# Impact of Soil Redistribution on the Mass Balance of Soil Organic Carbon in Hummocky Glacial Topography, Iowa

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## Introduction

The Soil Organic Carbon (SOC) budget is a function of the balance between vegetative production, oxidative losses, and mass transport by water/ tillage. Models for spatio-temporal prediction are needed that account for mass transport processes in a realistic manner. Past work has concentrated on water erosion but has neglected water deposition and soil transport by tillage. Understanding these processes is essential to successful numerical modeling and for the placement of sites to monitor SOC changes for carbon accounting. We have embarked on a study near Ames, Iowa to investigate these issues.

## Approach

To better understand and model these processes, two high-resolution (25 m) soil sample grids were collected on separate agricultural fields (chisel ploughed, corn soybean rotation). SOC and $^{137}$Cs (to model erosion/deposition) were measured for each soil sample point. Five meter resolution data were collected with GPS to provide topographic information (DEM).

## Modeling

### Environmental Correlation:

Make maps by correlations between dense and sparse environmental data

In this case, there are strong correlations between DEM based terrain analysis (wetness index), soil organic carbon and deposition rate.

This correlation is exploited to make maps by spatial interpolation (Cokriging) and non-spatial extrapolation (Linear Regression).

### Terrain Analysis:

Terrain data is key to interpolation in this study:

- A 2 meter DEM was created by kriging RTK-GPS data
- The DEM was smoothed to create DEMs from 2-20 meters
- 10 meter DEM was found in a previous investigation to be the best predictor of soil properties
- The Wetness index is a key predictor for this landscape
  - Wetness Index = ln (specific catchment area/tan slope).
  - Known proxy for annual wetness.
  - This study demonstrates that it is also has potential for erosion and deposition modeling.

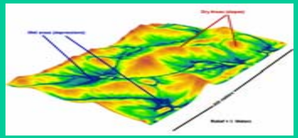
### Spatial Modeling:

Spatial models are needed for inventory:

- Sampling does not completely cover watershed
  1. Missing samples at edges of basins
  2. Spaces between samples

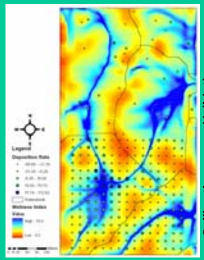
Various modeling approaches were used:

- Kriging can be used for watersheds well-covered by sample arrays
- Linear regression models and Cokriging based on wetness index can be used for watersheds with incomplete sampling.
- Ordinary Kriging with detrending has not been conducted yet but planned.



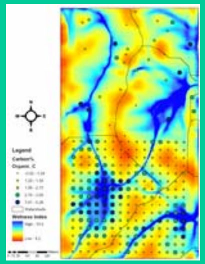
Derivation of wetness index from the DEM (FS2)

### Field Site 2

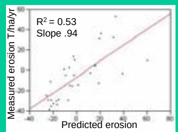


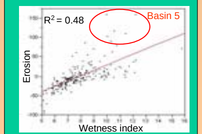

Development of a model for soil redistribution based on wetness index

### Field Site 2

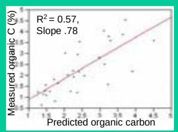


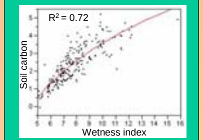

Development of a model for soil carbon based on wetness index



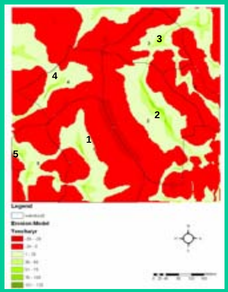

Calibration and validation data for erosion model



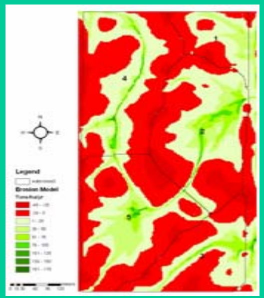

Calibration and validation data for soil carbon model

### Field Site 1




Patterns of soil redistribution in field site based on a wetness index model. Red colors represent soil loss. All basins in this landscape show slight negative balance of sediment. Mass balance estimates for soils based on kriging, cokriging (wetness index), and correlation modeling (wetness index) give similar values for basins 1 and 2 indicating that models are quite stable (Table 1).

### Field Site 2

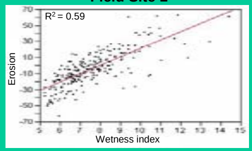


Patterns of soil redistribution in field site based on a wetness index model. Analysis indicates that basin 5 contains substantial imported sediment (9.4 Mt/ha/y) which differs from other basins within the two field sites.

**Table 1 Estimates of the mass balance for soil in basins within Field Site 1 using ordinary kriging, cokriging and regression modeling**

| Basin# | Kriging | Cokriging | Regression |
|---|---|---|---|
| | ---------------- | T/ha/yr | --------------- |
| 1 | -5.5 | -5.7 | -4.9 |
| 2 | -1.7 | -1.4 | -2.2 |

### Field Site 1




Calibration data for model based on wetness index

## Findings

A unique characteristic of the study fields is that they contain small (100 m from bottom to top, 5 meters relief) depressions which are generally thought to be closed depositional systems. Hence the mass balance of soil transport should sum to zero. Regression models involving wetness index were found useful for modeling soil redistribution and soil carbon distribution within this landscape. Ordinary kriging and cokriging (wetness index) models were also used. At field site 1, three different models converged on mean soil loss estimates of 1.7±0.4 and 5.4±0.4 Mt ha$^{-1}$ y$^{-1}$ for two basins. These numbers are within potential losses/ gains from wind erosion (±2.5-5 Mt ha$^{-1}$ y$^{-1}$). At field site 2, mass balance estimates provided strong evidence of significant deposition (9.4 Mt ha$^{-1}$ y$^{-1}$) of imported sediment within basin number 5. Adjustments in models for the two types of basins within this field will be needed for accurate mass balance accounting. Erosion/deposition models based on $^{137}$Cs concentration (Walling and He method) are giving reasonable results and do not show systematic bias towards erosion or deposition.

## Conclusions

The site is especially useful for the calibration of spatio-temporal soil and carbon erosion/deposition models. Mass imbalances can be used to expose biases in the modeling algorithms. These results demonstrate the need to take into account landscape redistribution of carbon when using the benchmark approach to assess temporal changes in SOC inventory.