design and performance. *New Phytologist* **150**, 251–260.

Rogers HH, Dahlman RC (1993). Crop responses to CO_2 enrichment. *Plant Ecology* **104/105**, 117-131.

Xu ZJ, Zheng XH, Wang YS *et al.* (2006) Effect of free-air atmospheric CO_2 enrichment on dark respiration of rice plants (Oryza sativa L.) *Agriculture, Ecosystems and Environment* **115**, 105–112.

Yang LX, Wang YL, Kobayashi K *et al*. (2008) Seasonal changes in the effects of free-air CO_2 enrichment (FACE) on growth, morphology and physiology of rice root at three levels of nitrogen fertilization. *Global Change Biology* **14**, 1844-1853.

The U.S. national cooperative soil characterization database

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Abstract
The National Cooperative Soil Survey (NCSS) is a partnership of federal, state, county, and private entities with the common goal of producing and maintaining a useful soil survey of public and private lands in the USA. Soil characterization data have been analysed by the cooperative laboratories using common, standard methods. The data have been used to support soil survey including assigning classification, estimating soil properties for map unit components, and developing predictions of soil behaviour. These data have been published in printed reports and electronic files and databases. Current demands to utilize the data for validating soil properties, evaluating soil variability, and improving applications are difficult with the data in their current forms. Aggregating the soil characterization data from various sources will improve the ability to meet these demands.

The measured characterization data for 36 pedons samples as the Miami soil series showed a significant difference between these data for clay content and soil organic-carbon content. Estimated and measured values for cation exchange capacity (CEC, pH 7) are comparable.

Key Words
Characterization data, Miami, soil organic carbon, clay, CEC, SSURGO

Introduction

Soil characterization data are essential to a strong soil survey program. As the soil survey program progresses, there is greater demand for evaluation of horizon properties from multiple pedons to evaluate variability, statistical confidence and to develop new and more reliable interpretations. A complete inventory of available data is needed to ensure maximum data collection efficiency.

The United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) Soil Survey Laboratory and university laboratories associated with the NCSS have measured horizon properties using common, standard methods. These data have been gathered for more than 50 years but have been published independently by each laboratory.

Because these data are difficult to access, a program was initiated with the objective of consolidating soil characterization data and associated soil profile descriptions from various laboratories into a single easily accessible and searchable database. The database is available online at http://ssldata.nrcs.usda.gov/. A secondary objective of this paper is to illustrate the utility of the consolidated database by comparing estimated properties to measured data for the Miami soil that has been analysed by several laboratories.

Methods

A database was developed to store the analytical results from various sources. The sample preparation techniques, analytical methods, instrument utilized, size fractions analyzed, and the reporting basis were identified and catalogued for each measurement. The sampling site, pedon, horizons, and associated information were also stored. The associated morphological descriptions were entered in the National Soil Information System (NASIS) and appropriate links between the description and analytical data established. Conversion routines were written as needed to map and convert existing electronic files and databases to a common database. Data entry routines were developed for information stored in paper archives (Fig.1).

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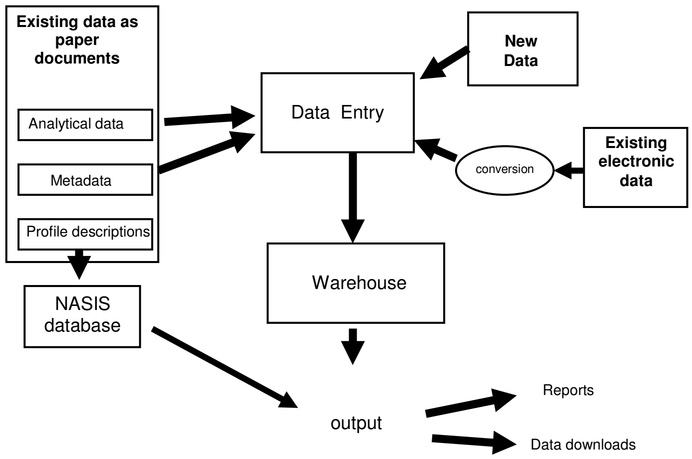

Figure 1. Soil characterization data flow.

The Miami soil series is classified as a member of the family of fine-loamy, mixed, active, mesic Oxyaquic Hapludalfs (Soil Survey Staff, 1999). These soils formed in a thin mantle of loess over till. Approximated 500,000 hectares have been identified and mapped in the United States. Cultivation of commodity crops, such as corn and soybeans, is the primary use of the soil. The soils were analysed by the USDA-NRCS, the University of Illinois, Purdue University, and the Ohio State University soil characterization laboratories at 69 different sites. The data were collected between 1954 and 1990. Particle-size distribution and CEC, pH 7 were measured using standard NCSS methods (Burt, 2004). Soil organic carbon content was measured by the NCSS Walkley-Black method. Estimated soil properties were obtained from the Soil Survey Geographic (SSURGO) Database (Soil Survey Staff, 2009). The estimated soil properties are reported as the representative (RV), high, and low value. The RV value is not defined statistically as the median or mean. The SSURGO spatial data were also used to determine if the sampled sites correlated as the Miami series were coincidentally located in a mapped polygon of the same name. The U.S. General Soil Map (STATSGO2), (Soil Survey Staff, 2009) was used to illustrate the geospatial distribution of the Miami series. The Miami polygons were selected if the Miami components comprised more than 20 percent of the composition in the map unit.

Results

The sampled sites are distributed in Illinois, Indiana, Michigan, and Ohio. Figure 2 shows the geospatial relation of the sampled sites to the geospatial distribution of the mapped Miami series. The geospatial distribution appears to be represented by the sampled sites except for those located in Michigan. Only 36 pedon locations were coincident with the Miami polygons. Measured characterization data from these 36 sites were compared to the estimated soil properties.

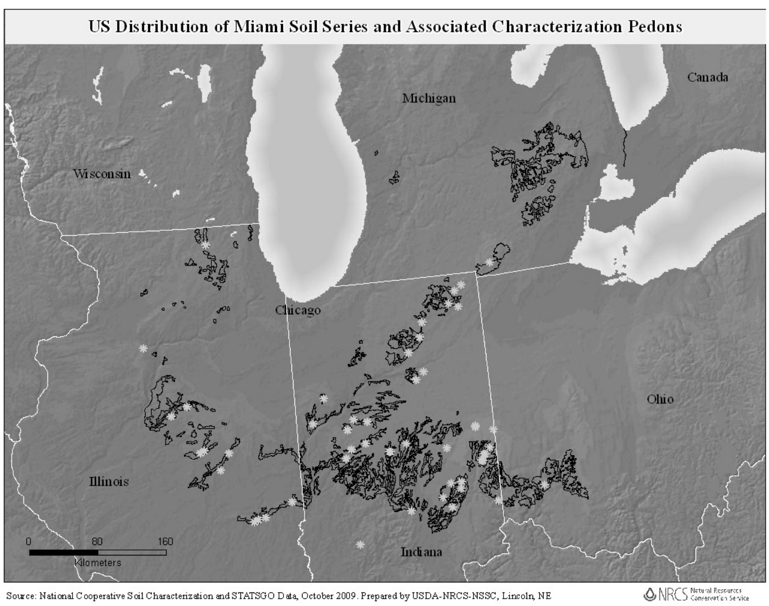

Figure 2. Geospatial distribution of Miami soil series.

The soil properties were partitioned into Ap horizons with no depth greater than 25 cm and Bt horizons with no depth greater than 1 m. These partitions represent the diagnostic surface (ochric epipedon) and subsurface horizons (argillic horizon) and include the particle-size control section. Descriptive statistics were calculated for the measured and estimated soil properties for each partition (Table 1). The soil property observations for each horizon are not available from every site, and these pedons were omitted from the analyses. Estimated CEC values were not available for the low and high estimates. There was no significant difference between measurements from the 4 laboratories for the selected properties therefore the results were combined for comparison with the estimated soil property data. The RV value is used to compare to the measured property mean even though the RV value does not statistically represent the mean of the estimated soil property.

Significant differences were observed between measured and estimated values for the clay content and soil organic carbon content (SOC) for the Ap and Bt horizons. The percent measured and estimated clay contents are both within the fine-loamy particle-size class. There were no significant differences observed between measured and estimated CEC. Potential sources of the differences in clay and SOC include: 1) estimated soil properties were assigned when an insufficient number of measured values were available to evaluate and underpin the values; 2) the selected soils were not current in their correlation to the Miami series; or 3) land use or agricultural management differs between estimated and measured values.

Table 1. Descriptive statistics of selected measured and estimated soil properties.

Combined Characterization Data	Clay %		CEC – pH 7 cmol(+)/kg		SOC %	
	Ap	Bt	Ap	Bt	Ap	Bt
Mean	18.98	30.37	13.33	15.85	1.22	0.46
Median	18.90	30.40	13.90	15.80	1.09	0.45
Standard Error	0.81	0.84	0.63	0.62	0.10	0.02
Minimum	12.40	21.30	10.40	7.20	0.81	0.89
Maximum	25.80	42.30	15.00	19.60	3.12	1.11
n	21	35	7	13	24	55
25th percentile	16.90	27.25	12.50	14.00	0.94	0.35
75th percentile	21.75	33.60	14.50	17.30	1.22	0.54
SSURGO Data						
Mean of RV	22.88	26.69	13.61	15.61	0.80	0.33
Standard Error	0.66	0.16	0.33	0.22	0.02	0.06
n	125	1380	125	1380	125	1380
Mean low	17.77	21.64			0.45	0.20
Mean high	28.92	31.47			1.19	0.46
Significant difference between measured and estimated value (α=.05)	*	*			*	*

Conclusion

The estimated and measured soil properties were compared for the Miami series. The number of available measured soil properties was increased by including values from several NCSS soil characterization laboratories. Based on this one example, significant differences exist between measured and estimated soil properties for the Miami series. There remain several tasks to fully utilize the measured soil data. These tasks include 1) assigning the sample pedons to the appropriate representative soils; 2) verifying the spatial location and associated map unit polygon; and 3) evaluating the estimated soil properties and updating them as needed. The aggregation of soil characterization data from all sources improves the reliability and population of estimated soil properties in a soil survey database. The quality of the aggregated data is highest when known standard methodologies were used.

References

Burt R (Eds.) (2004) Soil survey laboratory methods manual: soil survey investigations report No. 42 Version 4.0. Nebraska: United States Department of Agriculture, Natural Resources Conservation Service.

National Cooperative Soil Characterization Database. Available online at http://ssldata.nrcs.usda.gov/ accessed 7/24/2009.

Soil Survey Staff (1999) Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, 2nd ed. U.S. Dept. Agric. Handbook 436, U.S. Govt. Printing Office, Washington, DC.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available online at http://soildatamart.nrcs.usda.gov accessed 9/13/2009.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. U.S. General Soil Map (STATSGO2). Available online at http://soildatamart.nrcs.usda.gov accessed 9/13/2009.

Evaluating the amount of carbonic greenhouse gasses (GHGes) emission from rice paddies

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Abstract
Global temperature change is one of the most important issues of GHGes emission. A scientific consensus is forming that human activities including modern agriculture by increasing the emission of GHGes may play a key role in elevating the global temperatures. This study was conducted to evaluate the amount of three important carbonic GHGes emission from rice paddies. Carbonic GHGes emission for 3 kinds of rice cultivation in one field were measured at Khuzestan province in Iran. The 3 kinds of cultivation were: wet-bed-seeding (a), dry-bed-seeding (b) and transplanting (c). The experiment was performed with 4 sampling times at 4 different growth stages of rice cultivation and three repeats in a completely randomized design. We used a chamber method and gas chromatograph technique to measure the emission of CH_4, CO_2 and CO from rice paddies. Results showed that the highest emitted gas was CO_2 and its highest emission happened at (a) and at the rice cultivation stage. On the whole CH_4 emission was greatest for (a) and for all kinds of cultivation was high at the tillering and ripening stages and low at the rice cultivation and shooting stages.

Key Words
Rice paddy, carbonic greenhouse gas, emission

Introduction
Agriculture represents a significant source of the world's total anthropogenic greenhouse gas emission. In this regard flooded rice paddies have an important role in the global budget of CH_4 and CO_2 (IPCC, 1995). Methane is one of the most important GHGes with a 10 year life time and with 21 times as much greenhouse effect as CO_2 in 100 years (Neue *et al*., 1995) and it is the most abundant carbonic gas at atmosphere after CO_2. The current global average atmospheric concentration of CH_4, is 1.78 ppmv (Dlugokencky 2001). Global annual methane emission from rice fields were estimated to range from 25 to 100 Tg which contributed 10 to 30% of global methane emission (Crutzen, 1991; IPCC 1995). Atmospheric CO_2 is also increasing at the rate of 5% a year. Burning fuel and changing land use are two major human activities that result in this increase (Lal and Kimbel, 1995). Organic carbon in the soil is the main source of greenhouse gas emission from the soil (Post and Kwon, 2000). In croplands, organic carbon is supplied to the soil as root exudates, dead roots and stubble of crops. Some other additional organic carbon is also supplied by organic matter incorporation (Nishimura *et al*., 2008). The amount of organic carbon stored in paddy soils is greater than in upland soils because of different biochemical processes and mechanisms specifically caused by the presence of flooded water in paddy soils (Liping and Erda, 2001). The dynamics of carbon in paddy fields significantly differs from that in fields with upland crop cultivation in which the aerobic decomposition process is dominant. During the submerged period of paddy rice cultivation, CO_2 production in the soil is severely restricted under anaerobic conditions. Instead, CH_4 is actively produced in the soil and emitted to the atmosphere mainly through the rice plants (Nishimura *et al*., 2008). However CH_4 and CO_2 emission in paddy soils is universal and inevitable. For this study evaluating the effects of different kinds of rice cultivation on carbonic GHGes emission, CH_4, CO_2 and CO emissions were measured at different stages of rice cultivation from one field with 3 kinds of rice cultivation. To determine which kind of cultivation and which stage of growth cause more carbonic GHGes emission.

Materials and methods
Materials
This study was conducted in one field 70 Km North West from Ahvaz between Karkhe and Karoon rivers.

Methods
12 static chambers were built to collect the gasses. The chamber framework was built from poly-ethylene tube with 1 cm thickness and 20 cm diameter. One side of the tubes was locked with transparent polyethylene with 1 cm thickness and 2 orifices were constructed for a pipe (for air sampling) and a thermometer in the middle of framework. Nine chambers with 1 m height were used for rice cultivation. Although rice plants do not produce methane rice cultivation is a major way for methane to escape from soil to atmosphere (about 50 to 80% of total methane emission). It is necessary that the plant is placed in the chamber. On the other hand, to measure net soil

carbonic gasses emission, 3 other chambers with 40 cm height were without plants and with waterlogged soil (d) were used to measure CH_4, CO_2 and CO on collected soil air, chambers were placed in fields and inserted 5-7 cm in to soil and packed with mud, then after 4 h air sampling was done with a 60 mL syringe and the thermometer was read. Air sampling has been done 4 times during this study. 1 h after sampling air sampling were translocated to the laboratory and were read by a Gas Chromatograph (GC) system with FID (Flame Ionization Detector) and TCD (Thermal Conductivity Detector) detectors. Reading data were then revised for standard temperature and figures were drawn with Excel software.

Results and discussion

Results show that the amount of methane emission in (a) was more than the emission in (b); and (c) had the lowest amount of methane emission. This is due to the waterlogged soil with reduction conditions occurring since one month before the cultivation in (a) and (b) and dry soil with aerobic condition until cultivation time in (c). Also the higher amount of methane emission in (a) than (b) is for warmer water due to sunshine while seedlings in (b) protected the water from sunshine. Methane emission for (c) was more than in (d) in tillering and shooting stages. It is also due to a longer waterlogged time in (d) than in (c). Methane emission was high for tillering and ripening stages and low for shooting stage for all kinds of cultivation. This was due to the smaller size of seedlings at tillering than at shooting and warmer water around seedlings at the tillering stage and the highest reduction condition at the ripening stage. Due to the increasing growth of above ground biomass as compared to roots at the shooting stage, most of the assimilates were consumed within the above ground biomass and little of them remained for roots to grow, so the roots will have smaller discharges. Methane production by microorganisms that depend on these discharges, will be restricted and methane emission will decrease. CO_2 was the highest emitted gas and the greatest amount of emission happened for (a) at the rice cultivation stage. This is due to the warmer water around the seedlings in (a) than (b) and better oxidation condition during the cultivation stage. CO emission is high at the cultivation stage but very low at other stages. This is due to the better oxidation condition at the cultivation stage and high soil moisture at the other stages that caused oxidation of CO and prevented emission.

References

Crutzen PJ (1991) Methane’s sinks and sources. *Nature* **350**, 380-381.

Dlugokencky E (2001) NOAA CMDL carbon cycle greenhouse gasses, globalaverage atmospheric methane mixing ratios. (NOAA CMDL cooperative air sampling network).

IPCC (1995) The science of climate change. *In* 'Climate Change 1995'. (Eds Houghton JT, Meira Filho LG, Callander BA, Harris N, Kattenberg A, Maskell K) Cambridge Univ. Press: Cambridge).

Lal R, Kimble J (1995) Soils and global change. In 'Advances in Soil Sciences'. (1th Edn. CRC Press, FL Boca Raton, USA, 156670118X), pp. 1-2.

Liping G, Erda L (2001) Carbon sink in cropland soils and the emission of greenhouse gasses from paddy soils: a review of work in China. *Chemosphere-Global Change Science* **3**, 413-461.

Neue HU, Wassmann R, Lantin RS (1995) Mitigation Options for Methane Emissions from Rice Fields. *In* 'Climate Change and Rice'. (Eds Peng S, Ingram K, Neue HU, Ziska L), pp. 136-144. Springer-Verlag, Berlin U K, 3540589066.

Nishimura S, Yonemura S, Sawamoto T, Shirato Y, Akiyama H, Sudo S, Yagi K (2008) Effect of land use change from paddy rice cultivation to upland crop cultivation on soil carbon budget of a cropland in Japan. *Agriculture, Ecosystems and Environment* **125**, 9-20.

Post WM, Kwon KC (2000) Soil carbon sequestration and land use change: Processes and Potential. *Global Change Biol.* **6**, 317-327.

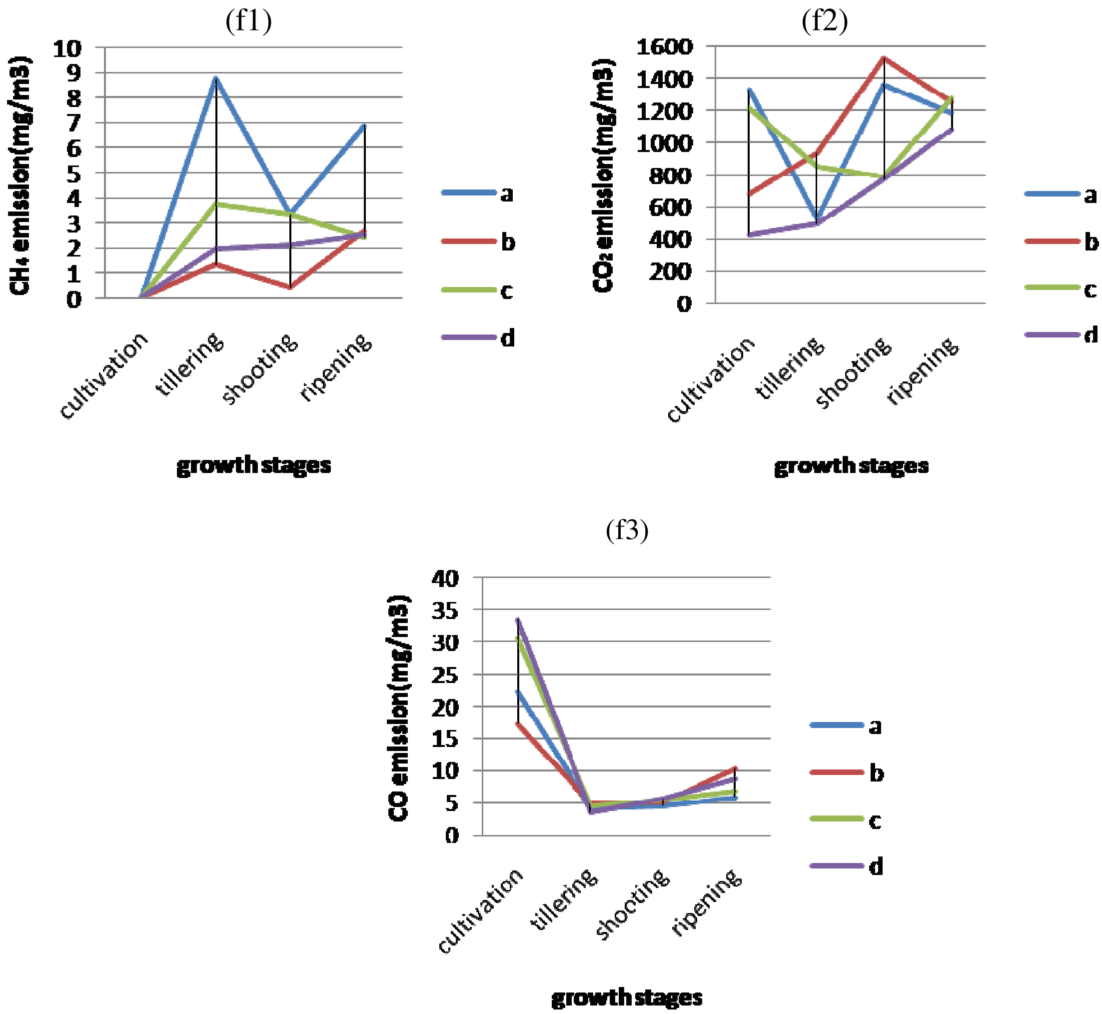

Figure 1. CH_4 emission at different growth stages of rice cultivation (f1) CO_2 emission at different growth stages of rice cultivation (f2) CO emission at different growth stages of rice cultivation (f3).