Energy Requirements of Conservation Tillage Tools in Coastal Plain Soils

A. Khalilian and R. R Hallman[1]

Abstract: Draft and energy requirements are an important consideration in selecting tillage systems. Tests were conducted to determine the effects of speed and depth on draft characteristics of three tillage tools in two typical coastal plain soils. Tillage tools included a 4 shank Tye Paratill, a 4 shank French Durou plow, and a 4 bottom Switch plow. The experiments were designed to operate each implement at three speeds and three depths. Draft was quadratic with speed for the Tye Paratill, French Durou plow, and Harrell Switch plow in both soil type. Draft was linear with depth for all tillage tools. Draft-speed relationships can be used to predict the power requirements of these tillage tools in similar soil types.

Introduction

Soil hardpans limit root penetration into the clay layer and are a significant problem in many soils in the Southeast. Deep tillage implements, such as an in-row subsoiler or Paratill, have been shown to improve yields in coastal plain soils and are a requirement for breaking hardpan layers (Garner et al., 1986; Khalilian et al., 1991). Since the early 1980s, the greatest change in tillage systems has been a significant shift to conservation farming. The trend has been intensified by conservation compliance requirements. There are a number of new tillage tools, such as the Tye Paratill and the French Durou plow, on the market. However, there are no technical data available to advise farmers on the energy requirements and tractor sizes necessary to operate these tools. The Harrell Company has developed a new bottom plowing concept called the "Switch Plow." Although the Switch Plow is not a conservation tillage tool, bottom plowing is still the recommended practice for peanut disease and weed management. In 1990 some 1,000 Switch plows were sold to farmers, primarily in the Southeast.

Draft and energy requirements of tillage tools are an important consideration in selecting tillage systems. The draft requirements depend on the soil type and condition, tool shape, travel speed and depth of operation. The objective of this study was to determine the effects of speed and depth on draft characteristics of three tillage tools in two typical coastal plain soils.

Materials and Methods

Tests were conducted at the Edisto Research & Education Center of Clemson University at two locations. Soil type at the first location was Clarendon loamy sand (depth 0-7 in loamy sand, 7-13 in sandy loam, 13-30 in sandy clay loam). At the second location soil type was Dunbar sandy loam (0-7 in sandy loam, 7-60 in clay). Both locations were disked in the fall of 1991 and the fields were left fallow until tillage in April 1992.

Prior to tillage tests, a microcomputer-based, tractor-mounted recording penetrometer was used to quantify soil penetration resistance. Soil cone index values were calculated from the measured force required to push a 0.5 in' base, 30° cone into the soil at constant velocity.

A randomized complete block design with 27 treatments (3 tillage tools x 3 ground speeds x 3 tillage depths) replicated 4 times was used in both locations. Tillage tools included a 4 shank Tye Paratill, a 4 shank French Durou plow, and a 4 bottom Switch plow. The Tye Paratill uses a slanted shank with subsoiler type points and an adjustable shatter plate behind each shank (Figure I). The shanks slice through the ground at a 45° angle, gently lifting the soil, allowing it to fracture along natural cleavage plains. This action loosens the bottom soil without disturbing surface residue. The Durou plow also has slanted shanks (20° from vertical position) with a 10-in long wing attached to the side of the shank (Figure 2). Each bottom on the switch plow is made of a 24x24-in curved plate with 17-in radius of curvature (Figure 3). The switch plow is a reversible moldboard plow designed for plowing in both directions. Width of cut for each bottom is 18 inches.

A mechanical front-wheel-assist. 120-HP instrumented John Deree tractor, with a microcomputer-based data acquisition system, described by Hale et aL (1989) was used to gather information on draft, ground speed, drive wheel slip, and fuel consumption. Implement depths were measured by hand at random locations in each plot following implement

[1]Department of Agricultural and Biological Engineering. Clemson University. Edisto Research and Education Center. Blackville, S.C.

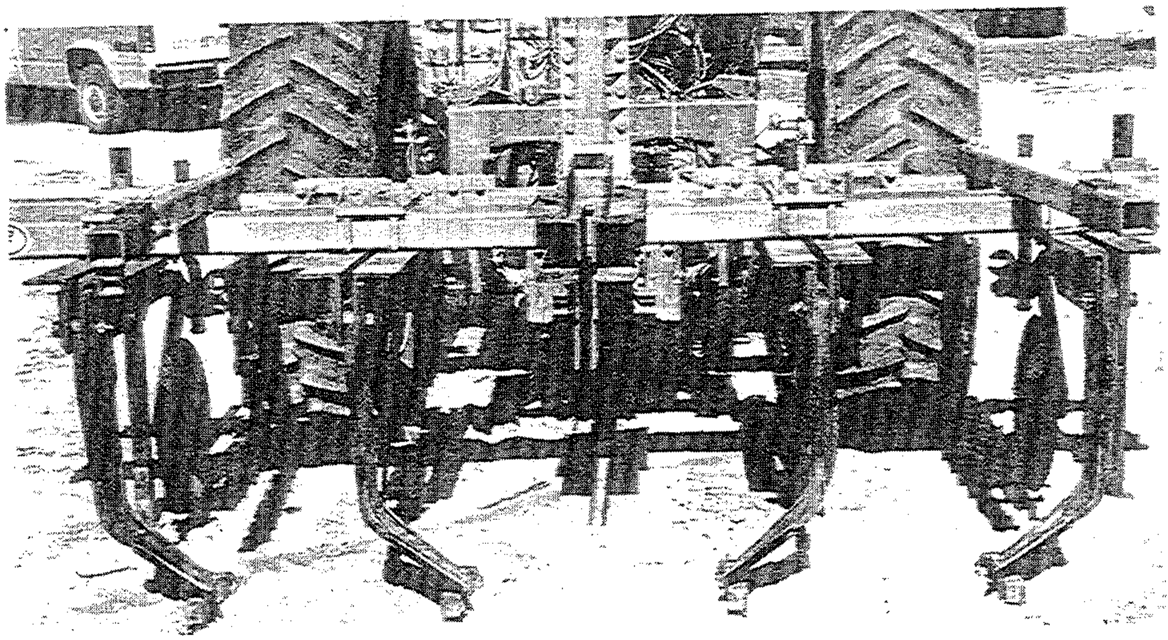

Figure 1. The Tye Paratill.

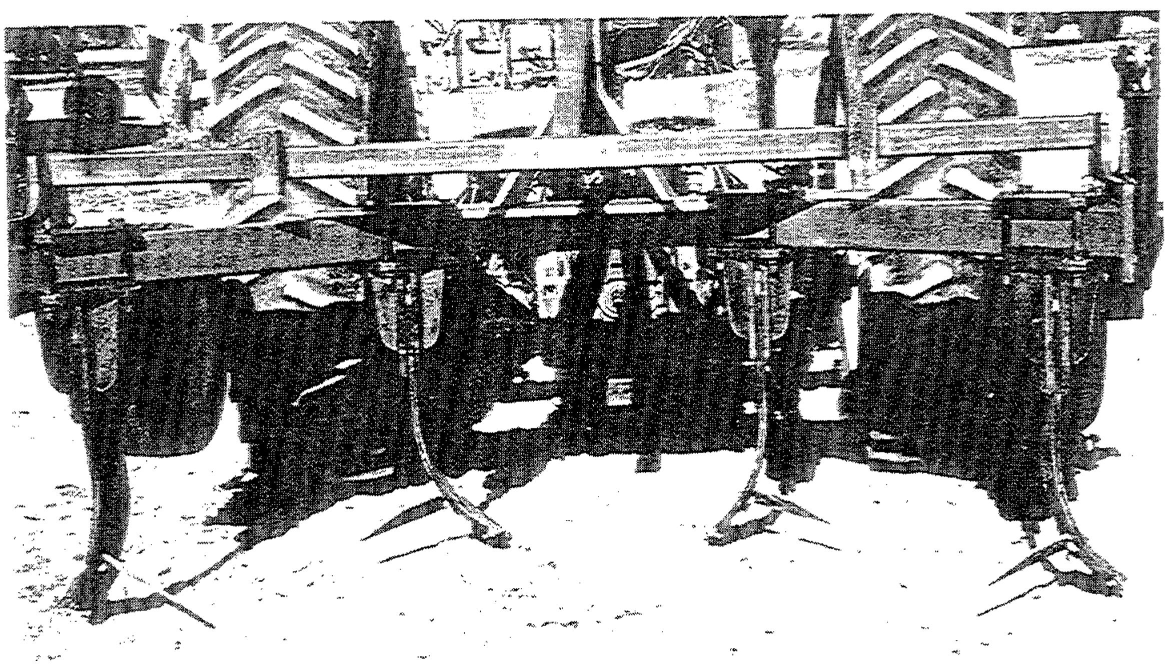

Figure 2. The French Durou plow.

passes. A reference was assumed to be level with the undisturbed soil surface adjacent to the tillage area.

The experiments were designed to operate each implement at three speeds and three depths. The speeds and depths were chosen to be within the normal range of field operations for each tool. Tillage tests were conducted when the soil moisture content was near optimum for both locations.

Results and Discussion

Figure 4 shows cross-sections of actual tillage depths for the three tillage tools measured at one-inch increments. The Tye Paratill with shank spacings of 22-26 in. and the Durou plow with shank spacings of 18-20 in., will create a broadcast tillage. Figure 5 shows profiles of cone index versus depth for the two experiment locations. Cone index values before tillage indicated that the test fields had a hardpan in the E horizon at about 10 to 13 in. depth. Soil resistance to penetration in Dunbar sandy loam field was higher than those for Clarendon loamy sand field. This effect is reflected in draft data presented later.

Depths of tillage for the implements are listed in Table 1. Variations in depths are due to not having an accurate reference when setting the plow depth and non-uniform nominal soil surface elevation. Figure 6 shows the relationship between draft and speed for the French Durou plow for the two tillage sites. Multiple linear regression was done on the data with powers of the velocity as the dependent variables. Draft was divided by depth and power of depth prior to regression. The best-fit draft relationships were the quadratic relationships shown in Table 2. The draft values for the Durou plow are given in lbs./ shank per inch of tillage depth.

Regression data for the Tye Paratill are given in Figure 7 and Table 2. Speed dependency was determined to be quadratic. Again draft values for the Paratill are in lbs./shank per inch of tillage depth. Figure 8 shows the relationship between draft and ground speed for the Switch plow. Draft data for the Switch plow was divided by depth and width of the plow prior to regression. Therefore the draft values are given in lbs. per unit cross-section of furrow slice (in.^{2}). The best-fit draft relationships were quadratic as shown in Table 2. Draft increased linearly with depth for Paratill, Durou plow and Switch plow. Also, draft values for all tillage tools in Dunbar sandy loam were greater than those in Clarendon loamy sand soil. This is due to greater compaction of the Dunbar soil as determined by the resistance to penetration shown in Figure 5.

The draft-speed relationships can be used to estimate the tractor horsepower required to pull each tillage implement for a given ground speed and operating depth. A formula for calculating drawbar power is: Drawbar power= speed (mph) x draft (lbs.)/ 375. To determine the PTO power we must use a factor to account for the traction capability of different soil conditions. These factors for different soil surface conditions are : 0.64 (firm soil): 0.55 (tilled soil); and 0.47 (soft/sandy soil). For example the tractor size (PTO power) required to pull a Switch plow with four 18-in. bottoms operating 10 in. deep in a tilled Clarendon loamy sandy soil at 5 mph is calculated as follows:
from Table 2, draft per square inch of cross section at 5 mph $= 6.1 + 0.05\ (52) = 7.35$ lbs./in^2; Cross-section $= 18 \times 4 \times 10 = 720$ in^2; Then total draft $= 720 \times 7.35 = 5292$ lbs.
Drawbar power = 5 (mph) x 5292 lbs./375 = 70.56 horsepower.
PTO power = drawbar power / 0.55= 70.56 / 0.55 = 128.3 horsepower.

Conclusions

Draft was quadratic with speed for the Tye Paratill, French Durou plow, and Harrell Switch plow in both soil type. Draft was linear with depth for all tillage tools. Draft-speed relationships can be used to predict the power requirements of the three tillage tools in similar soil types.

Acknowledgment

The authors acknowledge the support of the South Carolina State Energy Office; Harrell Company, Inc.; and Mr. P. Durou of DUROU Constructeur, France.

Literature Cited

Gamer, T.H., H.L. Musen and R. Dodd. 1986. Management data for primary tillage of Coastal Plain soils. Proc. Beltwide Cotton Production Conference, 4-9 January, 1986, Las Vegas, NV., pp 465-466.

Hale, S.A., A. Khalilian, R.B. Dodd, and T.H. Gamer. 1989. A second generation tractor performance data acquisition system for tractors. ASAE Paper No. 89-1578. ASAE. St. Joseph MI 49085.

Khalilian, A,, C.E. Hood, J.H. Palmer, T.H. Gamer, G.R. Bathke, 1991. Soil compaction and crop response to wheat/soybean interseeding. Transactions of the ASAE, Vol. 34(6): 1991, pp 2299-2303.

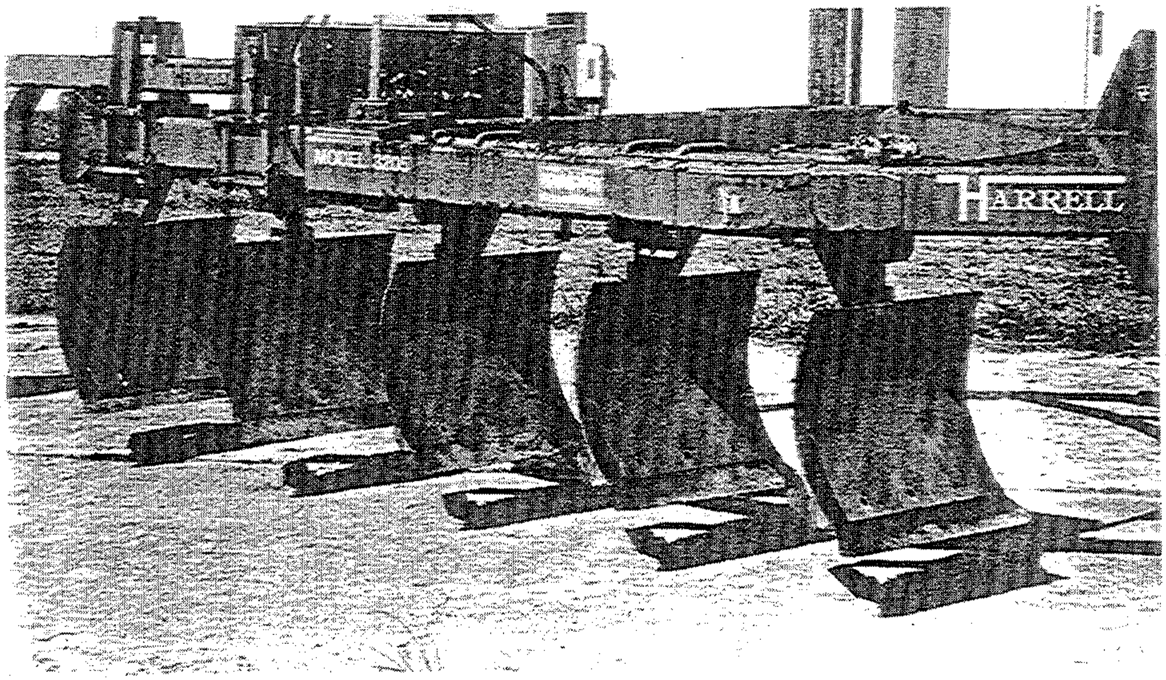

Figure 3. The Harrell Switch plow.

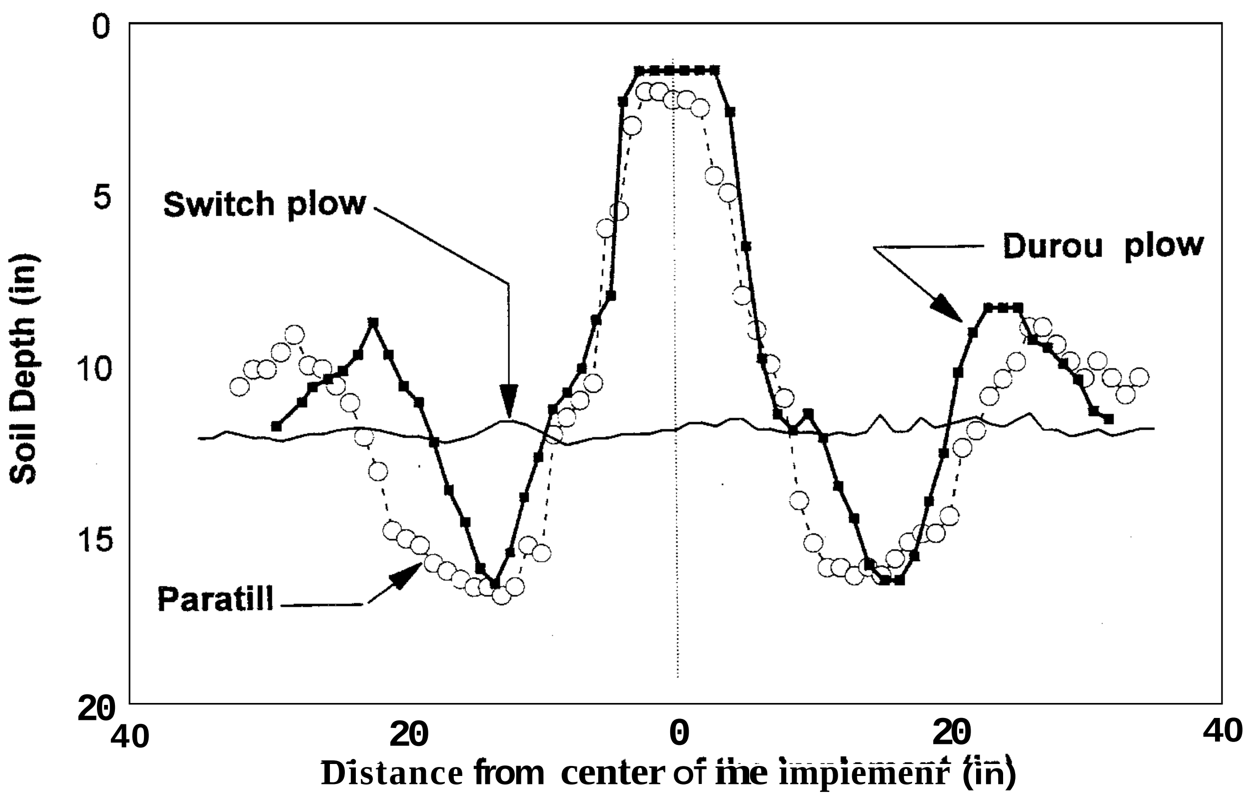

Figure 4. cross section of actual tillage depth for three tillage tools.

Table 1. Average tillage depth for the three primary tillage tools.

Implement	Relative Depth	Soil Type Clarendon loamy sand Depth (in.)	 Dunbar sandy loam Depth (in.)
Paratill	1	10.50	11.75
	2	14.50	14.25
	3	16.00	16.50
Switch Plow	1	8.00	7.75
	2	9.00	10.50
	3	13.00	13.00
Durou Plow	1	9.50	10.00
	2	14.00	14.00
	3	17.00	16.50

Table 2. Regression data for Paratill [*draft* (lb/in) = **A** + B (S)^2]; Switch plow [*draft* (lb/in^2) = **A** + B (S)^2]; and Durou plow [draft (lb/in) = **A** + B (S)^2], where S is ground speed in mph.

Implement	Soil type	**A**	B	R^2
Paratill	Clarendon loamy sand	64.6	0.50	0.846
	Dunbar sandy loam	73.7	0.27	0.892
Switch plow	Clarendon loamy sand	6.1	0.05	0.967
	Dunbar sandy loam	6.6	0.04	0.884
Durou plow	Clarendon loamy sand	66.4	0.49	0.826
	Dunbar sandy loam	66.5	0.61	0.905

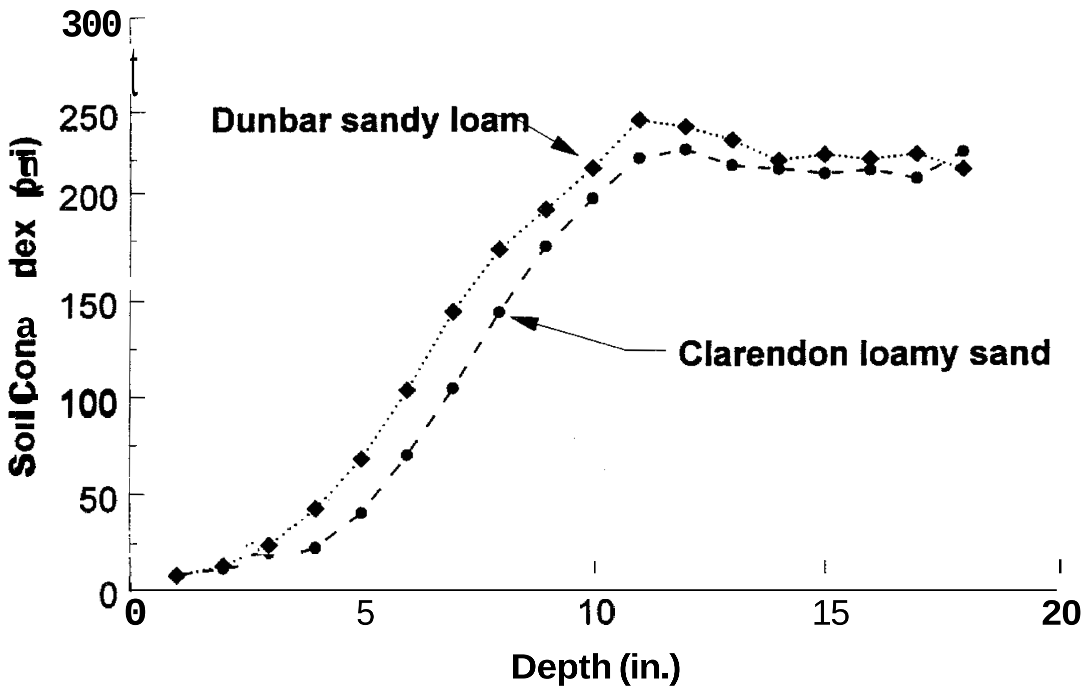

Figure 5. Average soil cone index profiles for the two tillage experiment locations.

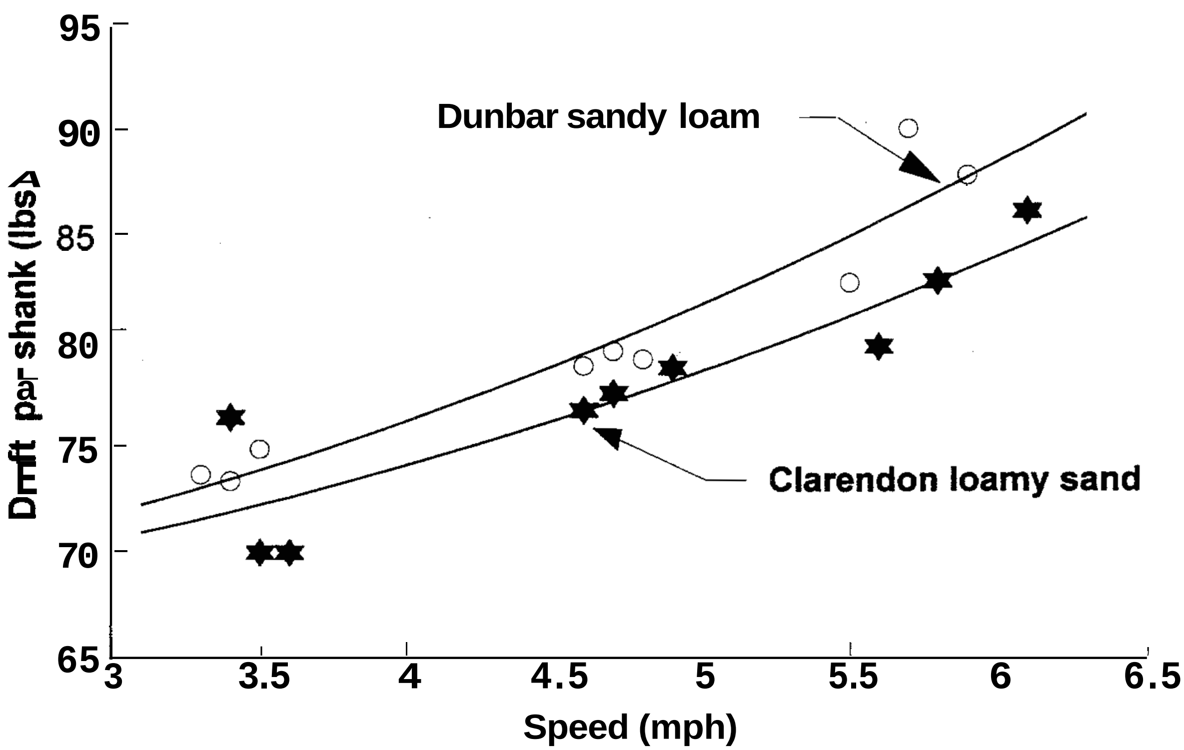

Figure 6. Durou plow draft requirements as a function of ground speed expressed in Ibs. per inch of depth for the two tillage sites.

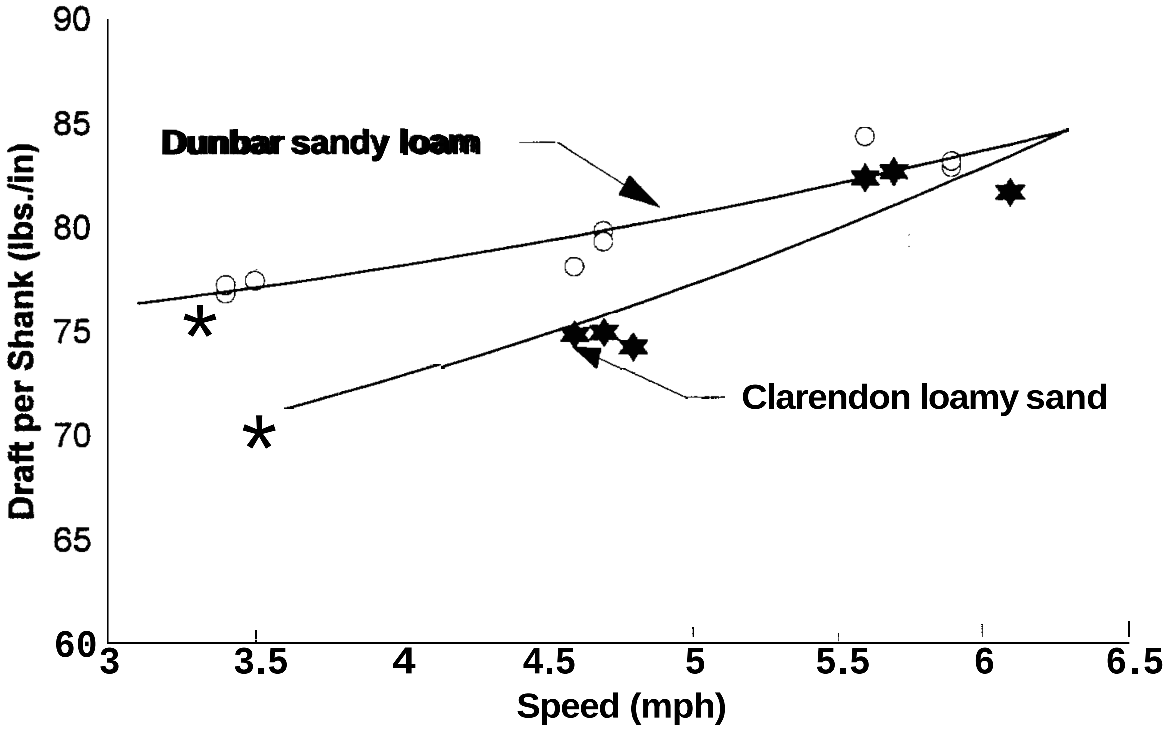

Figure 7. Paratill draft requirements as a function of ground speed expressed in lbs. per inch of depth for the two tillage sites.

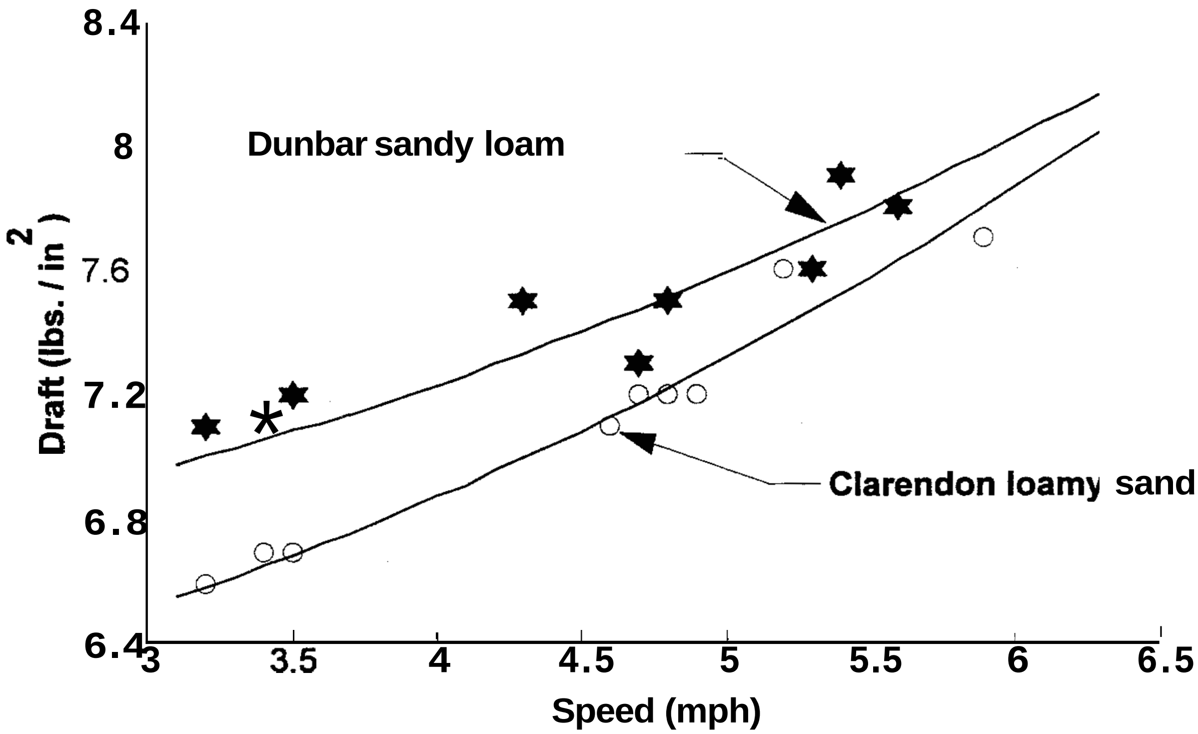

Figure 8. Switch plow draft requirements for the two tillage sites.