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ACCOUNTING FOR TILLAGE EQUIPMENT AND OTHER MACHINERY IN AGRICULTURAL ENERGY ANALYSIS

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ABSTRACT

The energy value of different tillage equipment and farm machinery is presented in this paper based on industry sources. Discounting, scrappage and utilization are discussed. Comparisons are made between the new disaggregated data and initial attempts to determine farm machinery's embodied energy content based on the energy content of automobiles.

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Even with continuing interest in energy analysis there have not been commensurate efforts to increase the data base available or even improve upon many of the sketchy figures utilized in a preliminary way a few years ago. One case in point is the data utilized for the energy capital embodied in farm machinery when considering energy utilization in agriculture. The purpose of this paper is to update the basic data available, consider some of the pitfalls involved in energy capital accounting and consider some alternative approaches.

Pimentel, Hurd, et. al., in their article "Food Production and the Energy Crisis," which appeared in the November 1973 issue of Science made some rough estimates of the energy embodied in the complement of farm machinery they hypothesized to produce corn. Based on data that 31,968,000 Kcal of energy were required to construct an automobile weighing 3400 pounds, the Pimentel group came up with an energy requirement of 18,804,706 Kcal per ton of farm machinery assuming an automobile was a reasonable proxy. Their machinery complement for corn production weighed 13 tons. This was assumed to be adequate to farm only 62 acres, and the energy in the machinery was discounted over a period of ten years. A 6% surcharge was added to these figures to allow for the energy embodied in spare parts which would

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be necessary over the life of the machinery. The final estimate for the production and repair of farm machinery per acre of corn per year for 1970 was 420,000 Kcal.

Recent information obtained from a farm machinery manufacturer* gives a more precise indication of the energy embodied in farm machinery. This was done by monitoring all the energy inputs into a plant producing a particular class of machinery. The total energy inputs were then divided by the tons of output. This is a value added concept, as it does not include the energy value of the raw steel or iron entering the plant. This value added concept is particularly suited for determining the machinery energy used in crop production. The piece of machinery can be depreciated on a straight line basis to zero over the useful life of the machine. What is left is the scrap value of the energy embodied in the metal stock as it entered the manufacturing plant. These 'value added' data are presented below. These data indicate a considerable reduction in the amount of energy

Table I

Energy Used Per Ton of Farm Machinery Produced

Equipment Category	Kcal x 10^6 Per Ton Fiscal 1972	Kcal x 10^6 Per Ton Fiscal 1974
Combine	4.59	3.72
Hay & Forage Harvesting	1.87	1.44
Primary Tillage Including Planters for Large Seeded Grain	3.91	2.55
Tractors	5.88	4.74
Secondary Tillage Including Sprayers, Small Grain Planters and Cotton Harvestors	3.18	1.97

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* This information was obtained from William Burrows at Deere & Co.

needed to produce a particular category of equipment for fiscal 1974 as compared with fiscal 1972. This largely reflects improved processes rather than changes in the scale or type of machinery.

These data do not reflect the energy in tires. Calculations were made for the probable complement of tires for given categories of equipment. These are given below. As tractor and implement tires are usually destroyed or abandoned after being worn out, it would appear logical to depreciate them fully over their life.

Table 2

Energy in Tires for Different Farm Machinery*

Equipment	Number and Tire Weight	Total Weight	Total Kcal
Combine	2 x 350 = 700		
(7700 J.D.)	2 x 70 = 140	840 lbs.	7.81×10^6
Hay Harvesting & Forage Harvesting	2 x 32 = 64	64 lbs.	$.60 \times 10^6$
Primary Tillage			
Plow (on furrow)	1 x 29	29 lbs.	$.27 \times 10^6$
Plow (on land)	3 x 29	87 lbs.	$.81 \times 10^6$
Planters			
4 row	4 x 28	112 lbs.	1.04×10^6
6 row	6 x 28	168 lbs.	1.56×10^6
8 row	8 x 28	224 lbs.	2.08×10^6
Tractors			
4430 J.D. (2 wheel dr.)	2 x 56		
	2 x 300	712 lbs.	6.62×10^6
8630 J.D. (4 wheel dr.)	4 x 300	1200 lbs.	11.16×10^6
Secondary			
Sprayers	2 x 32	64 lbs.	$.60 \times 10^6$
Disc	2 x 32	64 lbs.	$.60 \times 10^6$

* 9299 Kcal/lb. of rubber tire.

In addition to tires, the value added figures do not reflect the energy in belts, plastic parts and a limited number of component parts which are purchased fully manufactured. These are bearings, rings, generators and diesel fuel pumps. These would tend to be high energy components on a value added basis, while their weight would make up a relatively small proportion of the total machinery weight. In order to be sure that these components are more than adequately covered in an energy accounting, a 5% surcharge can be made to the value added energy of motorized equipment.

The calculation of Kcal of machinery stock per acre of corn is most sensitive to the acres over which the machinery is spread. A case farm currently being analyzed for energy flows at Purdue yielded the acreage base and data for an example of machinery energy accounting. The machinery complement is as follows:

Table 3

Machinery Complement for Corn

	Total Weight in Lbs. Including Tires	(Tire Weight)
Tractor: Oliver 1850-D	8,766	(650)
Combine: Oliver 545-G (4 row) including corn head	12,150	(650)
Moldboard Plow: 5 - 16"	2,129	(29)
Disc: 20' overall 16" blade squadron hitch	5,664	(64)
Applicator: 20' tool bar, 9" knife	4,464	(64)
Planter: 8 row, 30"	3,224	(224)
Rotary Hoe: 8 row, 30", 20' bar	2,164	(64)
	38,561	

On the basis of Pimentel's calculations @ 18.80 x 10^6 Kcal per ton this machinery would contain 362.47 x 10^6 Kcal. Adding 6% for repairs would bring the total to 384.22 x 10^6 Kcal.

Figuring each piece of equipment separately on the basis of the 1972 value added figures from Deere and adding in the Kcals in tires would give a total machinery complement of 98.22 x 10^6 Kcals. Utilizing the 1974 figures would give a total machinery complement of 77.32 x 10^6 Kcals, as given below.

Table 4

Value Added Energy in Farm Machinery

Equipment	Energy Used On 1972 Base (Kcal x 10^6)	Energy Used On 1974 Base (Kcal x 10^6)
Tractor: Oliver 1850-D	31.098	26.241
Combine: Oliver 545-G with corn head	33.757	28.504
Plow: Moldboard, 5 - 16"	4.376	2.948
Disc: Two 10' with squadron hitch, 16" blades	9.504	6.116
Applicator: 9 knife, 20' tool bar	7.596	4.934
Planter: 8 row, 30" on Oliver bar	7.945	5.905
Rotary Hoe: 8 row, 30" on 20' bar	3.939	2.669
TOTAL:	98.215	77.317

These were calculated by multiplying the weight of the piece of equipment, exclusive of tires, by the Deere estimate of energy used per ton to produce that category of equipment. For tractor and combine a 5% surcharge was added to cover components not manufactured by Deere. Finally, the energy embodied in the tires was added in for each piece of equipment. With the exception of the tires, what we have is a value added total for each piece of machinery. When the machinery is worn out the value added should be exhausted.

It is important to recognize the critical nature of the distinction that is being made here. As an example; the disc contains 5,600 lbs. of plain carbon steel. According to one estimate, energy is embodied in this steel from its manufacture at approximately 5,290 Kcal per pound of steel.[1] This means that the 5,600 lb. disc has 29.624×10^6 Kcal of energy embodied in its steel. Yet, we are only counting 8.904×10^6 Kcal for the disc (exclusive of its tires) based on the 1972 value added figures in the belief that much of the energy value remains locked in the metal rather than being used up in farming.

For some types of equipment repairs can be an important factor in calculating either dollar or energy cost. Pimentel's estimate appears low. An overall repair average of 6% (based on the automobile industry) is used for the full ten year life he assumes rather than taken repeatedly each year for ten years. Engineering estimates are available for the dollar value of repairs for different classes of agricultural machinery based upon the initial price of the machinery, its estimated life and the estimated usage over a given period. These are exponential functions reflecting increased repair incidence with age.[2] As an example; the total accumulated repair cost for a tractor is calculated as follows:

$$TAR\% = 0.096 \times \left(\frac{\text{accumulated hours of use}}{\text{estimated wear out life}}\right)^{1.5}$$

The TAR% is that proportion of a piece of machinery's list price that is expended for repairs. In this case the proportion of repairs is taken as a proxy for the amount of energy expended for repairs over the hypothetical life of the machine. The base is the value added energy required to produce the machinery. The functions are adjusted for different wear out rates for different machinery.

Different pieces of equipment are seldom matched so that all cover the same acreage at full capacity and simultaneously expire at the end of identical periods of useful life. Given that the equipment listed is part of an ongoing operation, the most conservative approach is taken, and the acres covered and life of the machinery is based on the most limiting piece of equipment. In this case it is the combine. Our estimate is that this machine could cover an average of 300 acres of corn a year for ten years, and it would then be ready for scrapping. On this basis the tractor and its implements would have many years of life remaining. However, for the basis of these aggregate comparisons the machinery complement is treated uniformly.

Accumulated hours of use were figured for each piece of equipment on the basis of 300 acres per year for ten years. The accumulated hours were then used to figure the total repairs for the ten year period based upon the exponential functions in the Agricultural Engineers Yearbook. Thus, while Table 5 presents a total repair cost on a ten year basis, the annual cost would have been less in earlier years than in later years.

Table 5

Total Ten Year Repair Energy

Equipment		Energy Used On 1972 Base (Kcal x 10^6)	Energy Used On 1974 Base (Kcal x 10^6)
Tractor:	Oliver 1850-D	3.701	3.123
Combine:	Oliver 545-G	14.025	11.843
Corn Head		5.990	5.058
Plow		1.742	1.174
Disc		1.781	1.147
Applicator		1.315	.854
Planter		2.432	1.808
Rotary Hoe		.401	.272
	TOTAL:	31.387	25.279

Table 6 includes analysis of the case farm's corn producing machinery stock analyzed on the basis of Pimentel's coefficients plus 6% for repairs. This analysis is also carried out for the 1972 and 1974 Deere figures with the ten year total repairs. While many tires might last the ten year period, they are included in the repair calculation for some replacement. In terms of the estimate of the total aggregated machinery stock there is approximately a three fold difference between the Pimentel automobile proxy estimate and the average of the 1972 and 1974 Deere based figures. However, the most sensitive variable for an energy analysis of machinery on a per acre basis is the level of productivity assumed for that machinery stock.

Table 6

Machinery Energy Per Acre of Corn

Machinery Stock	Total (Kcal x 10^6)	62 Acres Over 10 Years (Kcal x 10^6)	300 Acres Over 10 Years (Kcal x 10^6)
Pimentel Method (plus 6% repairs)	384.22	.620	.128
Deere 1972 Data (plus 10 years repairs)	129.60	.209	.044
Deere 1974 Data (plus 10 years repairs)	102.60	.166	.035

If one is willing to assume that a machinery stock of this nature can farm a total of 3,000 acres over its full life before it becomes obsolete, then the estimates for energy in machinery stock based on Pimentel's 62 acres over the life of the machinery are way off. Given the way Pimentel states the aggregate figures one cannot be sure exactly what the machinery stock was in his analysis of corn production. It is described as "all machinery (tractors, trucks, and miscellaneous) to farm 62 acres of corn." The machinery listed for the Purdue case farm does not include trucks, farmstead equipment or corn drying and storage equipment. Such equipment can be included as required.

If one is to make sense of energy analysis of agriculture, the data for equipment must be handled on a disaggregated basis, implement by implement. As one compares one cropping system with another, then one has to know the energy embodied in the equipment that might be replaced or shifted to change cropping systems. On this basis such a systems analysis of agricultural production will have to calculate the life, capacity and repair incidence for each type of machinery.

With the number of simulation and programming models already available today, there is little lead time involved in undertaking energy modeling if coefficients of some sort can be dredged from somewhere. However, the real need is for good disaggregated data based on actual equipment and experience. It can only be hoped that every well funded model builder will devote at least a small portion of his grant resources to helping improve the specific disaggregated data base necessary for accurate and meaningful results.

References

1. "Automobile Material Breakdown & Energy for Manufacture," in Auto Products Magazine, Oak Park, MI, November 1974.

2. Agricutlural Engineers 1976 Yearbook, American Society of Agricutlural Engineers, St. Joseph, MI, pp. 324-326 and 329, 1976.