ENERGY UTILIZATION AS AFFECTED BY TRAFFIC IN CONSERVATION AND CONVENTIONAL TILLAGE SYSTEMS

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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, cause energy utilization to play 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 system on the energy required to establish a cotton crop. Treatments for this study were applied annually since 1987 in a wheat-cotton double cropping system. The energy aspects of this study were conducted in 1990 and 1991. Traffic treatments included no traffic (controlled traffic) and a conventional traffic system. Tillage treatments included disking and field cultivation, both with and without subsoiling, and a strip tillage treatment which involved only subsoiling and planting into wheat 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 energy required for crop establishment. The strip-tillage system required less energy than all other treatments.

Introduction

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 is controlled traffic, as proposed and investigated by Dumas et al. (1973).

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 was almost eliminated after 3 years of wheel traffic, thus creating the need for some system of controlling traffic.

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 (4,214 lb/A 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 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 followed by potatoes, 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 has been underway for 5 years at the Alabama Agricultural Experiment Station, E. V. Smith Research Center, Agricultural Engineering Research Unit at Shorter, AL (Reeves et al., 1989). This experiment involves double-cropping of wheat and cotton, and permits determination of mechanical input energy for the cotton phase of the experiment. Therefore, the objectives 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 and planting season. Soils at this location are Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludult). The site had a well-developed hardpan from 8 to 12 inches deep. Before the study was initiated in 1987, an effort was made to form a uniform hardpan at the 8-in. depth by running heavy vehicles repeatedly in plowed furrows incrementally across the experimental site.

The experimental design was a split-plot with 4 replications. Main plots were: 1) Conventional traffic and 2) Zero-traffic. Subplots were tillage system for cotton: 1) Complete surface tillage without subsoiling, 2) Complete surface tillage and annual in-row subsoiling (16-in. depth), 3) Complete surface tillage with one-time only complete disruption of tillage pan, and 4) No surface tillage but planted with in-row subsoiling (strip-tillage). Main plots were 20 ft. wide and 600 ft. long, and divided into 150-ft. sections for subplots. The complete surface tillage sequence involved disking, chisel plowing (8-inch depth) when needed, disking, and field cultivating. The one-time only complete disruption involved subsoiling to a 20-in. depth on 10-in. centers in 1987, 3 years prior to starting the energy evaluations. The comparison of this complete disruption to annual subsoiling should indicate residual effects of subsoiling on energy utilization.

The strip-tillage cotton (treatment 4) was planted into wheat stubble with an 8-row KMC in-row subsoiler-planter. Cotton was planted each year in 30-in. 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 were conducted using a wide frame tractive vehicle (WFTV) which is a research facility of the USDA-ARS National Soil Dynamics Laboratory (Monroe and Burt, 1989). This machine operates on traffic paths and permits the growth of a crop without wheel traffic within the cropping zone. Tillage forces were determined during the establishment of the cotton crop in 1990 and 1991. A three-dimensional dynamometer, which mounts at the 3-point hitch system, was used for force measurements and has a force capacity of 20,000 lbs. These forces were subsequently used to determine the energy on a per acre basis so that comparisons could be directly made between implements and treatments. Traffic treatments were installed on the experiment artificially by use of a John Deere 4440 tractor.

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 and tillage, therefore, data are presented separately for effects of traffic and tillage systems. Figure 1 shows the overall effects of traffic on the energy required for soil preparation and planting of the crop for each of the crop years 1990 and 1991. Energy is expressed on a per acre basis so that energy from each of the tillage operations could be summed. There were no statistical differences, across all tillage operations, between the traffic and no-traffic treatments in either 1990 or in 1991.

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. Trash buildup on the field cultivator in 1990 prevented measurement of energy during the first 2 passes. Each plot receiving a field cultivator treatment in 1990 received 3 passes with the field cultivator, but energy was measured only during the third pass. However, on the 3rd pass in 1990, the no-traffic treatment required significantly more energy at the 95% probability level than did the traffic treatment. The field cultivation operation in 1991 required significantly more input energy at the 90% probability level in the no-traffic treatments than for the traffic treatment.

The no-traffic treatment in 1990 required significantly higher energy at the 90% probability level than did the traffic treatment for the first disking operation, and at the 95% probability level for the 2nd and 3rd diskings. Traffic had no significant effect on energy in 1991 for either the 1st or 2nd disking operations.

One possible explanation for the 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. The field cultivator and the disk harrow were both operated as free-floating implements which could seek their own depth. No attempt was made during this study to measure depth of operation of any of the tillage implements.

Figure 2 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 6-inch depth. 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 Figure 2 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 effects of subsoiling in 1987 on the input energy during the 1990 cropping season. The remaining tillage treatments were significantly different at the 95% probability level. Strip-tillage (designated in Figure 2 as SS+P), which involved only in-row subsoiling ahead of the planter, required 50% less tillage energy than did the sequence involving subsoiling, disking, field cultivation and planting.

In 1991, the sequence of disking, field cultivation, and planting (designated D, FC, P) was not significantly 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 Figure 2 as D, FC, P) was significantly different from the strip-till (designated SS+P) at the 90% probability level. The sequence of disking, field cultivating, in-row subsoiling + planting (designated in Figure 2 as D, FC, SS+P) required significantly more energy at the 95% probability level than any other tillage treatment.

Conclusions

1. Traffic, as applied in this study, had no effect on the energy required in soil preparation and planting of cotton.

2. Traffic caused a decrease in energy required for field cultivation and disking, probably because of reduced tillage depth.

3. The tillage system used did have an effect on the energy required for crop establishment.

4. Strip tillage in wheat residue/stubble required about 50% less energy than did the conventional tillage system involving disking, field cultivation, subsoiling and planting.

5. Subsoiling on 10 inch 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.

Disclaimer

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.

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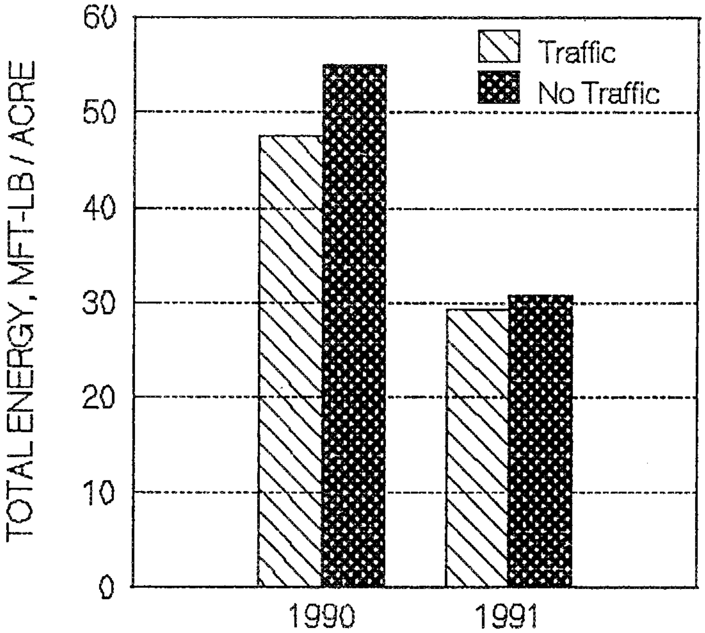

Figure 1. Effects of traffic averaged over all tillage systems (traffic and tillage effects cumulative since 1987) on total energy required for soil preparation and planting of cotton.

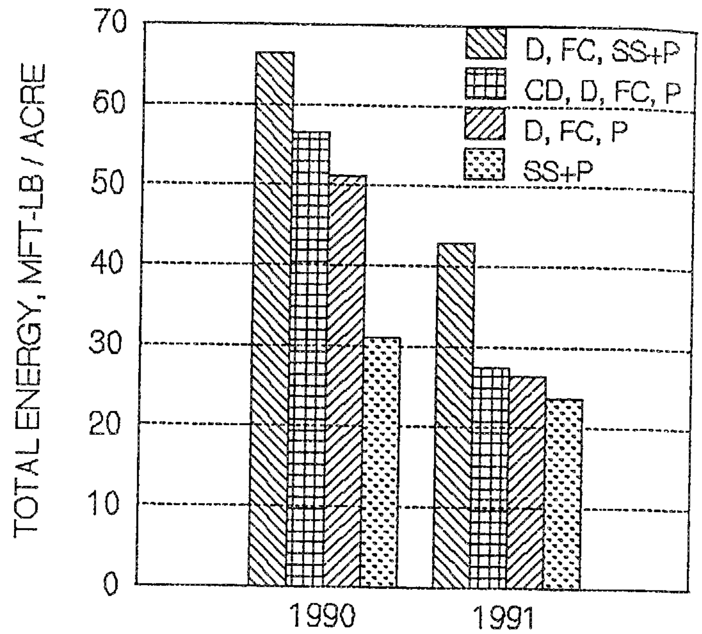

Figure 2. Effect of tillage systems averaged over traffic systems (traffic and tillage effects cumulative since 1987) on total energy required for soil preparation and planting of cotton.