Site-Specific Measurement of Site-Specific Compaction in the Southeastern United States

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ABSTRACT

Yield variations are common in most fields in the Southeastern U.S. Increasing yields to maximum uniform levels by site-specific measurement and modification of nutrient levels have mostly been unsuccessful. Researchers now recognize that extreme variation in soil physical conditions are much more important than previously thought. Measurement and modification of site-specific soil physical properties are now being attempted.

Cone index measurements have been obtained for many soils in the Southeastern U.S. Most of these soils have an impervious soil layer that restricts root growth, particularly during periods of temporary drought that plague the Southeastern U.S., and require annual subsoiling for maximum yields. Measurements of cone index demonstrate the extreme variability in depth to the hardpan layer. Geostatistical models were successfully constructed for this data to predict the approximate distance between sampling points. Results from upland soils showed that more variability may exist in the traffic and no-traffic middles than in the in-row position where tillage may have been extensively used. Similar distances between sampling points were also predicted for coastal plains soils.

INTRODUCTION

Significant variation in crop yields have been found in many parts of the U.S. using Global Positioning Systems (GPS) and yield monitors. Attempts to explain these differences have largely centered on pest and nutrient variability. In many areas of the country, research efforts have been partly successful with site-specific applications of pesticides and/or nutrients which have helped to increase yields in lower yielding areas of the field. In some cases, abandonment of low-producing areas has also improved the overall profitability of the producer.

However, soil variability is a likely culprit of extremely variable yields, particularly in highly weathered ultisols, the predominate soil order in the Southeast. In most cases, these soils do not provide adequate moisture storage for successful crop production. Inadequate amounts of topsoil create limited reservoirs of moisture. Soil compaction caused by natural forces or by vehicle traffic also limits the ability of plant roots to penetrate to depths of soil that could sustain plants during common short-term droughts.

Many producers in the Southeast rely on some form of annual deep tillage to break through this hardpan layer which allows crop roots to penetrate to less compact, more moist horizons. This tillage event can be fairly expensive, both in environmental and productivity cost terms. Excessively deep tillage can cover valuable crop residue which can increase surface erosion and also waste tillage energy. Some studies have also found that excessively deep tillage can slightly decrease crop yields, perhaps due to excessive soil disturbance. Excessively shallow tillage can also result in reduced crop yields if not performed to an adequate depth to disrupt the hardpan profile.

Therefore, the objectives of this study were:

1. To develop an effective procedure to determine the depth of hardpan,
2. To determine the effect of traffic on depth of hardpan, and
3. To determine the variation in depth of hardpan of selected Southeastern U.S. fields.

METHODS AND MATERIALS

A multiple-probe soil cone penetrometer (MPSCP) and a manually-operated Rimik[1] soil cone penetrometer were used to obtain cone index measurements in several fields in the Southeastern U.S. These measurement devices were used to sense the soil strength and to determine the depth of the root-impeding or hardpan layer. Fields consisting of upland soils of Grenada silt loam soil type near Senatobia, MS were first sampled for soil compaction variability. The three fields sampled were managed with (1) no-tillage with drilled soybeans for narrow row production, (2) conventional tillage (chisel, disk twice) for 90-cm row soybean production, and (3) no-tillage for 90-cm row soybean production. The MPSCP was used to acquire soil strength data on an approximate grid of 30 m x 30 m. Immediately following this sampling procedure, a complete set of soil moisture data was collected at the same locations at depths of 15 and 30 cm with a time-domain reflectometry (TDR) probe. A range level was also used to determine the topography more accurately than could be accomplished with GPS. A second location further south in the Coastal Plains region of the Southeastern U.S. was selected to analyze a different soil type. This 6.17-ha field consisted of a Toccoa fine sandy loam soil

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[1]Use of a company name does not imply USDA approval or recommendation of the product or company to the exclusion of others which may be suitable.

type and was located at the Alabama Experiment Station's E.V. Smith Research Station in Shorter, Alabama. The MPSCP and the Rimik soil cone penetrometers were both used at separate times to acquire soil strength data on an approximate grid of 0.10 ha. Immediately following this sampling procedure, a complete set of soil moisture data was collected at the same locations at depths of 0-15 cm with a TDR probe.

Statistical analyses were made using SAS software (SAS Institute, 1998). Semivariograms were also calculated for these data to determine their spatial dependence using GS+ (Gamma Design Software, 1999).

RESULTS AND DISCUSSION

To shorten and simplify the discussion, the results will be restricted to one field from each soil type: Field 2 at Senatobia, MS, and Field 1 at Shorter, AL. Soil strength from data obtained in Field 2 (MS) showed two peak values of cone index that required some discrimination. The upper peak that occurred at a depth of approximately 20 cm was considered a hardpan while the second peak that occurred at a depth of approximately 50 cm was considered a fragipan. These soils are prone to fragipan formation at this approximate depth. Throughout this field, a SAS procedure that searched for the peak value as the criteria for the hardpan was used to sort the data and predict depth of hardpan formation. The criteria used to locate these depths of hardpans consisted of locating at least 3 consecutive data points that were greater than 0.05 MPa from previous data points and ensuring that the magnitude of cone index was greater than 1.0 MPa.

Because the Field 2 (MS) data was collected with the MPSCP, we retained the ability to discriminate between depths of hardpan caused by wheel traffic. Segregated row middles were maintained in Field 2 (MS) and the cone index measurements obtained were analyzed for differences caused by vehicle traffic. It was obvious from the data that shallower hardpans were found when the row middles were trafficked (Figures 1 and 2). Using data collected in the trafficked row middles gave an average predicted depth of hardpan of 0.178 m compared to the data collected in the no-trafficked row middles which gave an average predicted depth of hardpan of 0.210 m (Table 1). We therefore determined that vehicle traffic caused the hardpan profile to move closer to the soil surface by 0.032 m, additionally restricting root growth and water movement. However, data obtained directly beneath the row showed the depth to the root-impeding layer to be 0.l89 m. This area lies between the tracked and no-tracked row middle and was likely influenced by traffic applied to the trafficked row middle. Cone index data collected in Field 1 (AL) was not segregated for traffic and showed an average depth to hardpan of 0.282 m, which was deeper than any of the Field 2 (MS) measurements.

The depth to hardpan data was next checked for spatial dependence. Table 2 shows the spherical models that most closely fit the depth to hardpan data obtained in the trafficked and no-trafficked middles from Field 2 (MS) and Field 1 (AL). For the Field 2 (MS) data, the spherical model for the depth of hardpan in the in-row position was more closely fitted and showed a higher degree of spatial structure than either the depth of hardpan in the trafficked middle, or the depth of hardpan in the no-trafficked middle. This closer fit was evidenced only by a higher correlation coefficient; all of the (sill-nugget)/sill values were the same. The latter value indicates a high degree of spatial structure and was close to 1.00 for all three measurements which was the best theoretical fit possible.

The range of the depth of hardpan in the in-row position was 26.4 m which can be an effective criteria for determining sampling distances. This value is the approximate sampling distance from one point to another within a field from which similar hardpan depths would be expected. This value decreased for the no-trafficked middle and trafficked middle to 13.0 m and 17.7 m, respectively. These measures indicate that the effect of in-row tillage likely reduced the natural and man-made variability present in this field to increase the sampling range for the in-row position. A slightly larger range for the trafficked middle may indicate a slight decrease in variability over the field due to the effect of traffic, but is so small that it is likely statistically insignificant.

The depth to hardpan from Field 1 (AL) gave a range of 27.5 m which is similar to the range found with the in-row position from Field 2 (MS). The fit of the data to the spherical model was also similar with a correlation coefficient of 0.31 and a (sill-nugget)/sill value of 0.82.

It may be surmised from the successful modeling of the depth to hardpan that this data was spatially related. Because of the perceived spatial relationship, it is therefore reasonable to consider altering this parameter with some form of site-specific tillage that may be more efficiently applied than uniform tillage.

CONCLUSIONS

1. An effective procedure to determine the depth to the hardpan was developed.
2. Traffic was found to bring the hardpan depth closer to the soil surface by 0.032 m for the Field 2 (MS) site.
3. The depth to hardpan was found to vary substantially in both of the Southeastern U.S. fields that were sampled. Similar models and predictions of range were found for each location.

Table 1. Descriptive Statistics of Depth to Hardpan, Soil Moisture, Elevation.

	Mean	Standard Deviation	Min Value	Max Value	Number of Values	Skewness	Kurtosis
Field 2 (MS) 90 cm Row Spacing							
Depth to In-Row Hardpan, (m)	0.189	0.058	0.085	0.335	53	0.4843	0.0530
Depth to No-Trafficked Hardpan, (m)	0.210	0.062	0.105	0.365	50	0.4659	-0.4146
Depth to Trafficked Hardpan, (m)	0.178	0.048	0.105	0.305	57	0.3923	-0.3477
Soil Water (0-15 cm), (%)	34.52	2.3076	28.9	39.6	60	-0.3969	-0.3572
Soil Water (0-30 cm), (%)	35.00	1.3474	31.5	37.9	61	0.0834	-0.2625
Elevation, (m)	150.1	1.9167	146.3	152.8	61	-0.2520	-1.0441
Field 1 (AL) 100 cm Row Spacing							
Depth to Hardpan, (m)	0.282	0.0911	0.13	0.52	108	0.4566	-0.5811

Soil Water (0-15 cm), (%)	26.68	5.24	11.6	42.7	158	0.4892	0.5856

Table 2. Descriptive Semivariogram Statistics for Depth to Hardpan.

	Model	Nugget $(m)^2$	Sill $(m)^2$	Range (m)	Regression Coefficient	(Sill-Nugget) / Sill
Field 2 (MS) 90 cm Row Spacing						
Depth to In-Row Hardpan, (m)	Spherical	0.00	0.004	26.4	0.46	1.00
Depth to No-Trafficked Hardpan, (m)	Spherical	0.00	0.004	13.0	0.00	1.00
Depth to Trafficked Hardpan, (m)	Spherical	0.00	0.002	17.7	0.22	1.00
Field 1 (AL) 100 cm Row Spacing						
Depth to Hardpan, (m)	Spherical	0.002	0.008	27.5	0.31	0.82

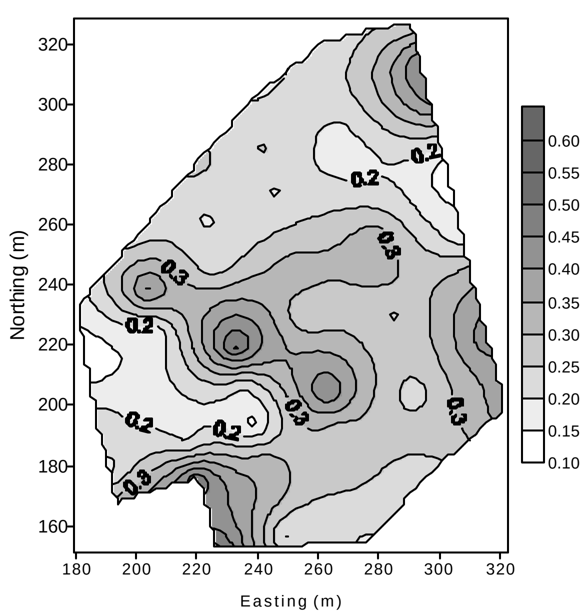

Figure 1. Contour Graph of Depth of Hardpan Layer as Measured in the No-trafficked Row Middle from Field 2 (MS).

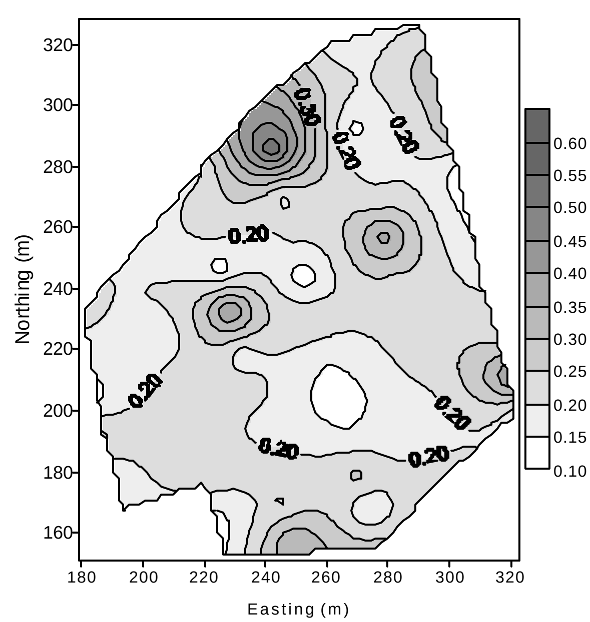

Figure 2. Contour Graph of Depth of Hardpan Layer as Measured in the Trafficked Row Middle from Field 2 (MS).