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DRAFT REQUIREMENTS AND SOIL BENEFITS OF PASTURE RENOVATION TILLAGE

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Summary:
Draft requirements and long-term soil benefits are determined for pasture renovation practices. A Paraplow required almost 40 kW of draft power while an Aer-way pasture renovator required less than 10 kW. Plots renovated with the Paraplow showed reduced soil strength measurements one year later. A tillage disruption index was defined to determine differences between an initial and final soil condition caused by a particular tillage implement.

Keywords:
Subsoil, soil compaction, implement, cone index, aeration

DRAFT REQUIREMENTS AND SOIL BENEFITS OF PASTURE RENOVATION TILLAGE

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ABSTRACT

An experiment was conducted to determine potential beneficial effects of pasture renovation practices that involve deep and shallow tillage. The portion of the experiment that is reported in this paper focuses on long-term effects of tillage on soil condition and necessary power requirements for each of the tillage practices. Draft measurements indicated that the Paraplow, a deep-tillage, non-inverting implement, required almost 40 kW of draft power while the Aer-way pasture renovator, a shallow, pitting-type implement, required less than 10 kW of draft power. Cone index measurements taken one year after tillage treatments showed long-lasting benefits in both grazed and ungrazed plots, particularly for the radically disrupted Paraplow plots. A tillage disruption index was defined that helped to determine differences between an initial and final soil condition caused by a particular tillage implement.

INTRODUCTION

Poultry litter is a valuable resource if properly managed. Litter is collected periodically from poultry production facilities and surface-applied to fields in the local vicinity (Edwards and Daniel, 1993). When applied to pastures, this waste material can supply valuable nutrients for grass production. However, it is often applied during winter months when large rainfall events are likely. The valuable nutrients can then be moved from pastures to streams where they can cause pollution.

Increasing infiltration of pasture soils where poultry waste is applied would divert water through the soil profile and decrease runoff, sediment, and nutrient loss. Overseas, researchers have investigated using tillage to loosen pasture soils and increase water infiltration, root development, and plant growth. Douglas (1994) reported that occasionally loosening the subsoil is a common practice in the U.K. Increases in grass yield were obtained when subsoiling was conducted under suitably dry soil conditions.

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Because of its ability to disrupt topsoil and subsoil without inverting the soil, a bent-leg type plow (Paraplow[5], Howard Rotovator Co., Inc.) has been used in pastures. Use of a Paraplow to loosen soil generated a 13% increase in dry matter yield at the first cut, but did not significantly affect yields thereafter (Smith et al., 1990). In another study, Frost (1988) found that using a Paraplow decreased yields immediately and, after a period of time, the soil reverted to a higher soil compaction than what was originally found prior to tillage.

Another method hypothesized to help increase water infiltration in pastures has been to use an “aerator”. These devices are relatively inexpensive to operate and do not require large tractors. They create small, shallow holes in the ground that can trap water and therefore increase infiltration. Davies et al. (1989) found in Wales that the use of a similar device can help alleviate the soil compaction caused by cattle traffic. Research in Florida (Williams and Kalmbacher ,1996) found that cone index was immediately reduced to a depth of 20-cm by use of an “aerator”, but renovated plots did not show increased forage production.

Other than the research reported by Williams and Kalmbacher (1996), little work has been conducted in the U.S. concerning the use of pasture renovation practices. The objectives of this research were thus:
(1) to determine the long term effects of spring tillage in pastures when cut for hay and when grazed, and
(2) to determine the draft forces necessary to apply possibly beneficial tillage treatments to southeastern pasture.

METHODS AND MATERIALS

An experiment was conducted on a Hartsells find sandy loam (fine-loamy, siliceous, thermic Typic Hapludult) at the Sand Mountain Substation of the Alabama Agricultural Experiment Station, DeKalb County, AL. A 1.6-ha (4-ac) endophyte-infected tall fescue-bermudagrass pasture was divided into 18 plots. Half of the plots were grazed continuously at a moderate to heavy stocking rate of 26 cow-calf pairs, and one-half of the pasture was cut for hay. The experimental design was a randomized complete block with three replications per treatment. Each plot was 7.3 x 30.5 m (24 x 100 ft). The tillage renovation treatments were (1) Paraplow, (2) Aer-Way pasture renovator (Holland Hitch Inc.),, and (3) no-tillage. The Paraplow is no longer commercially available, but Bigham Brothers Inc. sells a version of this bent-leg plow called the Paratill that includes multiple shanks mounted on a straight toolbar. Renovation treatments were applied annually during the early spring. A complete description of the experiment, the soil condition, and the resulting crop response is found in Self-Davis (1996).

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[5]The use of trade names does not imply endorsement by USDA-ARS or by Auburn University.

Bulk density, gravimetric moisture content, and cone index were determined throughout the experiment. Cores were obtained from five locations within each plot on 21 March 1994 and at three locations on 17 March 1995 and 25 March 1996. The bulk density information is not included in this paper but can be found in Self-Davis (1996). Cone index (ASAE, 1996) and gravimetric moisture content were measured prior to tillage treatments on 21 March 1994 and at approximate four month intervals thereafter.

Draft measurements were taken on 30 September 1994 for both the Paraplow and the Aer-way pasture renovator. Draft measurements were also taken for another implement that was owned by a local farmer, a Rhino RGM-6 Pasture Renovator (Rhino Manufacturing). Draft forces were measured with a 3-pt hitch tractor-mounted 3-dimensional dynamometer. A John Deere 2955 63-kW (85-hp) tractor was used for measuring draft force. Four locations within the grazed portion of the pasture were chosen and split into plots 3 x 9.1 m (10 x 30 ft). Each tillage tool was operated as done in the renovation experiment in each of these locations over the 9.1-m (30-ft) length. Cone index and moisture measurements were obtained before and after the tillage treatments.

RESULTS AND DISCUSSION

In March 1994, cone index profiles taken prior to renovation tillage in the grazed pasture showed a root-limiting profile (Taylor and Gardner, 1963); cone index values exceeded 2 MPa (290 psi) at the 10-cm (4-in) level (Figure 1). Previous management had been for typical grazing and hay production systems. Average soil moisture content was 11.5% by weight for the designated grazed area and 12.0% for the designated ungrazed area.

One year later in March 1995, the remnants of the renovation tillage treatments applied in March 1994 were still observed (Figure 2). Especially note how the Paraplow reduced cone index down to the bottom of the profile. Also note that the Aer-way did not greatly influence cone index in both grazed and ungrazed plots. The effect of grazing on these profiles was also obvious. At depths less than 12 cm, grazed plots had larger cone index values than those found in ungrazed plots. Below the 12-cm depth, the practice of grazing decreased the cone index values, irrespective of tillage treatment. Differences measured may be due to many factors, including cattle traffic and species composition (Self-Davis et al., 1996). Average soil moisture content was 14.0% for the grazed area and 14.5% for the ungrazed area.

Figure 3 shows cone index profiles in March 1996. The tillage treatment was conducted one year previously, so this graph is similar to Figure 2. The same trends were noted with respect to tillage treatment and grazing effects. Average soil moisture content was 13.6% for the grazed area and 14.2% for the ungrazed area. Differences in cone index cannot be attributed to differences in moisture content because this same relative difference between grazed and ungrazed areas were found in 1994 on the initial set of measurements.

Draft requirements for the three tillage implements showed that the Paraplow required much greater amounts of draft force than the other two tillage tools (Figure 4 and Table 1). Of course, the soil disruption and depth of tillage caused by the Paraplow were much greater than the other tillage tools. Figure 5 shows the cone index profiles taken immediately after the completion of the draft requirements. Especially note the deep disruption caused by the Paraplow.

Before the tillage studies were conducted, another set of cone index profiles was obtained. Due to the short time frame between the original and final set of cone index profiles, it is safe to assume that differences were due to the tillage operations. For this reason, at each depth that a cone index measurement was obtained, the final value of cone index was subtracted from the original value. Figure 6 shows the significant disruption caused by the Paraplow as compared to the other implements. The depth of operation was also determined by locating points where this difference profile crosses or touches the origin on the x-axis. The Paraplow disrupted the soil down to a depth of approximately 45 cm (17.7 in), while the Aer-way disrupted the soil profile down to 14 cm (5.5 in), and the Rhino disrupted the soil profile down to 20 cm (7.9 in). Average soil moisture content was 14.6% over all four replications for both sets of cone index profiles.

To increase our understanding of the disruption caused by these various tillage tools, it was helpful to develop a parameter that indicates the degree to which the soil strength had been decreased. This parameter was termed the tillage disruption index (TDI) and was defined as the area under the cone index difference graph until the curves cross the origin. The trapezoidal rule (Gerald and Wheatley, 1984) is used to determine this area.

$$TDI=\sum_{i=1}^{n} \frac{D}{2}(CID_i+CID_{i+1}) \qquad (1)$$

where D = depth increment
CID = cone index difference value per depth
n = depth that the cone index difference becomes negative or zero

The TDI values obtained from the average cone index difference values in Figure 6 are 0.49, 0.09, and 0.13 MPa-m for the Paraplow, Aer-way, and Rhino, respectively. These average values correlate very well with the average draft values obtained for these three tillage implements (Figure 4). However, to obtain more data for the correlation, the original data from each replication were examined. This procedure left 12 pairs of TDI and draft force values (Figure 7). Linear regression on this data gave an R^2 value of 0.65.

The use of the TDI shows a definite relationship between the amount of tillage force required to disrupt the soil and the overall disruption of the soil as measured by cone index. More uniform distribution of the data is required to fully examine such a parameter, but preliminary results are promising.

Of particular interest to producers is the cost/benefit relationship that must be established for an additional operation. Although no information on cost is available, the time required to perform each of these operations can be calculated based on the speed of the tractor, width of the implement, and drawbar requirements (Table 1). Because pastures are typically firm soils, a value of 0.78 can be used to convert drawbar horsepower to axle horsepower (Hunt, 1977). Assuming a load factor of 0.8 for the tractor, and considering the maximum load that was measured in the four replications, the 3-shank Paraplow would require a 75-kW (100-hp) tractor while the Aer-way would require a 25-kW (30-hp) tractor, and the Rhino would require a 40-kW (50-hp) tractor.

Calculation results show that a typical producer with a 40.5 ha (100-acre) pasture would require 85 hours to renovate the pasture with the Paraplow, 47 hours with the Rhino, and 36 hours with the Aer-way. Part of the reason for the large difference between the implements is that the Paraplow is 1-m (40-in) wide, while the Rhino and the Aer-way are both 2.1-m (84-in) wide (Table 1).

Further research is underway to determine benefits of using tillage energy to renovate pastures. This research will help determine changes or improvement in water infiltration and pasture production caused by renovation tillage. Preliminary results (Self-Davis et al., 1996) showed that the Paraplow tillage treatment was found to alter the structure and distribution of forage root systems by pruning roots near the surface, but not the total biomass. The Aer-way tillage treatment had no effect on total root biomass. Cumulative forage dry matter yields within a year (1994 and 1995) were not affected by renovation tillage. Until this research is completed, recommendations cannot be made about the usefulness of renovation tillage to decrease runoff, sediment and nutrient loss, and grass production.

CONCLUSIONS

Cone index profiles determined one year after pasture renovation tillage treatments indicated significant benefits only associated with the use of the Paraplow. More soil disruption was found with the Paraplow than the Aer-way pasture renovator and to greater depths. Plots that had been grazed also exhibited increased soil strength near the surface (<I2 cm) as compared to those plots that had been fenced and cut for hay.

The draft force requirements for the Paraplow are approximately four times greater than those for the Aer-way or the Rhino chisel plow. Cone index measurements taken immediately before and after the tillage operations showed that the disruption as indicated by the tillage disruption index (TDI) is also approximately four times greater for the Paraplow. The Paraplow also would take twice as much time to use because of its smaller width and larger energy requirements.

A new term was developed, TDI, which is a measure of the difference in soil strength caused by a tillage tool. This term correlated reasonably well with draft force requirements for the three tillage tools tested. Further research is needed to determine if this parameter may prove to be beneficial in classifying differences between tillage tools and their effect on the soil.

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Table 1. Measurements from pasture renovation study. Letters beside means indicate statistically different at the 0.05 level.

IMPLEMENT	WIDTH (m)	SPEED (m/s)	TIME (hr/ha)	DRAFT POWER (kW)
Paraplow	1.0	1.30 a	2.1	39.17 a
Aer-way	2.1	1.44 a	0.9	9.22 b
Rhino	2.1	1.14 a	1.2	11.45 b
LSD (0.05)		0.38		7.71

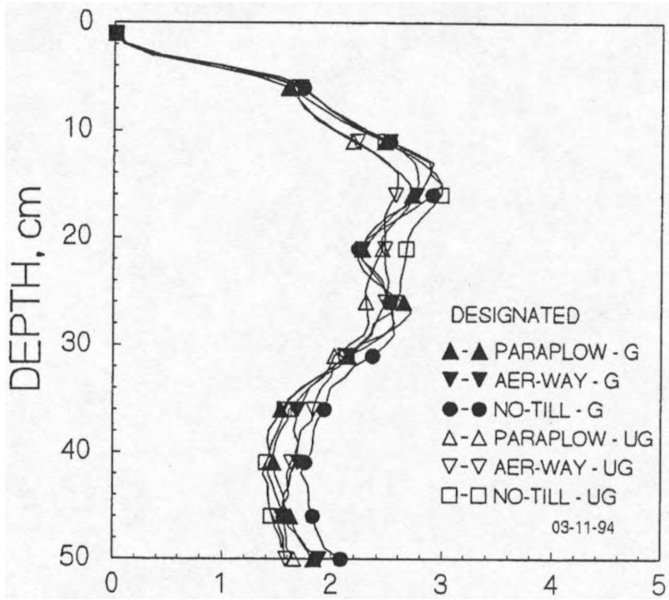


Figure 1. Cone index profiles of plots prior to first tiltage renovation treatment. The ‘G’ and ‘UG’ designations indicate grazed and ungrazed, respectively

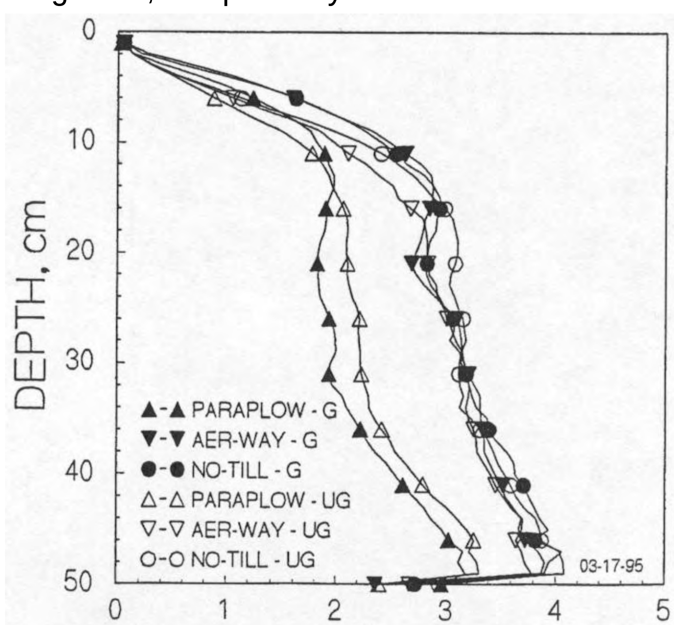


Figure 2. Cone index profiles one year after tillage practices were conducted. The ‘G’ and ‘UG’ designations indicate grazed and ungrazed, respectively

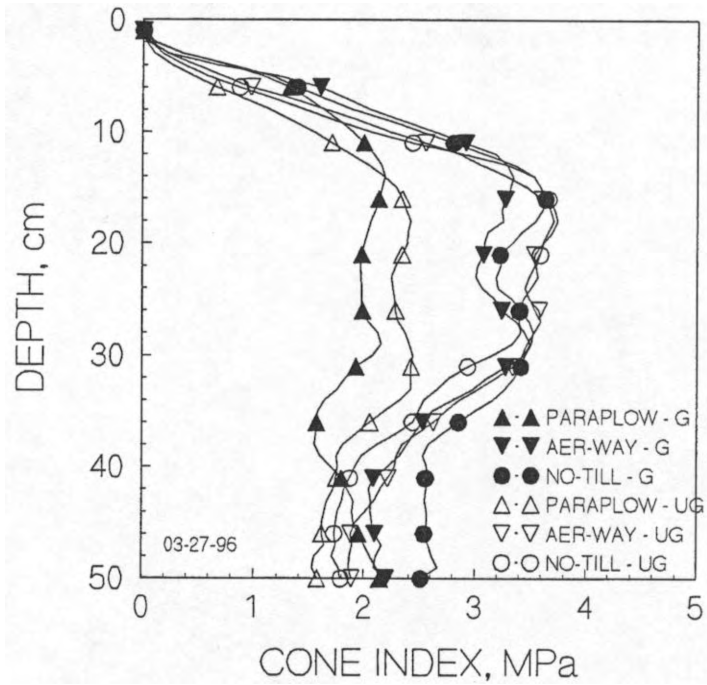


Figure 3. Cone index profiles one year after second tillage treatment. The 'G' and 'UG' stand for grazed and ungrazed, respectively.

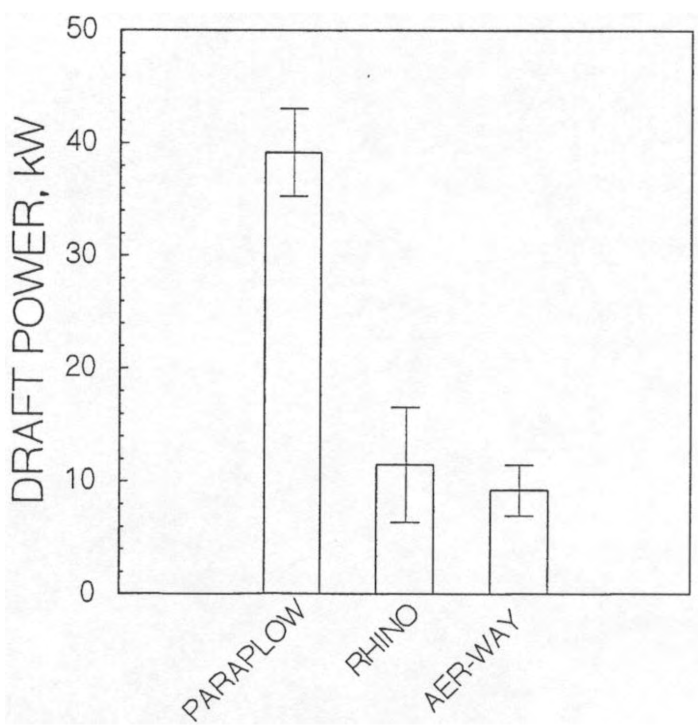


Figure 4. Draft force measurements taken on 3-11-94 on grazed section of field.

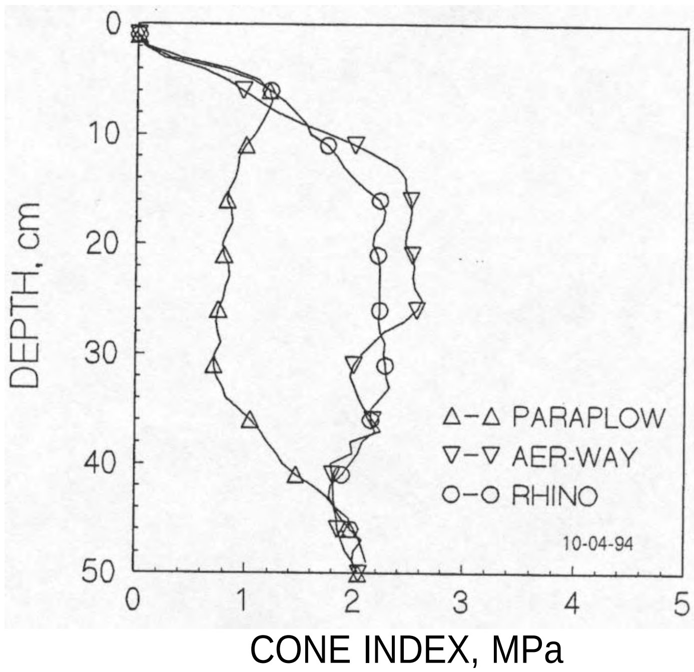


Figure 5. Cone index measurements taken immediately after the tillage force was established.

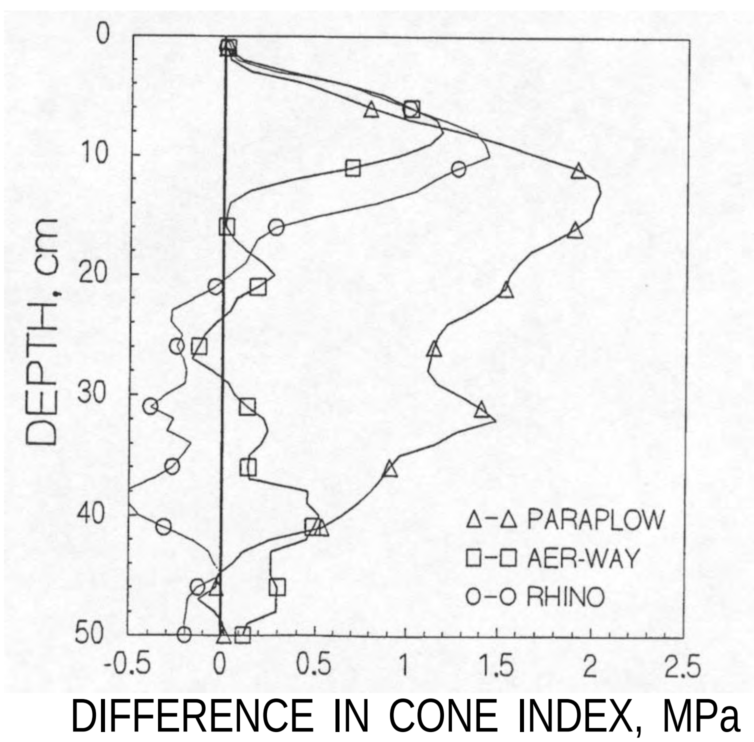
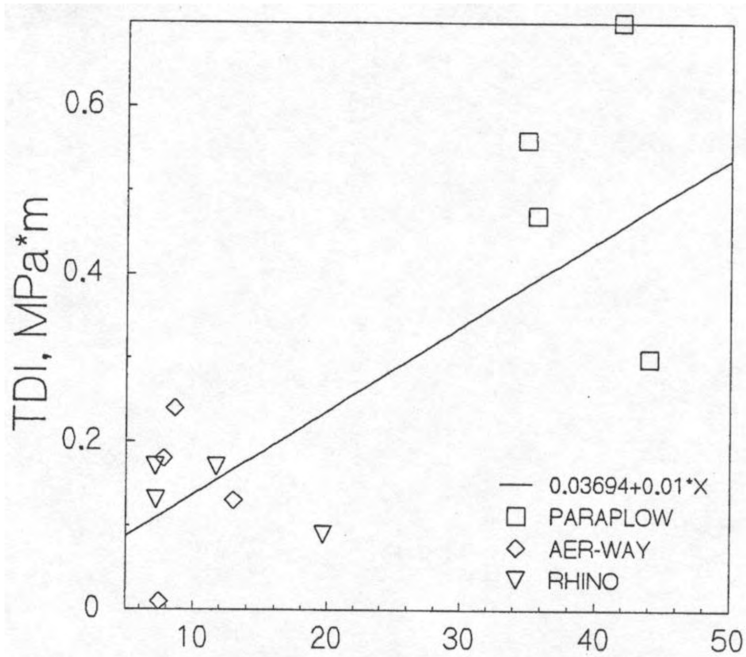


Figure 6. Difference in cone index measurements taken immediately before and after tillage was conducted.



DRAFT POWER, kW

Figure 7. Tillage disruption index (TDI) versus draft force requirements for three implements working in pasture. R^2=O.65.