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A DETERMINATION OF THE SUBSTITUTABILITY OF CAPITAL FOR LABOR IN THE CULTIVATION OF PRINCIPAL CROPS IN IRAN[1]

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ABSTRACT

The limited availability of farm management data in Iran has constrained the planning of rapid agricultural expansion at the national level. In order to construct the agricultural planning model of Iran, it was necessary to establish alternative capital/labor relationships for major crops. This was done by conducting time and motion studies for the most labor - intensive cultural practices and comparing these with published data on labor and capital inputs for the most capital - intensive cultural practices. Crude isoquants were then constructed for dryland and irrigated wheat and sugar beets. These isoquants formed the empirical basis from which enterprise budgets were estimated for Iran's 11 regions. General conclusions were drawn with respect to the substitution of capital for labor in wheat and sugar beet enterprises.

INTRODUCTION

There is considerable interest in the analysis of land and water use patterns, interregional competition, supply potential, and other spatial aspects of the agricultural industry as they relate to agricultural expansion in Iran. A rigorous analysis of these elements of agriculture is often enhanced with the use of complex mathematical models. An initial barrier to the construction of these models is the availability of farm management data. Specifically, the substitutability of capital for labor in the production of principal commodities is often unknown. For these reasons, national policies are initiated which do not consider the optimum combinations of these agricultural inputs.

The purpose of the research presented here was to generate data suitable to con-

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struct a large mathematical planning model of the agricultural economy of Iran (2). This model utilized a linear programming algorithm which consisted of 414 rows, 1, 409 vectors, and 3, 682 elements. Sub-matrices for each of the Iran's 11 regions were divided into vectors describing production, resource transfer, commodity transfer and consumption. This agricultural planning model of Iran was then proposed for development of new agricultural policies, programs and projects based on the comparative advantage among the regions (B.W. Cone *et al.* 1972. Series of 12 reports submitted to the government of Iran).

The model of Iran necessitated the construction of a complete set of capital-labor-commodity transformation relationships for each region. Crop budgets such as those utilized to construct the aggregate production analysis system of the United States are not available in Iran (6). As pointed out by Reisch (5), artistry in formulating models is of little value without the availability of adequate data. The budget to construct the agricultural planning model of Iran was not sufficient to allow a complete sample survey of the nation. The procedures and results which were utilized to generate the necessary farm management data are reported here.

MATERIALS AND METHODS

The economic construct utilized to generate farm management data for each of the Iran's 11 regions was the law of factor substitution. This law was presented in terms of an isoquant. The properties of an isoquant are well documented in the literature (4).

Assuming the following production function:

$$Y= f(N,K)$$

where

Y= regional agricultural output,
N= regional farm labor and
K= capital

one could obtain the equation of the isoquants as:

$$N= g(k \mid Y_i)$$

where

Y_i= the constant level of output.

Since

$$dY_i = \frac{\partial Y}{\partial N} dN + \frac{\partial Y}{\partial K} dK$$

and since, by definition, $dY_i = 0$, then

$$0 = \frac{\partial Y}{\partial N} dN + \frac{\partial Y}{\partial K} dK$$

and

$$MRS_{K,N} = \frac{\partial N}{\partial K}$$

where

MRS= the marginal rate of substitution.

The slope of the isoquant at any particular point is equal to the negative relationship between the marginal productivities of the inputs. This demonstrates the close relationship between the production function and the isoquants which make up the foundation of resource use planning for regional agricultural development. If two observations could be found which were at opposite extremes of an isoquant and a line was drawn between these two points, a crude isoquant could be obtained. It was then possible to define the approximate point on this crude isoquant which represented the specific region. With these estimates, it was possible to differentiate the existing use of labor and capital among the 11 regions during the study period (June 1971 to October 1972).

RESULTS

Capital-labor relationship: In the absence of a complete data series suitable to describe capital-labor-commodity relationships by region in Iran, it was necessary to construct a data series which made maximum use of available data and required a minimum number of field investigations. In order to do this, observations were sought for the most labor-intensive and the most capital-intensive field practices used in Iran for the major enterprises. These included dryland wheat, irrigated wheat and sugar beets. The same cultural practices were assumed for barley as for wheat and for cotton as for sugar beets. Only labor-intensive practices were analyzed for melons, cucumbers, squash, potatoes, pluses, onions, tomatoes, green vegetables, deciduous orchards, dates, nuts, rice, alfalfa,citrus, and corn which are not described here.

Time and motion studies were conducted in several parts of Iran to determine time estimates for labor-intensive practices. The temporal budget for labor-intensive dryland wheat in Iran is presented in Table 1. At the time of study, the most labor-intensive cultivation practice found was to plow the ground with two donkeys and a "scratch plow", sow the grain by hand, and drag the ground with a land-smoothing board pulled by the animals. The grain was harvested with a sickle, threshed on the ground by driving over it with animals pulling a "straw cutter", and winnowed by throwing it in the air. The various tasks are listed in Table 1 with the amount of time each takes for one ha.

Table 1. Time estimates for labor-intensive dryland wheat in Iran, per ha basis.

Activity	Time, days
Plow twice	4
Sow	.25
Drag	.75
Harvest	8
Thresh	1
Winnow, bag, and carry	1
Total	15

Capital equipment utilized in the labor intensive methods of cultivating wheat consisted of a plow, a straw cutter, a few hand tools, and two donkeys. The total purchase price of this equipment was estimated to be Rls 11, 000. It was assumed that the life of the donkeys and the equipment was 7 years. If a man and two donkeys work a 10 ha farm, then 10% of the annual fixed cost would accrue to one ha. This would result in a capital equipment cost of Rls 157 per ha. The variable cost was the feed for the donkeys. It was assumed that the donkeys were fed 3 kg of barley per day of field work or a total of 45 kg/ha. At an average farm gate price of Rls 3.73 per kg for barley, this was equivalent to Rls 168 per ha (1). The remainder of the time, it was assumed that the donkeys scavange for forage which had no other value. On the basis of these calculations, the annual capital equipment cost was estimated to be Rls 325 per ha.

In calculating the capital-intensive cultural practice it was assumed that 65-hp tractors and self-propelled combines were used. Time and costs for the use of this equipment are presented in Table 2.

Table 2. Time estimates for machine-intensive dryland wheat in Iran, per ha basis.

Activity	Time,hr	Cost,Rls
Plow	3.3	660
Disk	1.3	260
Drill	1.5	300
Combine	2.5	560
Total	8.6	1,780

The cost of a 65-hp wheel tractor, inclusive of implements, was Rls 200 per hr (Tahal Co. Ltd. 1966. Ghazvin area development project final report). The combine cost include Rls 31 for repairs, Rls 50 for fuel, and Rls 697 for depreciation. This assumed a purchase price of Rls 598,800 for a diesel self-propelled combine which had a life of 5 years and harvested 250 ha per year (3).

If it was assumed that one man did the plow and disking, while two were required for sowing and combining, the labor requirement would be 12.6 hr or 1.5 days.

In addition to the above labor and machinery costs, irrigated wheat required the construction of basins or borders to control the water. The labor intensive operation was done by two men who worked with a bordering tool. Although the time required for making the borders varied with terrain, it took two men about 3 days to construct the borders for one ha. The bordering could also be done by tractor. It took about 4 hr to border a ha with a tractor (3).

Surface irrigation was assumed and, therefore, the time for irrigation was the same for both methods. One man-day was utilized in irrigating if the wheat was irrigated twice. Irrigated wheat yields were generally 2.5 times higher than dryland wheat yields in Iran. More inputs were required for harvesting. It took about 12 days to harvest, 2.5 days to thresh, and 2.5 days to winnow, bag and carry the grain with labor-intensive methods. It took about 6 hr to combine a ha of irrigated wheat (3). With labor intensive methods, 29 man-days and Rls 350 were required for each ha of irrigated wheat. Using capital-intensive practices, 2 man-days and Rls 2,360 were required.

It was estimated that Rls 350 and 84 man-days were required to produce a ha of sugar beets as presented in Table 3. One ha of sugar beets could be produced mechanically with 26 man-days and Rls 4,320 on the substitution of Rls 3,970 for 58 man-days.

Table 3. Time estimates for labor-intensive sugar beet production in Iran, per ha basis.

Activity	Days
Plow twice	4
Drag	.75
Sow	.25
Construct borders	6
Irrigate	3
Thin and cultivate	30
Harvest and carry	40
Total	84

The machine time and cost is presented in Table 4. In addition to the 21.6 hr of man-machine time, 4 hr of labor was required for planting, 3 days to irrigate and 20 days to harvest and carry. Mechanical sugar beet harvesters were not used. But the harvest labor could be cut in half if the beets were first pulled with a tractor equipped with chisel bar (3).

Level of commodity output: Data collected by the Projects and Research Unit of the Ministry of Agriculture for 1970-71 (unpublished data) were utilized to estimate the level of commodity output in each of the 11 regions. These data are represented in

Table 4. Time estimate for machine-intensive sugar beet production in Iran, per ha.

Activity	Time, hr	Cost, Rls
Plow	3.3	660
Disk	1.3	260
Plant	4.0	800
Border	4.0	800
Cultivate twice	4.0	800
Harvest and carry	5.0	1,000
Total	21.6	4,320

Table 5. The 1970-71 national-average yield for dryland wheat, irrigated wheat and sugar beets were 590, 1 310 and 22 940 kg/ha, respectively.

Table 5. Average yield for wheat and sugar beets by geographic region, 1970-71 Iran.

Region	Dryland wheat, kg/ha	Irrigated wheat, kg/ha	Sugar beets, kg/ha
Gilan, Mazandaran, Gorgan	1,080	1,640	25,000
Azarbayejan	650	1,360	21,110
Tehran, Semnan, Zanjan	570	1,320	24,100
Khuzestan, Kuhkilluyeh	530	1,129	12,000
Hamedan, Lorestan	640	1.230	19,710
Esfahan, Yazd	430	1,830	33,570
Fars	546	1,273	20,000
Sistan, Baluchestan, Kerman	550	1,170	17,900
Khorassan	280	1,230	29,260
Kermanshahan, Kordestan, Elam	630	1,180	20,110
Bandar-Abbas, Bushehr	500	1,000	----------
National average	590	1,310	22,940

Estimated isoquants: On the basis of the preceding data, isoquants were derived for dryland wheat, irrigated wheat and sugar beets as follow:

$$N= 117K|590_{W_d}$$

$$N= 110K|1,310_{W_i}$$

$$N= 71K|22,940_S$$

where

W_d= dryland wheat,

W_i= irrigated wheat,

S = sugar beets and

the value to the right side of the vectical bar= the level of output.

DISCUSSION

Considerable thought has been given to policies which are directed at the mechanization of agriculture in Iran. On the basis of the research results reported here, efficient use of resources is attained if the opportunity cost of agricultural labor is greater than Rls 117 per day. Priority for mechanization should be (a) sugar beets, (b) irrigated wheat and (c) dryland wheat.

Given an opportunity to purchase small equipment that is within the budget constraints of individual farmers, it is concluded that most farmers would substitute capital for labor in their farm operations. There is thought to be sufficient economic incentive to develop self-sustaining programs of credit dissemination for purchasing machinery.

The kind of analysis used had not previously been published in Iran. The analysis is simple and the data are crude. A large mathematical model of the entire agricultural economy of the nation was constructed on the basis of relatively simple farm budgets. The primary recommendation for further research is that the values presented in this article should be used by Iranian agricultural economists who are in a position to understand and analyze the resource allocation problems on the farm level. The basic unit of agricultural production in Iran is the family farm. Yet, relatively little research has been carried out that is directed toward collecting farm management data to determine optimum resource allocation. Analysis of land and water use patterns, interregional competition, supply potential, and other spatial aspects of the agricultural industry are predicted on the sound estimation of basic production coefficients. Complex mathematical models designed to understand the functioning of the agricultural economy of Iran could be enhanced with the use of coefficients of resource substitution based on well-designed and carefully conducted field surveys.

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