A METHODOLOGY FOR DETERMINING ENERGY REQUIREMENTS ON MICHIGAN FARMS USING FARM RECORDS

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ABSTRACT

A METHODOLOGY FOR DETERMINING
ENERGY REQUIREMENTS ON MICHIGAN FARMS
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by

Frederick William Hall

A methodology using farm records was developed to collect energy use data from the major types of Michigan farms. Records used in the study were the Michigan Telfarm Records from which a limited sample were selected for the pilot study. From the comparison of fertilizer inputs provided by the records, Nitrogen was found to be the largest single input across all farms. The gallons of fuel consumed per acre for all farm uses were greater than expected. By enlarging the sample of farms selected and utilizing current monthly records, it is believed that an accurate determination of energy requirements for Michigan farms can be made.

Approved ______________________
Major Professor

Approved ______________________
Department Chairman

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by

Frederick William Hall

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To Linda, who worked as hard on this study as I did, and Tony, who unknowingly left his imprint here, also.

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My thanks to Bill Dexter who helped with the details of the Telfarm record keeping system and to all of the farmers who gave of their time and participated in the study. I hope that this study will eventually be of great help to them.

And finally, my appreciation to everyone in the Agricultural Engineering Department who have been an inspiration to me and a pleasure to work with.

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LIST OF ABBREVIATIONS

Amt.	amount
Amt. Prod.	amount produced
B.I.	beginning inventory
btu	British Thermal Unit
bu	bushel
Cal.	Large calorie
cwt	hundred weight
E.I.	ending inventory
Edible Prod.	edible product
ft^3	cubic foot
gal	gallons
g	gram
hrs	hours
kcal	kilocalorie
kg	kilogram
kw hrs	kilowatt hours
lbs	pounds
Ptshp	partnership
Pur	purchased
MCF	1000 cubic feet
T	ton
wt	weight

INTRODUCTION

The relationship between agricultural production and energy consumption has received much attention in the past few years. Even before fuel supplies became scarce, numerous studies were done to determine the power requirements for various farming operations. Those studies established an estimate of the power required and were based on approximations of actual farming conditions. The farmer used this information to help plan the size of equipment needed.

With the increasing awareness of a shortage in fuel supplies, various states have examined their agricultural industries to determine the amounts of energy required. The California Department of Food and Agriculture and the University of California at Davis have reported an estimate of the energy required to produce and distribute a ton of product.[1] The estimates were then multiplied by the tons of products produced in 1972 to determine the annual energy requirement.

The National Science Foundation sponsored a project to determine the quantity of energy necessary to grow, process, transport, wholesale, retail, refrigerate and cook food in the United States for the year 1963.[2]

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[1]Cervinka, V., W. J. Chancellor, R. J. Coffelt, R. G. Curley, J. B. Dobie. Energy Requirements for Agriculture in California. (Davis, California, California Department of Food and Agriculture, University of California, January 1974).

[2]Hirst, Eric. Energy Use for Food in the U.S. (Oak Ridge, Tennessee, Oak Ridge National Laboratory, October 1973).

Energy input-output tables were used to assign energy values to the dollar flows reported by the Bureau of Economic Analysis for food expenditures.

These studies have certainly contributed to an understanding of the energy situation. However, most figures recorded are estimates, or are based on theoretical conditions. Very little data exists on how much energy farms actually consume. Several recent computer simulations of farming operations have indicated the need for an accurate data base of energy consumption.[3] The report of the National Science Foundation program states, "the coefficients for the agricultural and trade sectors... are not well documented."[4]

At the present time, Michigan's agricultural industry has very little data on energy consumption. The energy requirements for agricultural production on a state-wide basis would help in planning fuel allocations. Even more important, the energy consumption for specific farming operations would help the farmer plan better use of his energy resources. Likewise, knowledge of the total requirements for handling a specific material or producing a product should lead to more efficient use of energy. Energy consumption in relation to farm size is also important as present indications are that farm size will increase.[5]

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[3]Hughes, Harold. Energy Consumption in Beef Cattle Feedlots as Affected by Size and Technology. (Ph.D. Thesis, Michigan State University, East Lansing, Michigan, 1972).

Misener, Gerry. Interviewed by Frederick Hall (Michigan State University, East Lansing, Michigan, July 1974).

[4]Hirst, op. cit., p. 28.

[5]Michigan State University Agricultural Experiment Station and Cooperative Extension Service, Highlights and Summary of Project '80 & 5. Research Report 180, (East Lansing, Michigan, February 1973).

This author is concerned that Michigan energy data for agricultural production are limited. The necessity of using energy efficiently is apparent now. Plans and policies are now being established that will affect Michigan's agriculture in the years to come. It is hoped that this study will contribute to the implementation of good planning.

OBJECTIVES

The objective of this study includes the following major goals.

1. The design and development of a methodology to collect energy use data from the major types of Michigan agricultural farms. Energy use data are to include all forms of non-renewable energy employed, the technology and management practices involved in utilizing the energy and the amounts of products produced.
2. The implementation of a pilot study to test the feasibility of the methodology.
3. A report of the results of the pilot study.
4. The establishment of an estimate of the variability among farms and types of farming.
5. The comparison of the results of the pilot study with other values established for energy consumption.
6. Recommendations for utilizing this methodology in further studies.

METHODOLOGY

The Basic Unit

The basic unit of the agricultural production system is the individual farm. The first combination of resources is selected at this level. Resources include land, water, equipment, animals, chemicals and non-renewable energies such as fuels and electricity. The production process is controlled through various management practices and technologies which consume energy. The products represent the output of the combination of the resources, labor, and management.

Parameters for the Model

A factor which influences the amount of energy consumed is the type of farm studied. A livestock farm is utilizing its resources in a different manner than a cash grain operation.

Within the type of farm, the size of the operation is expected to have an effect. Hughes has predicted an optimum size of beef operations with respect to electrical energy efficiency.[6] The effect on other types of operations is not documented.

The technology and management practices used are also expected to have an effect. Hughes predicted a solid waste handling system is more efficient than liquid wastes with respect to fossil fuels. Likewise, an all silage ration will require less electrical and fossil energy than a

[6]Hughes, op. cit., p. 117.

mixed corn and silage ration.[7]

The above information specifies a basic energy model of agricultural production with emphasis on type and size of farm as well as the technology involved. The next step is to consider Michigan's agricultural production.

Michigan Farm Types

Michigan's agricultural production can be divided into four major types of farms. The first will include Dairy enterprizes which received 28.4% of Michigan's 1971 cash receipts to agriculture. Livestock is the second type, where cattle and calves received 13.5% of the 1971 cash receipts, and Fruits and Vegetables received 10% of the cash receipts for the same year. Cash Crops representing the fourth type, include corn, wheat, beans and sugar beets. They received 24% of Michigan's cash receipts for 1971.

Michigan Farm Sizes

As was mentioned before, the size of operation within each type of farm is expected to have an effect on energy consumption. Specialists of agricultural production in Michigan were consulted for advise on the representative sizes of farms. The farms are classified into large, medium and small sizes in the manners specified below.

Dairy enterprizes in Michigan divide into sizes based on the number of milking cows per man. The small operation, or one-man, is thirty to forty head. The medium size is a two-man operation, or 100 head plus or minus twenty. The large operation would be 200 head or more.

Livestock enterprizes will vary depending on the type of animals. For beef, the small operation is up to 150 head on feed. This size of

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[7] Ibid., pp. 117-118.

operation will probably also be receiving income from crop sales. The medium size, one-man operation, will range from 200 to 500 head, and the large operation will have 800 to 1,000 head on feed. For swine, the small farm will have twenty to thirty sows, the medium size will have sixty to seventy sows and the large enterprize will have more than 100 sows.

The size of operation in Cash Crops is decided solely on the amount of actual land under production. The small size is less than 400 acres. Medium range is 400 to 800 acres, and over 800 acres is considered large.

Fruits and Vegetables are evaluated on a similar basis. Less than 100 acres is a small operation. Two hundred acres is the medium size, and the large operation is 400 acres.

Technological Factors

The technology incorporated in the farming operations must be considered also. The size of operation may dictate the technology used in some cases, however specific comparisons of machinery management should be made between operations of the same size and type. As an example of this comparison, one might contrast the energy requirements between utilizing a stanchion barn verses a milking parlor in a Dairy operation. Another example would examine the energy consumption between beef enterprizes using tower silos as compared to those using horizontal silos. A contrast could also be made between the use of heavy silage verses a heavy grain feeding program.

Data Collection

To implement the model the following information must be collected.

1. The gallons of gasoline and/or diesel fuel used in each operation.
2. The gallons of propane or cubic feet of natural gas used in drying or heating.
3. The kilowatt hours of electricity used for operations.

4. The hours of labor for all individuals involved in the operation.
5. The pounds of chemicals used in crop production.
6. The pounds of fertilizers used in crop production.
7. The pounds of other products brought to the farm unit and consumed such as feed suppliments.
8. The pounds of products produced.
9. The pounds of products stored and used on the farm.
10. The gallons of water used.

There are various other operations that will consume energy on the farm, but will not readily appear in products flowing into or out of the total operation. In separating the energy uses in the operations, the following data must be collected.

1. The pounds of manure used and the amount of land on which it is spread.
2. The horsepower sizes of both electrical and fossil fuel equipment used in the operations.
3. The pounds of products processed on the farm.

To demonstrate how the data collected can give rise to energy equivalents, an example is given as follows:

Suppose it is decided to determine the energy required to cool the milk on the farm. The pounds of milk produced per day (X) is multiplied by the number of BTU's per pound (Y) to be removed from the milk. This gives the total BTU's to be removed per day from the milk. The capacity of the cooler (w) is expressed in BTU's per unit of time. Dividing the total BTU's by the capacity gives the time (t) required to cool the milk per day. The coefficient of performance (u) of the cooler is the ratio of the useful refrigeration to the work supplied. Dividing the time required to cool the milk by the coefficient of performance for the cooler gives the actual time (t') the cooler must work. This time, multiplied by the horsepower (h) of the motor operating the cooler, provides a result which can be converted to the watts of electricity needed. The efficiency of the motor must also be considered in determining the actual energy consumed.

In summary: XY = Total BTU's removed/day from milk,

XY/w = t, time required to cool milk/day,

t/u = t', actual time cooler must work, and

t'h $\rightarrow$ watts of electricity required

Statistical Considerations

It is important to recognize the advantages of statistical methods when conducting a study for possible projections onto a larger scale. A "completely randomized design" should be considered first, for this study because the effects of all variables are uncertain. However, some variables such as size and type of farm are suspected of being directly related to energy consumption. This implies that a "cross-classification" of data for statistical analysis would make the most efficient use of the farms selected. The cross-classified plan has the advantage of maintaining the precision of estimated "main" effects of factors, while indicating possible interactions between factors.

Type and size can be considered to have fixed effects because the classes of both are deliberatly chosen for study. Type of farm, factor A, in this study, is divided into four classes. As mentioned before, they are Dairy, Livestock, Fruits and Vegetables, and Cash Crops. Size of farm, factor B, comprizes three classes, small, medium, and large. A linear model for this design can be written as follows:

$$Y_{ijk} = u+A_i+B_j+(AB)_{ij}+E_{(ij)k} \qquad (i=1,2\text{-}4,\ j=1,2,3,\ k=1,2,\ldots r)$$

Y_{ijk} is the observed energy use on the kth farm belonging to the ith class of A and the jth class of B. The "mean" or average effect of the farms sampled is represented by u. A_i and B_j represent the average effects of the ith type farm and the jth size farm, respectively. $(AB)_{ij}$ is the effect of the interaction of type and size, and $E_{(ij)k}$ is the random effect of all unspecified variables peculiar to the kth farm of that type and size. The number of farms at each combination of A and B is designated by r. The mathematics involved are much easier if all combinations of A and B have the same number of farms.

If specific technologies or management practices are to be compared, then a "mixed classification" design should be used. This design is similar to the cross-classified design, but it allows a third variable to be studied within the type or size, when classes of technologies differ from type to type or by size of farm.

IMPLEMENTATION OF METHODOLOGY

After the basic model was completed, it was decided to implement a pilot study to test the feasibility of the data collection procedures. The Telfarm system, a farm accounting program, was selected as a source of possible cooperating farmers for the study. Two benefits were realized from utilizing this source. First, the farmers participating in Telfarm have experience in keeping accurate records and second, most of the individuals have been known to be cooperative with the University in past research studies. A possible disadvantage is that this select group of farmers may not be typical in their ability to make efficient use of energy.

Because time and funds were limiting factors to the study, the farms in Ingham, Eaton and Clinton counties were the only ones considered. This limited the types of farming operations to three; Dairy, Livestock, and Cash Grain. More than fifty percent of the Telfarm cooperators in the Tri-County area are classified as Specialized Southern Dairy. This provided a large number of farms to select from in the Dairy Industry. Two of the farms chosen, were in the small-size classification, two, in the medium-size, and one in the large classification.

All of the beef and swine operations in the Telfarm system for the Tri-County area were considered because of the limited number. Three farms agreed to participate in the study. Two of the operations were medium-sized beef feeders and the third was a large hog enterprize.

In the Cash Grain operations, one farm was in the small-size group, two, in the medium-size, and one in the large. The limited number of cash grain farmers with Telfarm again affected the sample size.

The study was based on the 1973 records because the 1974 records were not as yet complete. The Telfarm records were examined for the required data and included such information as crop acreages, yields, products sold, animals sold, rations fed to livestock on the farm, animal weight produced, inventories of stored feed and equipment, and the hours of labor. Additional information such as gallons of fuel used was not available in the records at the time this study was conducted. This was gathered directly from the farmers.

A visit to each farm was arranged and management practices were recorded. These included items such as the tillage operations used, the amounts and types of fertilizer and chemicals used, types of harvesting methods, and the destinations and mode of transportation of produce. Twelve farms in all, participated in the study and each visit lasted about two hours in length.

RESULTS

The collected data were organized and each input to the farming operations was converted to its energy equivalent. Each of the products leaving the farm was also converted to its energy equivalent. The output-input ratio could then be determined. The results are presented in the tables which follow. There is a brief narrative description of each farm after the set of tables and the remainder of the original data collected is found in Appendix B.

TABLE 1.

FARM NO. 1

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Gasoline	2744	10386	$8.57x10^7$	$3.40x10^8$
Electricity	16000 kw hrs		$1.38x10^7$	$5.46x10^7$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	5.06	4590	$8.08x10^7$	$3.21x10^8$
Phosphorous	3.35	3039	$9.69x10^6$	$3.85x10^7$
Potassium	3.38	3066	$6.75x10^6$	$2.68x10^7$
Herbicides	0.10	90.7	$2.20x10^6$	$8.71x10^6$
Labor	2982 hrs		$4.08x10^5$	$1.62x10^6$
Total for Input			$1.99x10^8$	

OUTPUT					
Crops:		bu/cwt	kg		
Corn-shelled	(bu)	2827	71810	$2.50x10^8$	$1.05x10^9$
Wheat	(bu)	578	15731	$5.19x10^7$	$2.08x10^8$
Beans	(cwt)	289	13109	$4.46x10^7$	$1.77x10^8$
Dairy:	Amt. Prod.	Edible Prod.			
Animal Sales	196 cwt	7795 lbs	3535 kg	$9.41x10^6$	$3.73x10^7$
Milk Sales	3078 cwt		139618 kg	$9.08x10^7$	$3.43x10^8$
Total for Output				$4.47x10^8$	

OUTPUT-INPUT RATIO 2.24

*Conversion factors are given in Appendix A

TABLE 2.

FARM NO. 2

INPUT				Energy Equivalents*	
Fuel:		gallons	liters	kcal	btu
Gasoline		2860	10825	$8.95x10^{7}$	$3.55x10^{8}$
Electricity		27628 kw hrs		$2.37x10^{7}$	$9.42x10^{7}$
Fertilizers and Chemicals:		tons	kg		
Nitrogen		1.85	1669	$2.94x10^{7}$	$1.17x10^{8}$
Phosphorous		1.84	1669	$5.32x10^{6}$	$2.11x10^{7}$
Potassium		4.54	4119	$9.06x10^{6}$	$3.60x10^{7}$
Herbicides		0.08	76.2	$1.84x10^{6}$	$7.32x10^{6}$
Labor		3574 hrs		$4.90x10^{5}$	$1.95x10^{6}$
Total for Input				$1.59x10^{8}$	
OUTPUT					
Crops:		bu	kg		
Corn-shelled		1600	40643	$1.41x10^{8}$	$5.93x10^{8}$
Wheat		507	13798	$4.55x10^{7}$	$1.82x10^{8}$
Dairy:	Amt. Prod.	Edible Prod.			
Animal Sales	210 cwt	8352 lbs	3788 kg	$1.01x10^{7}$	$4.00x10^{7}$
Milk Sales	3878 cwt		175906 kg	$1.14x10^{8}$	$4.32x10^{8}$
Total for Output				$3.11x10^{8}$	
OUTPUT-INPUT RATIO				1.95	

*Conversion factors are given in Appendix A

TABLE 3.

FARM NO. 3

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	2423	9171	8.54×10^{7}	3.39×10^{8}
Gasoline	5500	20817	1.72×10^{8}	6.82×10^{8}
Propane	2595	9822	6.02×10^{7}	2.39×10^{8}
Electricity:				
Lights, Feeding	60781 kw hrs		5.22×10^{7}	2.07×10^{8}
Hot Water	12815 kw hrs		1.10×10^{7}	4.37×10^{7}
Fertilizers and Chemicals:	tons	kg		
Nitrogen	25.01	22689	3.99×10^{8}	1.58×10^{9}
Phosphorous	6.48	5879	1.88×10^{7}	7.44×10^{7}
Potassium	10.68	9689	2.13×10^{7}	8.46×10^{7}
Herbicides	0.77	694	1.68×10^{7}	6.66×10^{7}
Labor	6000 hrs		3.27×10^{6}	1.30×10^{7}
Total for Input			8.40×10^{8}	

OUTPUT					
Crops:		bu	kg		
Corn-shelled		8500	215914	7.51×10^{8}	2.98×10^{9}
Wheat		400	10886	3.59×10^{7}	1.43×10^{8}
Dairy:	Amt. Prod.	Edible Prod.			
Animal Sales	630 cwt	25055 lbs	11365 kg	3.02×10^{7}	1.20×10^{8}
Milk Sales	9131 cwt		414166 kg	2.69×10^{8}	1.06×10^{9}
Total for Output				1.09×10^{9}	

OUTPUT-INPUT RATIO 1.29

* Conversion factors are given in Appendix A

TABLE 4.

FARM NO. 4

INPUT				Energy Equivalents*	
Fuel:		gallons	liters	kcal	btu
Diesel		1516	5738	$5.34x10^7$	$2.12x10^8$
Gasoline		2380	9008	$7.43x10^7$	$2.95x10^8$
Electricity		27424 kw hrs		$2.36x10^7$	$9.35x10^7$
Fertilizers and Chemicals:		tons	kg		
Nitrogen		11.33	10279	$1.81x10^8$	$7.18x10^8$
Phosphorous		6.88	6242	$1.99x10^7$	$7.90x10^7$
Potassium		19.21	17427	$3.83x10^7$	$1.52x10^8$
Herbicides		0.40	359	$8.69x10^6$	$3.45x10^7$
Labor		8510 hrs		$1.17x10^6$	$4.63x10^6$
Total for Input				$4.00x10^8$	
OUTPUT					
Crops:		bu	kg		
Corn-shelled		3430	87127	$3.03x10^8$	$1.27x10^9$
Wheat		1400	38102	$1.26x10^8$	$5.03x10^8$
Dairy:	Amt. Prod.	Edible Prod.			
Animal Sales	616 cwt	24498 lbs	11112 kg	$2.96x10^7$	$1.17x10^8$
Milk Sales	10873 cwt		493199 kg	$3.21x10^8$	$1.14x10^9$
Total for Output				$7.80x10^8$	
OUTPUT-INPUT RATIO				1.95	

*Conversion factors are given in Appendix A

TABLE 5.

FARM NO. 5

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	4830	18282	$1.70x10^8$	$6.76x10^8$
Gasoline	3714	14057	$1.16x10^8$	$4.60x10^8$
Propane	2180	8251	$5.04x10^7$	$2.00x10^8$
Electricity	63517 kw hrs		$5.47x10^7$	$2.17x10^8$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	23.31	21147	$3.72x10^8$	$1.48x10^9$
Phosphorous	12.66	11485	$3.66x10^7$	$1.45x10^8$
Potassium	43.96	39881	$8.77x10^7$	$3.48x10^8$
Herbicides	0.46	416	$1.01x10^7$	$4.00x10^7$
Labor	13399 hrs		$1.84x10^6$	$7.29x10^6$
Total for Input			$8.99x10^8$	

OUTPUT					
Crops:		bu	kg		
Corn-shelled		4600	116847	$4.07x10^8$	$1.70x10^9$
Dairy:	Amt. Prod.	Edible Prod.			
Animal Sales	1252 cwt	49792 lbs	22586 kg	$6.01x10^7$	$2.38x10^8$
Milk Sales	18227 cwt		826777 kg	$5.37x10^8$	$1.02x10^9$
Total for Output				$1.00x10^9$	

OUTPUT-INPUT RATIO 1.12

*Conversion factors are given in Appendix A

TABLE 6.

FARM NO. 6

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	1849	6998	$6.52x10^7$	$2.59x10^8$
Gasoline	3551	13441	$1.11x10^8$	$4.40x10^8$
Electricity:				
Feeding	2495 kw hrs		$2.14x10^6$	$8.51x10^6$
Lights and Water	13000 kw hrs		$1.12x10^7$	$4.43x10^7$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	8.32	7548	$1.33x10^8$	$5.27x10^8$
Phosphorous	5.18	4699	$1.50x10^7$	$5.95x10^7$
Potassium	16.07	14579	$3.21x10^7$	$1.27x10^8$
Herbicides	0.64	582	$1.41x10^7$	$5.58x10^7$
Labor	6323 hrs		$8.67x10^6$	$3.44x10^7$
Total for Input			$3.92x10^8$	

OUTPUT					
Crops:		bu	kg		
Corn-shelled		5386	136813	$4.76x10^8$	$1.99x10^9$
Wheat		1654	45015	$1.49x10^8$	$5.95x10^8$
Cattle:	Amt. Prod.	Edible Prod.			
Animal Sales	1004 cwt	49206 lbs	22320 kg	$7.83x10^7$	$3.11x10^8$
Total for Output				$7.03x10^8$	

OUTPUT-INPUT RATIO 1.79

*Conversion factors are given in Appendix A

TABLE 7.

FARM NO. 7

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	3519	13318	$1.24x10^8$	$4.93x10^8$
Gasoline	5913	22381	$1.85x10^8$	$7.33x10^8$
Electricity	9600 kw hrs		$8.25x10^6$	$3.27x10^7$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	4.57	4146	$7.30x10^7$	$2.90x10^8$
Phosphorous	15.51	14071	$4.49x10^7$	$1.78x10^8$
Potassium	27.62	25057	$5.51x10^7$	$2.19x10^8$
Herbicides	0.39	354	$8.56x10^6$	$3.40x10^7$
Labor	8261 hrs		$1.13x10^6$	$4.50x10^6$
Total for Input			$5.00x10^8$	

OUTPUT

Crops:		bu	kg		
Corn-shelled		10981	278935	$9.71x10^8$	$4.07x10^9$
Wheat		3600	97978	$3.23x10^8$	$1.29x10^9$
Soybeans		1927	54193	$2.18x10^8$	$8.65x10^8$
Cattle:	Amt. Prod.	Edible Prod.			
Animal Sales	2250 cwt	110273 lbs	50020 kg	$1.76x10^8$	$6.97x10^8$
Total for Output				$1.69x10^9$	

OUTPUT-INPUT RATIO 3.38

*Conversion factors are given in Appendix A

TABLE 8.

FARM NO. 8

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	250	946	$8.82x10^6$	$3.50x10^7$
Gasoline	3163	11972	$9.88x10^7$	$3.92x10^8$
Gasoline (custom hauling)	317	1201	$9.91x10^6$	$3.93x10^7$
Gasoline (hauling hogs)	2850	10787	$8.90x10^7$	$3.53x10^8$
Propane (drying)	11755	44493	$2.72x10^8$	$1.08x10^9$
Propane (heating)	3000	11355	$6.96x10^7$	$2.76x10^8$
Electricity	136800 kw hrs		$1.17x10^8$	$4.66x10^8$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	9.67	8773	$1.54x10^8$	$6.11x10^8$
Phosphorous	4.42	4010	$1.28x10^7$	$5.08x10^7$
Potassium	4.42	4010	$8.82x10^6$	$3.50x10^7$
Herbicides	0.84	758	$1.83x10^7$	$7.27x10^7$
Labor	5827 hrs		$7.99x10^5$	$3.17x10^6$
Total for Input			$8.60x10^8$	

OUTPUT					
Crops:		bu	kg		
Corn-shelled		5609	142478	$4.96x10^8$	$2.08x10^9$
Wheat		557	15159	$5.00x10^7$	$2.00x10^8$
Swine:	Amt. Prod.	Edible Prod.			
Animal Sales	6407 cwt	402242 lbs	182457 kg	$9.36x10^8$	$3.71x10^9$
Total for Output				$1.46x10^9$	

OUTPUT-INPUT RATIO 1.70

* Conversion factors are given in Appendix A

TABLE 9.

FARM NO. 9

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	1772	6707	$6.25x10^7$	$2.48x10^8$
Gasoline	2712	10265	$8.47x10^7$	$3.36x10^8$
Propane	2790	10560	$6.48x10^7$	$2.57x10^8$
Electricity	14000 kw hrs		$1.20x10^7$	$4.76x10^7$
Fertilizers and Chemicals:	tons	kg		
Nitrogen	15.22	13808	$2.43x10^8$	$9.64x10^8$
Phosphorous	5.60	5080	$1.62x10^7$	$6.43x10^7$
Potassium	15.60	14152	$3.11x10^7$	$1.24x10^8$
Herbicides	0.75	678	$1.64x10^7$	$6.51x10^7$
Labor	2796 hrs		$3.84x10^5$	$1.52x10^6$
Total for Input			$5.31x10^8$	

OUTPUT				
Crops:	bu	kg		
Corn-shelled	15345	389788	$1.36x10^9$	$5.69x10^9$
Wheat	836	22753	$7.51x10^7$	$3.00x10^8$
Total for Output			$1.44x10^9$	

OUTPUT-INPUT RATIO	2.70

*Conversion factors are given in Appendix A

TABLE 10.

FARM NO. 10

INPUT				Energy Equivalents*	
Fuel:		gallons	liters	kcal	btu
Diesel		3018	11423	1.07×10^8	4.23×10^8
Gasoline		1996	7555	6.22×10^7	2.46×10^8
Propane		2925	11071	6.78×10^7	2.69×10^8
Electricity		11400 kw hrs		9.79×10^6	3.89×10^7
Fertilizers		tons	kg		
Nitrogen		9.98	9054	1.59×10^8	6.32×10^8
Phosphorous		8.74	7929	2.53×10^7	9.35×10^7
Potassium		8.74	7929	1.74×10^7	6.92×10^7
Herbicides		0.73	665	1.61×10^7	6.38×10^7
Labor		3428 hrs		4.70×10^5	1.87×10^6
Total for Input				4.65×10^8	
OUTPUT					
Crops:		Amt.	kg		
Corn-shelled		7554 bu	191884	6.68×10^8	2.80×10^9
Oats		1190 bu	17273	5.87×10^7	2.33×10^8
Hay		29 T	26309	6.05×10^7	2.40×10^8
Navy Beans		576 cwt	26124	8.88×10^7	3.52×10^8
Other Beans		798 cwt	36197	1.23×10^8	4.88×10^8
Soybeans		2186 bu	61477	2.48×10^8	9.83×10^8
Cattle:	Amt. Prod.	Edible Prod.			
Animal Sales	85 cwt	3380 lbs	1533 kg	4.08×10^6	1.62×10^7
Total for Output				1.25×10^9	
OUTPUT-INPUT RATIO				2.69	

*Conversion factors are given in Appendix A

TABLE 11.

FARM NO. 11

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	6106	23111	$2.15x10^{8}$	$8.55x10^{8}$
Diesel (custom work)	205	775	$7.22x10^{6}$	$2.87x10^{7}$
Gasoline	1700	6435	$5.31x10^{7}$	$2.11x10^{8}$
Gasoline (custom work)	182	687	$5.67x10^{6}$	$2.25x10^{7}$
Electricity	-		-	-
Fertilizers and Chemicals:	tons	kg		
Nitrogen	17.75	16103	$2.83x10^{8}$	$1.05x10^{9}$
Phosphorous	11.75	10660	$3.40x10^{7}$	$1.35x10^{8}$
Potassium	15.83	14361	$3.16x10^{7}$	$1.25x10^{8}$
Herbicides	0.51	459	$1.11x10^{7}$	$4.41x10^{7}$
Labor	4946 hrs		$6.78x10^{5}$	$2.69x10^{6}$
Total for Input			$6.41x10^{8}$	

OUTPUT				
Crops:	bu/cwt	kg		
Corn-shelled (bu)	26800	680763	$2.39x10^{9}$	$9.40x10^{9}$
Wheat (bu)	6755	183844	$6.07x10^{8}$	$2.41x10^{9}$
Navy Beans (cwt)	898	40733	$1.38x10^{8}$	$5.50x10^{9}$
Total for Output			$3.12x10^{9}$	

OUTPUT-INPUT RATIO 4.87

*Conversion factors are given in Appendix A

TABLE 12.

FARM NO. 12

INPUT			Energy Equivalents*	
Fuel:	gallons	liters	kcal	btu
Diesel	15326	58009	5.41×10^{8}	2.15×10^{9}
Gasoline	6824	25829	2.13×10^{8}	8.46×10^{8}
Propane	475	1998	1.10×10^{7}	4.37×10^{7}
Nat. Gas	5700 MCF		1.53×10^{9}	6.08×10^{9}
Electricity	115000 kw hrs		9.88×10^{7}	3.92×10^{8}
Fertilizers and Chemicals:	tons	kg		
Nitrogen	106.56	96671	1.70×10^{9}	6.95×10^{9}
Phosphorous	105.40	95619	3.05×10^{8}	1.21×10^{9}
Potassium	168.23	152618	3.36×10^{8}	1.33×10^{9}
Herbicides	10.45	9477	2.29×10^{8}	9.10×10^{8}
Labor	21580 hrs		2.96×10^{6}	1.17×10^{7}
Total for Input			4.97×10^{9}	

OUTPUT				
Crops:	Amt.	kg		
Corn-shelled	179697 bu	4564591	1.59×10^{10}	6.30×10^{10}
-silage	1000 T	907200	6.96×10^{8}	2.76×10^{9}
Oats	7246 bu	105177	3.58×10^{8}	1.42×10^{9}
Hay	45 T	40824	9.39×10^{7}	3.73×10^{8}
Wheat	8772 bu	238739	7.88×10^{8}	3.13×10^{9}
Navy Beans	1891 cwt	85776	2.92×10^{8}	1.16×10^{9}
Soybeans	7087 bu	199309	8.03×10^{8}	3.19×10^{9}
Total for Output			1.89×10^{10}	

OUTPUT-INPUT RATIO 3.81

*Conversion factors are given in Appendix A

Farm Descriptions

Farm No. 1: This farm was a one-man dairy operation with a milking herd of 27 cows.* He used a switch barn for milking. Silage was stored in a tower silo and comprized about half of the roughage fed. There were 140 acres of cropland. Solid wastes were handled by scraper and spread on 16 acres of wheat. There were nine acres of pasture. Crops were hauled by truck six miles to the elevator and animals were hauled nine miles to market.

Farm No. 2: This farm was a 1.2 man dairy operation with a milking herd of 29 cows. The barn was used as a switch barn, and had an electric gutter cleaner. Cropland totaled 130 acres with eight acres of pasture. Crops were hauled by wagon to an elevator 1.5 miles away. Animals were picked up at the farm.

Farm No. 3: This farm was a two-man dairy operation with a milking herd of 73 cows. The barn was also a switch barn with an electric gutter cleaner. Four hundred tons of silage were stored in tower silos and 900 tons in a bunker silo. Nine thousand bushels of high moisture corn were also blown into storage. In 1973, 10,500 bushels of corn were dried. A seperate calf barn was heated and had automatic feeding, watering and nursettes. Cropland totaled 390 acres.

Farm No. 4: This farm was a 2.84 man dairy operation with a 94 cow milking herd. The barn was used as a switch barn with a mechanical feed bunk and forage wagon outside. One thousand tons of silage were stored in a bunker silo and 600 tons in a tower silo. Two hundred and fifty tons of haylage and 150 tons of dry hay were stored. Cropland totaled 343

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*Telfarm records 3000 hours of labor as one man-year.

acres with 74 acres of pasture.

Farm No. 5: This was a 4.5 man dairy operation with a 133 cow milking herd. It had a double four herringbone parlor and used wagon feeding. Nine hundred tons of silage were stored in tower silos and 1500 tons were stored in bunker silos. Haylage totaled 335 tons. Seven thousand bushels of corn were dried in 1973. Solid wastes were handled by a scraper. Cropland totaled 549 acres.

Farm No. 6: This was a 2.1 man beef operation using mechanical feeders. The average number head on feed was 260. The amount of silage fed was 318 tons, hay, 119 tons, and corn, 136 bushels. Cropland totaled 208 acres with 20 acres of pasture. Cattle were hauled 27 miles to market.

Farm No. 7: This farm was a 2.75 man beef operation using wagon feeding. The average number head on feed was 599. The silage fed was 1600 tons, hay, 105 tons, and corn, 7800 bushels. Cropland totaled 492 acres. Shelled corn was hauled four miles to an elevator and cattle were hauled twelve miles to the market.

Farm No. 8: This was a 1.94 man swine operation which produced 2500 head. All feeding was automatic. The nursery and farrowing house was maintained at 75°F. Forty-six thousand bushels of corn were dried in 1973. Total miles for hauling animals to market was 7500. Cropland totaled 175 acres and it was all custom harvested.

Farm No. 9: This was a 275 acre cash grain operation. It had a portable dryer and a 5000 bushel storage capacity. Corn yield was 75 bushels per acre. Ten thousand bushels of corn were dried in 1973.

Farm No. 10: This was a 377 acre cash grain operation with 15 head of dairy stock also being fed. Crop yields were 92 bushels per acre for corn, 70 bushels per acre for oats, 2 tons per acre for hay, 11 hundred weight per acre for navy beans, 12 bushels per acre for other beans and 23 bushels per acre for soy beans. In 1973, 7500 bushels of corn were dried.

Farm No. 11: This was a 508 acre cash grain operation. None of the products were processed or stored on the farm. Crop yields were 105 bushels per acre for corn, 45 bushels per acre for wheat, and 7.2 hundred weight per acre for navy beans. Custom work included harvesting 150 acres of corn, 80 acres of beans and 30 acres of wheat in 1973.

Farm No. 12: This was a 2539 acre cash grain operation. Some of the corn handled was seed corn. Crop yields were 111 bushels per acre for corn, 65 bushels per acre for oats, 3 tons per acre for hay, 52 bushels per acre for wheat, 12 hundred weight per acre for navy beans and 29 bushels per acre for soy beans. One hundred and seventy-nine bushels of corn were dried and 100,000 bushels of custom drying was done in 1973.

Discussion of the Results

Since this study is concerned with energy consumption in agricultural production, an analysis of the inputs is essential. Several parameters should be considered to determine their influence in energy requirements. The largest inputs for all farms are presented in the table below. Together, these inputs make-up 80.3% of the total inputs for all twelve farms.

TABLE 13. Kilocalories of the Major Inputs by Farm

Farm No.	gasoline	diesel	propane	nitrogen	nat. gas
1	$8.57x10^7$	-	-	$8.08x10^7$	-
2	$8.95x10^7$	-	-	$2.94x10^7$	-
3	$1.72x10^8$	$8.54x10^7$	$6.02x10^7$	$3.99x10^8$	-

Farm No.	gasoline	diesel	propane	nitrogen	nat. gas
4	$7.43x10^7$	$5.34x10^7$	-	$1.81x10^8$	-
5	$1.16x10^8$	$1.70x10^8$	$5.04x10^7$	$3.72x10^8$	-
6	$1.11x10^8$	$6.52x10^7$	-	$1.33x10^8$	-
7	$1.85x10^8$	$1.24x10^8$	-	$7.30x10^7$	-
8	$1.98x10^8$	$8.82x10^6$	$2.72x10^8$	$1.54x10^8$	-
9	$8.47x10^7$	$6.25x10^7$	$6.48x10^7$	$2.43x10^8$	-
10	$6.22x10^7$	$1.07x10^8$	$6.78x10^7$	$1.59x10^8$	-
11	$5.88x10^7$	$2.22x10^8$	-	$2.83x10^8$	-
12	$2.13x10^8$	$5.41x10^8$	$1.10x10^7$	$1.70x10^9$	$1.53x10^9$
Totals	$1.45x10^9$	$1.44x10^9$	$5.26x10^8$	$3.81x10^9$	$1.53x10^9$

The total for all inputs was $10.9x10^9$ kcal. It is significant to note that the total for nitrogen over all farms is 35% of all the inputs considered. Also, the input for drying with natural gas on farm twelve was 14% of the total.

To further analyze the inputs, some additional parameters were examined. These include the gallons of fuel used per acre, the machinery investment to crops per gallon of fuel, the machinery expense per gallon of fuel, and the bushels dried per gallon of fuel.

TABLE 14. Fuel Inputs to Agricultural Production

Farm No.	fuel gal/acre	M. I. to crop / gal of fuel	mach. expense / gal of fuel
1	19.60	$3.16	$3.20
2	22.00	2.09	2.56
3	20.32	-	-

Farm No.	fuel gal/acre	M. I. to crop / gal of fuel	mach. expense / gal of fuel
4	11.36	5.46	4.90
5	15.56	4.76	2.96
6	25.96	4.89	3.29
7	19.17	4.59	2.81
8	37.60	4.65	4.04
9	16.31	3.92	1.95
10	13.30	3.91	2.33
11	16.13	4.40	2.27
12	8.54	5.62	3.90
Average	18.82	$4.31	$3.11

The gallons of fuel used per acre were determined by dividing the gallons reported in the study by the total tillable acres for each farm. The second column is the machinery investment attributed to crops divided by the gallons of fuel used. The third column is the machinery expense (operating costs plus interest on investment) divided by the gallons of fuel.

The gallons of fuel used per tillable acre on these farms included all fuel for farm use. Thus, in the case of farm number 8, the gasoline used for hauling pigs to market was included. If that fuel is left out, the figure drops to 21.31 gallons per acre.

The machinery investment to crops per gallon of fuel indicates that all farms have similar cropping equipment investments regardless of size. In particular, the livestock farms 6, 7, and 8 are very similar. The cash grain operation of 9, 10, 11, and 12 also show little deviation in investment patterns. The values for farm number three are missing because there was no financial analysis available for that farm.

The machinery expense per gallon of fuel shows the smallest deviation across all farms. These are only a few of the parameters that might be examined to determine fuel input relationships.

The propane inputs for drying corn were compared across all farms. The bushels dried per gallon of fuel is presented in Table 15. The farm using natural gas for drying is also shown with the units being cubic feet of gas per bushel.

TABLE 15. Inputs for Drying

Farm No.	bu/gal	kcal/bu
3	4.05	5740
5	3.21	7200
8	3.91	5910
9	3.58	6480
10	2.56	9040
12	20.43 cu ft/bu	5480

Farm number 10 was also using propane to heat a shop and it was impossible to seperate the usage. The average kilocalories per bushel for the remaining five farms is 6162.

A statistical analysis of variance was done on the output-input ratios and the computations and discussion are found in Appendix C. Due to the small sample size, no significant differences were found between types of farms. At least 15 farms of each type should be examined to determine if significant differences do exist.

Conclusions

It is important to remember that the pilot study imployed only a small sample of farms. With this in mind some conclusions can be presented.

First of all, the methodology is a relatively uncomplicated process for determining the energy requirements for agricultural production. The present Telfarm system has the capability of recording all the energy inputs and printing them out on various records, provided the farmers supply the information.

Second, the methodology uses actual energy consumption patterns verses estimated efficiencies. The figures prepared in other studies appear to be substantiated by the pilot study. For example, the cash grain operations had an average output-input ratio of 3.54. Pimentel et al. reported an estimated ratio of 2.52 for corn production.[8] Also, the indirect energy inputs such as fertilizers and chemicals, are generally larger than the direct energy inputs. Hirst estimated that of the total energy consumed in agricultural production, 44% was consumed directly on the farm.[9] The remaining 56% was consumed in other sectors to produce indirect energy inputs for the farm.

Third, the calculated gallons of fuel per tillable acre is relatively large. A range of 8 to 12 gallons per acre is the generally accepted figure for fuel consumption. Some possible explainations for this difference could be that the 8 to 12 gallon figure does not include

[8] Pimentel, D., W. R. Lynn, W. K. MacReynolds, M. T. Hewes, S. Rush. Workshop on Research Methodologies for Studies of Energy, Food, Man and Environment, Phase 1. (Ithaca, New York, Cornell University, 1974).

[9] Hirst, op. cit., p. 15.

idling time, breakdowns, interruptions by weather or time of day, or inefficient use of fuel by the operator.

Fourth, the drying operations are relatively efficient. Patterson reports efficient dryers should dry about 3.29 to 4.63 bushels of corn at 30% moisture per gallon of propane.[10] The average of the four operations in this study was 3.69 bushels per gallon.

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[10] Patterson, R. J., R. L. Maddex, Effective Energy Utilization in Grain Drying. (East Lansing, Michigan, Agricultural Engineering Information Series #292, Michigan State University, 1974).

SUMMARY AND RECOMMENDATIONS

Summary

This study has developed a methodology using farm records to collect energy use data from the major types of Michigan agricultural farms. A pilot study was conducted to test the method and the results compare favorably with other studies. Nitrogen was found to be the largest single input across all farms and the gallons of fuel consumed per acre were greater than had been expected. Other parameters were examined to determine their influence on energy requirements, yet no single factor was found having a definitive relationship with the total amount of energy consumed. Due to the small number of farms, no significant differences in the output-input ratios between types of farms were discovered.

Recommendations

1. It is recommended that the gallons of fuel per acre be examined further with additional farms. This pilot study indicates a possible inefficient use of fuel or that previous estimates are inaccurate.
2. It is recommended that additional studies include at least 15 farms per group to aid in any statistical analysis desired.
3. To develope possible predictive parameters, it is also recommended that a "multiple-regression" analysis be considered.
4. It would be helpful for future studies if all Telfarm cooperators were requested to include in their monthly reports

the amounts of fuel purchased, pounds of fertilizers and chemicals purchased, and the kilowatt hours of electricity used, as some cooperators already do.

5. It is recommended that a combination of both records studies and visits with the individual farmers be retained. This would provide the most accurate information and variations in operating procedures which may aid in explaning farm energy use differences.

APPENDICES

APPENDIX A

APPENDIX A

CONVERSION FACTORS

	Energy Equivalents
Produce:[11]	Cal/100 g (Edible Portion)
Milk	65
Corn	348
Oats	340
Rye	334
Wheat	330
Beans	340
Soybeans	403
Beef	351
Dairy	266
Pork	513
Fuels:[12]	Btu/gal
Diesel	140000
Gasoline	124000
Propane	92000
Natural Gas	1067.5 Btu/ft^3
Fertilizers and Chemicals:[13]	kcal/kg
Nitrogen	17600
Phosphorous	3190
Potassium	2200
Herbicides	24200
Forage Equivalents:[14]	kcal/ton (Gross Energy)
Hay	2.09×10^6
Silage	6.96×10^5

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[11] Watt, B. K. and M. L. Merrill. Composition of Foods. (USDA Agricultural Handbook No. 8, 1963).

[12] Cervinka, op. cit.

[13] Pimentel, op. cit.

[14] Based on replacement equivalence for corn in rations.

	Energy Equivalents
Labor[15]	21770 kcal/40 hr wk

Live Weight to Edible Portions:[16]	% Dressing of live wt.	% Bone in carcass
Beef	58	15.5
Dairy	48.5	18
Pork	74.74	16

Standard Conversions:

1 kw hr	=	3409.52 Btu's
1 kcal	=	3.9683 Btu's
1 lb	=	.4536 kg
1 ton	=	907.2 kg
1 gal	=	3.785 liters
1 hectare	=	2.471 acres

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[15]Pimentel, op. cit.

[16]Introduction to Livestock Production. H. H. Cole, ed., (W. A. Freeman & Co., 1962).

Pecot, Rebecca K., C. M. Jaeger, and B. K. Watt. Proximate Composition of Beef from Carcass to Cooked Meat. (Home Economics Research Report No. 31, ARS, USDA, 1965).

APPENDIX B

APPENDIX B

TABLE B.1.

FARM NO. 1

Crop Production:

		Acre	Prod	Fed	B.I.	E.I.	Pur	Sales
Corn-shelled	(bu)	42	3800	831	4300	3900	761	2827
-silage	(ton)	16	160	120	85	85		
Hay	(ton)	36	126	129	54	50		
Pasture	(ton)	9	18	18				
Wheat	(bu)	16	578		735	578		1500
Beans	(cwt)	21	289		192	289		200
		140						

Cropping Practices:

Corn	Wheat	Beans	Hay
Plow - 4-16"	Disc - twice	Plow	Int. 430 Baler
Disc - twice	Plant	Disc - twice	
Plant- 4-38"	Gleaner - K	Plant	
Picker-sheller 2 row		Gleaner - K	
Chopper			

Fertilizer:

Corn Amt.	Corn type	Wheat Amt.	Wheat type	Beans Amt.	Beans type
170 lb/A	18-46-0	250 lb/A	8-32-16	250 lb/A	17-17-17
150 lb/A	NH_3				
150 lb/A	Potash				

Chemicals:

Corn Amt.	Corn type	Beans Amt.	Beans type
2 lb/A	Atrizine	2 qt/A	Eptam

Tractors:

Int. 706 - 67 HP
Int. 560 - 62 HP
Int. H

Electric Motors:

5 HP Silo Unloader
1 HP Compressor
½ HP Pump
⅓ HP Cooler

Dairy:

		B.I.	E.I.	Sales
Milking Head	27	40 HD	30 HD	26 HD
Calves Born	22			

TABLE B.2.

FARM NO. 2

Crop Production:

	Acre	Prod	Fed	B.I.	E.I.	Sales
Corn-shelled (bu)	46	3184	1490	2800	3000	1600
-silage (ton)	9	130	97			
Hay (ton)	52	107	89	70	50	
Pasture (ton)	8	24	24			
Wheat (bu)	15	507				507
	130					

Cropping Practices: (Corn)

Lift Harrow
Plow - 3-16"
Planter - 4-32"

Fertilizer:

Amt.	type
10 tons	16-16-16
3960 lbs	12-12-12
9000 lbs	Potash

Chemicals:

168 lb/A Atrizine

Tractors:

JD 2510 - 54 HP
JD 630 - 44 HP
Case 40 HP

Electric Motors:

3 HP Gutter Cleaner
3 HP Compressor
1 HP Pump
$\frac{1}{3}$ HP Cooler

Dairy:

		B.I.	E.I.	Sales
Milking Head	29	55 HD	60 HD	18 HD
Calves Born	33			

TABLE B.3.

FARM NO. 3

Crop Production:

	Acre	Prod	Fed	Sales
Corn-shelled (bu)	270	17000		8500
-silage (ton)		1300	800	
Hay (ton)	70	100	50	
Oats (bu)	20	800		
Wheat (bu)	30	500		400
	390			

Cropping Practices: (Corn)

Plow - 6-18"
Disc
Harrow
Planter - 6-30"
Picker-Sheller 3 row
Chopper - 3 row
PTO Blower - 400 T

Fertilizer:

Corn		Wheat		Oats		Hay	
Amt.	type	Amt.	type	Amt.	type	Amt.	type
165 lb/A	NH_3	250 lb/A	NH_3	250 lb/A	NH_3	200 lb/A	Potash
200 lb/A	6-24-24						

Chemicals: (Corn)

Amt.	type
1½ lb/A	Atrizine
2 pt/A	Bladex
2 pt/A	Lasso

Tractors:

Gas - 70 HP
60 HP
Diesel - 140 HP
84 HP

Electric Motors:

25 HP	Dryer
3 HP	Auger
5 HP	Silo Unloader
7½ HP	Silo Unloader
2 HP	
3 HP	Milker
3 HP	Gutter Cleaner
3 HP	Cooler
3 HP	Conveyor
1½ HP	Conveyor

Electric Motors (Cont.)

3 HP Auger
3 HP Auger
5 - $\frac{3}{4}$ HP Misc.

Dairy:

	E.I.	Sales
Milking Head 73	18 Bred Heifers	45 Calves
Calves Born 72	15 Open Heifers	27 Cows

TABLE B.4.

FARM NO. 4

Crop Production:

	Acre	Prod	Fed	B.I.	E.I.	Pur
Corn-shelled (bu)	60	6030	2616	5000	6030	16
-silage (ton)	84	1680	874	1280	1455	
Hay (ton)	97	487.5	494	100	60	
Pasture (ton)	74	294	306			12.5
Wheat (bu)	28	1400			2933	
	343					

Cropping Practices: (Corn)

Plow - 6-18"
Drag - twice
Disc
Cultipacker
Planter - 4 row 36"
Gleaner 10-W
NH 2 row Chopper

Fertilizer:

Corn		Wheat		Hay	
Amt.	type	Amt.	type	Amt.	type
175 lb/A	NH_3	400 lb/A	5-20-20	300 lb/A	0-0-60
200 lb/A	5-40-25				
200 lb/A	Potash				

Chemicals: (Corn)

Amt.	type
1½ lb/A	Atrizine
2 qt/A	Lasso

Tractors:

Gas - 75 HP
45 HP
Diesel - 130 HP
75 HP

Electric Motors:

15½ HP Total

Dairy:

		B.I.	E.I.	Sales
Milking Head	94	185 HD	188 HD	53 HD
Calves Born	75			

TABLE B.5.

FARM NO. 5

Crop Production:

	Acre	Prod	Fed	B.I.	E.I.	Sales
Corn-shelled (bu)	180	15852	7648	17465	13500	4602
-silage (ton)	187	2431	1691	1379	1470	
Hay (ton)	114	335	350	391	250	
Wheat (bu)				1000		1014
Rye (bu)	6	180	180			
Summer Fallow	62					
	549					

Cropping Practices: (Corn)

Plow - 5-16"
Cultimulcher
Planter - 4 row 40"
Cultivate
Picker-sheller - 2 row
Chopper

Fertilizer:

Corn

Amt.	type
100 lb/A	NH_3
150 lb/A	18-46-0
275 lb/A	Potash

Hay

Amt.	type
400 lb/A	Potash

Chemicals: (Corn)

2½ lb/A Atrel 80-W

Tractors:

Gas - 40 HP
40 HP
17 HP
Diesel - 115 HP
2 - 95 HP
40 HP

Electric Motors:

2 - 7½ HP Silo Unloader
5 HP Silo Unloader
2 HP Conveyor
¾ HP Wagon Loader
½ HP Protein Conveyor
1 HP Old Milker
2 - 1 HP Corn Bin
1 HP Soy Bean Bin
3 HP Well

Electric Motors (Cont.)

5 HP	Cooler
3 HP	Cooler
2 HP	Vacuum
1 HP	Milker
2 - $\frac{1}{4}$ HP	Agitation
1 HP	Grain Auger
1 HP	Fan Furnace
2 - $\frac{1}{2}$ HP	Vent Fans

Dairy:

		B.I.	E.I.	Sales
Milking Head	133	297 HD	352 HD	57 HD
Calves Born	121			

TABLE B.6.

FARM NO. 6

Crop Production:

		Acre	Prod	Fed	B.I.	E.I.	Sales
Corn-shelled	(bu)	83	6640	136	9000	8500	5386
-silage	(ton)	45	450	318	600	450	
Hay	(ton)	30	150	119	30	50	
Pasture	(ton)	20	40	40			
Wheat	(bu)	30	1800		1000		1654
		208					

Cropping Practices:

Corn
Plow - 5-16", 7-16"
Disc
Drag
Planter - 4 row 36"
Chopper - 2 row
Corn Head - 2 row
Wagon Transport
Silo-H.M. Storage
Grinder
Auger
Feed Bunk

Wheat
Plow
Cultipack
Drag - 2 or 3
Drill
Gleaner Combine
Straw Chop

Fertilizer:

Corn

Amt.	type
100 lb/A	NH_3
300 lb/A	Potash
200 lb/A	9-32-6

Wheat

Amt.	type
300 lb/A	6-24-24

Hay

Amt.	type
300 lb/A	5-0-60

Chemicals:

Amt.	type
2 lb/A	Atrizine
2 lb/A	Lasso

Tractors:

Gas - 40 HP
60 HP
60 HP

Electric Motors:

3 HP Silo Unloader
2 - 5 HP Silo Unloader
2 - 5 HP Forage Auger

Tractors (Cont.)

Gas - 60 HP - Combine
40 HP - Windrower
Diesel - 130 HP
97 HP
40 HP

Electric Motors (Cont.)

1/2 HP Supplement
1/3 HP Supplement
7 1/2 HP Grinder
3 HP Auger
3/4 HP Pump

Beef:

	(cwt) Sales	B.I.	Pur	E.I.	Prod
Average Head on Feed 260	2628	1975	1238	1589	1004

TABLE B.7.

FARM NO. 7

Crop Production:

	Acre	Prod	Fed	B.I.	E.I.	Sales
Corn-shelled (bu)	201	20100	7815	34800	20300	10981
-silage (ton)	139	2333	1592	3500	2800	
Hay (ton)	30	105	105			
Wheat (bu)	75	3600				1618
Soybeans (bu)	47	1927			1125	750
	492					

Cropping Practices:

Corn	Wheat	Beans
Plow - 7-16"	Plow	Plow
Cultimulcher	Roller Harrow	Roller Harrow
Planter - 6 row 30"	Drill	Disc
Combine - 4 row Corn HD	13' Header	Plant
Chopper		

Fertilizer:

Corn Amt.	Corn type	Wheat Amt.	Wheat type	Soybeans Amt.	Soybeans type
300 lb/A	7-23-3	300 lb/A	6-24-24	200 lb/A	7-23-3
200 lb/A	0-0-60			200 lb/A	0-0-60

Chemicals:

Corn Amt.	Corn type	Soybeans Amt.	Soybeans type
2 lb/A	Atrizine	2 lb/A	Lorax

Tractors:

Gas - 60 HP Hydromatic
130 HP Combine
Diesel - 130 HP
130 HP
90 HP

Electric Motors:

3 - 7½ HP Silo Unloader
1 HP Forage Auger
¾ HP Grain Auger
¼ HP Load Mill
5 HP Wagon Loader
¾ HP Water
¾ HP Supplement

Beef:

	(cwt)	Sales	B.I.	E.I.	Pur	Prod
Average Head on Feed	599	4864	3726	2388	1276	2250

TABLE B.8.

FARM NO. 8

Crop Production:

		Acre	Prod	Fed	B.I.	E.I.	Pur	Sales
Corn-shelled	(bu)	155	13640	8903	40769	28619	28619	5609
Pasture	(ton)	10	20	20				
Wheat	(bu)	10	557		580			1090
		175						

Cropping Practices: (Corn)

Plow
Rotovator
Spray

Fertilizer: (Corn)

Amt.	type
9.7 tons	NH_3
10.0 tons	13-26-26
7.0 tons	6-26-26

Chemicals:

Amt.	type
65 gal	Atrex 4-L
95 gal	Lasso
150 lbs	Atrex 80-W
400 lbs	Aldrin

Tractors:

Gas - 92 HP 1855 Oliver
25 HP 66 Oliver
Diesel - 43.5 HP 88 Oliver

Electric Motors:

97½ HP Total

Swine:

	(cwt) B.I.	E.I.	Sales	Prod
Produced 2500 HD	2222	2831	5798	6407

TABLE B.9.

FARM NO. 9

Crop Production:

		Acre	Prod	B.I.	E.I.	Sales
Corn-shelled	(bu)	250	18075	6750	12000	10095
Wheat	(bu)	25	750			836
		275				

Cropping Practices:

Corn
Plow - 5-16"
Cultimulcher
Planter - 4 row 38"
Picker-sheller 2 row

Wheat
Plow
Drag
Drill

Fertilizer:

Corn

Amt.	type
100 lb/A	18-40-60
100 lb/A	0-0-60
125 lb/A	NH_3

Wheat

Amt.	type
200 lb/A	6-24-24

Chemicals:

Amt.	type
1½ lb/A	Atrizine
2 qt/A	Lasso
2 lb/A	Atrizine (60 acres)

Tractors:

Gas - 35 HP
Diesel - 100 HP
50 HP
35 HP

Electric Motors:

7 HP Dryer
5 HP Auger
3 HP Auger

TABLE B.10.

FARM NO. 10

Crop Production:

	Acre	Prod	Fed	B.I.	E.I.	Sales	Ptshp*
Corn-shelled (bu)	93	7555	209	9100	6600	8651	615
-silage (ton)	18	180	180	110	130		
Oats (bu)	17	1190	5		19		
Hay (ton)	18	36	7	15	40		
Navybeans (cwt)	60	576					848
Other Beans (cwt)	72	798					849
Soybeans (bu)	99	2186		337	1700		513
	377						

Cropping Practices:

Plow
Drag
Plant

Fertilizer:

Corn

Amt.	type
100 lb/A	NH_3
300 lb/A	6-24-24

Oats

Amt.	type
200 lb/A	6-24-24

Beans

Amt.	type
250 lb/A	15-15-15

Chemicals:

Corn

Amt.	type
2½ lb/A	Atrex
2½ lb/A	Bladex

Soybeans

Amt.	type
2 lb/A	Lorax

Beans

Amt.	type
2 qt/A	Eptam
1 pt/A	Treflan

Tractors:

Gas - 80 HP 1750 Oliver
Diesel - 100 HP 1855 Oliver
50 HP 65 Massey
50 HP D17 Allis-Chalmers
50 HP 300 Massey Combine

Electric Motors:

3 HP Silo Unloader
1½ HP Auger
¼ HP Bale Elevator

*Partnership

Beef:

	(cwt) B.I.	E.I.	Sales
Average Head on Feed 15	67	96	55

TABLE B.11.

FARM NO. 11

Crop Production:

	Acre	Prod	B.I.	E.I.	Sales	Ptshp
Corn-shelled (bu)	255	26775	20000	25295	16662	2535
Wheat (bu)	128	6775			4198	758
Navybeans (cwt)	125	898		200	248	86
	508					

Cropping Practices:

Corn	Wheat	Beans
Plow - 5-16"	Disc	Plow
Planter - 4 row 30"	Drill	Disc & Drag
		Drag - twice

Fertilizer:

Corn

Amt.	type
140 lb/A	NH_3
280 lb/A	5-20-10
100 lb/A	0-0-60

Wheat

Amt.	type
300 lb/A	6-24-24

Chemicals:

Corn

Amt.	type
2½ lb/A	Atrizine

Beans

Amt.	type
1½ pt/A	Eptam
1½ pt/A	Treflan

Tractors:

Gas - 40 HP Combine Int. 403
Diesel - 105 HP
90 HP
90 HP
70 HP
83 HP MFSIO Combine

TABLE B.12

FARM NO. 12

Crop Production:

	Acre	Prod	Pur	Sales
Corn-shelled (bu)	1664	179697	7124	182386
-silage (ton)	69	1000		1000
Oats (bu)	135	8775		7246
Hay (ton)	15	45		4
Wheat (bu)	185	8772		21267
Navybeans (cwt)	159	1891		1891
Soybeans (bu)	312	7087		3024
	2539			

Cropping Practices:

Corn	Beans	Wheat
Fall Plow	Spray-Disc	Spray-Disc
Cultivate	Cultimulcher	Drill
Level	Plant	
Plant		
Spray		

Fertilizer:

Corn Amt.	Corn type	Beans Amt.	Beans type	Wheat Amt.	Wheat type
100 lb/A	NH_3	200 lb/A	6-24-12	300 lb/A	6-24-24
200 lb/A	6-24-12				
200 lb/A	0-0-60				
100 lb/A	0-60-0				

Chemicals:

Corn Amt.	Corn type	Corn Acre	Beans Amt.	Beans type	Beans Acre	Wheat Amt.	Wheat type
1 lb/A	Atrizin	500	1 pt/A	2-4D	300	1½ lb/A	Lorax
2 lb/A	Atrizin	800	2 qt/A	Eptam	225	2 qt/A	Lasso
1 gal/A	Oil	500	1 pt/A	Treflan	225		
3½ lb/A	Bladex	100					
1 lb/A	Fearidan	800					
12 lb/A	Diazon	600					

Tractors:

Gas - 67 HP
41 HP
150 HP Ag. Gator

Electric Motors:

5 - 7½ HP
10 HP
5 - 5 HP

Tractors (Cont.)

Gas - 90 HP Combine
30 HP Clark Loader
Diesel - 151 HP
135 HP
140 HP
150 HP
125 HP Hydrostatic
120 HP Combine

Electric Motors (Cont.)

7½ HP
20 HP Seed Mill
3 HP

APPENDIX C

APPENDIX C

STATISTICAL MODEL FOR PILOT STUDY

Since the pilot study was limited to a small number of farms, a one-way analysis of variance was used with the farms grouped by type of operation. Considering the type of farm to be a fixed variable, the model for this design is:

$$Y_{ij} = \mu+\tau_i+E_{(i)j} \qquad i=1,2,3$$

where Y_{ij} is the observed effect of the jth farm on the ith type of farming, μ is the overall "mean" effect, τ_i is the effect between types of farms and $E_{(i)j}$ is the effect of the individual farm. The computations are presented below. One represents the dairy type, 2 is the livestock type, and 3 is the cash grain type.

TABLE C.1. Table of Output-Input Values

	i=1	i=2	i=3
	2.24	1.79	2.70
	1.95	3.38	2.69
	1.29	1.70	4.87
	1.95		3.81
	1.12		
$y_{i\cdot}$ =	8.55	6.87	14.07
r_i =	5	3	4
$\bar{y}_i$ =	1.71	2.29	3.52
$\Sigma^{r_i} y_{ij}^2$ =	15.54	17.52	52.76
$y_{i\cdot}^2/r_i$ =	14.26	15.73	49.49
$\Sigma^{r_i} y_{ij}^2 - y_{i\cdot}^2/r_i$ =	.92	1.79	3.27

	$\underline{i=1}$	$\underline{i=2}$	$\underline{i=3}$	
$(r_i-1) =$	4	2	3	$\nu_E = 9$
$s_i^2 =$	.23	.89	1.09	

$$y.. = 29.49 \qquad y..^2/n = 72.47 \quad (A) \qquad n=12$$

$$y_{ij}^2 = 85.82 \quad (B)$$

$$y_i.^2/r_i = \underline{79.48} \quad (C)$$

$$6.34 = SS_E$$

$$(B) - (A) = SS_y = 13.35 \quad \text{Total}$$

$$(C) - (A) = SS_T = 7.01 \quad \text{Trt.}$$

$$MS_T = (SS_T/(t-1)) = 3.51$$

$$MS_E = (SS_E/\nu_E) = .70$$

The data can now be put in an analysis of variance table,

TABLE C.2. Analysis of Variance

Source	d.f.	SS	MS	(E)MS
Trt. (among groups)	2	7.01	3.51	$\sigma^2 + \sum_{i=1}^{t} r_i \tau_i^2/(t-1)$
Exp. Error (within groups)	9	6.34	.70	σ^2

To test the hypothesis that $\tau_i=0$, the appropriate test statistic is:

$$f = \frac{MS_T}{MS_E} = \frac{3.51}{.7} = 5.01 \qquad f_{0.05,2,9} = 4.26$$

$$f_{0.01,2,9} = 8.02$$

Since the sample size is so small, it would be unwise to accept the hypothesis at the 95% confidence level.

When using this method of analysis of variance, the assumption is made that the variance is homogeneous from group to group. This assumption can be tested by using the test statistic:

$$f_{max} = (s^2_{max}/s^2_{min}) = 1.09/.23 = 4.74$$

This value is far less than the value for f_{max} at $\alpha=.05$ with three degrees of freedom in the numerator and denominator, of 27.5. It indicates that the assumption is acceptable.

A pilot study such as this can be of benefit to other studies that follow by providing an estimate of the variability of the groups. The estimate can be used to determine the minimum number of farms in each group needed, to observe significant differences between groups. For example, if this study were to be conducted again, the following computations will give the number of farms required in each type of farming to detect significant differences between the types.

The average observation of each type of farming can be used to specify an array of values to be detected. The $\bar{y}_i$ from the computations provides the following array, {1.71, 2.29, 3.52}. The "mean" of this array, μ, is 2.76. Therefore the τ_i's are {-1.05, -.47, .76}. These are differences that are to be detected. The formula,

$$\phi = \sqrt{r/t \sum_{i=1}^{t} (\tau_{di}/\hat{\sigma})^2}$$

will be used to determine the number of farms which is represented by r, t is the number of types, and can be estimated from the expected mean square for error from the pilot study.

$$\hat{\sigma} = \sqrt{.70} = .84$$

$$(\tau_{di}/\hat{\sigma}) = (-1.25, -0.56, 0.90)$$

$$\phi = \sqrt{r/3\ (2.68)} = \sqrt{.39\ r}$$

Using $\nu_1=2$, $\nu_2= t(r-1)$ and standard statistical tables, the value for r can be determined by inspection. If it is desired to detect a difference with 95% confidence ($\alpha= .05$) with a power of 95% ($\beta= .05$), the number of farms in each type of farming should be 15.

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