# The Prediction of Soil Moisture Distribution for a Small Catchment by the Distributed Hydrology Soil Vegetation Model (DHSVM)

Zamir Libohova [1 & 2], Laura Bowling [1], Phillip Owens [1], Philip Schoeneberger[2], Brad Lee[1], and Hans Edwin Winzeler[1]
[1] Purdue University, West Lafayette, IN 47907
[2] Natural Resource Conservation Service, Indianapolis, IN 46278

## Introduction

The soil series applied to map unit interpretations include ranges for most soil characteristics; therefore, inherent variability exists within a soil map unit. The soil map units may include more than one soil series which introduces another source of variability. These shortcomings can be critical when the soil map units are viewed from a watershed perspective and modeling for quantitative assessment of the role that soil characteristics have on soil moisture distribution, interflow, surface runoff, water table depth, and vice versa.

The objective of this research was to evaluate the difference in hydrologic indicator predictions (soil moisture) using the Distributed Hydrology Soil Vegetation Model (DHSVM) using the full range of one of these soil characteristics, the depth to the lithic contact from the Order 2 SSURGO data.

## Materials and Methods

### *Study Site*

The study site is located in Dubois County, Indiana at the Southern Indiana Purdue Agricultural Center (SIPAC) (Fig. 1).

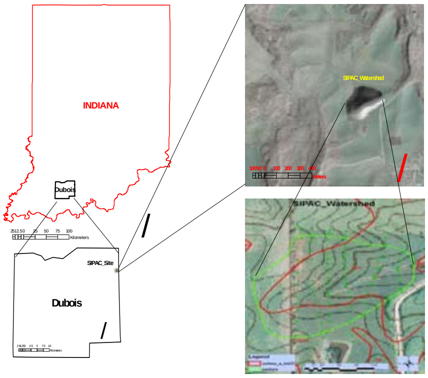


**Figure 1**. Location of the Study Area.

### *Soils*

According to the Dubois County Soil Survey, soils within the catchment boundary are Gilpin and Wellston Soil Series. The Taxonomic Groups for the soils are:

Wellston - Fine-silty, mixed, active, mesic Ultic Hapludalfs;
Gilpin - Fine-loamy, mixed, active, mesic Typic Hapludults.

Soil ranges for selected soil properties were derived from the Soil Survey and Official Series Description (OSD) (Table 1).

**Table 1.** Ranges in soil characteristics for the series within the SIPAC watershed boundaries.

| | Range | | | |
|---|---|---|---|---|
| Soil Series | Wellston | | Gilpin | |
| Soil Characteristics | Minimum | Maximum | Minimum | Maximum |
| Solum Thickness (cm) | 81 | 140 | 46 | 91 |
| Depth to Lithic (cm) | 102 | 183 | 51 | 102 |
| Horizons | Texture Classes | | | |
| A | sil, sicl | | sil, l | |
| Bt | sil, sicl | | sil, l, cl, sicl | |
| C | ch, vch, extch, gr, vgr, extgr, sil | | scl, cl, sal | |
| R | sandstone | | shale, siltstone, sandstone | |

ch - channery; vch and extch – very and extremely channery; gr – gravelly; vgr and extgr – very and extremely gravelly; sil – silt loam; sicl – silty clay loam; scl – sandy clay loam; cl - clay loam; l – loam; sal – sandy loam;

Two data sets were created for the depth to the lithic contact based on the minimum and maximum soil ranges and used as input to the Distributed Hydrology Soil vegetation Model (DHSVM).

The soil moisture from the DHSVM output as Volumetric Water Content (VWC) was also expressed as percent moisture saturation of the total soil pore volume.

## DHSVM

DHSVM is a physically based, distributed hydrology-vegetation model that utilizes GIS for watershed hydrology analysis at sub-daily to daily timescales (Wigmosta et al., 1994). A distinguishing feature of the model is its ability to redistribute the soil moisture on a pixel by pixel basis, thus requiring assignment of soil properties to each pixel. Preparation of model inputs required the following steps:

- The Soil Shape file downloaded from SSURGO was converted to a raster format, using ArcGIS software.
- Two separate raster files were created for the minimum and maximum soil depth to the lithic or paralithic contact.
- Soil properties from Soil Data Mart were used as input values for each pixel within each soil map unit for both raster files.
- Other spatial data such as the Digital Elevation Model (DEM), aerial photos, topographic sheets were processed in ArcGIS to obtain vegetation, elevation and stream input files.
- Weather data were provided by a nearby weather station.
- The model was simulated for a period of 10 years (1986-1996) on a hourly time basis, and only the last year from October 1, 1995 to September 30, 1996 was selected for analysis. This allowed for initial soil moisture conditions to be similar to the field conditions.
- The rooting depth was less for the minimum soil range compared to the maximum soil range to accommodate for the differences in depth to the lithic contact.
- Model outputs were soil moisture for three soil layers: A, E and AE horizons (Soil_Layer_1); Bt horizons (Soil_Layer_2); and BC/C horizons (Soil_Layer_3).

## Results and Discussions

A paired t-test analysis was used to compare average soil moisture for all three soil layers and the whole soil profile moisture for minimum and maximum ranges for depth to lithic contact.

Soil pore moisture saturation was significantly higher for the minimum depth to lithic for all three soil layers and the weighted soil profile moisture (p<0.01) than for the maximum depth (Fig. 2).

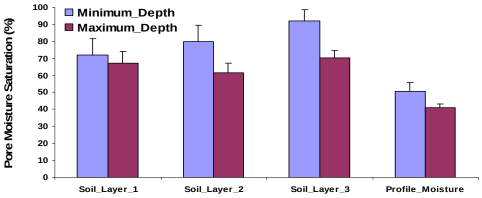


**Figure 2**. Annual mean soil moisture for 3 soil layers for minimum and maximum ranges in depth to the Lithic contact for October 1995-September 1996 period.

Soil pore moisture saturation showed large differences in seasonal variability between minimum and maximum depth to lithic (Fig. 3), with greater seasonal variability using the minimum depth (Fig. 3).

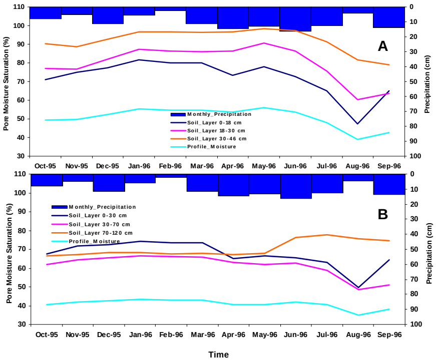
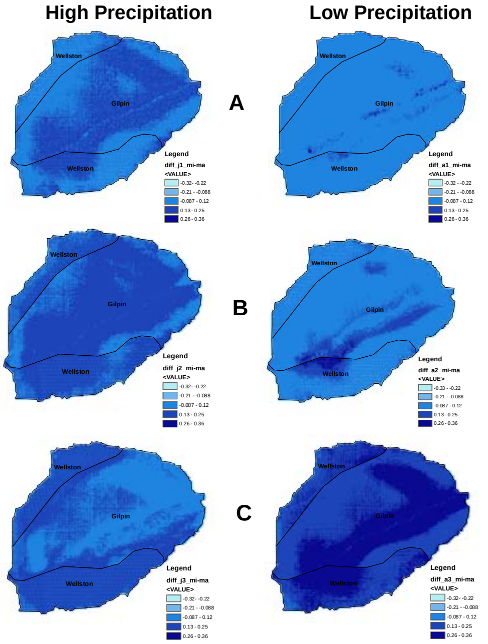


**Figure 3**. Seasonal soil moisture content for 3 soil layers for (A) minimum and (B) maximum depth to the Lithic contact for October 1995-September 1996 period.

The spatial distribution of volumetric soil moisture content showed differences between minimum and maximum depth to the lithic (Fig. 4). The differences in predicted volumetric water content (VWC) between minimum and maximum depth to lithic increased with soil depth and were more pronounced for the deeper soil layer. During the high precipitation month, the differences in VWC were less and showed a more uniform pattern within the watershed. During the low precipitation month the differences in VWC were greater, especially for the deeper soil layers (Fig. 4). This has implications for quantifying spatial distribution of soil pedogenic processes and development of redoximorphic features as they are influenced by water.


High Precipitation

Low Precipitation

**Figure 4.** Volumetric water content difference between minimum and maximum depth for (A) top; (B) second; and (C) third soil layers for June (high antecedent precipitation) and August (low antecedent precipitation), 1996.

## Conclusions

The observed differences in the predicted soil moisture distribution between minimum and maximum soil depths from this preliminary research emphasize the importance of mapping the spatial distribution of soil properties on the landscape. Soil maps would be more useful if based on a continuum or raster, like the DEM, rather than discrete boundaries.

Models like DHSVM can potentially be used to predict the spatial distribution of soil saturation conditions and other soil interpretations on landscape and watershed scales as well as on a site-specific scale, given the soil data is provided on a continuum or raster format. Work in the future will be focused on:

(i) collecting intensive field data to better represent the spatial variability of soil properties;
(ii) validate the DHSVM based on these field data; and
(iii) use the relationships between spatial distribution of soil properties related to hydropedologic processes and geomorphic features to predict soil properties on similar landscapes.

Figure 5 shows an example of the spatial distribution of loess thickness interpolated from the field data of soil borings and its relationship with elevation.

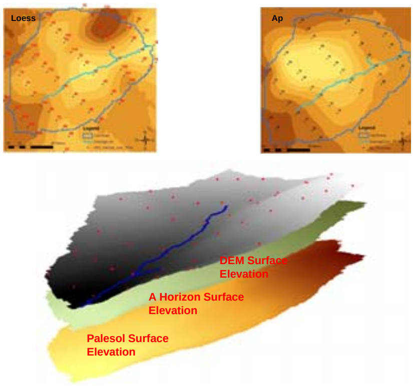


**Figure 5.** Predicted spatial distribution of loess thickness derived from the field soil borings for the catchment.

## References

**Storck, P, L. Bowling, P. Wetherbee, and D. Lettenmaier,** 1998. Application of a GIS-based distributed hydrology model for prediction of forest harvest effects on peak stream flow in the Pacific Northwest. Hydrological Processes. 12, 889-904.
**Wigmosta M.S, L.W.Vail, and D.P. Lettenmaier** , 1994. A distributed hydrology-vegetation model for complex terrain. Water Resources Research. Volume 30. No. 6 1665-1679 pp.