SOIL COMPACTION MODELING IN COTTON

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RESEARCH PROBLEM

Soil compaction causes problems for farmers by preventing root growth and development of plants. Compacted soil has smaller pores and fewer natural channels and hence water infiltration is drastically reduced. It causes increased surface wetness, increased runoff and erosion, and longer drying time. Wet fields also delay planting and harvesting, and decrease crop yields. Plant roots experience more resistance to growth in compacted soils, causing inadequate moisture and nutrients absorption by the plant. Plant growth depends on rooting ability, nutrient status, and accessibility of roots to nutrient, soil aeration, and water availability. The objective of the ongoing research are to evaluate the use of soil electrical conductivity data and remote sensing technology for identifying soil compaction levels in the field, and to develop sub-soiling guidelines for cotton production in Arkansas based on the soil electrical conductivity maps and remotely sensed data.

BACKGROUND INFORMATION

Within-field Cone index (CI) provides a measure of soil resistance to penetration. Soil compaction maps and soil electrical conductivity maps have been investigated to explain within-field yield variation. Perumpral (1987) studied soil compaction caused by wheel traffic and tillage operations and concluded that it can cause yield depression within fields. Clark et al. (2000) investigated the use of cone penetrometer data to develop soil strength maps at several different spatial scales. Bakhsh et al. (2000) showed that low yield was influenced by soil and topography and high yield was influenced by topography and management practices. When the cone index value is above 1.4 MPa (200 psi), the soil is considered compacted. It was determined that site-specific subsoiling at a critical CI value of 2 MPa (300 psi), compared to field scale subsoiling, could reduce fuel consumption by 50 % (Fulton et al., 1996). However, it is important to map soil compaction in the field using cost effective and fast methods.

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RESEARCH DESCRIPTION

Two cotton fields in Arkansas were chosen for the 2003 experiments; a grower's 160-acre irrigated cotton field in Forrest City and a 1.16 acre, non-irrigated field at the Arkansas Agricultural Experiment Station in Fayetteville. The 1.16 acre field was an experimental field with 16 plots (each four rows wide). It was treated with four tillage treatments; namely Control (no soil disturbance, no-till); Conventional (chisel disked and bedded); Chisel compacted (by running a tractor or a roller), and Compacted with no-till (by running a tractor or a roller to create different levels of compaction). These two fields were harvested on November 1st and 21st, 2003, respectively. In the grower's field at Forrest City, 4 out of the total 7 plots were subsoiled. The general elevation and coordinates were measured with a Global Positioning System (GPS). Soil electrical conductivity for the Forrest City field was measured with Veris, the 2000 Soil EC Mapping System. Soil compaction was measured in both the experimental fields with a digital cone penetrometer (Spectrum Technologies "Field Scout" Model SC900 soil compaction meter, Plainfield, Ill.). Yield was also measured at both fields at harvest.

Remotely sensed spectral data for the Fayetteville field was collected using an EPP2000 spectrometer (Stellar Net Inc., Tampa, Fla.) with wavelength range from 250 to 900 nm. Periodic airborne images of both fields during 2003 growing season were also taken using a four passband Multi-Array Camera developed by Tetracam Inc. (Chatsworth, Calif.).

At Forrest City, a yield monitor was used for yield data collection, whereas at Fayetteville manual yield measurements were carried out. Spatial data layers were generated in ArcView 3.2 and ArcGIS 8.2 using the location information collected using a Leica 500 standard Global Positioning System in Forrest City. In Fayetteville a Trimble TSC1 Asset Surveyor was used for obtaining location information. Linear regression analysis was performed for each field separately to investigate possible statistical links between soil electrical conductivity, cotton yield, and soil compaction.

RESULTS AND DISCUSSION

Higher soil compaction areas exhibited higher soil electrical conductivity at 4, 5, and 6 inches in depth. A strong linear correlation exists between electrical conductivity and mean CI at the depths where the maximum CI existed (CI> 200 psi, $R^2 = 0.92$ at 4 inches, 0.99 at 5 inches, and 0.98 at six inches). The reason for the strong correlation between EC and soil compaction can be supported based on the pore continuity and its effects. Conductivity of electricity in soils takes place through the moisture-filled pores that occur between individual soil particles. Therefore the EC of soil can be influenced by interaction between the pore continuity and soil compaction. The soils in the study area in Forrest City were a Loring silt loam and Arkabulta silt loam. These soils have higher moisture contents. Logically, the soil compaction should normally increase with higher soil EC. Preliminary results of geographically weighted regression (GWR) analysis showed no statistical significant relationship between soil compaction and yield alone, as the yield depends on a host of parameters such as soil type, irrigation, nutrient management, etc. Classifications of airborne images have shown patterns of yield based on irrigation management and soil types present in the fields.

PRACTICAL APPLICATION

Based on the primary results, we recommend further investigation on a substantial number of cotton fields and compilation of a large dataset on electrical conductivity and soil compaction for analysis. Locating highly compacted areas using soil electrical conductivity maps and classified airborne images may then avoid time-consuming soil sampling and tedious soil compaction measurements, and can be used for site-specific tillage operations. Farmers can use Global Positioning System technology to create customized soil compaction maps using soil electrical conductivity mapping as well.

LITERATURE CITED

Bakhsh, A., T.S. Colvin, D.B. Jaynes, R.S. Kanwar, and U. S. Tim. 2000. Using soil attributes and GIS for interpretation of spatial variability in yield. Trans. ASAE 43: 819-828.

Clark, R.L., D.E. Kissel, F.Chen, and W. Adkins. 2000. Mapping soil hardpans with the penetrometer and soil electrical conductivity. ASAE Paper 001042. St. Joseph, Mich:ASAE.

Fulton, J.P., L.G. Wells, S. A. Shearer, and R. I. Barnhisel. 1996. Spatial variation of soil physical properties: A precursor to precision tillage. ASAE Paper No. 96-1002. St. Joseph, Mich.: ASAE.

Perumpal, J.V. 1987. Cone Penetrometer Applications- A review Trans. ASAE 30:939-944.