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## Remote Sensing Derived Topsoil and Agricultural Economic Losses, Midwestern USA

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### Summary

This dataset provides estimates of topsoil loss and economic loss associated with decreased crop productivity resulting from topsoil loss at county- and state-levels across the Corn Belt region of the Midwestern USA. Intermediate products used to derive topsoil loss are provided and include 4 m gridded estimates of study sites elevation, curvature, slope, soil organic carbon index (SOC<sub>I</sub>), and the probability of exposed B-horizon soil. Topsoil loss at the county- and state-levels was derived from analyses of agricultural land at selected sites across the study area. From WorldView imagery, 759 fields were identified that had exposed bare soil (210 km<sup>2</sup>) and were grouped into 28 sites. Gridded estimates of the SOC<sub>I</sub> and of the probability of exposed B-horizon soil were determined for each field within the sites. Topography measures, including elevation (m), curvature (m<sup>-1</sup>), and slope (deg), were extracted over the entire study area from LiDAR-derived digital elevation models at a 4 m resolution acquired from 2003-2018. Within each of the 28 study sites, the SOC<sub>I</sub> and topographic curvature values were extracted from co-located pixels. Topsoil loss was estimated from the relationship between subsoil exposure and topography and averaged across each site. The relationship between topsoil loss and topographic curvature was used to up-scale and predict topsoil and economic losses at the county and state-levels across the entire 375,000 km<sup>2</sup> study area. The data have been used to demonstrate a robust and scalable method for estimating the magnitude of erosion in agricultural landscapes.

There are 141 files total; 140 files in GeoTIFF (\*.tif) format and 1 file in Comma Separated Value (\*.csv) format.

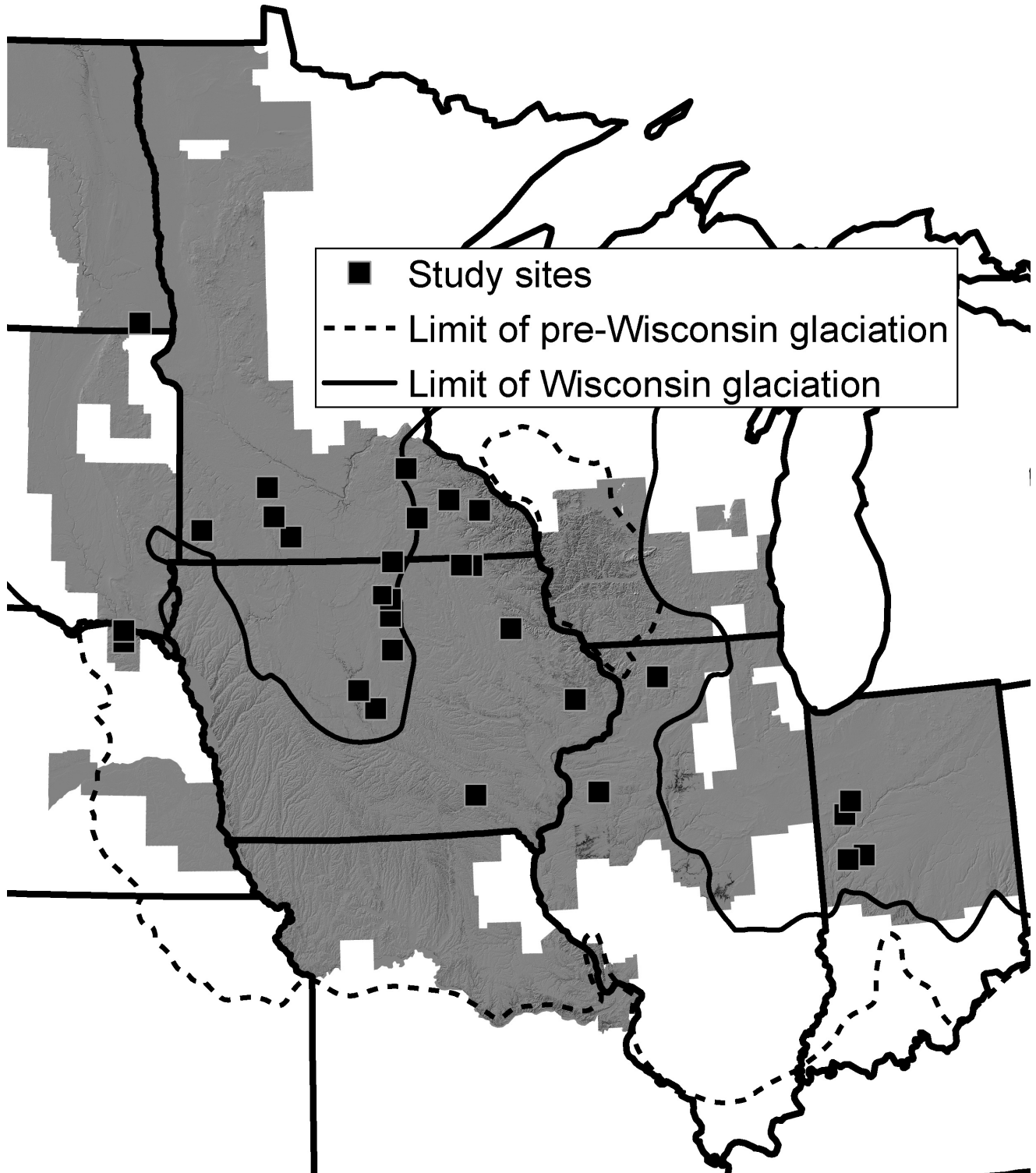


Figure 1. Study area in the Midwestern US with study site locations and extent of analysis. The study area was limited to the spatial extent of LiDAR topographic data (gray hillshade). Squares represent the 28 sites, a total of 210 km<sup>2</sup>, that were selected for having plowed, bare soil. Source: Thaler et al., 2020

## Citation

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## 1. Dataset Overview

This dataset provides estimates of topsoil loss and economic loss associated with decreased crop productivity resulting from topsoil loss at county- and state-levels across the Corn Belt region of the Midwestern USA. Intermediate products used to derive topsoil loss are provided and include 4 m gridded estimates of study sites' elevation, curvature, slope, soil organic carbon index (SOCi), and the probability of exposed B-horizon soil. Topsoil loss at the county- and state-levels was derived from analyses of agricultural land at selected sites across the study area. From WorldView imagery, 759 fields were identified that had exposed bare soil (210 km<sup>2</sup>) and were grouped into 28 sites. Gridded estimates of the SOCi and of the probability of exposed B-horizon soil were determined for each field within the sites. Topography measures, including elevation (m), curvature (m<sup>-1</sup>), and slope (deg), were extracted over the entire study area from LiDAR-derived digital elevation models acquired from 2003-2018 and at a 4 m resolution. Within each of the 28 study sites, the SOCi and topographic curvature values were extracted from co-located pixels. Topsoil loss was estimated from the relationship between subsoil exposure and topography and averaged across each site. The relationship between topsoil loss and topographic curvature was used to up-scale and predict topsoil and economic losses at the county and state-levels across the entire 375,000 km<sup>2</sup> study area. The data have been used to demonstrate a robust and scalable method for estimating the magnitude of erosion in agricultural landscapes.

### Related Publication:

Thaler, E.A., I.J. Larsen, and Q. Yu. *in review*. The scale of agriculturally-induced topsoil loss in the Corn Belt of the Midwestern U.S.

Thaler, E.A., I.J. Larsen, and Q. Yu. 2019. A New Index for Remote Sensing of Soil Organic Carbon Based Solely on Visible Wavelengths. *Soil Science Society of America Journal*, 83(5), pp.1443-1450. <https://doi.org/10.2136/sssaj2018.09.0318>

### Acknowledgments:

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## 2. Data Characteristics

**Spatial Coverage:** 375,000 km<sup>2</sup> of the Midwestern United States known as the Corn Belt

**Spatial Resolution:** 4 m

**Temporal Coverage:** Non-continuous satellite imagery captured from April 2003 to July 2018

**Temporal Resolution:** Once

**Study Area:** Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Midwestern US	-97.32451	-86.98604	46.04608	40.03966

### Data File Information

This dataset includes 140 files in GeoTIFF (\*.tif) format. There are five files for each of the 28 sites. And one file in Comma Separated Value (\*.csv) format.

The naming convention for GeoTIFF files is **site\_##\_X.tif**, where:

**##** is the site number (01-28) and

**X** is one of five variable types (carb, curv, elev, probs, slope)

**Table 1.** File names and descriptions.

File Name	Units	Description
site_##_carb		soil organic carbon index (SOCi; Thaler et al. 2019)
site_##_curv	m-1	topographic curvature (i.e., hillslope) in reciprocal meter; negative values signify convex topography, positive values signify concave topography, and a value of zero signifies a linear surface
site_##_elev	m	surface elevation in meters
site_##_probs	fraction	probability of B-horizon soil presence, 0 to 1
site_##_slope	deg	topographic slope in degrees
topsoil_loss.csv		county data used to estimate topsoil and economic losses

### Data File Details

Missing values are represented by -9999. The coordinate reference system includes EPSG: 32614, 32615, and 32616 (WGS 84 / UTM zones 14N, 15N, and 16N). Each of the five files for a site contain the same number of rows and columns.

**Table 2.** Variable names and descriptions for **topsoil\_loss.csv**.

Variable	Units	Description
county_name		county name
state_name		state name
fips		unique county identifier

area_ha	ha	land area in hectares
farm_cnt	cnt	number of farms
farm_area_mean_ac	ac	mean farm area in acres
farm_area_km2	km <sup>2</sup>	farmland area in square kilometers
corn_planted_ac	ac	corn planted in acres
soy_planted_ac	ac	soybean planted in acres
corn_harvest_ac	ac	corn harvest in acres
corn_harvest_ha	ha	corn harvest in hectares
soy_harvest_ac	ac	soybean harvest in acres
soy_harvest_ha	ha	soybean harvest in hectares
corn_yield_bu_per_ac	bu/ac	corn yield in bushels per acre
corn_yield_kg_per_ha	kg/ha	corn yield in kilograms per hectare
soy_yield_bu_per_ac	bu/ac	soybean yield in bushels per acre
soy_yield_kg_per_ha	kg/ha	soybean yield in kilograms per hectare
corn_econ_loss_usd	usd	economic loss from decreased corn yield in United States dollars
soy_econ_loss_usd	usd	economic loss from decreased soybean yield in United States dollars
farm_econ_loss_mean_usd	usd	mean economic loss per farm in United States dollars
farm_econ_loss_min_usd	usd	minimum economic loss per farm in United States dollars
farm_econ_loss_max_usd	usd	maximum economic loss per farm in United States dollar
econ_loss_mean_usd	usd	mean economic loss in United States dollars
econ_loss_min_usd	usd	minimum economic loss in United States dollars
econ_loss_max_usd	usd	maximum economic loss in United States dollars
econ_loss_usd_per_ha	usd/ha	mean economic loss in United States dollar per hectare
econ_loss_usd_per_km2	usd/km <sup>2</sup>	mean economic loss in United States dollar per square kilometers
topsoil_loss_km2	km <sup>2</sup>	topsoil loss in square kilometers
topsoil_loss_frac	frac	topsoil loss as fraction, 0 to 1
topsoil_loss_error_frac	frac	uncertainty of topsoil loss as fraction, 0 to 1
state_econ_loss_usd	usd	mean economic loss for state in United States dollars
state_topsoil_loss_frac	frac	mean topsoil loss for state as fraction, 0 to 1

### 3. Application and Derivation

This dataset provides estimates of topsoil loss across the Corn Belt region in the Midwestern US using a novel remote-sensing method for quantifying topsoil loss at individual fields and by relating topsoil loss and topography. The data have been used to demonstrate a robust and scalable method for estimating the magnitude of erosion in agricultural landscapes. See Thaler et al. (2020) for details.

### 4. Quality Assessment

The validity of the model predicting the SOCI was validated by plotting the receiver operator characteristic curve and calculating the area under the curve (AUC) for each site. AUC values ranged from 0.75 to 1.0, indicating that the logistic regression model well-classifies soil horizon based on SOCI values.

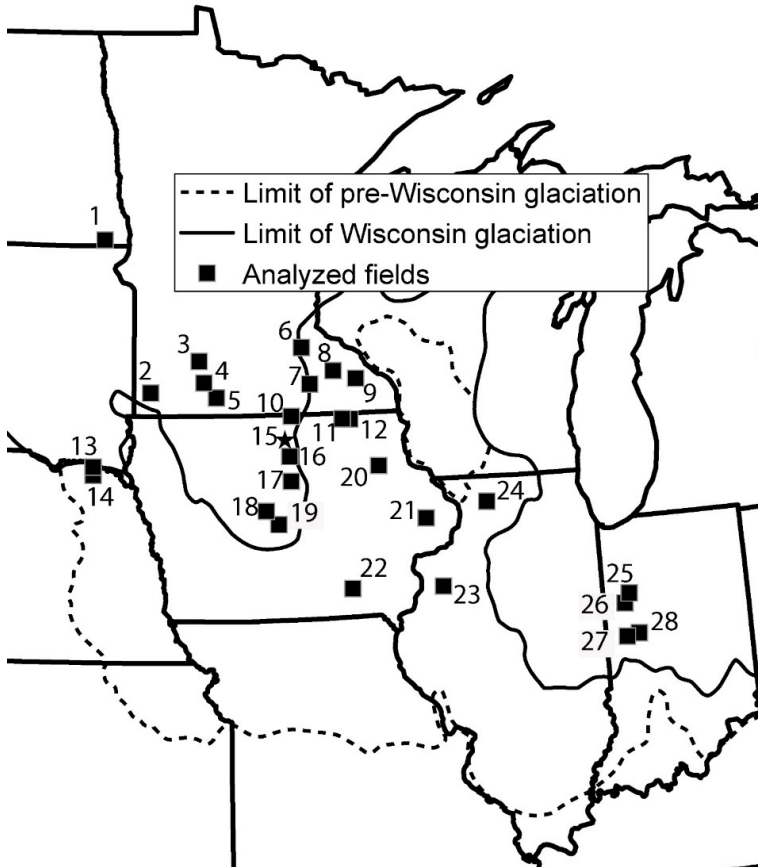
The uncertainty in estimates of topsoil and economic losses is derived from the standard deviation of the relationship between topsoil loss and topographic curvature. See Thaler et al. (2020) for details.

### 5. Data Acquisition, Materials, and Methods

#### Study Area

The dataset spatial extent covers an approximately 375,000 km<sup>2</sup> region of the Midwestern US that is colloquially known as the Corn Belt, as it is where 75% of corn and 60% of soybeans are produced in the USA.

The availability of LiDAR-derived digital elevation models (DEMs) through The National Map Download Client (USGS 2019) dictated the specific extent of the study area. The LiDAR data were clipped to the Herbaceous Agricultural Vegetation layer from the US Geological Survey Gap Analysis Program (USGS 2011) so that analyses excluded areas with non-agricultural land. A total of 210 km<sup>2</sup> (759 fields) of agricultural land across 28 sites were selected for analyses (Fig. 2).



**Figure 2.** Location of study sites with site numbers corresponding to file names. For example, site\_01\_carb.tif and site\_28\_slope.tif. Source: Thaler et al., 2020

### Soil Horizon

The National Geospatial-Intelligence Agency catalog of Digital Globe (Neigh et al., 2013) was used to identify WorldView-2 and WorldView-3 satellite imagery of plowed fields with exposed soil; 759 individual fields within 28 sites were selected. Soil horizon and soil organic carbon data for the area were retrieved from the US Department of Agriculture Natural Resources Conservation Service Rapid Carbon Assessment database (Willis et al. 2014). A newly developed soil organic carbon index (SOC<sub>I</sub>; Thaler et al. 2019) was used to differentiate between soil A- and B-horizons (i.e., topsoil and subsoil, respectively) of the plowed fields. Where soil A- and B-horizons were distinguishable, topographic slope and curvature were calculated as the first and second derivatives of elevation, respectively, using a 4 m resolution DEM (USGS 2011). Logistic regression was used to model the relationship between B-horizon exposure and topographic curvature at each site.

### Soil & Economic Loss

Topsoil and annual economic loss were determined at the county and state levels. The relationships between B-horizon exposure and topographic curvature at the 28 sites (210 km<sup>2</sup>) were used to upscale the estimate of topsoil loss of the 3.7x10<sup>5</sup> km<sup>2</sup> Corn Belt region. The estimate of annual economic losses incurred from topsoil loss relied on the similarity between yield reductions for corn and soybeans in severely eroded soils (Langdale and Shrader 1982).

For details of the analyses and image processing, see Thaler et al. (2020).

## 6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

[Remote Sensing Derived Topsoil and Agricultural Economic Losses, Midwestern USA](#)

Contact for Data Center Access Information:

- E-mail: [uso@daac.ornl.gov](mailto:uso@daac.ornl.gov)
- Telephone: +1 (865) 241-3952

## 7. References

- Langdale, G.W. and Shrader, W.D. 1982. Soil erosion effects on soil productivity of cultivated cropland 1. Determinants of Soil Loss Tolerance. ASA Special Publication 45. Determinants of Soil Loss Tolerance, pp. 41-51. <https://doi.org/10.2134/asaspecpub45.c4>
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