# Applying hydropedological principles to analyse soil moisture variability at a field scale

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## Abstract

The aim of this study was to investigate soil moisture variations and how soil and terrain data can be used in combination to explain the spatial variation in soil moisture contents. Field monitoring of surface soil moisture content on eight occasions in three different fields in Bedfordshire (UK) was undertaken. The results from regression models show that up to 80% of the variation in surface soil moisture can be explained using information derived1:10,000 soil series maps and terrain variables. An index of Short-wave radiation on a sloping surface (SWRSS), calculated by SRAD, and a topographic wetness index combined explained a maximum of 44% of the variation. The additional variation explained by adding 1:10 000 soil series information to terrain variables was up to 50% and adding 1:25 000 soil series information increased the variation explained by up to 29%. These results show that the terrain effect on soil moisture is modified by soils. They also indicate that there is temporal stability to soil moisture patterns which highlights this modification. The interactions in the variation explained by soil and landscape indices at different scales show that pedological knowledge is key to understanding hydrological processes at a landscape scale.

## Key Words

Hydropedology, digital terrain model, Theta probe.

## Introduction

The literature points to soil properties being a major driver in the spatial distribution of soil moisture at a small-catchment scale. It also suggests that detailed soil mapping is the key to representing distributed soil moisture patterns (Lin *et al.* 2006). However, detailed scale soil mapping is only available for very small areas. In this study where detailed soil mapping is available, there is the opportunity to compare its ability to predict soil moisture contents with that of lower resolution soil mapping combined with terrain variables, the aim being to quantify the difference in the predictive power of the different data sets (Baggaley *et al.* 2009). The objectives of this research are to identify key soil, terrain and meteorological properties that influence the spatial distribution of soil moisture throughout the growing season and assess the temporal stability of the soil moisture patterns.

## Methods

### *Field methods*

Field monitoring of surface soil moisture content on eight occasions in three different fields in Bedfordshire (UK) was undertaken between April and July in 2004 and 2005. Between 100 and 120 points were sampled on an approximately 30 m paced grid in each survey using a Delta-T ML2x Theta Probe.

### *Soil and terrain variables*

The 10 m Ordnance Survey Land-Form PROFILE™ elevation data was used to calculate two wetness indices (Quasi-Dynamic Wetness Index (QDWI) and Steady State Wetness index (SSWI)) and a solar radiation index (Short-wave radiation on a sloping surface (SWRSS)). These were chosen as surrogates to represent both lateral (wetness indices) and vertical (radiation index) movement of soil moisture. Soils data was available at1:25 000, scale in the form of the Biggleswade Sheet TL14 (Wright 1987) for all three field sites and at 1:10 000 scale for Stone Hill and Church Meadow (Burton 2003 unpublished).

### *Analysis methods*

Two analyses were undertaken:

- An ANOVA of the soil moisture in each of the field sites with respect to the different mapping scales. The significant effects were then investigated using Fisher least significant difference (Fisher LSD).
- Two regression analyses. First, on the soil moisture contents with respect to the three terrain variables

(SSWI, QDWI and SWRSS) and second on the soil moisture contents with respect to SSWI and SWRSS combined with the two different mapping scales.

## Results and discussion

### *ANOVA with respect to soil mapping scales*

At Stone Hill in 2004, the variance in soil moisture explained by the eight soil series that were identified at the 1:10 000 scale decreases from 55 to 29% between April and July as the soils dry out. This compares to 19 to 15% of the variation being explained by 1:25 000 scale soils data. The patterns in soil moisture, however, appear to display temporal stability (Figure 1). Fisher LSD shows the soil series at 1:10 000 at Stone Hill generally fall into three groups based on the measured soil moisture content. These are slowly permeable clay rich soil soils, freely draining loamy soils and freely draining sandy soils, in order of decreasing soil moisture content.

In Church Meadow in 2005, the variance explained by the eight soil series mapped at 1:10 000 scale decreases from 76 to 61% between June and July. This compares to 38 to 33% of the variation being explained by 1:25 000 scale soils data. The average moisture is driven by the patterns in rainfall, however, as in Stone Hill, the patterns appear to be temporally stable (Figure 1). Investigating the soil series effect using Fisher LSD highlights three groups of soil series based on the measured soil moisture content. These are slowly permeable clay rich soils, freely draining loamy soils and freely draining sandy soils, in order of decreasing soil moisture content.

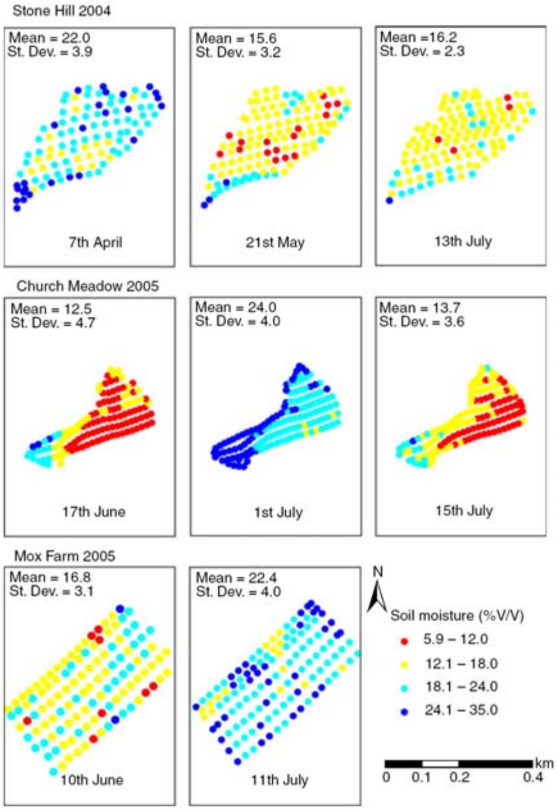

**Figure 1. Surface soil moisture measurements (top 100 mm) at Stone Hill, Church Meadow and Mox Farm. Taken using Delta-T ML2x Theta Probe.**

### *Combining terrain and soils*

In Stone Hill the variance explained by terrain variables was at a maximum on 21 May. Here, the SSWI explains 35% and the SWRSS 31% and when combined they explain 44% of the variation in soil moisture content. Adding 1:10 000 scale soil data to the regression models developed for the terrain variables explained an additional 14–21% of the variance. When soil data at 1:25 000 are used, the additional variation explained varies from not being significant on 7 April and 21 May to 8% on 13 July. The variation explained by soils at 1:25 000 scale and terrain indices was always less than the variation explained by soils alone at 1:10 000 scale (Table 1).

In Church Meadow the maximum variation explained by the combination of SSWI and SWRSS was 31% on 17 June, decreasing to 22% on 15 July. Adding 1:10 000 scale, soil data to the regression models developed for the terrain variables explained 42–50% more variation. When soil data at 1:25 000 are used, the additional variation explained varies from 26% on 15 July to 29% on 1 July (Table 1). At Mox Farm terrain explained a maximum of 7% of the variation in the soil moisture in the field and together with the soils data at 1:25,000 scale the variation explained was 20% (Table 1).

**Table 1. Regression models explaining the largest proportion of variation in surface soil moisture for each of the eight sampling dates in Stone Hill, Church Meadow and Mox Farm.**

| Field | Date | Regression Model | Non significant variables | % Variance in Soil moisture explained |
|---|---|---|---|---|
| *Stone Hill* | 7 April 2004 | SSWI + SWRSS | | 38 |
| | | 1:10,000 soil + SWRSS | SSWI | 59 |
| | | SSWI + SWRSS | 1:25,000 soil | 38 |
| | 21 May 2004 | SSWI + SWRSS | | 44 |
| | | 1:10,000 soil + SSWI + SWRSS | | 58 |
| | | SSWI + SWRSS | 1:25,000 soil | 44 |
| | 13 July 2004 | SSWI | SWRSS | 12 |
| | | 1:10,000 soil | SSWI + SWRSS | 32 |
| | | 1:25,000 soil + SSWI | SWRSS | 20 |
| *Church Meadow* | 17 June 2005 | SSWI + SWRSS | | 31 |
| | | 1:10,000 soil + SWRSS | SSWI | 80 |
| | | 1:25,000 soil + SSWI + SWRSS | | 57 |
| | 1 July 2005 | SSWI + SWRSS | | 24 |
| | | 1:10,000 soil + SWRSS | SSWI | 74 |
| | | 1:25,000 soil + SSWI + SWRSS | | 53 |
| | 15 July 2005 | SSWI + SWRSS | | 22 |
| | | 1:10,000 soil + SWRSS | SSWI | 64 |
| | | 1:25,000 soil + SSWI + SWRSS | | 48 |
| *Mox Farm* | 10 June 2005 | SSWI | SWRSS | 3 |
| | | 1:25,000 soil + SSWI | SWRSS | 7 |
| | 11 July 2005 | SWRSS | SSWI | 7 |
| | | 1:25,000 soil + SSWI + SWRSS | | 20 |

Model (i) SSWI + SWRSS + 1:10 000 soil data (ii) SSWI + SWRSS + 1:25 000 scale soil data. Only the variables significant in the regression models are shown.

## Conclusion

This paper highlights the modification of landscape-driven hydrological processes by pedology. The temporal variations in mean soil water content are driven by rainfall events in the days preceding sampling but the patterns of soil moisture observed appear to show temporal stability. To understand these patterns we need to examine the spatial distribution of soil moisture with respect to topography together with the modifying effect of subsurface soil properties. In addition, when modelling hydrological processes in soils it is important to consider what the impact that soils may have on modifying the terrain effect on soil moisture and consequently water movement. The patterns observed will differ in areas with increased terrain variation and increased variation in soil permeability characteristics which result from differing underlying parent material. This work could be developed and by applying soil moisture retention curves to high spatial resolution soil moisture data and examining the spatial variability of pressure head with respect to terrain. This would give further valuable insight into the nature of water movement within fields.

## References

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