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# Topsoil Loss Does Not Necessarily Equal Lost Crop Yield Potential:

## Evaluating Agronomic Characteristics of Surface Soils on a Pipeline Right-of-Way

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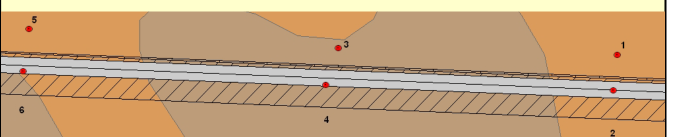
## OBJECTIVE

Determine if the lack of adequate topsoil depth replaced on a pipeline right-of-way, as compared to adjacent off right-of-way locations, negatively effects agronomic soil characteristics and therefore crop yield potential.



## ABSTRACT

Lack of adequate topsoil depth and perception of lost soil fertility on pipeline construction right-of-ways (ROW) 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 adversely affect the crops ability to withstand environmental stress and therefore reduce crop yield.

Topsoil that had been stockpiled and replaced on the construction ROW of a 1.07 meter (42 inch) natural gas pipeline through Kansas and Missouri was evaluated and compared to the topsoil adjacent to the ROW one year after construction. Soils were evaluated on and off the ROW to compare the topsoil depths, soil fertility, texture and other agronomic factors of each location.

Sample locations were selected based on landowner reports of inadequate depths of replaced topsoil. Approximately 69% of those 78 sample locations had less topsoil present on ROW than in adjacent off-ROW areas of similar landscape position. An average of 4.5 cm (1.8 inches) of topsoil loss was found across the entire sample set, this represents a 33% loss when compared to off-ROW topsoil samples. The differences recorded between the on-ROW and off-ROW values for other soil parameters tested were typically not significant.

The lack of significant change in tested parameters of the upper soil on-ROW, compared to that of the undisturbed topsoil off-ROW would indicate that no effect on crop yield potential is expected due to the reduction in depth of topsoil material on the ROW.

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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 Right of Way (ROW) post-construction, the most common suspected causes are lost soil fertility, lost topsoil, compaction and drainage issues.

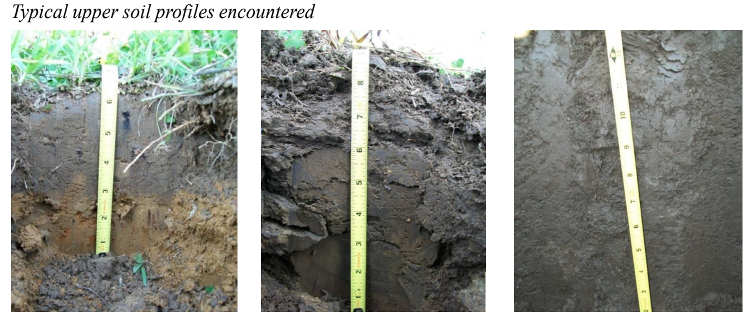
Most previous research regarding depth of topsoil in relation to crop yield have been with a soil erosion perspective and conducted in areas where varying degrees of erosion are pre-existing or by removing topsoil in incremental depths at undisturbed locations to simulate various levels of erosion.

In many cases, grain yield reduction of the artificially eroded soil was found to be a function of nutrient removal (Batchelder et al. 1972; Malhi et al. 1999; Izaurralde et al. 2006). Despite this relationship, the amendments that most effectively restored crop yields were not commercial fertilizers alone but rather manure with commercial fertilizers (Robbins et al. 1997; Larney et al. 2000; Brye 2006; Sui et al. 2009).

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, such as increasing organic matter and micronutrients, as well as cation exchange capacity (CEC) may explain, to some degree, why commercial fertilizer alone does not restore yields to the same extent as manure with commercial fertilizer.

The amount of yield loss observed may vary widely due to inherent soil characteristics (Weesies et al. 1994) and depth of the original topsoil soil (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 do not correlate well to percent yield loss (Duncan et al, 2009) for some crops.

*Typical upper soil profiles encountered*



## METHODS

Soil samples were collected from on-ROW and adjacent off-ROW locations in similar landscape position, thus creating paired samples for each location. 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 18 centimeters (cm) (7 inches) whichever was greater. The samples were collected in this manner to account for the depth of topsoil stripping that had occurred at each on-ROW location.

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. 35 paired samples from eleven tracts in Missouri and 50 paired samples from 18 fields in Kansas were collected.

Samples were analyzed for particle size (percent sand, silt, clay) – pipette method; organic matter content – Loss on Ignition; plant available phosphorus, potassium, magnesium, calcium – Mehlich 3; and cation exchange capacity (CEC) – sum of bases.

All laboratory procedures were conducted using methods as described in the Soil Survey Laboratory Methods Manual (Soil Survey Staff. 1992). Cation exchange capacity 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).

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.

Sample data were grouped by various geographic and geomorphic changes. Analyses were also conducted after the data was split according to original topsoil depths and amount of change from the original topsoil depth. Two data grouping were used to compare the effect of the original topsoil depth; original topsoil depth less than 15 cm (shallow, less than 6 inches) and original topsoil depth greater than or equal to 15 cm (deep).

## RESULTS

The average topsoil depth found on the ROW was 10.6 cm, 5.1 cm less than the 15.7 cm found off-ROW. 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 off-ROW topsoil samples, the average depth of topsoil was 11.4 cm and 8.6 cm off-ROW and on-ROW respectively, a net loss of 2.8 cm. For samples Deep Topsoil Sites off-ROW, 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 was as low as 24.4% for samples originating in shallow topsoil locations off-ROW to as high as 38.6% for samples originating with deep topsoil off-ROW. No significant differences were found at the 0.05 or 0.01 confidence level for topsoil depths On-ROW vs. off-ROW for the data sets; all sample sites, Kansas sites, Missouri sites, or Deep Topsoil off-ROW sites. 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).

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 and CEC. 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.

The expected error for each laboratory parameter tested is as follows: ±1.0 for particle sizes; ±0.2 for O.M. and pH; ±0.1 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 are indicated.

*Table 1. Table of Average Value for Each Parameter Measured for a Given Population.*

| Table 1. | All samples | | Kansas Samples | | Missouri Samples | | Samples with < 15 cm of Original Topsoil Depth | | Samples with ≥ 15 cm of Original Topsoil Depth | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Off-ROW | On-ROW | Off-ROW | On-ROW | Off-ROW | On-ROW | Off-ROW | On-ROW | Off-ROW | On-ROW |
| Topsoil Depth* (cm) | 15.7 | 10.6 | 16.4 | 11.8 | 15.2 | 9.8 | 11.4 | 8.6 | 21.0 | 13.0 |
| SAND (%) | 9.5 | 11.8 | 4.4 | 5.8 | 13.0 | 16.0 | 9.5 | 12.7 | 9.4 | 10.7 |
| SILT (%) | 65.5 | 61.8 | 63.7 | 62.6 | 66.8 | 61.3 | 64.2 | 60.6 | 67.1 | 63.4 |
| CLAY (%) | 25.0 | 26.3 | 31.9 | 31.6 | 20.2 | 22.6 | 26.3 | 26.7 | 23.5 | 25.9 |
| O.M. (%) | 1.90 | 1.73 | 1.99 | 1.77 | 1.85 | 1.69 | 1.98 | 1.74 | 1.82 | 1.70 |
| P (ppm) | 19 | 20 | 25 | 23 | 16 | 17 | 17 | 20 | 22 | 19 |
| K (ppm) | 172 | 176 | 192 | 194 | 158 | 163 | 188 | 189 | 152 | 159 |
| MG (ppm) | 449 | 480 | 592 | 607 | 349 | 391 | 485 | 506 | 404 | 448 |
| CA (ppm) | 2904 | 3188 | 3291 | 3628 | 2633 | 2879 | 3040 | 3318 | 2736 | 3027 |
| pH | 6.24 | 6.53 | 6.04 | 6.51 | 6.38 | 6.54 | 6.42 | 6.57 | 6.02 | 6.47 |
| pHb | 6.73 | 6.81 | 6.62 | 6.79 | 6.81 | 6.84 | 6.78 | 6.81 | 6.68 | 6.82 |
| CEC | 21.00 | 21.96 | 25.11 | 25.52 | 18.12 | 19.47 | 21.64 | 22.89 | 20.21 | 20.81 |

* Expected error for topsoil depth measurements is ±1.3 since topsoil depth was measured in 0.5 inch (1.3 cm) increments.

Indicates values differ by more than the expected error of the laboratory procedure used.

Particle size analysis and pH were the only parameters with changes in value greater than 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, therefore an insignificant change in the clay content changes the texture class of that soil. The 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.

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. 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. This non-argillic upper subsoil horizon is more common in Kansas than in Missouri. 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 associated changes in soil physical and chemical properties.

The largest increase in clay content 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 lack of non-argillic upper subsoil horizons in the Missouri soils. If we assume the missing 5.4 cm of topsoil in Missouri 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% [example: 20.2% x 1.2 = 24.2%, (24.2% x 0.355) + (20.2% x 0.645) = 21.6%].

## RESULTS (continued)

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 population exhibiting an increase in clay content greater than expected error is 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 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 replaced topsoil's increased clay content at these sample locations was also due to the incorporation of, or immediate contact with, an argillic sub-soil material.

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. The lack of significant changes in soil O.M. and CEC in all data sets indicate 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.

The only parameters significantly different at the 0.01 or 0.05 confidence levels are topsoil depth for originally shallow topsoil and pHb in Kansas (Table 2). All other tested parameters were correlated between the off and on ROW samples for that data set indicating the change in topsoil depth 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, O.M., 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. Correlations and Significance of Off-ROW vs. On-Row Parameters Measured.*

| Table 2. | Entire Data Set | Kansas Samples | Missouri Samples | Samples with < 15 cm (6 in.) of topsoil Off-ROW | Samples with ≥ 15 cm (6 in.) of topsoil Off-ROW |
|---|---|---|---|---|---|
| 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 related at 0.05 ** = significantly related at 0.01

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 and 0.01 confidence levels 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.

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 said 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 soil horizons are not of significantly different texture and do not contain a potentially crop limiting characteristic.

## REFERENCES

Literature cited is shown on a supplemental "References" page. Contact author for a copy of the complete paper.