IMPLICATIONS OF FUEL SHORTAGES ON COTTON AND GRAIN SORGHUM PRODUCTION AND PRODUCER RETURNS--SOUTHERN HIGH PLAINS OF TEXAS*

James E. Casey, Lonnie L. Jones, Ronald D. Lacewell

Shortages of hydrocarbon-based fuels (petroleum and natural gas) for all uses in the United States have caused concern among agricultural leaders and farmers over their ability to obtain fuel for agricultural production purposes in competition with other users. During the 1973 crop year, for the first time in recent years, farmers were faced with the consequent need to make necessary adjustments in production and harvesting practices to utilize the fuel available. Analyses that have appeared since the recent widespread recognition of the energy crisis conclude that this is not a short-run phenomenon. Rather, farmers are likely to find themselves competing with other major users for limited petroleum supplies for some time to come [2, 4].

Agriculture is not a major fuel-using industry if use is measured in proportion to all energy use in the United States. Direct energy use in producing food and fiber products amounts to 3 to 4 percent of total U.S. energy consumption [5]. This figure does not include energy used by supporting agri-business enterprises such as fertilizer and machinery manufacturing or product processing and transportation. Moreover, the degree of dependence of agricultural output upon energy is not accurately reflected in this relatively small percentage. Much of the increased productivity (output per manhour or per acre) achieved in the past has resulted from the substitution of machines and chemicals for human labor and the introduction of new varieties that increase yields if used in combination with more chemicals. Hence, fuel shortages threaten the productivity gains of the past since they limit the ability of farmers to apply known technical innovations.

If farmers are faced with fuel shortages sufficient to limit present farming practices, it will become necessary for them to adjust to alternative production techniques and harvesting strategies. Unfortunately, little research has been conducted on alternative producing and harvesting strategies that farmers may adopt under fuel shortage conditions. On balance, it can be expected that alternatives adopted will be those that improve the net returns per unit of fuel used in the farming enterprise as fuel becomes the most limiting resource. Clearly, fuel-saving practices are available for farmers at present [2]. But, there exist no reliable estimates of how much shortage can be absorbed by farmers before major shifts in practices and/or crops occur. Neither is there knowledge of the types of adjustments that farmers can be expected to make under varying levels of fuel availability. The purpose of this paper is to estimate the effects of shortages of fuel on agricultural producers' output, income, and practices within a major commercial agriculture area - the Southern High Plains of Texas.

PROCEDURE AND DATA[1]

The Southern High Plains of Texas can be divided into two major soil groups, hardlands and mixed soils. The hardlands are fine textured soils, and the mixed soils are of medium texture. For this analysis, the region was subdivided into acreages

James E. Casey is research associate and Lonnie L. Jones and Ronald D. Lacewell are associate professors, of agricultural economics at Texas A&M University.

*Texas Agricultural Experiment Station Technical Article No. 11350. Special recognition and gratitude is expressed to personnel at the Texas A&M Extension and Research Center at Lubbock for their contribution in developing the input data, especially to Arthur Onken, Lavon Ray, and Elmer Hudspeth. Of course, any errors are the responsibility of the authors.

[1] Additional information is available from the authors. A complete discussion of the model and input data is included in a forthcoming Texas Agricultural Experiment Station publication.

within each general soil type.

The analysis was confined to cotton and grain sorghum, the primary crops produced in the study area. However, several production alternatives were included for these crops. Activities were incorporated so that the crops could be produced dryland (without irrigation), with a low level irrigation or with a typical level of irrigation. In addition, for each of the irrigation levels (including no irrigation), low tillage and high tillage operation alternatives were considered. Therefore, for cotton and grain sorghum on the two general soil types, 24 alternative production activites were available.[2] Each production activity was unique with regard to fuel consumption.

To estimate the regional effect on output and producers' net returns of cotton and grain sorghum with fuel shortages, the data were organized in a linear programming framework. An upper restraint, reflecting recent actual irrigated acres, was placed on acres in each soil group that could be irrigated [6]. Also, 1973 acres of each crop produced on each soil type were accepted as a typical cropping pattern and not permitted to adjust, since fuel shortages can only be anticipated and there is incomplete information on the nature and extent of a possible fuel shortage when planting decisions are made [5]. Since fuel shortages may be expected to evolve any time during the growing or harvest season, the farm operator probably selects a cropping pattern based on past years' experience. Otherwise, by permitting cropping pattern shifts, an assumed harvest season fuel shortage would cause adjustments in the cropping pattern which, in actuality, the producer would not be able to foresee or make.

Fuel use was included for each crop production activity by (1) nonharvest use, (2) an optimum harvest period, (3) a secondary harvest period, (4) a third harvest period, and (5) for irrigation. Fuel for tractor operations was expressed in gallons of diesel, while irrigation fuel was expressed in cubic feet of natural gas.

The effect of delayed harvest on each crop was quantified using Texas Agricultural Experiment Station and Texas Agricultural Extension Service data from the study area. Scientists from the Texas A&M University Agricultural Research and Extension Center at Lubbock who are familiar with production in the area cooperated with the authors to develop expected or typical yield and quality effects from delayed harvest.

It was estimated that to delay cotton harvest to a secondary harvest period would result in an 8 percent yield decline and grade decline sufficient to reduce price per pound of lint by 5 cents. The primary effect expected for grain sorghum would be an 8 percent yield decline.

To delay harvest to the third harvest period would cause a 12 percent yield decline for cotton and a loss of 10 cents per pound from a grade decline. A 22 percent yield decline would result for grain sorghum. Of course, in any given year this effect can range from none to a loss of practically all the crop. This risk consideration is not included in this study.

The initial solution of the model was one which included no fuel restraints. This solution provided estimates of total fuel use with no shortages and serves as a reference base for the remainder of the analysis. Using parametric procedures, the fuel available was systematically reduced from the initial base.[3] Effects of fuel shortages (relative to the base) were estimated for (1) nonharvest fuel, (2) harvest fuel, and (3) irrigation fuel. These different fuel requirements were considered separately (i.e., a simultaneous fuel shortage among the different groups was not included) for this paper in the interest of space.[4]

RESULTS AND IMPLICATIONS

As discussed above, the major energy needs of the High Plains farmers were divided into three categories: (1) growing season fuel requirements, (2) harvest period fuel requirements, and (3) irrigation fuel requirements. The farmer's inability to acquire fuel when needed will have a depressing effect on output and net returns. However, the manner in which each of these will be affected depends upon the timing and type of shortage relative to requirements.

Base Solution: No Fuel Restrictions

The initial model run was made to determine a base solution assuming no fuel restrictions. This solution serves as a basis of comparison for each of the solutions with imposition of a fuel restriction. Table I gives the total land used by irrigation practice and land classification along with total output. The effects of cropping pattern shifts and reductions in net returns can be estimated from the base solution.

---

[2] Texas Agricultural Extension Service enterprise budgets were modified using the enterprise budget generator [3,7].

[3] Basic parametric procedures of the MPS-360 linear programming routine were utilized in the analysis [2].

[4] Simultaneous fuel shortages for all above classes as well as nitrogen and herbicide shortages are considered in a forthcoming Texas Agricultural Experiment Station publication.

Table 1. ESTIMATES OF COTTON AND GRAIN SORGHUM ACRES AND OUTPUT ASSUMING NO FUEL RESTRICTION: SOUTHERN HIGH PLAINS OF TEXAS.[a]

	Units	Hardlands	Mixed Lands	Total
Cotton[b]	(1,000) Acres			
Irrigated	(1,000) Acres	386.9	1,246.4	1,633.3
Dryland	(1,000) Acres	43.1	1,018.7	1,061.8
Grain Sorghum[b]	(1,000) Acres			
Irrigated	(1,000) Acres	1,367.8	981.9	2,349.7
Dryland	(1,000) Acres	432.2	553.1	985.3
Cotton Output	(1,000) Bales	477.2	2,480.7	2,957.9
Grain Sorghum Output[c]	(1,000,000) Cwt.	109.1	72.4	181.5

[a]Total producer net returns to the aggregate region were $1.2 billion.

[b]Acres in this table were taken from Texas Crop Reporting Service [6].

[c]Output is based on the acreage shown and the average yield for 1973 [6].

Table 2. EXPECTED EFFECT OF GROWING SEASON FUEL SHORTAGE ON TYPE OF TILLAGE: SOUTHERN HIGH PLAINS OF TEXAS

	Acreage shift to low tillage			
Percent Fuel Restriction	Cotton[a]	Grain Sorghum[b]	Total	Reduction in Total Net Returns[c]
	1000 acres			$1,000,000
5	689	553	1242	1.3
10	1541	1535	3076	4.5
15	2308	2633	4941	10.2
20	2308	2903	5211	14.6

[a]For cotton in the hardland soils, 386,940 acres begin with minimum tillage assuming no fuel restrictions; hence, these acres do not shift to minimum tillage.

[b]For grain sorghum in the hardland soils, 432,240 acres begin with minimum tillage assuming no fuel restrictions; hence, these acres do not shift to minimum tillage.

[c]Total regional net returns are an estimated $1.2 billion with no fuel shortages.

Without restrictions to available fuel, total regional producer net returns were estimated to be $1.2 billion.

Growing Season Fuel Restrictions

As fuel becomes short in supply, the producer must find alternative strategies to reduce machine operations to conserve existing fuel. Options exist for a reduced tillage strategy with increasing herbicide rates as opposed to multi-cultivation practices.

The effects of shortages during the growing season must be considered in terms of the number of acres switched to alternative cultivation strategies. Table 2 gives the number of acres in the High Plains that shift to low tillage strategies due to imposition of fuel restrictions during the growing season and the impact on producer net returns.

A 5 percent fuel restriction would be expected to cause farmers to change tillage practices to reduce tillage on 1.2 million acres. This shift includes 689,000 acres of cotton and 553,000 acres of grain sorghum. Net returns per acre are less under the low tillage strategy as opposed to the high tillage strategy because of higher variable costs associated with the use of herbicides.[5] Thus, total net returns to producers are reduced by $1.3 million. The shift in tillage practices occurs primarily on nonirrigated land in the hardland soils. With a 10 percent fuel shortage, over 3 million acres shift to a low tillage strategy, i.e., all cotton produced on the hardland soils plus almost a half million acres of irrigated cotton in the mixed soils. Monetary effect of the shift was a $4.5 million reduction in net returns to the area.

At the 15 percent growing season fuel shortage level, all cotton in the High Plains area was produced with a low tillage strategy, and only irrigated grain sorghum in the hardlands continued to be produced with conventional soil tillage practices. A 20 percent reduction in growing seasons fuel resulted in all cotton and grain sorghum being produced with low tillage practices. Low tillage production on all of these acres caused an estimated $14.6 million reduction in net returns.

Implications of Fuel Shortages at Harvest

One of the critical points of farmers' fuel needs is at harvest when relatively large quantities of fuel are needed in a relatively short time. An average of approximately 8 gallons of diesel fuel per acre is used by High Plains farmers during the 4- to 5-month production season.[6] Of this total, 25 to 30 percent is required in about a 1-month span during the harvest period. Moreover, there is often considerably more flexibility in the operational machinery use requirements during the growing period than at harvest.

Table 3 indicates the expected effect on cotton and grain sorghum with various levels of fuel deficiencies in the first and second harvest periods, assuming ample fuel is available during the growing season. Period I corresponds to the point in time when the crop is initially ready to harvest (optimum harvest period). Fuel availability for this period is shown from full requirement down to a 20 percent reduction. In the second period, the farmer must complete harvest as the fuel becomes available. The fuel requirements for this period are the portion of the total requirements unavailable in the initial time period. The requirements in this period are also ranged from full needs up to a 20 percent reduction.

Table 3 shows the farmers' priorities between cotton and grain sorghum at harvest if he is not able to harvest his entire acreage at maturity. For any restriction level up to 15 percent of the total requirements, producers will harvest the cotton and then use the remaining fuel to harvest as much grain sorghum as possible. When grain sorghum is forced into a late harvest, the total output is reduced, since yields per acre decline as harvest is delayed. If 5 percent of the fuel requirement is unavailable in the first harvest period, 4.2 million hundredweight of grain sorghum (300,000 acres) is forced to await harvest until the second period, with .3 million hundredweight lost due to late harvest yield reductions.

A 10 and 15 percent reduction results in 7.9 (598,000 acres) and 11.6 million hundredweight (902,000 acres), respectively, of grain sorghum being delayed to late harvest. Total output loss would be .6 and .9 million hundredweight for each of these reductions. A 20 percent fuel reduction results in 20,000 bales of cotton (43,000 acres) forced to late harvest along with 21.9 million hundredweight of grain sorghum (1,143,000 acres), which represents 11.6 percent of the potential grain sorghum harvest.

The above discussion considers a fuel shortage only in harvest period I; i.e, all required harvest fuel was assumed to be available in the second time period. The last four rows of Table 3 present a more restrictive situation in which the fuel shortage is held constant at 20 percent in the first harvest period, and the second harvest period is subsequently restricted. Total cotton output is affected only slightly by increasing shortages in period II, but total grain sorghum output continues to decline. A 5 percent

---

[5] Fixed investments in machinery and equipment are not included in the model. Hence, in the long run, net returns may not be reduced by a shift to low tillage practices.

[6] Eight gallons per acre is a rounded approximation of requirements for cotton and grain sorghum during the production season. This figure does not include any harvest requirements.

Table 3. **AGGREGATE IMPLICATION OF FUEL SHORTAGES ON COTTON AND GRAIN IN NORMAL AND DELAYED HARVEST PERIODS: SOUTHERN HIGH PLAINS OF TEXAS**

Percent shortage[a] in harvest fuel requirements		Cotton			Grain Sorghum			
Period I	Period II	Normal Harvest	Late Harvest	Total Output	Normal Harvest	Late Harvest	Total Output	Reduction in Net Returns
		------1,000,000 Bales------			------1,000,000 cwt.--------			----$1,000,000--
0	0	2.96	0.0	2.96	181.5	0.0	181.5	0
5	0	2.96	0.0	2.96	177.0	4.2	181.2	1.16
10	0	2.96	0.0	2.96	173.0	7.9	180.9	2.31
15	0	2.96	0.0	2.96	169.0	11.6	180.6	3.46
20	0	2.94	0.02	2.96	157.8	21.9	179.7	7.08
20	5	2.94	0.01	2.95	157.8	21.0	178.8	7.84
20	10	2.94	0.01	2.95	147.8	20.2	178.0	8.30
20	15	2.94	0.01	2.95	157.8	19.4	177.2	8.76
20	20	2.94	0.01	2.95	157.8	18.6	176.4	9.22

[a]Percentage shortages in Period II are percentages of total fuel required to harvest the crop delayed to Period II. Period I shortage is the percent of total harvest requirements.

reduction in fuel available in period II coupled with the 20 percent reduction in period I reduces total output of grain sorghum by 2.7 million hundredweight. The addition of a 5 percent restriction in period II, as opposed .to an unlimited supply in period II, caused grain sorghum output to decrease by almost a million hundredweight. The increasing restrictions in period II harvest fuel forced harvest to a third period. A 20 percent reduction in fuel for period I and period II harvests causes only 18.6 million hundredweight to be harvested in period II, compared to 21.9 million hundredweight if norestriction were present. Total loss in grain sorghum output with a 20 percent fuel shortage in periods I and II would be about 5.1 million hundredweight.

The total output associated with restriction on normal harvest and late harvest could be slightly low, as a third harvest period was assumed, allowing for some residual output to be harvested as fuel became available after the second harvest period. However, quantities harvested in this third period are small and do not add significantly to the total output.

Implications from this table indicate that the High Plains farmers in aggregate would try to harvest cotton first if a fuel shortage threatened to restrict the total harvest. Each additional fuel restriction reduced the total output of grain sorghum, however, this reduction was not severe enough to restrict cotton harvest until a 20 percent fuel shortage in period I was imposed.

The last column of Table 3 indicates the reduction in total net returns due to each of the harvest season fuel restrictions assumed. A 5 percent harvest season fuel restriction in period I causes a $1.16 million reduction in total net returns. The loss increased to $2.31 million and $3.46 million for a 10 and 15 percent reduction, respectively. The losses in these three cases are due to losses in grain sorghum output. However, if a 20 percent period I reduction is assumed, a $7.08 million reduction in net returns is indicated with the reduction due to grain sorghum losses.

The additional reduction in producer net returns due to a 20 percent period I fuel shortage and up to a 20 percent reduction in period II fuel availability is relatively small. Reduction in total net returns increased to $7.84 million if a 5 percent restriction were assumed in period II along with a 20 percent fuel shortage period I harvest. It is estimated that net returns would be reduced about $9.22 million if a 20 percent fuel shortage were assumed in both periods.

Irrigation Fuel Restrictions

Another major fuel requirement for the High Plains is natural gas which provides the power for the majority of the irrigation wells. In essence, a shortage of natural gas would force a shift in irrigation from the typical level of application to a low or non-irrigated production practice. Table 4 shows the number of acres of irrigated land that shift to dryland production due to various levels of natural gas shortages along with associated reduction in total area net returns.

Because of the relative profitability of cotton and grain sorghum on the two soil types, natural gas

Table 4. ESTIMATED AGGREGATE OUTPUT AND NET RETURNS EFFECTS OF NATURAL GAS SHORTAGES ON COTTON AND GRAIN SORGHUM: SOUTHERN HIGH PLAINS OF TEXAS

Percent shortage in Irrigation fuel requirements[a]	Reduction in Irrigated Acres[b]	Reductions in Net Returns[a]
	1,000 acres	$1,000,000
0	0	0
5	183.8	35.7
10	367.7	61.3
15	551.4	91.9
20	735.2	122.6
25	919.0	153.2

[a]Even though both cotton and grain sorghum are considered, all acreage reductions were in grain sorghum acreage.

[b]Compared to the base solution; i.e., no fuel shortages (see Table 1).

shortages first affect irrigated grain sorghum production on the hardlands. That is, farmers in the area would devote the available irrigation fuel to the production of cotton, with any residual used for grain sorghum. With a 5 percent reduction in irrigation fuel, more than 183,000 acres of irrigated grain sorghum on hardland soils would be shifted to dryland production. Such a cropping pattern shift would result in a $35.7 million reduction in net returns in the area. Subsequent reductions in availability of irrigation fuel continue to force irrigated grain sorghum to dryland production. With a 25 percent natural gas shortage, 919,000 acres of irrigated grain sorghum in the mixed lands change to dryland, resulting in a $153 million reduction in net returns.

The model indicates that irrigation will be reduced gradually in cotton, as farmers shift to lower levels of irrigation in contrast to the sudden shift from typical irrigation to dryland found in grain sorghum. This indicates that farmers would find it most profitable to use available natural gas to irrigate fewer acres of grain sorghum at high levels and switch remaining production to dryland. Conversely, the most profitable alternative for cotton would be a gradual reduction in irrigation levels on a larger number of acres and a shift to dryland production only as a last resort.

SUMMARY AND CONCLUSIONS

Shortages of energy have caused concern among farmers over their ability to obtain fuel when needed in the production process. Insufficient quantities of diesel and natural gas force farmers to search for fuel conservation alternatives in their production practices. Estimates are needed to determine what levels of fuel shortages will cause major shifts in production characteristics. This study estimates the type of adjustments that may be expected in the Southern High Plains of Texas if energy shortages arise. The methodology used is applicable to any agricultural area.

The study area is divided into two characteristic soil types (i.e., hardland soils and mixed soils) with dryland and irrigated production in each soil type. A linear programming model augmented by a parametric procedure was developed to estimate the effects of fuel shortages on area output and net returns and shifts to alternative fuel conservation practices.

Three fuel shortage situations were assumed, corresponding to shortages in: (1) the growing period, (2) the harvest period and (3) irrigation fuel. Shortages during the growing season force the producer to search for strategies to reduce total machine operations. Model results indicate that a 20 percent fuel shortage could force all the acres of the study area to be produced with low tillage practices. Since higher variable costs for herbicides are required to maintain yields, this would result in a $14 million reduction in net returns in the first crop year.

A fuel restriction during the harvest period forces the producers to delay harvest beyond the normal or optimum period. A harvest delay also is associated with decline in yield for grain sorghum and cotton and quality decline for cotton. The model indicates that, with harvest season fuel shortages, the optimal returns are realized if cotton is harvested first, using remaining fuel to harvest grain sorghum.

Two alternatives, lower level irrigation or dryland, are available if irrigation fuel (natural gas) is in short supply. Results indicate that if natural gas were restricted, grain sorghum would initially shift from irrigated to dryland production in the hardland soils. However, with more stringent shortages, cotton production would shift to lower irrigation levels but not directly to dryland as would grain sorghum.

The types of shifts in cropping patterns indicated by this analysis could be expected under conditions in which market prices allocate natural gas to the alternative uses. Hence, these are estimates of minimum output and net return reductions that would be expected at the various fuel reductions. If limited quantities of fuel were allocated among producers under some institutional arrangement other than the market, shortages probably would be uniform, with all crops and areas affected simultaneously. This would be expected to cause greater losses in output and regional net returns than those estimated in this analysis.

REFERENCES

[1] Batterham, Robert, and Lowell Hill. "Procedures For Using the MPS/360 Linear Programming Routine." AE-4256, Dept. of Agricultural Economics, University of Illinois College of Agriculture, Urbana-Champaign, undated.

[2] Breimyer, Harold. "Impact of Energy Shortages on Rural Development." Paper presented at the Seminar on Energy and Agriculture, Texas A&M University, April 1974.

[3] Extension Economists-Management. "Texas Crop Budgets." MP-1027, Texas A&M University Agricultural Extension Service, 1972.

[4] Pimentel, David, L.E. Hurd, A. C. Bellotti, M. J. Forster, I. N. Oka, O. D. Sholes, and R. J. Whitman. "Food Production and the Energy Crisis." *Science,* 182:443-449, Nov. 1973.

[5] Schneeberger, K. C., and Harold F. Breimyer. "Agriculture in an Energy-Hungry World." *Southern Journal of Agricultural Economics*, Vol. 6, No. 1 pp. 193-198 July, 1974.

[6] Texas Crop and Livestock Reporting Service. *Texas Cotton Statistics, 1973.* Statistical Reporting Service, U.S. Dept. of Agriculture, June 1973.

[7] Walker, Rodney L., and Darrel D. Kletke. *The Application and Use of the Oklahoma State University Crop and Livestock Budget Generator*. Oklahoma State University Agricultural Experiment Station Research Report No. P-663, July 1973.