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

L. J. Hathaway-Jenkins[A], R. J. Godwin[A], B. Pearce[B], R. Sakrabani[A] and A. Whitmore[C]

[A]Cranfield University, College Road, Cranfield, Bedfordshire, MK43 0AL, Email l.j.hathaway-jenkins@cranfield.ac.uk
[B]Organic Research Centre, Hamstead Marshall, Newbury, Berkshire, RG20 0HR.
[C]Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ.

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

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

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

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

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

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

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

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

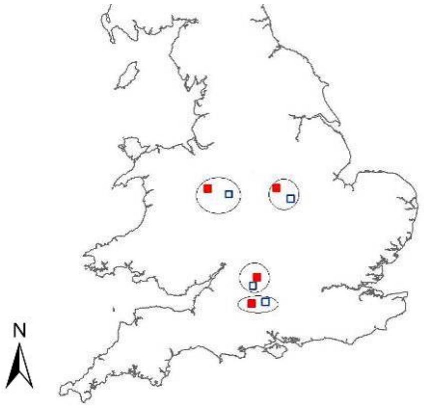

Figure 1. Map of the sites showing the clusters in organic ■ (hot - more than 12% organic land use) or conventional □ (cold - less than 2% organic land use) used during infiltration measurements (RELU 2007).

Field sampling and analysis

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

Statistical analysis

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

Results and discussion

Hydrology of soil type (HOST)

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

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

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

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

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

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

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

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

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

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

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

Conclusion

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

References

Bodhinayake W, Si BC, Noborio K (2004) 'Determination of Hydraulic Properties in Sloping Landscapes from Tension and Double-Ring Infiltrometers.' *Vadose Zone Journal* **3,** 964–970.

Boorman DB, Hollis JM, Lilly A (1995) 'Hydrology of soil types: a hydrologically-based classification of the soils of the United Kingdom.' (Institute of Hydrology report no. 126: UK).

Brady NC (1990) 'The nature and properties of soil'. (Maxwell Macmillan Publishing: New York).

Carsel J, Parrish L (1988) 'Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils.' *Journal of Contaminant Hydrology* **2,** 1-11.

Godwin RJ, Dresser ML (2003) 'Review of Soil Management Techniques for Water Retention and Minimising Diffuse Water Pollution in the River Parrett Catchment' (R &D Technical Report P2-261/10/TR).

Holman IP, Hollis JM, Thompson TRE (2002) 'Impact of agricultural soil conditions on floods – Autumn 2000.' R&D Technical Report W5B-026/TR. (Environment Agency: Bristol)

Lettens S, Van Orshoven J, van Wesemae B, Muys B (2004) 'Soil organic and inorganic contents of landscape units in Belgium derived using data from 1950 to 1970.' *Soil Use and Management* **20,** 40-47.

Mckenzie N, Coughlan K, Cresswell H (2002) 'Soil physical measurement and interpretation for land evaluation' (CSIRO publishing: Melbourne).

Metzger L and Yaron B (1987) 'Influence of sludge organic matter on soil physical properties.' *Advanced Soil Science* **7,** 141-163

Norton L, Johson P, Joys A, Stuart R, Chamberlain D, Feber R, Firbank L, Manley W, Wolfe M, Hart B, Mathews F, Macdonald D, Fuller RJ (2009) 'Consequences of organic and non organic farming for field, farm and landscape complexity.' *Agriculture, Ecosystems and Environment* **129,** 221-227.

Oquist K, Strock JS, Mulla DJ (2006) 'Influence of alternative and conventional management practices on soil physical and hydraulic properties.' *Vadose Zone Journal* **5,** 356-364.

RELU (2007) 'Maps from the project by D Gabriel'.

Reganold JP, Palmer AS (1995) 'Significance of gravimetric and volumetric measurements of soil quality under biodynamic, conventional and continuous grass management.' *Journal of Soil and Water Conservation* **50,** 298-305.

Schwab P (1993) 'Soil and Water Conservation Engineering' (Wiley: London).

Witzel P (2008) 'Personal communication about infiltration rates'.

Zhang R (1997) 'Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer'. *Soil Science Society of America Journal* **61,** 1024-1030.