TOPSOIL LOSS: EVALUATING AGRONOMIC CHARACTERISTICS OF SURFACE SOILS ON A PIPELINE RIGHT-OF-WAY[1]

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Abstract. Lack of adequate topsoil depth and perception of lost soil fertility on pipeline construction rights-of-way are major concerns for landowners and can become extensive post-construction costs for pipeline companies. Reduction in crop productivity can occur in agricultural fields after pipeline construction due to numerous factors including compaction, drainage, and changes in surface soil characteristics. Significant changes in soil texture and/or organic matter content can change cation exchange capacity (CEC) and water holding capacity of the soil. Reduced CEC, as well as low soil fertility levels, can reduce the crops ability to withstand environmental stress, therefore reducing crop yield. Topsoil stockpiled and replaced on the construction right-of-way (ROW) of a 42-inch (107 cm) natural gas pipeline through Kansas and Missouri was evaluated and compared to the topsoil adjacent to the ROW. Soils were evaluated on and off the ROW to compare topsoil depths, soil fertility, texture and other agronomic factors. Varying amounts of topsoil loss were found at a majority of sample sites. Differences between the on-ROW and off-ROW values for the other soil parameters tested were not significant. The lack of significant change in tested parameters on-ROW, compared to the undisturbed topsoil off-ROW indicate no loss of crop yield potential would be expected due to the reduction in topsoil depth.

Additional Key Words: crop productivity, soil fertility, topsoil removal, topsoil replacement, yield loss.

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Introduction

Loss of soil productivity on agricultural fields as a result of constructing large pipelines has long been a concern to landowners and energy companies due to potential lost income to the landowner as well as increased costs to the company. When crop yields are reduced within the post-construction Right of Way (ROW), the most common suspected causes are lost soil fertility, lost topsoil, compaction, and drainage issues.

Most previous research regarding the depth of topsoil in relation to crop yield have been from a soil erosion perspective and conducted in areas where varying degrees of erosion are pre-existing or by removing topsoil in incremental depths at undisturbed locations to simulate various levels of erosion. Crop productivity reductions are often not detectable when erosion is in its early stages and the depth of topsoil lost is small, (Bakker et al. 2004; Govers et al. 2004). In some studies, as the depth of topsoil decreases from the undisturbed depth, the crop yield loss increases (Larney et al. 2000; Sui et al. 2009). In many cases, grain yield reduction of the artificially eroded soil was found to be a function of nutrient removal (Batchelder and Jones 1972; Malhi et al. 1999; Izaurralde et al. 2006). Despite this relationship between yield loss and topsoil loss, the amendments that most effectively restored crop yields were not commercial fertilizers alone but rather manure in conjunction with commercial fertilizers (Robbins et al. 1997; Larney et al. 2000; Brye 2006; Sui et al. 2009). A significant decline in the soil organic matter content, the source of long-term inherent soil fertility, will likely cause any short term enhancement of soil fertility from commercial fertilizers to be short lived (Miller et al. 1990, Miller et al. 1991).

Additional research has shown that the presence of a marked contrast in the soil physical and/or chemical properties of the subsoil as compared to that of the topsoil characteristics has a significant influence on the relationship of topsoil depth and yield (Veseth 1987; Gollany et al. 1992; Shaffer et al. 1995; Walker et al. 2003; Al-Kaisi 2008). The influence of the subsoil properties on the remaining topsoil, as well as the beneficial properties manure contributes to soil physical and chemical properties, including increasing organic matter, micronutrients, and cation exchange capacity (CEC). This may explain why commercial fertilizer alone does not restore yields to the same extent as when it is combined with manure.

Significant changes in soil texture and/or organic matter content may change the CEC and water holding capacity of the soil. Reduced CEC and water holding capacity, as well as low soil fertility levels, can adversely affect a crops ability to take up nutrients as well as withstand environmental stress, therefore reducing crop yield. The amount of yield loss observed may vary widely due to inherent soil characteristics (Weesies et al. 1994) and depth of the original topsoil (Iowa State Extension, 2001). It has also been shown that soil compaction can account for a significant portion of yield losses on pipeline rights-of-way (Meinke et al. 2008) and that nutrient contents of the topsoil does not correlate well to percent yield loss (Duncan et al. 2009) for some crops.

The objective of this study was to determine if measureable soil parameters which influence soil productivity and crop growth would differ as the depth of topsoil within a pipeline construction ROW varied from the original topsoil.

Methods and Procedures

Site Selection

Replaced topsoil that had been striped and stockpiled on the 125 foot (38 meter) wide construction ROW of a 42-inch (107 cm) natural gas pipeline through Kansas and Missouri were evaluated and compared to the topsoil adjacent to the ROW one year after construction. Fields selected for this study were those reported by landowners to have inadequate depths of replaced topsoil. Samples were collected from 29 properties across 280 miles in Kansas and Missouri.

Sample Collection

Undisturbed soil samples were collected from adjacent off-ROW locations that were similar in landscape position to each on-ROW sample collected, thus creating a paired set of samples for each location. Different landscape topographies, slopes and soil types were paired and sampled. Depth of topsoil material, defined as the A horizon, was recorded at each sample site. Soil samples were collected to the off-ROW topsoil depth for each paired (on-ROW vs. off-ROW) set of samples, or to a maximum depth of 30 cm, whichever was less. The samples were collected in this manner to account for the depth of topsoil stripping that had occurred at each on-ROW location. Soil fertility levels can be stratified with depth in the pre-stripped topsoil layer, whereas construction topsoil that has been stripped, stockpiled, and then replaced are physically mixed making them homogeneous. Therefore, the off ROW soil samples were taken to the depth of stripping and not to the traditional agricultural sampling depth of 15-18 cm (6-7 inches). This was done to assure the laboratory results will accurately represent the soil fertility levels present in the soil.

Multiple samples were collected from each of 29 tracts in Kansas and Missouri so multiple topographic positions would be represented at each location. A total of 170 samples, 85 paired samples (85 off-ROW and 85 on-ROW) were collected and analyzed. Included were 35 paired samples from eleven tracts in Missouri and 50 paired samples from 18 fields in Kansas were collected. An example of the sampling placement within a field is shown in Fig. 1. Soil types are indicated by the background colors, the temporary work space areas are shown with hash marks, the permanent ROW is shaded gray and sampling locations are numbers and shown as red circles. Due to client confidentiality the field locations cannot be disclosed.

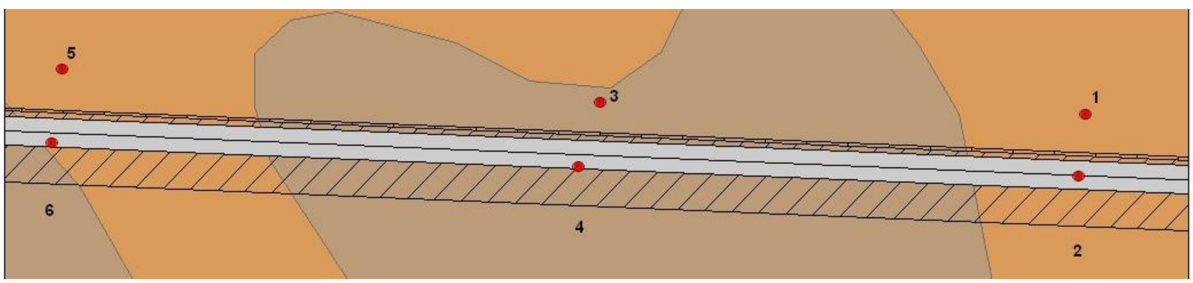

Figure 1. Typical sample location pattern

Laboratory Methods

All samples were analyzed for percent sand, silt, clay, organic matter content, plant available P, K, Mg, CA, and sum of the bases to calculate the cation exchange capacity. Upon visual evaluation of the samples collected, it was decided to not measure for percent coarse fragments due to the lack of coarse fragments in the samples.

Particle size analysis (percent sand, silt and clay). The percent sand silt and clay was determined using the pipette method as described in the Soil Survey Laboratory Methods Manual (Soil Survey Staff. 1992).

Soil Organic Matter. The "loss on ignition" (LOI) method was used to calculate percent organic matter as described in "Recommended Chemical Soil Test Procedures for the North Central Region" (Agricultural Experiment Stations et al. 1998) pH. pH was determined using the 1:1 soil/water dilution method as described in "Recommended Chemical Soil Test Procedures For The North Central Region" (Agricultural Experiment Stations et al. 1998).

Buffer pH. Buffer pH *(pHb)* was determined using the SMP method as described in "Recommended Chemical Soil Test Procedures For The North Central Region" (Agricultural Experiment Stations et al. 1998).

Available Phosphorus (P) and exchangeable potassium (K), calcium (Ca), and Magnesium (Mg). Available P as well as exchangeable K, Ca, and Mg were determined using the Mehlich 3 extraction method as described in "Recommended Chemical Soil Test Procedures for the North Central Region" (Agricultural Experiment Stations et al. 1998).

Cation Exchange Capacity (CEC). The CEC was determined using the sum of the bases method as described in "Recommended Chemical Soil Test Procedures For The North Central Region" (Agricultural Experiment Stations et al. 1998).

Data Analysis

The entire data set was analyzed for relationships between the various measured parameters using correlations and statistical significance of those correlations evaluated at the 0.05 and 0.01 levels. The paired soil samples were evaluated to compare the topsoil depths, soil fertility, texture, and other agronomic factors for each location sampled. Sample data were also grouped based on various geographic and geomorphic changes. The state, soil orders, soil parent materials, and soil series were all reviewed as possible methods of creating sub-sets of data to be analyzed. Due to the location of the parent material changes and the number of soil types encountered, these splits were found to result in sample sets that were not of adequate size to conduct statistical analyses. The sample locations also proved analysis by soil order was not viable since over 91% of the samples originated in one soil order, Mollisols.

Over time, agricultural practices greatly affect soil characteristics and soil productivity potential. The agricultural practices utilized by farmers are greatly influenced by the recommendations derived by the state universities and state extension offices. For this reason the sample locations were grouped and analyzed for relationships at the state level in Missouri and Kansas.

Some research has indicated that the depth of topsoil influences the crop yield potential (Thompson et al., 1991). Other research indicates that soil productivity is influenced by depth to a limiting layer (physical or chemical) more than the actual depth of the topsoil lost or removed Veseth, 1987). To investigate this potential interaction, analyses were also conducted after the data set was split according to original topsoil depths and the amount of change from the original topsoil depth. Two data grouping were used to compare the effect of original topsoil depth, original topsoil depth less than 15 cm (shallow) and original topsoil depth greater than or equal to 15 cm (deep). To analyze soil parameter relationships by depth of topsoil lost, the data were split into the following groupings: samples with a loss, gain, and unchanged topsoil depth relative to the undisturbed sample site.

Results and Discussion

Topsoil Depth

The average topsoil depth found on the ROW was 10.6 cm, 5.1 cm less than the 15.7 cm depths observed off-ROW (Table 1). When the samples were grouped by state, the average topsoil loss was 4.6 cm and 5.4 cm in Kansas and Missouri, respectively.

When sample locations were grouped by Shallow (off-ROW) topsoil depths (less than 15 cm) and Deep (greater than or equal to 15 cm), the amount of topsoil lost was found to vary. For the Shallow Topsoil Sites samples, the off-ROW samples had an average topsoil depth of 11.4 cm while the on-ROW samples averaged 8.6 cm, an average loss of 2.8 cm. For Deep Topsoil Sites samples, the off-ROW samples had an average topsoil depth of 21.0 cm while on-ROW samples averaged 13.0 cm, an average loss of 8.0 cm.

The percent of topsoil lost or missing ranged from 24.4% in the shallow topsoil locations to 38.6% in the deep topsoil. Significant relationships were found at the 0.01 confidence level for topsoil depths On-ROW vs. off-ROW for the following data sets; all sample sites, Kansas sites, Missouri sites, or Deep Topsoil off-ROW sites (Table 2). The only data sub-set that did not show a significant relationship between the on and off-ROW topsoil depths are locations originating with shallow topsoil prior to construction (off-ROW) (Table 2).

Based strictly on the depth of topsoil lost, 24.4% to 38.6% of the undisturbed areas, it might be assumed that there would be a loss of soil productivity. This would be the case if the quality of soil material replaced as topsoil, and/or the upper subsoil material, is changed in a way that detrimentally affects plant nutrients, soil organic matter content, pH, texture, CEC and water holding capacity. Often when the topsoil depths post-construction are less than those prior to construction, much or all of the missing topsoil has not been lost but rather has been incorporated into the upper subsoil. The depth of replaced topsoil decreases when some of the topsoil is mixed with the upper subsoil but the quality of the upper subsoil increases. Should the quality of the upper subsoil be similar to or better than that of the topsoil with respect to texture, pH, CEC, and nutrient content, the productivity of the surface soil where topsoil has been lost can be equal or in some cases better than that of the adjacent undisturbed topsoil area, assuming that the structure of the soil was not impacted.

Soil Physical and Chemical Property Analysis

The texture, soil OM content, pH, CEC, available P, and exchangeable K, Mg, and Ca were analyzed for changes between off and on ROW samples to determine if there were significant changes in measured soil productivity parameters.

Laboratory procedures have typical or acceptable levels of variability associated with them due to the limitations inherent with each extraction, procedure or calculation utilized to conduct an analysis. When the difference in soil fertility estimates is within the acceptable variability for the parameter tested, those results should be considered equivalent. This is an important concept to understand when attempting to relate soil test results between sample groups. This, in conjunction with natural variability in nutrient supplying power of soils due to environmental conditions is why university recommended soil test levels are presented as a range of values, rather than as individual numbers. Typically, soil fertility test results are presented as very low, low, adequate, high, and very high, with a range of numerical values associated with each category.

Using the previously stated laboratory methods, the expected error for each parameter tested is as follows: ±1.0% for particle sizes; ±0.2% for OM and pH; ±0.1 standard unit for Buffer pH; and ±10% of the value for Available P and Exchangeable K, Mg, Ca, and CEC.

Table 1 shows the average value on-ROW and off-ROW for each parameter tested for all samples as well as samples grouped by state and original (off-ROW) topsoil depth. Off-ROW vs. on-ROW differences that are greater than the acceptable variability for the method used is indicated.

Based on the average values and acceptable variability of the laboratory procedures, there were no changes between the off-ROW and on-ROW samples for OM, P, K, Mg, Ca, pHb, or CEC for the entire data set, the sample groupings by state or by original topsoil depth. Particle size analysis and pH were the only parameters with a change in value greater than that of the expected margin of error. Particle size changes did not result in changes in the soils texture class in most cases. In the few cases where the texture class did change, the original texture was near the line that divides its current texture class and the adjacent one. Lack of change in texture class in conjunction with the lack of significant OM change indicates there was little to no change in the water holding capacity of the soil. Due to the texture of these soils, the maximum change in soil water holding capacity would only be 0.37 inches per foot according to models (Saxton and Rawls, 2006)

<u>Particle Size – Clay</u>. Particle size changes, although greater than the acceptable margin of error in some cases, were typically small. Throughout the areas sampled for this study subsoil horizons were typically argillic. A horizon is argillic if there is a clay increase of 1.2 times that of the horizon above when the clay concentration of the upper horizons are 15% - 40% (Soil Survey Staff, 2003). There can be a non-argillic subsoil horizon between the topsoil and argillic horizon. In many cases, the non-argillic subsoil horizon located immediately below the topsoil only differs from the topsoil in organic matter content and or soil structure (arrangement of soil particles into units such as granules or blocks). This non-argillic upper subsoil horizon is more common in Kansas than in Missouri. Most soils encountered in Missouri transitioned directly from topsoil into the argillic subsoil horizon.

An argillic horizon will typically differ greatly from that of the topsoil in soil productivity characteristics such as OM content, bulk density, plant available water holding capacity, CEC, nutrient content, pH and ease of compaction and rutting. A substantial increase in clay content of the replaced topsoil would indicate the addition of subsoil material from the argillic horizon. A significant increase in clay content in the topsoil can be detrimental to soil productivity due to the soil physical and chemical property changes associated with such an increase.

The largest change in clay content compared to off-ROW samples was 1.12 times; found in the sample sub-set from Missouri while the clay content in Kansas was unchanged (Table 1). This would be expected due to the general presence of argillic upper subsoil horizons in Missouri soils. The off-ROW clay content in Missouri was 20.2%. The depth of topsoil lost in Missouri samples averaged 5.4 cm, or 35.5% of the original depth. If we assume the missing 5.4 cm of topsoil was replaced with an argillic sub-soil, then by calculating a weighted average, the resulting clay content on-ROW would need to be at minimum 21.6%, see equations 1 and 2 below.

Minimum clay content required to be argillic ($\text{Argillic}_{\text{min}}$)

$$\text{\% Clay Off-ROW} \times 1.2 = \text{Argillic}_{\text{min}} \qquad \textbf{(1)}$$

Minimum % Clay needed to have had an argillic subsoil replace the missing topsoil (Clay_{min})

$$(\text{Argillic}_{\text{min}} \times \text{\% Topsoil lost}) + (\text{\% Clay Off-Row} \times \text{\% topsoil not lost}) = \text{Clay}_{\text{min}} \qquad \textbf{(2)}$$

Example: 20.2% x 1.2 = 24.2%, (24.2% x 0.355) + (20.2% x 0.645) = 21.6%

The average clay content found on the ROW in Missouri was 22.6%; therefore, it would be reasonable to assume the clay increase was due to the incorporation of, or immediate contact with, an argillic subsoil material with the replaced topsoil.

The only other data set exhibiting an increase in clay content greater than the expected error was for those samples originating with deep topsoil. The off-ROW and on-ROW clay contents were found to be 23.5% and 25.9%, respectively. This sample set also had the greatest loss in topsoil depth, a loss of 8 cm or 38.6% relative to the undisturbed off-ROW locations. For the missing 8 cm of topsoil to have been replaced entirely with an argillic sub-soil, the resulting clay content on-ROW would need to be at minimum 25.3%. Therefore, it is conceivable that the increased clay content in these sample locations was also due to the incorporation of, or immediate contact with, an argillic subsoil material with the replaced soil.

Based on the change in clay content, samples from Missouri and areas that originated with deep topsoil might be expected to have changes in soil physical and chemical properties to a level that could affect soil productivity negatively.

Particle Size – Sand. The sand content on-ROW increased relative to off-ROW samples across all sites, Missouri sites, and sites that originated with Shallow topsoil, by 2.3%, 3.0%, and 3.2% respectively (Table 1). An increase in sand can reduce the CEC and therefore plant available nutrient holding power of the soil, but in each of these cases the CEC of the soil remains unchanged. The lack of change in CEC where sand content increases is likely due to the corresponding increases in silt or clay content found in these sample sets.

Table 1. Average value of measured parameters for given sample populations.

Sample Population	Sample Location	Topsoil Depth (cm)	Sand (%)	Silt (%)	Clay (%)	O.M. (%)	P (ppm)	K (ppm)	MG (ppm)	CA (ppm)	pH	pHb	CEC
All samples	Off-ROW	15.7	9.5	65.5	25.0	1.90	19	172	449	2904	6.24	6.73	21.00
	On-ROW	10.6	11.8	61.8	26.3	1.73	20	176	480	3188	6.53	6.81	21.96
Kansas Samples	Off-ROW	16.4	4.4	63.7	31.9	1.99	25	192	592	3291	6.04	6.62	25.11
	On-ROW	11.8	5.8	62.6	31.6	1.77	23	194	607	3628	6.51	6.79	25.52
Missouri Samples	Off-ROW	15.2	13.0	66.8	20.2	1.85	16	158	349	2633	6.38	6.81	18.12
	On-ROW	9.8	16.0	61.3	22.6	1.69	17	163	391	2879	6.54	6.84	19.47
Samples with < 15 cm of Original Topsoil Depth	Off-ROW	11.4	9.5	64.2	26.3	1.98	17	188	485	3040	6.42	6.78	21.64
	On-ROW	8.6	12.7	60.6	26.7	1.74	20	189	506	3318	6.57	6.81	22.89
Samples with ≥ 15 cm of Original Topsoil Depth	Off-ROW	21.0	9.4	67.1	23.5	1.82	22	152	404	2736	6.02	6.68	20.21
	On-ROW	13.0	10.7	63.4	25.9	1.70	19	159	448	3027	6.47	6.82	20.81

NOTE: Yellow shading indicates a difference between the off-ROW and On-ROW measurement which is greater than the expected margin of error for that test procedure, i.e.- a true numerical difference.

Particle Size Summary. It is assumed that the changes observed in particle size distribution did not affect the overall productivity of the soil in regards to nutrient or water holding capacities due to the lack of significant changes in CEC and soil OM in all data sets. What has not been evaluated is the potential change in compactability due to particle size distribution changes. Although bulk density can be measured through the collection of intact samples, there has only been up to one year and in some cases no crops yet grown since construction of the pipeline. For this reason, bulk density data collected at the time of this study would not necessarily be representative of soil compactability or potential root penetration. Collection of penetrometer data using a constant rate cone penetrometer after 2-3 years of cropping will better indicate the potential for increased root limitation.

pH. Ideal pH values for Midwestern crops range from 6.5 to 6.8. In all cases, the pH values were found to increase on the ROW compared to off-ROW. For the data sets “all samples,” Kansas, and Deep samples; the increased pH value was significant (Table 1). Average pH values for all data sets off-ROW ranged from 6.0 to 6.4, and on-ROW from 6.5 to 6.6. Although pH values increased on the ROW, the resultant pH is an improvement in regards to crop productivity and potential nutrient availability.

The improvement in pH levels on-ROW was likely due to the inherently high pH levels of the mixed subsoil or to liming of the ROW. Kansas subsoil parent materials tend to have higher pH levels than Missouri soil parent materials, which can be seen in the change in pH values of 6.04 off-ROW vs. 6.51 on-ROW in Kansas, compared to 6.38 off-ROW vs. 6.57 on-ROW in Missouri (Table 1).

High levels of free carbonates in the subsoil can be detrimental to crop productivity. Typically, free carbonates are not of concern until the soil pH is approximately 7.4 or greater. A pH level of ≥7.4 was observed in a total of 8 samples locations on-ROW, 4 in Missouri and 4 in Kansas. Of the 8 locations with a pH ≥ 7.4, only three of the locations in Kansas had an increase in pH relative to the off-ROW paired sample. These three locations could potentially develop crop productivity issues not expected in locations were pH remained below 7.4. High subsoil free carbonate levels need to be taken into consideration in some regions of Kansas and other agricultural states when planning construction and restoration practices.

Statistical Analyses

Using Microsoft Excel each parameter tested was analyzed for correlations and significance at the 0.05 and 001 confidence levels between off-ROW and on-ROW values within the data sets; all samples, Kansas, Missouri, and sample locations originating with shallow and deep topsoil depths (Table 2). The only parameters not significantly related at the 0.01 or 0.05 confidence levels in these analyses are topsoil depth for originally shallow topsoil and pHb in Kansas.

Even though there was a lack of correlation between topsoil depth in shallow samples, all other tested parameters were correlated between the off and on ROW samples for that data set (Table 2) indicating the change in topsoil depth, although significant, did not result in changes in the soil productivity parameters tested. Therefore, a loss in productivity at these sample locations would not likely be due to fertility, OM, or particle size changes, but rather from other issues such as compaction or drainage created by the construction equipment traffic, settling, or failed drain tile repairs.

Table 2. Summary of analysis for correlation and significance between the off-ROW and on-ROW samples for given sample populations.

Parameter	Correlation and Level of Significance				
	All Samples	Kansas Samples	Missouri Samples	Originating with < 15 cm Topsoil	Originating with ≥ 15 cm Topsoil
Depth of Topsoil	0.538**	0.606**	0.457**	0.263	0.472**
SAND (%)	0.835**	0.812**	0.810**	0.799**	0.916**
SILT (%)	0.761**	0.716**	0.797**	0.671**	0.870**
CLAY (%)	0.812**	0.788**	0.586**	0.816**	0.816**
O.M.	0.700**	0.445**	0.781**	0.609**	0.815**
P	0.557**	0.715**	0.450**	0.631**	0.731**
K	0.682**	0.748**	0.648**	0.620**	0.731**
MG	0.829**	0.549**	0.702**	0.818**	0.831**
CA	0.694**	0.437**	0.761**	0.717**	0.592**
pH	0.636**	0.402*	0.769**	0.688**	0.544**
pHb	0.485**	0.302	0.717**	0.568**	0.459**
CEC	0.746**	0.339*	0.708**	0.775**	0.664**

* = significantly correlated at 0.05 **= significantly correlated at 0.01

(highlighted) = parameters with statistical change between off-ROW and on-ROW

The post-construction goal is to have sample locations with no change in topsoil depth on the ROW relative to off-ROW. Therefore, when comparing topsoil depth to the other tested parameters, for samples with no change in topsoil depth, only those significantly related parameters can be expected to be correlated to topsoil depth in other sample sets or sub-sets (Table 3). Therefore, parameters without a significant relationship in this comparison cannot be expected to be related between on-ROW and off-ROW locations regardless of topsoil depth changes.

The parameters that were directly correlated at the 0.05 or 0.01 confidence levels at sample locations with no change in topsoil depth were: sand, silt, clay, Mg, Ca, pH, pHb, and CEC. No parameters were found to be indirectly correlated. There was no correlation between OM content, P, or K at the 0.01 or 0.05 confidence levels.

Table 3. Correlation and significance of populations based on observed topsoil change between off-ROW and on-ROW samples for given sample populations.

Sample Population	Percent of total data	On-ROW Depth	SAND (%)	SILT (%)	CLAY (%)	O.M.
59 with TS depth loss	69.4%	0.711**	0.821**	0.766**	0.830**	0.773**
7 with a Gain in TS	8.2%	0.810 *	0.893**	0.870 *	0.673	0.656
19 with No TS Change	22.4%	1.000**	0.873**	0.740**	0.824**	0.396

* = significantly correlated at 0.05 ** = significantly correlated at 0.01

Sample Population	P	K	Mg	Ca	pH	pHb	CEC
59 with TS depth loss	0.545**	0.762**	0.812**	0.639**	0.639**	0.513**	0.719**
7 with a Gain in TS	0.970**	0.419	0.825 *	0.772 *	0.250	-0.275	0.690
19 with No TS Change	0.427	0.328	0.908**	0.904**	0.824**	0.721**	0.909**

* = significantly correlated at 0.0 ** = significantly correlated at 0.01

Sample sites where there was a loss of topsoil were directly correlated to the parameters in samples without a change in topsoil depth which indicate that there was not a statistical difference between sand, silt, clay, Mg, Ca, pH pHb, or CEC based on topsoil loss. In addition to these relationships, samples with a loss of topsoil relative to off-ROW were found to have significant direct relationships between OM, P, and K, which comprise all remaining parameters tested. This indicates that in areas where less topsoil is replaced than originally removed the quantities of OM, P, and K present in the original topsoil affects the quantity present in the replaced topsoil to a greater degree than that of the locations where the correct amount of topsoil has been replaced. Therefore, as the depth of topsoil replaced decreased the OM, P, and K contents in the on-ROW topsoil also decrease. This relationship may indicate that at locations where the quantity of topsoil lost is great, the change in OM, P, and K levels may pose a productivity limitation, should the resultant soil test levels decrease beyond their respective critical levels for the crops grown at those locations.

Conclusions

The analysis conducted for this study at the 0.05 confidence level found that almost all parameters, when compared off-ROW vs. on-ROW, were significantly related to each other.

Therefore, even though there were changes in the on-ROW value of a parameter relative to the undisturbed off-ROW, those changes were not significant. Similar results were found at the 0.01 confidence level.

Loss of soil productivity is not expected to be related to loss of topsoil across most of this data set due to the lack of significant change in soil fertility, organic matter content, pH, particle size distribution, and nutrient and water holding capacities in the replaced topsoil as compared to the undisturbed topsoil.

The value and role of topsoil in the overall productivity of soils is not to be discounted, nor is it the intention of this research to disprove its importance. What can be reasonably argued from the results of this study is that although preserving and replacing topsoil is a good practice, the importance of replacing the exact amount of topsoil removed is most likely not critical to the future productivity of the soil in regions where the upper subsoil horizons are not of significantly different texture and do not contain a potentially crop limiting characteristic.

Without loss of topsoil depth as a probable cause for soil productivity losses, the most likely cause of lost productivity, should a loss be observed, is a compaction or drainage issue.

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