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James B. Kliebenstein

Robert M. Finley

Douglas C. Farthing

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THE IMPACT OF CHANGING NET RETURNS ON MINIMUM ENERGY REQUIREMENTS FOR GRAIN FARMS

James B. Kliebenstein, Robert M. Finley,
and Douglas C. Farthing
University of Missouri
Columbia, Missouri

Abstract

With sources of energy more restricted and higher priced, optimal combinations of enterprises must logically be considered on the basis of energy efficiency. One method of ascertaining this efficiency is to optimize solutions for given levels of income on the basis of energy used (e.g., the objective function was in terms of energy kilocalories). In general, soybeans were most feasible at lower levels of income regardless of farm size and labor circumstance. As income levels increased, double-cropping (wheat soybeans) was first substituted and finally corn at highest income levels.

1. INTRODUCTION

As the cost of energy increased greatly, shockwaves were sent through all industries, agriculture not excepted. The farm-input industry, which is heavily dependent on fossil fuels, i.e., gasoline, diesel fuel, nitrogen fertilizer, pesticides, etc., is affected, and in turn, farmers are affected. The input industry will doubtless pass its increased costs to the farmer. Those enterprises which were once most feasible under one set of energy availabilities and costs, may not be under another. In the area of crop production, an almost unlimited number of tillage and cultural techniques exist, each utilizing varying amounts of energy and each returning varying amounts of income.

Implications of the energy crises have received widespread attention recently, both at the micro and the macro level. While much has been written about energy price impacts on world and national economies, others have singled out the agriculture sector (1,3,6,8,9,11,13). Still others have looked at some of the more micro-related energy questions, such as irrigation impacts (5,7), machinery-size (10), harvesting strategies (12), and overall crop production patterns (2,4) of the agricultural sector. Warnken (14) studied the impact of energy-price increases on the development policies of less-developed countries and found that a reassessment will be necessary regarding "traditional" agriculture. Under energy shortages, the relevant question may not be that of profit maximization, but that of energy minimization. The real problem will be one of minimizing physical energy cost in producing given amounts of income. Thus, the major objective of this paper is to illustrate an example of minimizing petroleum-energy usage (in terms of kilocalories) for various net return levels and farm sizes.* An iterative program was designed where minimum energy requirements were determined for given net return levels. The net return constraint was then increased until a maximum income (infeasability) level was obtained from the given set of resources other than energy. Of course, the "mix" of enterprises comprising the optimal minimum energy solution changed as the iterative process progressed.

2. ALTERNATIVE PRODUCTION METHODS

For the purpose of illustration, a typical cash grain farm of 400 acres was chosen. Those cropping activities which are most commonly associated with such a farm were developed. (While the cropping activities refer primarily to those typical to the Midwest, the purpose is to illustrate an example of adjustments between crops requiring a relatively low, intermediate and high level of energy per acre.) A wide range of cropping systems were considered, from cropping activities requiring a relatively low energy requirement per acre (for example soybeans) to a relatively high energy requirement per acre (for example corn) and the more intermediate energy-using crops, such as double cropping wheat-soybeans or single-crop wheat.

Resource requirements, costs, returns and energy levels were estimated for these crops under conventional, minimum and no-tillage methods of production. Fertilization levels were varied under each tillage method with different fertilization levels represented by different activities. Chemical treatments were assumed to be intensive for no-tillage production methods and extensive for conventional tillage-production methods.

Data were derived from farmers in the area, technical specialists and cost of production studies. Prices and costs refer to average levels in 1975. Selected per acre-input requirements, production techniques, and yield levels for those activities selected by the model are presented in Table 1.

To trace the pattern of minimum energy solutions to changes in the initial set of resources, land and labor availabilities were varied, while all other constraints and activities remained the same. The different land and labor combinations are shown in Table 2.

For the first, or original set of solutions (Combination A), land was assumed to be 400 acres with labor availability comparable to a one-man farm or 2880 hours. In B, land and labor availabilities were both decreased by 50 percent In D, land increased by 50 percent (to 600 acres) with available labor remaining unchanged from A. In E, the amount of land was increased by 50 percent, but available labor decreased 50 percent. Available land stayed the same in F (400 acres), but labor decreased by 50 percent. Land was decreased by 50 percent and labor was unchanged in G. In H, land was decreased 50 percent (to 200 acres), and labor was increased by 50 percent. In combination I, land stayed the same, while available labor increased by 50 percent. In J, the opportunity to buy labor was available. It should be noted that optimal solutions for land and labor

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*Net returns are returns to land, labor, overhead, and management.

combinations E and F were the same and the same situation prevailed for G and H.

3. EFFECT ON ENERGY REQUIREMENTS DUE TO INCREASING NET RETURN LEVELS

The impact on energy requirements due to increases in net returns was determined by parametric programming. The effects of net returns increases on energy usage were calculated for the typical 400-acre farm with the varying land and labor availabilities discussed above. Net returns were varied from $20,000 to infeasibility with optimal minimum energy solutions generated for all land and labor combinations studied. Solutions for these combinations are depicted in Tables 3, 4, 5, and Figure 1.

For the 400-acre farm with an equivalent labor availability, the optimum minimum energy solutions at relatively low net returns levels included only single-crop soybeans and idle land (Table 3, Combination A). Crop mix solutions for the 200 (Combination B) and 600-acre (Combination C) farms portrayed those of the 400-acre farm. As net return levels increased, double cropping (wheat soybeans) replaced single-crop soybeans. At still higher net return levels, corn (a relatively large user of energy) entered the solutions. Also, when net returns were relatively high, single-crop soybeans left the "crop mix." Relative to income, single-crop soybeans are a relatively low energy consumer, with double cropping being intermediate, and corn, a large energy consumer. In Figure 1, lines A, B and C show the increasing rate in energy usage relative to net returns as production shifts from single-crop soybeans to double cropping to corn for the 400, 200, and 600-acre farms.

Optimum solutions when labor was short, relative to land, are shown in Table 4. Here, crop substitutions occur as net return levels increase again from soybeans to double cropping to corn. However, the corn activities entering are slightly less labor and energy intensive and of a lower yield than those where labor was not short relative to land (Table 3). Also, the relative level of corn production becomes greater when labor was short. Note also that single crop soybeans are produced at all return levels. Double crop acres, although significant, were relatively less important than when labor was more abundant. In Figure 1, lines D. E and F show rather clearly the substantial increase in kilocalories required when corn becomes a major production activity.

When land was short, relative to labor, primary production activities were single-crop soybeans at low, net returns levels (Table 5). As return levels increased, double-crop wheat soybeans became relatively more important. Corn entered only for Combination I, and then only at a relatively low level. The absence of corn is reflected in the slower rate of kilocalorie requirement increase at the relatively high net return levels shown in lines G, H, and I in Figure 1.

For combination J, a labor-buying activity at $2.50 per hour was included. This rate was comparable to seasonal labor charges in the planning area. Comparing these results with those for the 400-acre farm (Combination A) in Table 2 reveals some interesting findings. By allowing labor to be purchased, it enables a greater level of labor for energy substitution. With this substitution, a given level of net return can be obtained with a lower level of energy usage. This is seen by comparing line J with line A in Figure 1. For example, to produce a net return level of $57,000, a minimum of 618.4 million kilocalories of energy are needed when labor was not purchased as compared to only 388.9 million kilocalories when labor was purchased. This represents an energy savings of 229.5 million kilocalories or about 37 percent. In addition, the labor purchase activity allowed maximum net returns to increase by $5,697 (62,941 vs. $57,244) while requiring substantially less total kilocalories than when labor was not purchased (414.8 million vs. 639.6 million kilocalories).

In all solutions, soybean production technology selected was minimum tillage and for corn, it was no-till. Thus, for a given level of energy, energy use was minimized through some form of reduced tillage. The higher net return levels result in higher nitrogen fertilizer, fuel, chemicals, and propane use.

Using Figure 1, comparisons can be made of land and labor combinations to minimize energy usage for given levels of net returns. For example, a net return level of $55,000 can be obtained under a number of energy-usage levels ranging from 215.1 million kilocalories for the 600-acre farm (Line C) to 444.3 million kilocalories for the 400-acre farm (Line A).

Also, Figure 1 can be used to observe expected net returns given preselected levels of kilocalorie availability or usage. For example, if 300 million kilocalories per farm are available, expected net return levels would range from approximately $28,500 for the 200-acre farm (Line B) to $67,500 for the 600-acre farm (Line C).

For most land and labor combinations, the marginal amount of energy needed to increase net returns was rather substantial, after returns had reached a relatively high level. For example, for the 400,200, and 600-acre farms 87,047 kilocalories are needed to increase net returns by $1.00 at these high levels (Marginal Energy Income column in Table 3). As expected, when net returns were relatively lower, substantially less energy was needed in order to increase net returns by $1.00. When labor was short, relative to land (Table 4), 551,914 kilocalories were needed in order to increase net returns by $1.00 at these high return levels.

When hired labor was an alternative, the marginal energy needed at relatively high net return levels was reduced substantially. For example, on order to increase net return from $57,000 to $57,001, 87,047 kilocalories were needed for the 400-acre farm without labor purchasing (Table 3, Combination A), as contrasted to only 12,343 kilocalories for the same size farm with hired labor (Table 5, Combination J). When hired labor was available, there was a substitution to more labor intensive and petroleum-energy extensive crops.

When labor was abundant relative to land, the marginal energy requirements at high net return levels were mixed. As long as the relative availability of labor was at least twice as large as the land constraint (Combination G, H, Table 5), marginal energy requirements were relatively low. However, as shown in Combination I, marginal energy requirements shot up sharply when the labor constraint was less than twice as large as the land constraint.

4. SUMMARY

With a relative, and perhaps an absolute decrease in availablities of fossil fuels, future production adjustments in agriculture are likely. In this situation, the more pressing question is not one of maximizing short-run profits, but one of minimizing energy utilization, while simultaneously meeting given levels of return. Shifts in "crop mix" patterns were from single-crop soybeans to double-crop wheat soybeans to corn as net return levels increased. Energy requirements increased rapidly when corn entered the optimal solutions. The marginal amount of energy needed to increase net returns after net returns had reached a relatively high level was substantial. When labor was abundant, relative to land, labor was substituted for energy. Also, when labor could be hired, total energy requirements were reduced while net returns increased.

Table 1. INPUT REQUIREMENTS FOR PRODUCTION COMBINATIONS SELECTED BY THE MODEL

Activity	Chemical pounds	Phosphate pounds	Nitrogen pounds	Diesel gallons	Propane gallons	Oil quarts	Total Kcal (Thou)[1]	Tillage method	Yield[2] Bu	Width inches
Soybean										
I	8.5	30	---	5.27	---	2.20	442.7	MT	35	15
II	3.0	30	---	5.90	---	2.20	379.9	MT	30	30
Double Crop										
Soybean	3.0	20	---	3.92	---	2.20	270.2	MT	20	30
Wheat	---	40	60	3.92	---	1.65	766.3	--	50	---
Corn										
I	6.3	80	200	5.23	18.3	1.90	2,356.1	NT	110	30
II	6.3	60	150	4.95	16.7	1.90	2,096.4	NT	100	30
III	6.3	110	110	4.65	15.0	1.90	1,679.1	NT	90	30

[1] Input quantities are converted to their equivalent in calories of fossil fuel. The factors used for conversion are 11,000 kcal. per pound of chemical, 1520 kcal per pound of phosphate and 8,400 kcal per pound of nitrogen. One gallon of diesel=46,710 kcal., 1 gallon of propane= 25,300 kcal, 1 quart of oil=11,678 kcal (4).

[2] MT=Minimum Tillage, tillage is with a chisel plow and one other operation.
NT=No-tillage, seed is planted in undisturbed soil with no-till plants.

Table 2. LAND-LABOR COMBINATIONS CONSIDERED

Land & Labor Combination	Amount of Land	Amount of Labor
A	100	100
B	50	50
C	150	150
D	150	100
E	150	50
F	100	50
G	50	100
H	50	150
I	100	150
J	100	100 plus labor purchase

Table 3. OPTIMUM MINIMUM ENERGY SOLUTIONS AND NET RETURN LEVELS FOR A 400, 200, and 600 ACRE GRAIN FARM

Net Return[a]	Soybeans I (Acres)	Double Crop (Acres)	Corn I (Acres)	Total Kcal Energy (Millions)	Marginal Energy Income[b]
		COMBINATION A (400-ACRE FARM)			
20,000	190.25	---	---	78.2	3,909
25,000	237.82	---	---	97.8	3,909
30,000	285.38	---	---	117.3	3,909
35,000	332.95	---	---	136.9	3,909
40,000	380.51	---	---	156.4	3,909
45,000	346.03	53.97	---	198.2	11,440
50,000	254.59	145.41	---	255.3	11,440
55,000	109.81	215.70	74.49	444.3	87,047
57,000	11.96	228.00	160.04	618.4	87,047
57,244	---	229.51	170.49	639.6	87,047
		COMBINATION B (200-ACRE FARM)			
20,000	190.25	---	---	78.2	3,909
22,000	182.16	17.84	---	93.3	4,243
24,000	145.58	54.42	---	116.2	4,843
26,000	109.00	91.00	---	139.1	5,350
28,000	30.44	110.93	58.63	265.6	9,486
28,622		114.75	85.25	319.8	11,172
		COMBINATION C (600-ACRE FARM)			
45,000[c]	428.97	---	---	175.2	3,909
50,000	475.64	---	---	195.5	3,909
55,000	523.20	---	---	215.1	3,909
60,000	570.77	---	---	234.6	3,909
65,000	564.76	35.24	---	257.2	11,440
70,000	473.32	126.68	---	325.9	11,440
75,000	381.88	218.12	---	383.1	11,440
80,000	287.02	308.19	4.79	448.7	87,047
85,000	42.40	338.93	218.68	883.9	87,047
85,886	---	344.26	255.74	959.4	87,047

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[a] Net return is the return to land, unpaid labor, overhead and management.

[b] This represents how much Kcal usage would increase for each $1.00 increase in net returns at each net return level.

[c] Solutions for the 600-acre farm (Combination C) are the same for the 400-acre farm (Combination A) at income levels from 20,000 to 40,000.

FIGURE 1: Minimum Kilocalories Required Given Net Return Levels for Grain Farms Under Varying Land and Labor Availabilities

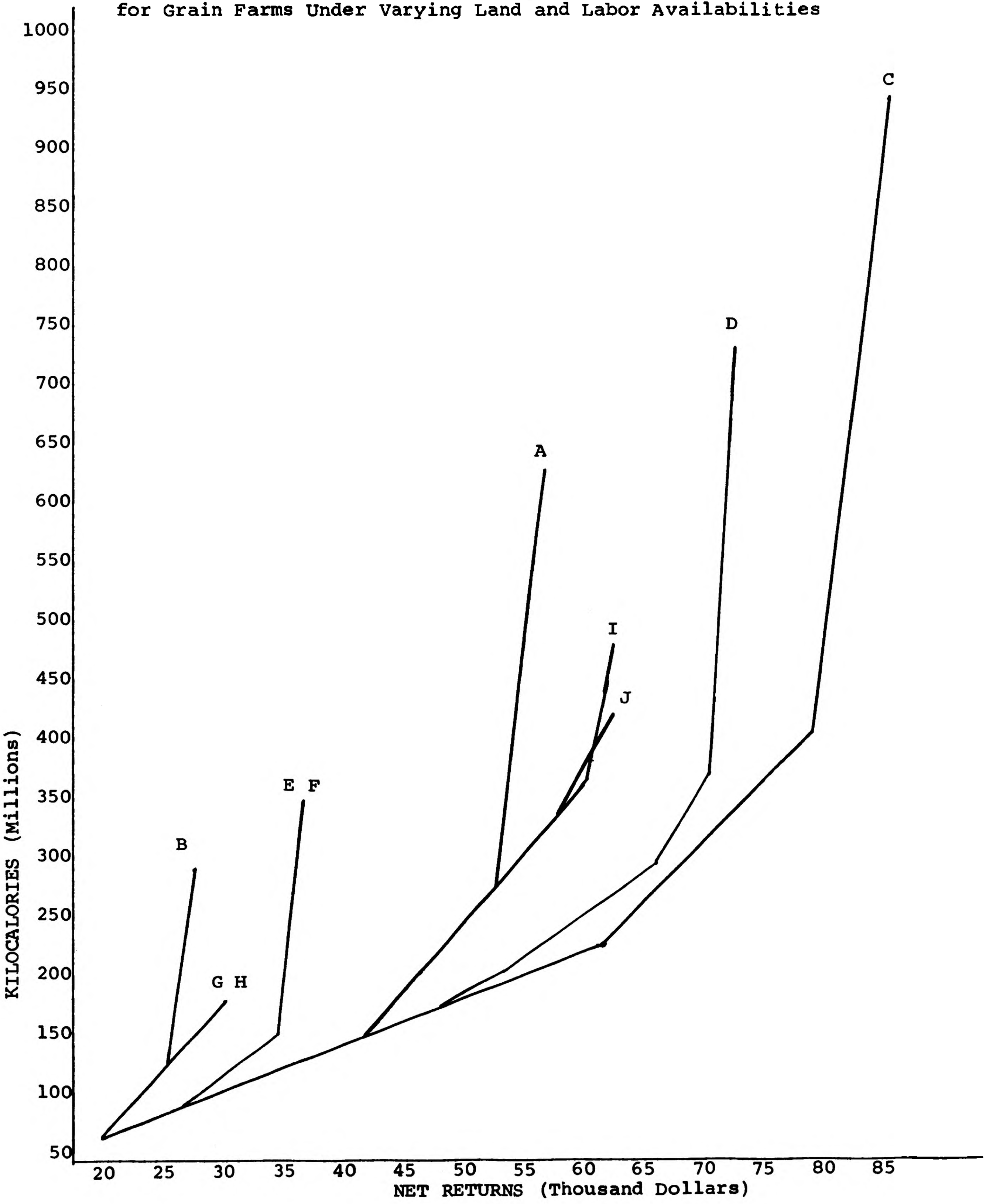

Table 4. OPTIMUM MINIMUM ENERGY SOLUTIONS AND NET RETURN LEVELS WHEN LABOR IS SHORT RELATIVE TO LAND

Net Return	Soybean I (Acres)	Soybean II (Acres)	Double Crop (Acres)	Corn II (Acres)	Corn III (Acres)	Total Kcal Energy Million	Marginal Energy Income[b]
Combination D[c] (600-Acre Farm)							
55,000	469.9	---	17.3	---	---	222.2	6,826
60,000	450.4	36.0	57.5	---	---	258.4	7,340
65,000	395.10	79.92	98.76	---	---	295.1	7,340
70,000	399.19	55.79	141.86	---	---	332.3	7,657
72,000	378.75	---	165.60	54.53	---	418.9	221,360
73,000	188.35	---	189.76	218.06	---	640.2	221,360
73,220	153.76	---	195.82	---	225.67	739.2	551,914
Combination E, F (600, 400 Acre Farm)							
20,000	190.25	---	---	---	---	78.2	3,909
25,000	237.82	---	---	---	---	97.8	3,909
27,000	249.10	---	5.10	---	---	107.7	6,826
29,000	236.26	9.24	20.49	---	---	121.9	7,340
31,000	214.14	26.80	37.00	---	---	136.5	7,340
33,000	192.02	44.35	53.49	---	---	151.3	7,340
35,000	199.60	27.90	70.93	---	---	166.1	7,657
36,000	189.37	---	82.80	27.27	---	209.5	221,360
36,610	76.88	---	97.91	---	112.8	369.7	551,914

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a/ Net Return is the return to land, unpaid labor, overhead and management

b/ This represents how much Kcal would increase for each $1.00 increase in net returns at each net return level.

c/ Solutions for net return levels below $55,000 are the same as for the 600 acre farm (Combination C) in Table 3.

Table 5. OPTIMUM MINIMUM ENERGY SOLUTION AND NET RETURN LEVELS WHEN LABOR IS ABUNDANT

Net Return[a]	Soybeans Acres	Double Crop Acres	Corn Acres	Total Kcal Energy (Million)	Marginal Energy Income [b]
Combination G.H. (200-Acre Farm)					
20,000	190.25	---	---	78.2	3,909
22,000	182.16	17.84	---	93.4	11,440
24,000	145.58	54.42	---	116.3	11,440
26,000	109.00	91.00	---	139.1	11,440
28,000	72.43	127.57	---	161.2	11,440
30,000	35.86	164.40	---	184.9	11,440
31,960	---	200.00	---	207.3	18,533
Combination I[c] (400-Acre Farm)					
53,000	199.73	200.27	---	289.7	11,440
55,000	163.15	236.85	---	312.6	11,440
57,000	126.58	273.42	---	334.5	11,440
59,000	90.00	310.00	---	358.3	11,440
60,000	71.71	328.29	---	369.8	11,440
62,000	18.62	358.31	23.07	433.4	87,047
62,380	---	360.66	39.34	466.5	87,047
Combination J[c] (400-Acre Farm)					
53,000	199.7	200.3	---	289.7	11,440
55,000	160.7	239.3	---	314.1	12,343
57,000	121.2	278.8	---	388.9	12,343
59,000	81.7	318.3	---	363.5	12,343
60,000	61.8	338.2	---	375.9	13,154
62,000	19.8	380.2	---	402.3	13,154
62,941	---	400.0	---	414.8	19,154

[a] Net return is the return to land, unpaid labor, overhead and management.

[b] This represents how much Kcal would increase for each $1.00 increase in net returns at each net return level.

[c] Solutions for net return levels below $53,000 are the same as for the 400-acre farm (Combination A) in Table 3.

References

1. Carter, Harold O., and James G. Youde, "Some Impacts of the Changing Energy Situation on U.S. Agriculture, "American Journal of Agricultural Economics. Vol. 56, December 1974.

2. Casey, James E., Lonnie L. Jones, Ronald D. Lacewell, "Implications of fuel shortages on cotton and Grain Sorghum Production and Producer Returns--Southern High Plains of Texas." Southern Journal of Agricultural Economics , December 1974.

3. Dawning, C.G.E. and M. Feldman, "Energy and Agriculture," Canadian Farm Economics IX, 1,February 1974, pp. 24-31.

4. Dvoskin, Dan and Earl O. Heady, "U.S. Agricultural Production Under Limited Energy Supplies, High Energy Prices, and Expanding Agricultural Exports." The Center for Agri. and Rural Development, Iowa State University, Ames. November 1976.

5. Eidman, Vernon, Craig Dobbins, and Harold Schwartz, "The Impact of Changing Energy Prices on Net Returns, Production Methods and kilocalories of Output for Representative Irrigated Farms," Ag. Exp. Station paper #230, Oklahoma State University.

6. Lovering, James, "The Inputs Required to Enable Farmers to Realize the Opportunities of the 1980's, "Canadian Journal of Agricultural Economics, C.A.E.S. Proceedings, 1974, pp. 320-342.

7. Mapp, Harry P. Jr., and Craig L. Dobbins, "Implications of Rising Energy Costs for Irrigated Farms in the Oklahoma Panhandle." American Journal of Agricultural Economics, December 1976, p. 971.

8. McKinsey, James W. Jr., "Energy Resources and Agriculture," Department of Agricultural Economics Special Report No. 174, University of Missouri, June 1975.

9. Moriak, Theo F., "Implications of Energy and Environment Upon Growth in the Food and Fiber Sector" American Journal of Agricultural Economics, 1975, p.819.

10. Musser, Wesley N., Ulysses Marable, Jr., "The Impact of Energy Prices on Optimum Machinery Size and the Structure of Agriculture, A Georgia Example." Southern Journal of Agricultural Economics, July 1976, p. 205.

11. Piemntel, David, L.E. Hurd, A.C. Bellotti, M.J. Forster, I.N. Oka, O.D. Sholes; R.J. Whitman, "Food Production and the Energy Crisis," Science, Vol. 182, November 2, 1973, pp. 443-449.

12. Raikes, Ronald, and Duane G. Harris, "Corn Prices, the Fuel Shortage and Optimal Corn Harvesting Strategies." Southern Journal of Agricultural Economics, July 1974.

13. Schneeberger, K.C. and Harold F. Breimyer, "Agriculture in an Energy Hungry World." Southern Journal of Agricultural Economics, July 1974

14. Warnken, P.F., "Impact of Rising Energy Costs on Traditional and Energy Intensive Crop Production: The Case of Nicaragua," Canadian Journal of Agricultural Economics 23, 1976, pp. 15-22.

Biography

James B. Kliebenstein is Assistant Professor, Agricultural Economics, University of Missouri-Columbia. A Wisconsin native, he received his B.S. degree from the University of Wisconsin-Platteville and his M.S. and Ph.D. from the University of Illinois. He is currently involved in farm management teaching and research. Current interests lie in the areas of swine economics, energy, and risk assessment. Prior to joining the University of Missouri-Columbia staff, he taught agricultural economics courses for two years at Northwest Missouri State University-Maryville, Missouri. He is married and the father of two children.

Robert M. Finley is a Professor of Agricultural Economics at the University of Missouri-Columbia. His B.S. and M.S. degrees are from Kansas State University and his Ph.D. is from the University of Illinois-Urbana.

Douglas C. Farthing is a Graduate Assistant at the University of Missouri-Columbia. He received a B.A. degree at Trinity University-San Antonio. He has worked as an independent consultant to management in addition to First National Bank at Dallas.