Reducing Draft Requirements and Maintaining Crop Yields with Site-Specific Tillage

Randy L. Raper[1], D. Wayne Reeves[2], Joey N. Shaw[3], Edzard van Santen[3], Paul L. Mask[3] and Tony E. Grift[4]

[1]USDA-ARS National Soil Dynamics Laboratory, Auburn, AL Email: rlraper@auburn.edu, USDA-[2]ARS J. Phil Campbell Sr. - Natural Resource Conservation Center, Watkinsville, GA
[3]Agronomy and Soils Department, Auburn University, Auburn, AL
[4]Agricultural Engineering Department, University of Illinois, Urbana, IL

Abstract: Deep tillage is often required to alleviate soil compaction, however subsoiling can be an expensive and time-consuming tillage event. If this tillage operation is conducted deeper than the compacted soil layer, energy is wasted. On the other hand, if this tillage operation is conducted shallower than the compacted soil layer, energy is again wasted and plant roots will also not be able to penetrate the compacted layer. Technologies are now available which allow tillage to be conducted at the specific depth of the compacted layer. Natural resources should be able to be conserved without sacrificing crop yields. An experiment was conducted to evaluate the concept of site-specific tillage in a field in Southern Alabama in the United States for three years to evaluate whether the concept of site-specific tillage (tilling just deep enough to eliminate the hardpan layer) would reduce tillage energy requirements and/or reduce crop yields. Average corn (*Zea mays L.)* yields over this three-year period showed that site-specific tillage produced yields equivalent to those produced by the uniform deep tillage treatment while requiring 25% less tillage fuel.

INTRODUCTION

Soil compaction continues to reduce yields of various crops throughout the world. In some situations, subsoiling can help reduce the negative effects of soil compaction (Campbell *et al.*, 1974). This tillage process provides increased rooting depth to withstand short-term drought conditions prevalent during the growing season in the southeastern United States. A typical depth of annual subsoiling is between 0.3 m and 0.5 m. The depth of tillage is chosen based on average needs of the soil and the capability of the tractor and implement.

For these reasons, the concept of site-specific tillage was investigated as a potential method for adjusting tillage depth on-the-go as a farmer traverses a field. A map created using geospatial technology could be used to reduce tillage depth in areas where deep tillage was not needed or a sensor could be used to make an immediate adjustment in tillage depth. This reduction in tillage depth could reduce tillage energy and fuel requirements. If the depth of tillage chosen is too deep, energy will be wasted and surface residue will be covered. If the depth of tillage chosen is too shallow, tillage may be inadequate to remove the root-restricting layer and thus, all energy used for this tillage operation is wasted. Site-specific measurements of hardpan depth taken in several locations in the Southeastern U.S. indicate that between 25 and 75% of tillage energy could be saved if some form of site-specific tillage could be developed and used (Fulton *et al.*, 1996; Raper, 1999). Also, some data indicate that tillage deeper than necessary may reduce yields (Raper *et al.*, 2000a; Raper *et al.*, 2000b). Therefore, it is important to determine the depth of the root-impeding layer and to till only deep enough to eliminate this layer of soil compaction. A variable-depth tillage (site-specific tillage) system is needed that considers the crop's needs and the soil's variability.

METHODS AND MATERIALS

In 1999, a 8-ha field was selected at Alabama Experiment Station's E.V. Smith Research Station in southern Alabama, USA that exhibited a great amount of yield variability. This field contained a Coastal Plain soil, Toccoa fine sandy loam soil, that had excessive soil strength and routinely required subsoiling. The source of the yield variability was thought to be attributed to excessive soil compaction that varied substantially throughout the field. To attempt to understand the degree of variation, a set of bulk soil electrical conductivity measurements was obtained with the Veris Technologies electrical conductivity sensor to determine if subsurface differences in soil could be present at the site. Secondly, a complete set of cone penetrometer measurements (ASAE, 1999a; ASAE, 1999b) were obtained with the Multiple-Probe Soil Measurement System (Raper *et al.*, 1999) on an approximate 100 m grid. Cone index measurements were analysed for differences in the depth to hardpan over the entire field. A corn yield map was also obtained for the entire field in 1999 using a yield monitor. The yield variation data, the electrical conductivity data, and the cone index data were then used to locate the experimental plots.

The cone index data indicated that the depth of extreme values of soil compaction that could restrict root growth ranged from 15-45 cm over the entire field. This range of depth of compaction was split into three distinct hardpan depth ranges of 15-25 cm, 25-35 cm, and 35-45 cm, which were replicated four times within the field. Three tillage treatments were imposed within each of the test plots in the spring of 2000, 2001, and 2002:

- no-tillage (zero-depth tillage)
- site-specific tillage (25-cm, 35-cm, or 45-cm depth tillage)
- deep tillage (45-cm depth tillage)

As an example, for the plots with the shallowest hardpan (the 15-25 cm hardpan depth), a 25-cm tillage depth was selected for the site-specific tillage depth. Therefore, three tillage treatments were applied in these shallow hardpan areas; (1) no-tillage, (2) site-specific tillage (with a depth of 25 cm), and (3) deep tillage.

Subsoiling treatments were conducted with a John Deere (JD) 955 Row Crop Ripper equipped with 7-cm wide LASERRIP™ Ripper Points. This subsoiler was supplied as part of a Cooperative Research and Development Agreement with Deere & Co (Moline, IL). Modifications were made to this implement to allow for a tillage depth of 25-45 cm and to incorporate heavy residue handling attachments which were supplied by Yetter (Colchester, IL). For each particular tillage depth desired, this subsoiler was manually adjusted by moving the coulters and the residue handling attachments.

The JD 955 implement was mounted on a three-dimensional dynamometer which measured draft, vertical, and side forces required for tillage of each plot. A radar gun was used to obtain tillage speed which was used along with the mean draft data to obtain horsepower and fuel requirements necessary for tillage. A JD 8300 tractor was used to pull the implement through the soil.

The first tillage in the plots was conducted in Spring of 2000. The field was split into two halves (Field 1 and Field 2) to allow for a corn-cotton (*Gossypium hirsutum* L.) rotation. Cotton was planted in 1.02 m rows with 4-row equipment while corn was planted in 0.76-cm rows with 6-row equipment. Plot size was either 4 rows x 30.5 m for cotton or 6 rows x 30.5 m for corn. Half of each plot was planted in a cover crop and the other half was left bare. Prior to planting cotton, the cover crop was rye (*Secale cereale* L.). Prior to planting corn, the cover crop was crimson clover (*Trifolium incarnatum* L.).

The corn data will only be discussed in this paper. An Agleader Technology, Inc. (Ames, IA) yield monitor was used to obtain corn yield data for each of the plots. The yield data obtained over the middle 4-row section for each plot were averaged to determine a mean value for each plot.

A split plot arrangement with four replications with main plots of cover crop and subplots of tillage treatment was analysed with an appropriate ANOVA model using SAS. A significance level of P>0.1 was chosen to separate treatment effects.

RESULTS AND DISCUSSION

Discussions will be limited to main treatment effects although some slight interactions between depth of hardpan, tillage treatment, cover crops, and years were found.

Corn yield averaged across replications, depth of hardpan, and cover crop for years 2000-2002 showed that site-specific tillage had yields statistically equivalent to those plots that received deep tillage (Figure 1). Site-specific tillage (6.96 Mg/ha) and deep tillage (7.40 Mg/ha) both had yields which were greater than no-tillage (5.83 Mg/ha) due to the yield-limiting soil compaction that was present in the Coastal Plain soil found in the experimental field.

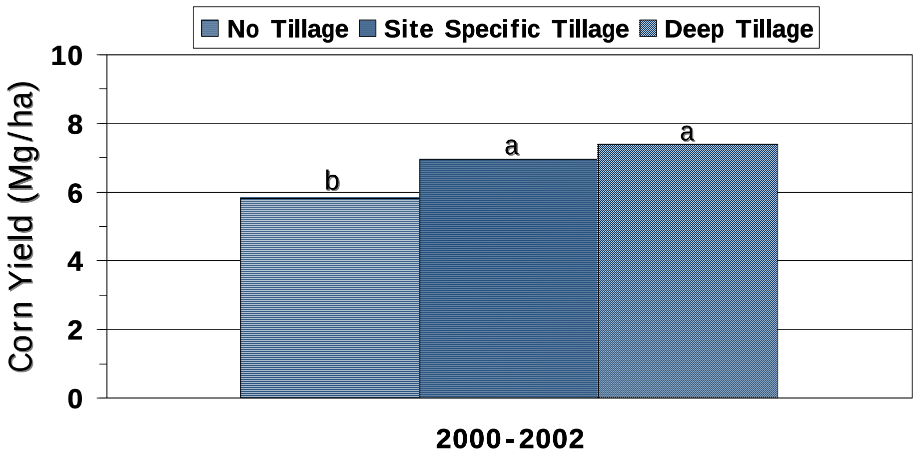

Figure 1. Corn yield averaged over all replications and cover crop treatments for years 2000-2002. Letters indicate statistical difference at the 0.1 level.

No difference in the effect of the cover crop was found when the corn yield data were averaged across replications, depth of hardpan, and tillage treatments for years 2000-2002 (Figure 2). Similar yields were found for those plots that received the crimson clover cover crop (6.59 Mg/ha) as compared to those plots that didn't receive any cover crop (6.90 Mg/ha).

The drawbar power necessary for tillage showed definite benefits of site-specific tillage (68 kW) as compared to uniform deep tillage (83 kW; Figure 3). Reducing tillage depth from 45 cm to the site-specific depth of tillage necessary to disrupt the compacted layer reduced the tillage power requirement by 18%.

Knowing the draft requirements of the tillage treatments and the fuel requirements of the JD 8300 tractor for the specified draft loads used for tillage allows the estimated fuel use to be calculated for subsoiling. Site-specific tillage is estimated to use 13.5 l/ha which is significantly less than the 17.9 l/ha necessary for uniform deep tillage (Figure 4). Total fuel use for site-specific tillage for the 8-ha field is estimated to be 108 l while uniform deep tillage would take 143 l. Reducing tillage depth from 45 cm to the site-specific depth of tillage is estimated to reduce fuel use by 25%.

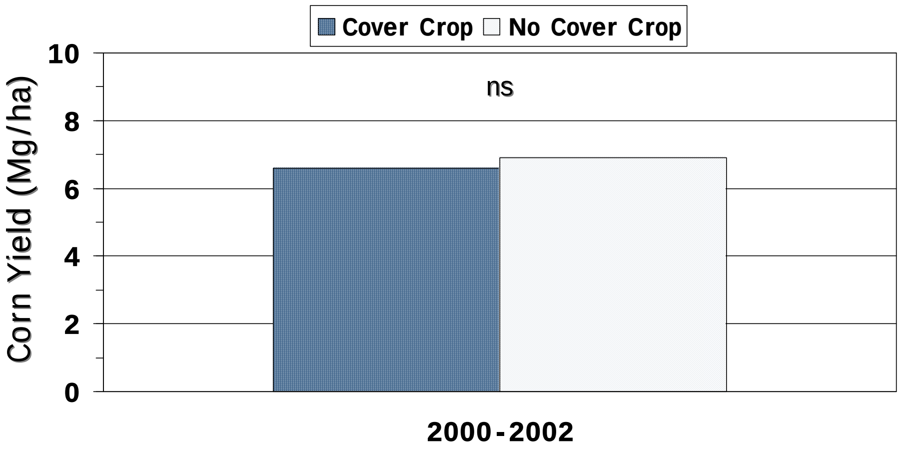

Figure 2. Corn yield averaged over all replications and tillage depth treatments for years 2000-2002. Letters 'ns' indicate no statistical difference at 0.1 level.

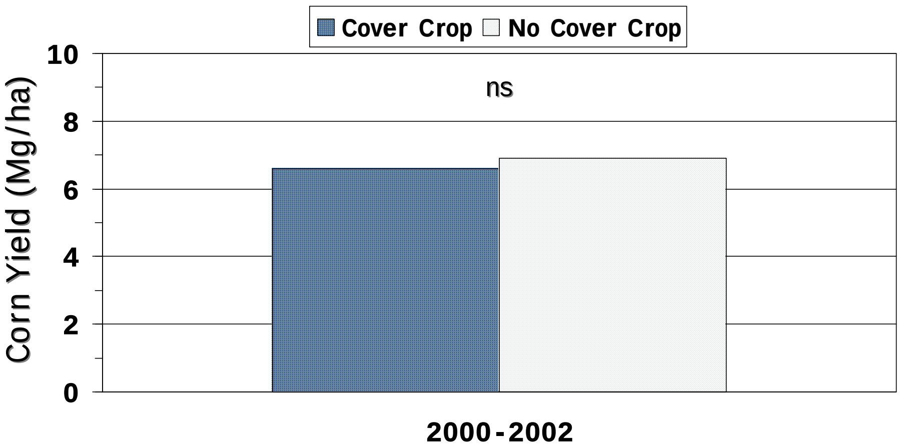

Figure 3. Drawbar power averaged over all replications and cover crop treatments for years 2000-2002. letters indicate statistical difference at 0.1 level

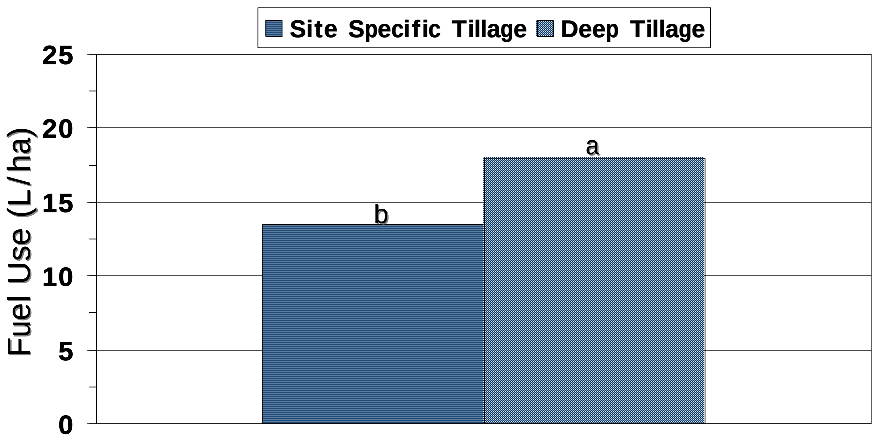

Figure 4. Calculated fuel use averaged over all replications and cover crop treatments for years 2000-2002. Letters indicate statistical difference at 0.1 level

CONCLUSIONS

Site-specific tillage produced corn yields equivalent to those produced by uniform deep tillage.

Cover crops had no effect on corn yield.

Site-specific tillage reduced tillage power necessary for subsoiling by 18 % compared to uniform deep tillage.

Site-specific tillage reduced fuel use by 25% as compared to uniform deep tillage for the Coastal Plain soil.

DISCLAIMER

The use of trade names or company names does not imply endorsement by USDA-ARS, Auburn University, or the University of Illinois.

References

ASAE. Procedures for obtaining and reporting data with the soil cone penetrometer EP542, p. 964-966, *ASAE Standards, ASAE, St. Joseph, MI, 1999a.*

ASAE. Soil cone penetrometer S313.2, p. 808-809, *ASAE Standards*, ASAE, St. Joseph, MI, 1999b.

Campbell, R.B., D.C. Reicosky and C.W. Doty. Physical properties and tillage of Paleudlts in the southeastern Coastal Plains, *J. Soil Water Cons.* **29**(September-October), 220-224, 1974.

Fulton, J.P., L.G. Wells, S.A. Shearer and R.I. Barnhisel. Spatial variation of soil physical properties: a precursor to precision tillage, *ASAE Paper* **961002**, 1-9, 1996.

Raper, R. L. Site-specific tillage for site-specific compaction: Is there a need? In. *Proc. International Conference Dryland Conservation/Zone Tillage*, 66-68. Beijing, China, 1999.

Raper, R.L., D.W. Reeves, C.H. Burmester and E.B. Schwab. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements., *Applied Eng. Agric.* **16**(4), 379-385, 2000a.

Raper, R.L., D.W. Reeves, E.B. Schwab and C.H. Burmester. Reducing soil compaction of Tennessee Valley soils in conservation tillage systems, *J. Cotton Sci.* **4**(2), 84-90, 2000b.

Raper, R.L., B.H. Washington and J.D. Jarrell. A tractor-mounted multiple-probe soil cone penetrometer, *App. Eng. Agric.* **15**(4):287-290, 1999.