ENERGY UTILIZATION AS AFFECTED BY TRAFFIC IN A CONVENTIONAL AND CONSERVATION TILLAGE SYSTEM

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ABSTRACT. *The increased emphasis on conservation tillage, as a result of the compliance guidelines in the 1985 and 1990 Farm Bills, causes mechanical energy utilization to ploy an important role in the choice of systems for managing soil compaction. Therefore, a study was conducted to determine the effects of traffic and tillage systems on the energy required to establish a cotton* (Gossypium hirsutum L.) *crop. Traffic treatments included no-traffic and a conventional traffic system. Tillage treatments included disking and field cultivation. both with and without subsoiling, and a conservation tillage treatment (ship-tillage) which involved only subsoiling and planting into wheat* (Triticum aestivum L.) *residue/stubble over the subsoiled slot. Results showed that traffic had no effect on the energy required for crop establishment. Results also showed that tillage treatment had an important effect on the mechanical energy required for crop establishment. The strip-tillage system required less energy than all other treatments.* ***Keywords.*** *Tillage, Energy, Traffic, Soil compaction, Cotton.*

Soil compaction has been recognized for years as a problem in cotton production, particularity on sandy Coastal Plain soils. A number of procedures have been proposed to alleviate the compaction problem. One such procedure was controlled traffic, as proposed and investigated by Cooper et al. (1969).

Controlled traffic is a concept in which a crop growing area is permanently divided into "cropping zones" and "traffic zones." This concept permits the soil condition within each zone to be prepared as either the appropriate "rootbed" for crop growth or as a "roadbed" to provide traction and flotation. The reported advantages of controlled traffic, especially under highly compactible soil conditions, include deeper rooting, increased yields, and reduced tillage energy consumption.

Cooper et al. (1969) discussed the early field work in Alabama concerning traffic effects on cotton production. They found important increases in cotton yields on sandy soils from deep tillage. However, the residual effects of this deep tillage were almost eliminated after three years of wheel traffic, thus indicating that some system of controlling traffic perhaps could extend the period between deep tillage operations.

Dumas et al. (1973) evaluated the controlled traffic concept in a study utilizing controlled traffic and deep tillage (subsoiling) for cotton production. They found that deep tillage, regardless of traffic, resulted in larger cotton plants. Without deep tillage, controlled traffic resulted in a 9% increase in plant height. Both deep tillage and controlled traffic were necessary to obtain maximum yield (4722 kg/ha seed cotton).

Williford (1980, 1982) reported that cotton yield was significantly increased with a controlled traffic system which used wide beds and commercially available machinery. His results also suggested that subsoiling every year was unnecessary in order to maintain yield levels with the controlled traffic system.

Carter et al. (1988) discussed experiences with a controlled traffic system which used a wide frame vehicle in alfalfa *(Medicago sativa* L.) production. They reported that removal of traffic increased infiltration and eliminated the need for primary tillage.

There have also been reports concerning the effects of traffic on energy requirements. Voorhees (1979) reported that wheel traffic caused an increase in draft in subsequent tillage operations. Five passes with tires over the entire. surface of the soil caused a 43% increase in tillage draft when compared to tillage draft for no traffic. Tullberg and Murray (1987) reported that, under Australian conditions, controlled traffic can reduce the fuel cost of a grain crop establishment by 40%, allow the crop establishment operations to be conducted with a tractor having 30% less power, and maintain crop yields without the necessity for deep tillage operations. Dickson and Campbell (1988) reported that for a cropping sequence in Scotland of winter barley *(Hordeum vulgare* L.) followed by potatoes *(Solanum tuberosum* L.), draft forces with no traffic for primary tillage were reduced by 14% for barley and 50% for potatoes.

A controlled-traffic field study utilizing the USDA-ARS Wide-Frame Tractive Vehicle (WFTV) was conducted for five years at the Alabama Agricultural Experiment Station, E. V. Smith Research Center,

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Agricultural Engineering Research Unit at Shorter, Alabama (Reeves et al., 1989). The WFTV, as reported by Monroe end Burt (1989), is a research tool which allows a 6-m cropping zone to be kept free of any wheel traffic. Raised traffic paths for the wheels allow the vehicle to completely span this area. This vehicle permits research to determine the effects of traffic end tillage on soil condition without any confounding effects from nearby traffic. The experiment using the WFTV involved double-cropping of wheat end cotton, end permits determination of mechanical input energy for the cotton phase of the experiment. Therefore, the objectives of the energy phase of this study were to determine the interactive effects on energy utilization of traffic and tillage systems with deep and surface tillage components.

METHODS AND MATERIALS

The energy aspects of this study were initiated during the cotton phase of the 1990 soil preparation end planting season. Soils at this location are Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludults). The site had a well-developed hardpan from 20 to 30 cm deep. Before the study was initiated in 1987, an effort was made to form a uniform hardpan at the 20 cm depth by running heavy vehicles repeatedly in plowed furrows incrementally across the experimental site.

The experimental design was a split-plot with four replications. Main plots were:

* Conventional wheel traffic applied with a farm tractor.
* No-traffic.

Subplots were tillage systems for cotton:

* Complete surface tillage (using a disk harrow plus chisel plow if needed to obtain penetration into the soil, field cultivator, and planter) without subsoiling (designated D, FC, P).
* The same complete surface tillage plus annual in-row subsoiling (41 cm depth) and planter, (designated D, FC, SS+P).
* Complete surface tillage with one-time only (in 1987) complete disruption of tillage pan, (designated CD, D, FC, P).
* No surface tillage but planted with in-row subsoiling (strip-tillage, designated SS+P).

The strip-tillage system was a conservation tillage treatment which tilled a narrow 12 to 18 cm wide area directly in the crop row. The tillage treatments which involved complete surface tillage, with and without subsoiling, were considered in this article to be conventional treatments. The complete surface tillage sequence involved disking, chisel plowing (20 cm depth) when needed, disking, and field cultivating. The one-time only complete disruption involved subsoiling to a 50 cm depth on 25 cm centers in 1987, three years prior to starting the energy evaluations. Main plots were 6 m wide and 182.8 m long, divided into 45.7-m sections for subplots.

The strip-tillage cotton (treatment 4) was planted into wheat residue/stubble with au eight-row KMC in-row subsoiler-planter. The remaining treatments were planted with the same planter system with or without the subsoilers es required. Cotton was planted each year in 76-cm rows. Beginning in the fall of 1987 and for each fall thereafter, each tillage treatment received the necessary cultivation to permit planting of the wheat. Traffic associated with planting of the wheat was applied on each of the traffic treatments.

All tillage operations in the conventional tillage end strip tillage treatments were conducted using the WFTV. Traffic treatments were artificially installed on the experiment immediately following each tillage treatment in a four-row traffic pattern by use of a John Deere® 4440 tractor. The number of passes with the tractor were determined by the sequence of operations for each of the tillage systems as normally used by farmers in the Coastal Plain area of the southeastern United States.

Tillage forces were determined during the establishment of the cotton crop in 1990 and 1991. A three-dimensional dynamometer, which mounts at the three-point hitch system of the WFTV and has a force capacity of 90 kN, was used for force measurements. These forces were subsequently used to determine the energy on a per hectare basis so that comparisons could be directly made between implements end treatments,

An intensive cone penetrometer evaluation of the test plots was conducted at the end of the growing season in 1991 to determine the effects of the tillage and traffic treatments on soil condition. Each replication within each tillage and traffic treatment was sampled with a cone penetrometer at five different locations. At each of these locations, cone index versus depth determinations (to a depth of about 0.7 m at depth increments of 0.003 m) were taken at the center of a row and 19 cm and 38 cm on either side of the row. In plots which had received traffic, one of these row middles had received traffic and one had received no traffic. Therefore, each data point of cone index versus depth represents a mean of 20 measured values.

RESULTS

Analysis of variance of the energy data revealed a treatment-by-year interaction, which necessitates an independent analysis for each year. There were no interaction effects of traffic end tillage, therefore, data are presented separately for effects of traffic and tillage

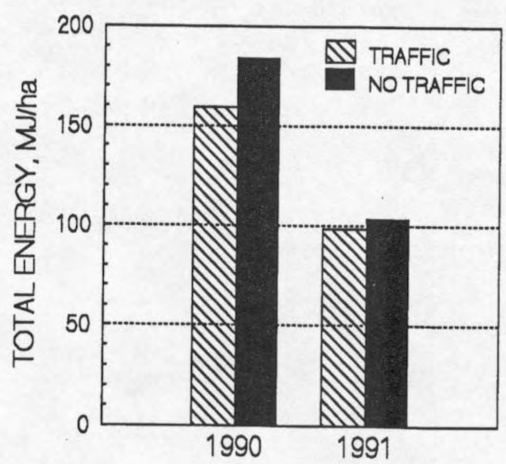

Figure 1–Effects of traffic averaged over all tillage systems (traffic and tillage effects cumulative since 1987) on energy required for soil preparation and planting of cotton.

systems. Figure 1 shows the overall effects of traffic on the energy required for soil preparation and planting of the crop for the crop years 1990 and 1991. Energy is expressed on a per hectare basis so that energy from each of the tillage operations could be summed. There were no statistical differences in mechanical energy requirements, across all tillage operations, between the traffic and no-trafiic treatments in either 1990 or in 1991. However, there existed a trend for the traffic treatment to require less energy than the no-traffic treatment. Further analysis revealed that subsoiling and chisel plow operations were not statistically affected by the traffic. The field cultivation and the disking operations were responsible for the higher energy for the no-traffic treatments. Each plot which was scheduled to receive a field cultivator treatment in 1990 actually received three passes. Trash buildup on the field cultivator prevented measurement of energy during the first two passes, therefore, energy was measured only during the third pass. On the third pass in 1990, the no-traffic treatment required significantly more energy at the 95% probability level than did the traffic treatment. Again, in 1991, the field cultivation operation required significantly more input energy at the 90% probability level in the no-traffic treatments than the traffic treatment. The disking operation showed the same trends as the field cultivation operation in 1990, with no-traffic treatment requiring significantly higher energy at the 90% probability level than did the traffic treatment for the first disking operation, and significantly higher energy at the 95% probability level for the second and third diskings. Traffic had no significant effect on energy in 1991 for either the first or second disking operations.

One possible explanation for the trend for higher energy requirement on the no-traffic treatments could be that the field cultivator and the disk harrow operated at a greater depth in the no-traffic treatments. Since these implements operate only on the surface soil, the traffic could have created a resistance to penetration and therefore forced the implements to operate at a lesser depth. Depth of the field cultivator was roughly controlled by gauge wheels, and the disk harrow was operated as a free-floating implement which could seek its own depth. No attempt was made in this study to control the depth of operation of the disk harrow in the conventional tillage treatment, since this is standard practice for fanners in the southeastern United states.

The results from cone index measurements (fig. 2) corroborate the hypothesis that the tillage implements operated at deeper depths in the no-traffic plots. Differences in initial slopes between the traffic and no-traffic treatments can be seen, particularly in the three tillage treatments with surface tillage, even though the data shown are from no-traffic row middles. The disc harrow and field cultivator in the no-traffic plots seems to have operated at a depth of about 0.2 m, while tillage depth in the traffic plots seems to be slightly over 0.1 m.

Figure 3 presents the total energy required for soil preparation and planting for each of the four different tillage systems. The soil was extremely dry in 1990, and each treatment which received any surface tillage, also received a chisel plowing to about 15 cm depth in order to obtain penetration of the tillage tools. Energy required for this chisel plow operation is included in each surface tillage treatment.

In 1990, the sequence of disking, field cultivation, and planting (designated in fig. 3 as D, FC, P) was not significantly different from the sequence. of one-time complete disruption in 1987, disking, field cultivating, and planting (designated CD, D, FC, P). Therefore, there was no residual effect of subsoiling in 1987 on the input energy during the 1990 cropping season, regardless of traffic. The remaining tillage treatments were significantly different at the 95% probability level. Strip-tillage (designated in fig. 3 as SS+P). which involved only in-row subsoiling ahead of the planter, required 50% less energy than did the sequence involving in-row subsoiling, disking, field cultivation, and planting.

In 1991, the sequence of disking, field cultivation, and planting (designated D, FC, P) was not significantly

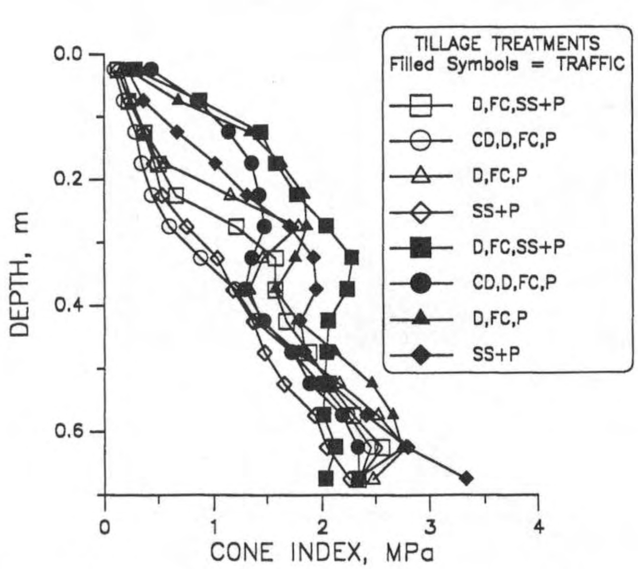

Figure 2–Cone index for the tillage treatments in the no-traffic row middle taken in 1991. The filled symbols represent values obtained in plots that received traffic.

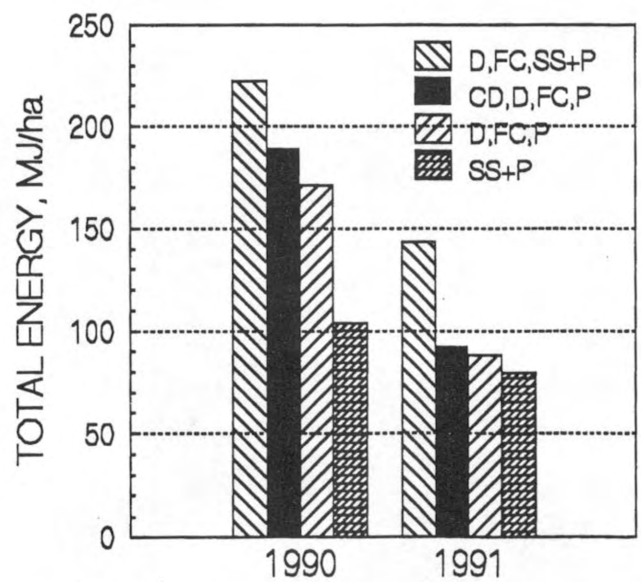

Figure 3–Effect of tillage system averaged over traffic systems (traffic and tillage effects cumulative since 1987) on the energy required for soil preparation and planting of cotton.

different from the sequence of complete disruption in 1987, disking, field cultivating, and planting (designated CD, D, FC, P), again indicating no residual effects of the earlier complete disruption of the hardpan. The sequence of disking, field cultivation, and planting (designated in fig. 3 as D, FC, P) as well as the sequence of one-time complete disruption in 1987, disking, field cultivating, and planting (designated CD, D, FC, P) required significantly greater energy than strip-tillage (designated SS+P) at the 90% probability level. The sequence of disking, field cultivating, in-row subsoiling, and planting (designated in fig. 3 as D, FC, SS+P) required significantly more energy at the 95% probability level than any other tillage treatment.

CONCLUSIONS

- Traffic, as applied in this study, had no effect on the energy required in soil preparation and planting of cotton.
- Traffic caused a decrease in energy required for field cultivation and disking, probably because of reduced tillage depth.
- The tillage system used had an effect on the energy required for crop establishment.
- Strip tillage in wheat residue/stubble required about 50% less energy than did the conventional tillage system involving disking, field cultivating, subsoiling, and planting.
- Subsoiling on 25-cm centers over the entire soil area in 1987 had no residual effects on the energy required for cotton crop establishment in either 1990 or 1991.

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