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Quantifying Erosion and Deposition in Long-Term Tillage Plots Using Ground-Based Lidar Scanning

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Introduction

While much has been done to reduce erosion from agricultural land, recent estimates indicate 41.7 million ha are eroding excessively, resulting in 1.8 billion Mg of soil lost annually in the U.S.A (Source: Conservation Technology Information Center, 2005). While studied extensively, long-term erosional soil loss and deposition remain difficult to quantify directly. Ground-based lidar can provide extremely detailed digital elevation data which may be useful for quantifying erosional soil loss and deposition. The objective of this study was to apply lidar for comparison of relative differences in surface elevation in adjacent systems under different tillage practices.

Materials & Methods

The study site is a long-term (27-yr), side-by-side tillage comparison maintained in the North Carolina Piedmont under an annual corn-soybean rotation (Fig. 1). Soils at the site are mapped as a Casville sandy loam (Fine, mixed, semiactive, Typic Kanhapludults). Experimental units are 6 m by 17.5 m. The overall study site is 54 m by 88 m meters (0.47 ha). Nine tillage treatments are arranged in a RCB design in four blocks, and include: no-till (NT), no-till + in-row subsoiling (IRS), fall or spring chisel plow (CHfa, CHsp), disk [in spring, always] (D), fall or spring chisel + disk (CHfa+D, CHsp+D), and moldboard plow in fall or spring (MPfa, MPsp).

Four scans, each representing a separate site quadrant, were made using a Leica ScanStation 2 (Leica Geosystems AG, Heerbrugg, Switzerland) in June 2011 (Fig. 2). Vertical and horizontal resolutions were 2.5 cm. The four scans were merged using Leica's proprietary scanner software.

To examine the relative elevations of the tillage plots, PROC GLM (SAS Institute, Cary, NC) was used to remove the trend (hillslope), using 2nd and 3rd order polynomials. The average residual elevation for each plot was determined using the Zonal Statistics tool in ArcGIS (ESRI, Redlands, CA). ANOVA was performed with PROC GLM to determine effect of tillage treatment on elevation. The difference in relative elevation of each plot was used to estimate relative gain or loss of soil due to soil erosion, compaction, loosening, etc.

Results & Discussion

Over 2.5 million data points were collected during the scanning operation (Fig. 3). A hillshaded surface derived from actual lidar point data indicates the overall slope at the site running from the lower left of the field to the upper right portion (Fig. 4). The range of elevation at the site is 5.8 m. The resulting surfaces created once the trend was removed are shown in Figs. 5 and 6.

ANOVA indicated that tillage had a significant effect on plot elevation for both models (Tables 1 & 2), with the 3rd order polynomial providing a stronger effect than using the residuals of the 2nd order polynomial. Both models indicated that approximately 60% of the variability in elevation was explained by tillage treatment (R-square 0.63 and 0.61 for the 2nd and 3rd order polynomial data, respectively).

Results showed that relative elevations differed amongst treatments (Figs. 7 & 8). Using a 2nd order polynomial, both moldboard plow treatments had significantly lower elevations than other plots. In both analyses, MPspD, MPfaD, had significantly lower elevations than the remaining treatments.

Conclusions & Future Work

Elevation differences corresponding to plot boundaries were detected by ground-based lidar scanning. The effect of trend was removed successfully, and significant differences in plot elevation due to tillage were measurable using ANOVA after removing trend.

Raw data points reflecting non-soil surface elevations such as standing dead grass, stubble, crop residue and low-lying winter annual vegetation can be removed and the data re-analyzed should provide better results and means separation.

Techniques for measuring success of trend removal can be employed.

Fig. 1. The study site at the time of lidar data collection.

Fig. 2. The lidar scanner used for data collection.

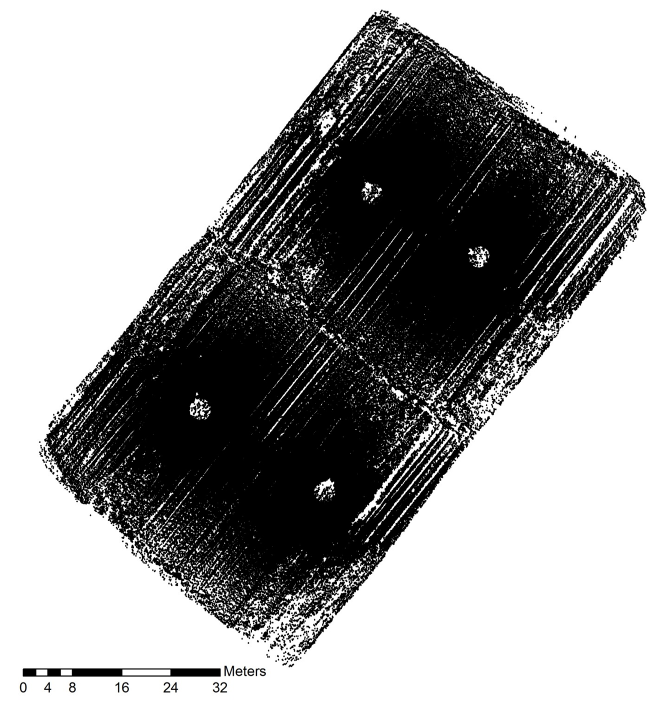

Fig. 3. Raw point data generated by lidar scans. The light-colored circles indicate the position of the scanner during data collection for each site quadrant.

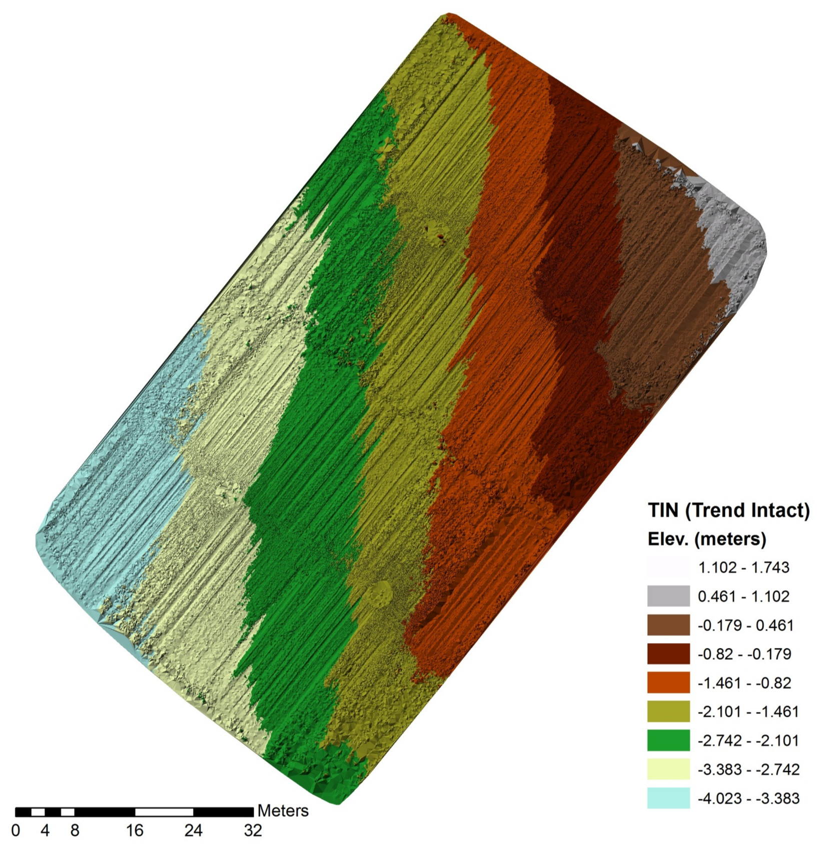

Fig. 4. Hillshaded surface of plot with hillslope evident. Actual elevation increases from left to right.

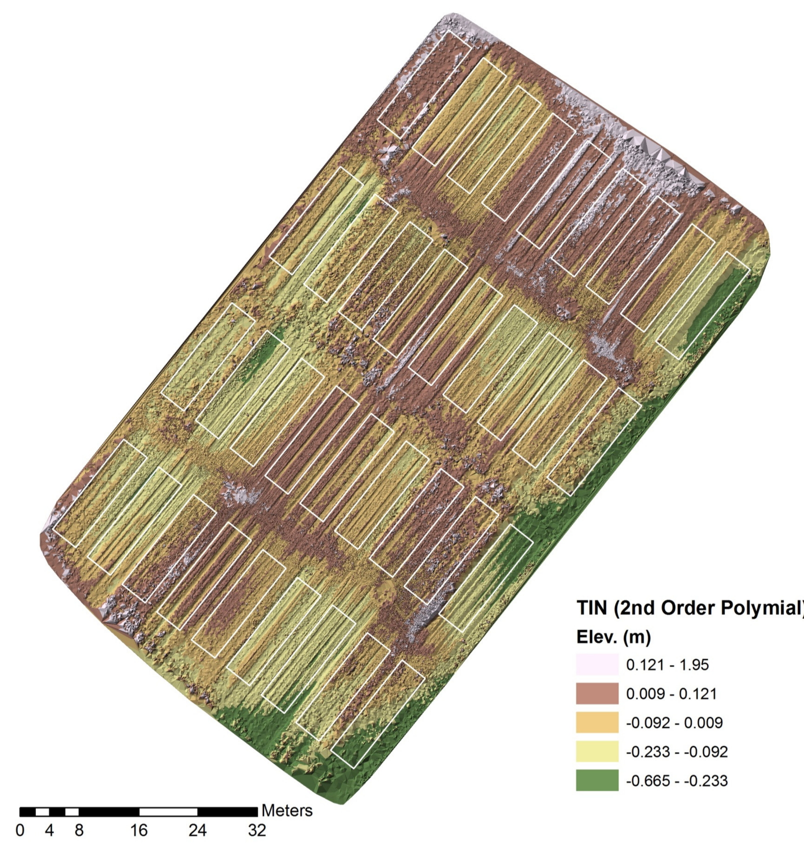

Fig. 5. Hillshaded surface after trend removal with 2nd order polynomial. Buffered plot boundaries shown.

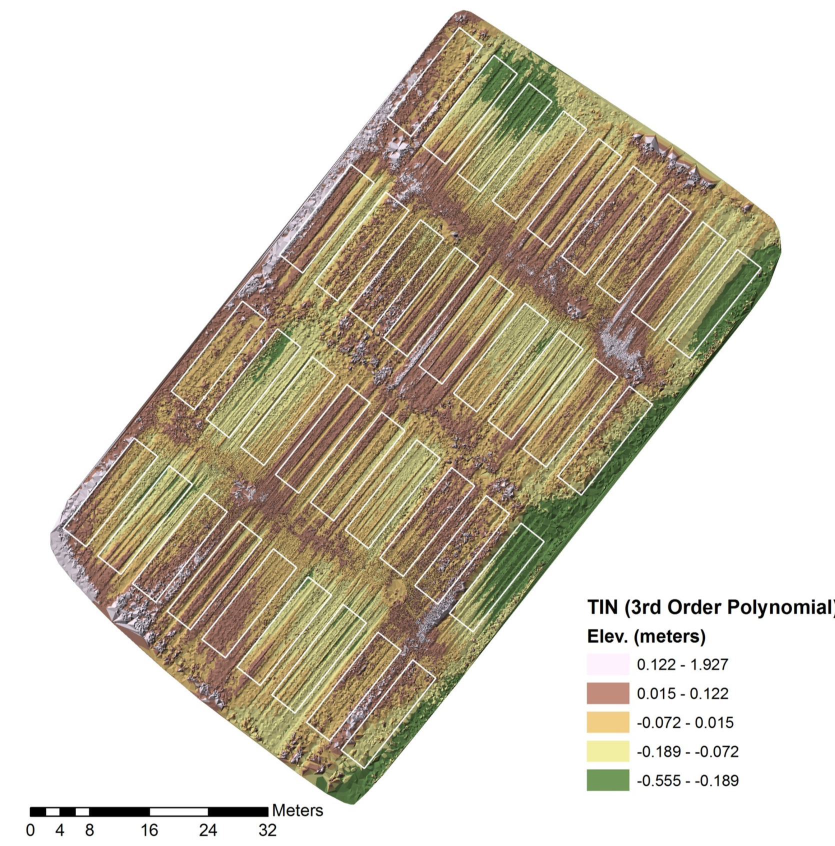

Fig. 6. Hillshaded surface after trend removal with 3rd order polynomial Buffered plot boundaries shown.

Table 1. ANOVA for residuals from 2nd order polynomial trend removal.

Source	df	SS	MS	F	Pr > F
model	11	0.11079298	0.01007209	3.83	0.0029
error	24	0.06303539	0.00262647		
corrected total	35	0.17382837			
R-square	**CV**	**Root MSE**	**Mean**		
0.637370	-157.58	0.051249	-0.032523		
Source	**df**	**SS**	**MS**	**F**	**Pr > F**
blk	3	0.02650107	0.00883369	3.36	0.0353
tillage	8	0.08429191	0.01053649	4.01	0.0038*

* Indicates significance at α = 0.05 level

Table 2. ANOVA for residuals from 3rd order polynomial trend removal.

Source	df	SS	MS	F	Pr > F
model	11	0.09419195	0.00856290	3.44	0.0055
error	24	0.05969511	0.00248730		
corrected total	35	0.15388705			
R-square	**CV**	**Root MSE**	**Mean**		
0612085	-154.47	0.049873	-0.032286		
Source	**df**	**SS**	**MS**	**F**	**Pr > F**
blk	3	0.00327387	0.00109129	0.44	0.7273
tillage	8	0.09091808	0.01136476	4.57	0.0018*

* Indicates significance at α = 0.05 level

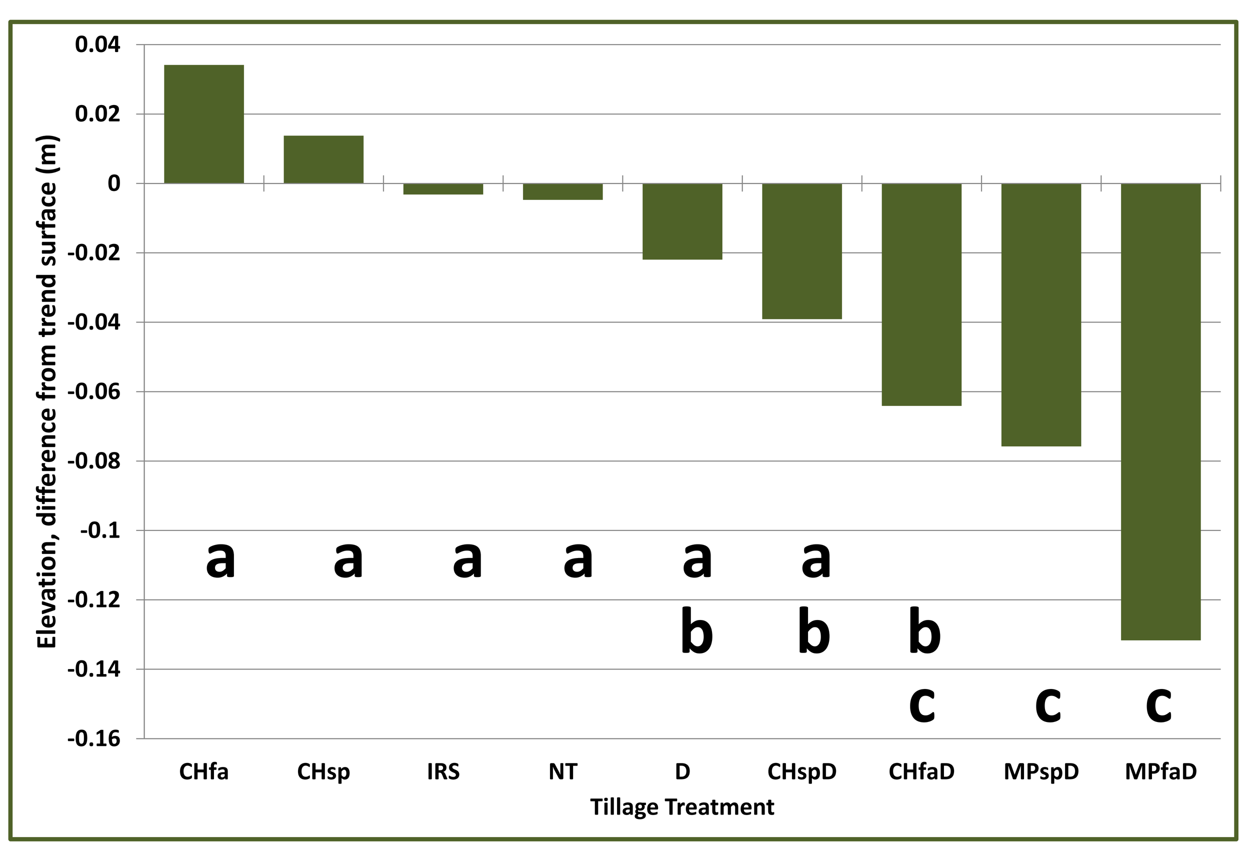

Fig. 7. Mean relative elevations of tillage treatments when trend removed with 2nd order polynomial. Treatments with same letter are not significantly different at α = 0.05 level.

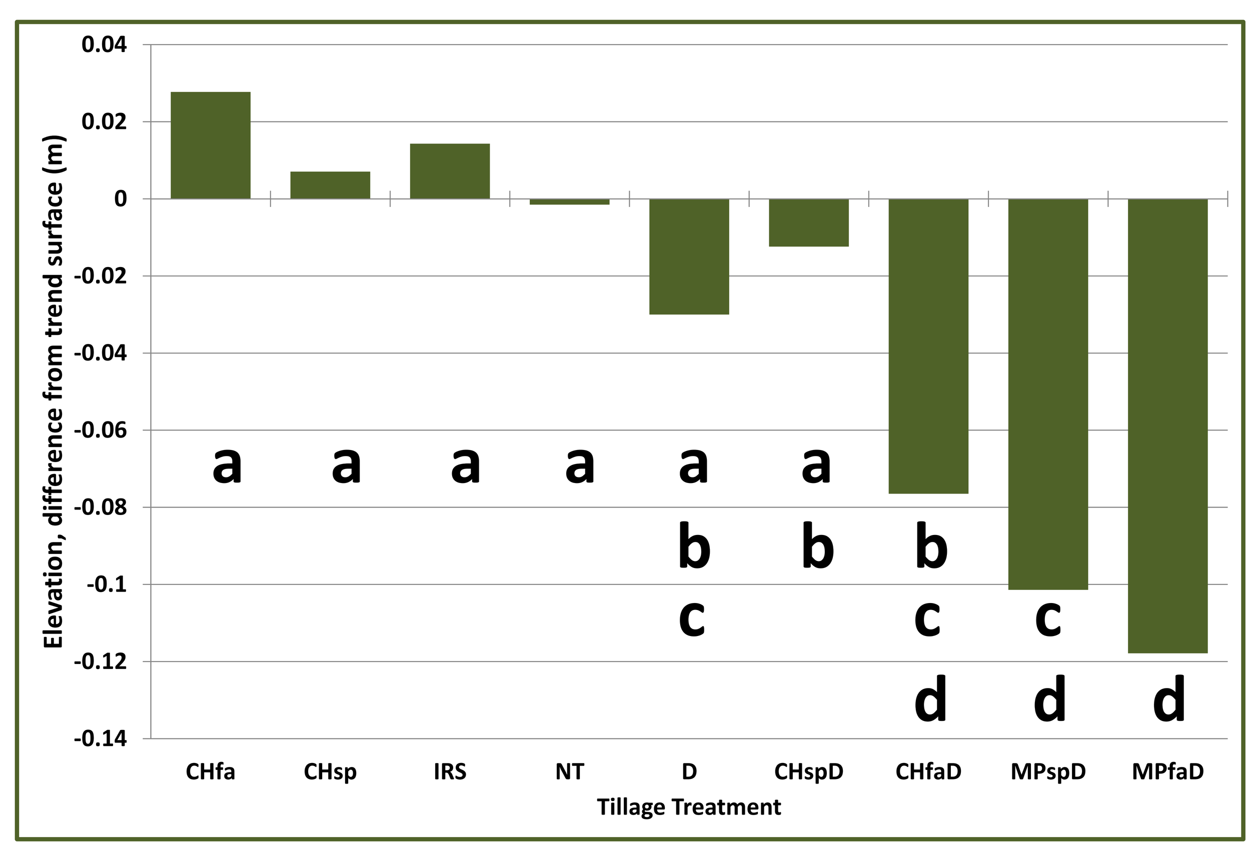

Fig. 8. Mean relative elevations of tillage treatments when trend removed with 3rd order polynomial. Treatments with same letter are not significantly different at α = 0.05 level.

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