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EXAMINING THE OPTIMAL USE OF CEREAL GRAIN AND STRAW IN THE MAFRAQ FARMING REGION OF JORDAN WITH A MIXED INTEGER PROGRAMMING MODEL

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Grazing in-lieu of harvest is an important decision for dryland crop and livestock farming in the Middle East. The harvest versus graze decision and the use of cereal grains and straw is examined with a mixed-integer programming model. The harvest decision is relatively insensitive to changes in key variables such as levels of alternative feed sources.

INTRODUCTION

Cereal grain residues are an important source of livestock feed in mixed livestock-cropping systems throughout the Middle East and North Africa. Cereal straw is often gathered along with grain harvest and stored for livestock feed. Croplands are generally grazed following harvest until livestock have consumed virtually all remaining above ground biomass--spilled grain, stems and leaves, and weeds. Another common practice, especially in dry years when grain yields are low, is grazing of the standing crop--grain as well as stems and leaves--in lieu of harvesting.

Both crop and livestock production decisions obviously must take into account the substantial economic value of the feed that can be obtained from the grazing of residues. Nordblom has noted the economic importance in northern Syria of the option to graze a mature grain crop in a dry, low-yield- year. Nordblom used budget and graphical analysis to indicate the economic variables that influence the decision of when to graze rather than harvest the grain.

This paper presents a mixed integer mathematical programming model for evaluating the graze versus harvest decision in the context of alternative seasonal feed sources and livestock management options. The Mafraq area of northern Jordan is the specific locale for this study. The study is a part of the USAID sponsored project, Technologies for Soil and Moisture Management (TSMM), which focuses on dryland agriculture in West Africa and the Middle East.

AGRICULTURE IN JORDAN AND THE MAFRAQ REGION

Agriculture is an important component of the economy of Jordan and provides employment for 14 percent of the work force (el-Hurani). Most of Jordan's farmers rely on cultivation of lands in the semi-arid area with

only between 200-350 mm. (7.9-13.8 inches) of rainfall (Oglah and Jaradat).

The climate in Jordan is Mediterranean. Most precipitation falls in winter and is characterized by extreme variability from year to year. Farming strategies that make maximum use of the available moisture and provide insurance of at least some production in a dry year are very important.

The Mafraq area includes a western portion, between the 300 mm. and 350 mm. isohyets (11.8 - 13.8 inches), where wheat, lentils, vetch, and summer vegetables are grown. Further east, below the 300 mm. isohyet, barley is the major crop, wheat is a relatively minor crop, and cereal crops are often alternated with fallow. Olives are an important crop throughout the region. Farms in the 200-300 mm. rainfall area average about 18 hectares of cropland.

With relatively low long-term average precipitation and a fairly high variation in rainfall patterns, cereal grain crop failures caused by drought conditions are common occurrences. On a typical farm in the Mafraq region, four out of the last ten barley crops have been grazed rather than harvested (Oglah and Jaradat).

Livestock are important, particularly in the drier and hence more marginal cropping areas. Over 40 percent of surveyed farmers maintain flocks of goats or sheep (Oglah and Jaradat). Sheep and goats graze on range land, fallow cropland, aftermath stubble, and, especially in dry years, on mature crops. Some harvested barley grain is fed to livestock. In dry years, barley often is purchased from outside the area to supplement local feeds. Also, livestock are sometimes moved to higher rainfall areas when local feed is in short supply.

Use of yield-enhancing technologies by area farmers, as in the rest of Jordan, is limited. Only 8 percent of all Jordanian farmers use nitrogen fertilizer (Duwayri). In the low rainfall areas, such as Mafraq, fertilizer use is even less common. Labor shortages are a problem in Mafraq agriculture as well as in the rest of Jordan (el-Hurani) primarily because many workers move to the cities where wages are higher. The labor shortages are especially acute during harvest when labor requirements are highest. Also, labor shortages may be inducing greater use of machinery either on a custom hire or less often on a cooperative basis.

Structure of the Mixed Integer Model

Overall Structure of the Model

A mixed integer programming model is used to simulate decision making for a typical farm in the Mafraq region. All coefficients except crop yields are based on survey data for the 1988 and 1989 crop years, on published data, and on expert opinion. Expected crop grain and biomass yields are estimated with a version of the Erosion Productivity Impact Calculator (EPIC) crop growth model (Steiner, Williams, and Jones) as adapted for conditions in Jordan by Jaradat.

A typical farm in the Mafraq area is assumed to have 18 hectares of land available for crop production and 20 hectare of steppe land for sheep grazing. Labor shortages are assumed to occur only during the June-July harvest period. The farm family is assumed to provide 121 man-days of labor for the gathering, processing, and transport of harvested crops. Additional harvest-period labor can be purchased at the rate of JD (Jordan Dinar) 2.5 per man-day.

The farmer has a choice of cropping activities including continuous barley, barley or wheat alternated with summerfallow, and barley or wheat alternated with vetch hay. For each of these rotations, the model

allows for choosing minimum tillage or conventional tillage, and fertilizing with nitrogen and phosphorous or not fertilizing. Virtually all crop residue is removed from the field either by harvesting or by grazing of the mature crop.

Sheep production activities in the model allow a choice between low, medium, and high quality feeding regimes (Nordblom and Thomson). Higher quality feeding results in higher lambing rates, higher milk production, and better quality wool, but it also requires more energy from feeds and greater concentration of crude protein in feeds. Feed can be supplied by purchased or own-farm produced barley grain and barley straw hay, own-farm produced vetch hay, and purchased wheat bran. Steppe land is also grazed. Saleable output from the flock are lambs, cull ewes, cheese, milk, and wool.

Structure of the Graze Versus Harvest Decision

Unique to this model is the mixed integer portion that allows for the choice between harvesting barley and wheat by combine or by manual labor and grazing the crop with either own-farm animals or renting-out the crop to migrant herdsmen for grazing. Equations 1 through 3 as shown in Table 1 indicate how these choices are incorporated into the model for harvest of barley versus its grazing by own-farm animals.

Table 1. Use of Integer Variables to Incorporate the Harvest versus Graze Decision into the Mathematical Programming Model

Equation	Manual Harvest	Grazing	Integer Variables IHRVMANL	INOWNGZB	Right-Hand Side
1)			1	1	<= 1
2)	1		-99999		<= 0
3)		1		-99999	<= 0

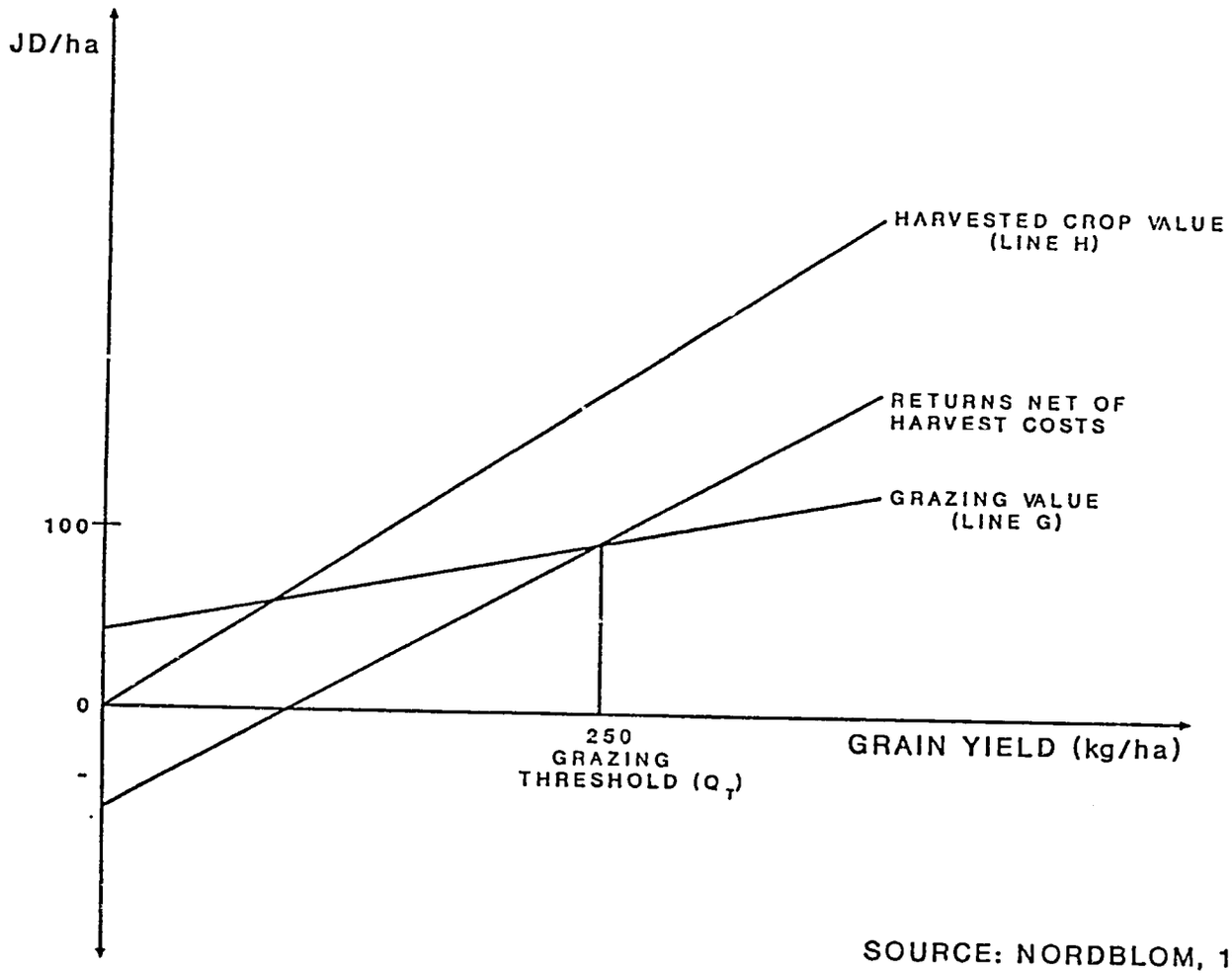
Equation 1 provides for the model choice between harvesting by manual labor (integer variable IHRMANL) and mature crop grazing by own-animal (INOWNGZB). Equation 2 allows manual harvest to occur or not occur while Equation 3 serves the same purpose for the grazing activity.

Key Variables in the Harvest Versus Graze Decision

As shown in Figure 1, the decision to graze rather than harvest rests on the relative profitability of two alternatives: 1) returns to the harvested crop net of harvesting costs (line H) versus; 2) returns to the crop as a grazed input to livestock (line G). Net return in the harvest alternative equals returns to the harvested output minus the costs of harvesting, transporting, threshing, winnowing, bagging, and storing crop grains plus harvest and storage of crop residues. Harvesting costs consist primarily of the opportunity costs of family labor plus costs incurred for hired labor. For harvest by combine, a charge for the custom hire of the combine is also included. Total returns to the harvested output depends on cereal grain and harvestable straw yield, and on either the selling prices of cereal grains and hays, or, if the harvested output is fed to own-farm animals, the marginal value of the harvested grain or straw as a feed source. The imputed value of the crop as a grazed input (line G) is determined by the profitability of livestock production and the marginal costs of alternative feeds.

The intersection of line H and line G in Figure 1 determines the grazing threshold which is the level of "grain yield at which the farmer is indifferent between grazing or harvesting" (Nordblom, p.2). At harvestable levels greater than 250 kilograms grain per hectare (quantity Q_T in Figure 1), a profit maximizing farmer would harvest his crop, while for grain yields of less than Q_T the mature crop would be grazed rather than harvested.

FIGURE 1. HYPOTHETICAL EXAMPLE OF COSTS AND RETURNS FOR GRAZING VERSUS HARVEST OF A CEREAL GRAIN CROP



SOURCE: NORDBLOM, 1985.

The relative availability of alternative feed sources through the year is an important factor in the harvest versus graze decision. If alternative sources of purchased feeds are anticipated to be in relatively short supply in the fall, winter, and spring months, then the farmer is more likely to harvest and store his crop as a hedge against short supplies even in a dry year. Likewise, if the farmer anticipates relatively high market prices for cereal grains and residues, he may choose to harvest and sell his crop at a later date. On the other hand, if alternative supplies of summer feed sources such as native pasture are in short supply and market supply of purchased feeds are expected to be relatively plentiful, the graze as harvest alternative becomes more attractive. Finally, the farmer can increase or decrease the size of his livestock flock in light of the availability and costs of the various feed sources and the profitability of mixed livestock-crop farming versus purely cropping activities.

Presentation of Model Results

Model results presented in Table 2 are for two years. The first is a year in which grain and straw yields are at expected levels. The second is a dry year where there is sufficient soil moisture for good plant stand establish and growth, but when significant moisture stress in the critical grain fill period severly reduces cereal grain yield. Grain yields in the dry year are 60 percent less than yields in an expected year and total biomass declines by 20 percent from expected levels. Net returns predicted by the model for the "basic" dry year (scenario 1.0, Table 2), where the crop is grazed rather than harvested, are 23 percent lower than net returns for the basic expected year (scenario 2.0 Table 2). Despite the decline in net returns, predicted ewe flock size more than doubles in the basic dry year run. The large ewe flock is supported by grazed

TABLE 2. Selected Results of Mixed Integer Program Farm Decision Model for the Mafraq Area of Jordan.

	Harvest Method	Net Returns (JD)	Ewe Flock Size	Grazed Biomass	Barley Grain Fed	Barley Hay Fed	Vetch Hay Fed	Barley Grain Sold	Barley Hay Sold
				(KG)					
Dry Year Scenarios:									
1.0 Basic[1]	Graze	1,628	169	22,664	8,162	27,010	42,783	0	0
1.1 No Vetch	Manual	1,299	63	0	8,162	15,117	-----	6,966	25,51
1.2 Increase Labor	Manual	2,188	117	0	8,162	15,117	17,507	5,827	12,84
1.4 Decrease Other Feeds	Manual	1,522	68	0	4,897	8,705	11,184	5,746	17,41
1.5 Increase Crop Prices	Manual	1,662	85	0	8,162	10,951	11,184	5,746	17,414
1.6 Decrease Livestock Prices	Manual	1,272	59	0	0	6,322	11,184	5,746	18,597
Expected Year Scenarios:									
2.0 Basic	Manual	2,121	74	0	8,162	9,560	5,704	14,193	21,08
2.1 No Vetch	Manual	2,072	63	0	8,162	8,011	-----	16,185	27,35
2.3 Decrease Pasture	Manual	1,570	0	0	0	0	0	16,185	35,36
2.5 Decrease Crop Prices	Manual	1,796	130	0	19,754	28,401	8,423	0	0
2.6 Increase Livestock Prices	Graze	3,115	192	26,147	8,162	47,615	42,783	0	

NOTE: A high quality feeding regime is optimal for all solutions that include sheep production. Reported levels of fed barley grain and hay and vetch hay include both own-farm production and purchased inputs. 6336 kilograms of wheat bran are also fed to livestock except for scenario 1.4, decrease other feed sources, where 4320 kilograms of wheat bran are fed.

[1]For the basic dry year scenario (1.0), 4.1 hectares of wheat are rented-out to herdsmen for grazing.

biomass, the feeding of large amounts of vetch, and the feeding of significant amounts of purchased barley grain and barley hay.

Vetch hay is currently recommended by area experts as means of increasing farm productivity and profitability, but vetch is currently grown by only a few farmers in the Mafraq area. Therefore, a dry year run is made with all vetch rotations excluded (Table 2 Scenario 1.1 No Vetch). The removal of vetch allows the shift of labor from vetch harvest to grain harvest and thereby results in harvest by manual labor replacing grazing as the optimal solution. Removing vetch as a farmer option also leads to a decline in the size of the farm sheep flock and the level of livestock products to levels close to those currently observed for a typical farm in the region. The model predicts that increasing the level of family labor available for harvest (Table 2 scenario 1.2) would also allow barley to be harvested rather than grazed under the dry year scenario. Increasing the amount of family labor would be represented in Figure 1 by an upward shift of line H and an increase in the grazing threshold level Q_T.

Decreasing the upper limits on the purchase of high quality wheat bran and barley grain feed by 40 percent also results in the manual harvest replacing grazing as seen for scenario 1.4 in Table 2. Such a scenario represents a situation where the farmer has adequate supplies of feed in the summer when grazing occurs, but anticipates possible shortages of high quality feed in the three other seasons. Accordingly, the model predicts a switch to harvesting the crop and a large decrease in the optimal size of the farm ewe flock.

The optimal solution for a year when yields are at expected levels results in a manual harvest (2.0 Expected Year Basic, Table 2). Decreasing the level of available steppe pasture to zero (scenario 2.3 Decreased Pasture) leads to a solution where the mixed crop-livestock system is

replaced by a cropping operation. Similarly, decreasing crop prices by 10 percent (scenario 2.5) does not cause a switch to grazing in instead of harvest as might be expected. It does result in the feeding all of farm produced barley grain and hay as such outputs are no longer sold.

The model predicts a switch to grazing with expected grain and biomass yields if a 10 percent increase in the selling price of all livestock products occurs as seen for scenario 2.6, Table 2. In this case, both line H and line G in Figure 1 would shift upward, but the increase in the marginal value of the crop as a grazed input in the summer (line G) would be greater than its contribution to farm profitability in other seasons (the shift in line H) and the grazing threshold, Q_T would increase as a result.

CONCLUSIONS

Presented in this paper is a mathematical programming model of optimal use of grain and straw in a typical livestock-cropping system in Jordan. Important in such systems is the decision to graze rather than harvest a mature grain crop in dry years. This decision is incorporated into the model through the use of integer variables.

One would expect variables other than grain yields, such as the availability of alternative feed sources, to play an important role in the decision concerning how to best utilize grain and straw yields. In some cases, such as when family labor is increased under the dry year scenario, these variables do affect the grazing versus harvest decision. However, model results indicate that the harvest decision is relatively insensitive to changes in many variables such as altering the level of alternative feed sources in the expected year run. Accordingly, further research concerning the grazing versus harvesting decision process is needed to determine why model results differ from the expectations held by researchers.

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