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A MODEL TO DETERMINE THE IMPACT OF IMPROVED AGRICULTURAL EFFICIENCY

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This paper presents in evaluation of various studies conducted to determine the efficient organization agriculture sector. It suggests a methodological improvement through the use of technical coefficients of optimum sized farm firm rather than those of firms which are not of optimum size. Key words: linear programming; optimum firms; efficient organization; Manitoba.

INTRODUCTION

Several studies have been conducted to determine the efficient organization of agricultural sector [2-8]. In these studies spatial optimal organization was constrained through the use of technical coefficients of an "average producing units" of a region or technical coefficients of various sized firms. Economic theory suggests that the efficient use of resources among other things depends upon the size of the firm and the method of production. In order to produce the product at the minimum possible average cost, the firm should be of optimum size and must use the best method of production. Use of technical coefficients of average producing units or those firms of different sizes which were not employing the inputs by using most efficient methods of production meant that these firms were not producing the output at the minimum possible average cost. Thus the efficient organization of agriculture determined by using the technical coefficients of those firms which are not producing at the minimum possible cost was not therefore strictly efficient.

This study eliminates this source of inefficiency and determines the efficient organization by using the technical coefficients of optimum sized farm firms which use the most efficient methods of production and produce at the minimum possible average cost.

The objectives of the present paper are:

1. to estimate the profit maximizing organization of crop production that would result on the basis of production techniques employed by currently economically efficient Manitoba farms,
2. to determine the net income that would result from an efficient Manitoba agriculture,
3. to make a comparison of the locational distribution of optimal average and net income with the actual ones.

METHODOLOGY

The method to develop the most profitable organization involved two steps; firstly, the determination of efficient farm firm size● and secondly, use of technical coefficients of these efficient size firms to determine the potenital optimum crop production.

Efficient Farm Size. Economic theory suggests that in the long run, the firm uses that size of plant and produces that level of output at which minimum average cost is equal to price and the firm makes zero profit (and zero losses). The market adjustment of the individual firm takes place by requiring the prices of commodities to fall to a level which allows continued existence of firms of optimum size having minimum average cost. Various procedures have been used to determine the optimum size. These include: use of regression analysis, economic engineering method and survivor analysis.

The regression analysis method combines and confuses cost changes that are accompanied from the more complete utilization of a plant of a given scale with the cost changes that accompany changes in scale. Heterogeneity of products, differences in the basis of valuation of physical assets, the operation of many plants below their optimum values and unavailability of relevant data made its application impractical [11]. The economic engineering method was not used because it did not take into account all factors in the

● Efficient firm size is defined as one at which output can be produced as the minimum possible average cost. In order to produce the output at lowest possible cost, these farm firms must use the most efficient methods production.

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environment in which plant operate [10, 11]. Survivor analysis technique was used in determining the optimum size because of its simplicity and availability of data on the number of farms in different sizes. This techniques is based on the concept that the minimum average cost size firms survive best in a common market where all the firms sell. The competition among firms of different sizes selects out the most efficient firms [10, 11]. This technique was used in finding the efficient farm size by determining the share of industry output coming from different sizes of firms over time. If the share of output of a given size is increasing in its industry output, then that size lies within the range of optimum size; while if the share of a given size falls, then that size lies out of the range of optimum size. Use of this technique to the Manitoba data resulted in concluding that farm firms of 760 acres and above are in the optimum range [1]. These farms were assumed to be "efficient" for the present study.

The Model. The model was applied to 14 crop districts of Manitoba. Two soil types and nine crops were considered. The objective of the model was to maximize net income given the land, production and consumption constraints. Algebraically, the model is summarised below:

Maximize

$$Y = \sum_{i=1}^{14} \sum_{J=1}^{2} \sum_{k=1}^{15} r_{ijk} X_{ijk} - \sum_{i=1}^{14} \sum_{v=1}^{14} \sum_{k=13}^{15} t_{ivk} T_{ivk}$$

Subject to the following constraints.

Land Availability

$$\sum_{k=1}^{15} a_{ijk} X_{ijk} \leqslant L_{ij} \text{ for all i and j.}$$

Production Maximums and Minimums

$$\sum_{j=1}^{2} b_{ijk} X_{ijk} \leqslant MAPR_{ik} \text{ for all i and k = 1-9}$$

$$\sum_{j=1}^{2} b_{ijk} X_{ijk} \geqslant MIPR_{ik} \text{ for all i and k = 1-9}$$

Minimum Feed Demand Constraints for Each Crop District

$$\sum_{k=10}^{12} \sum_{j=1}^{12} M_k b_{ijk} X_{ijk} \pm \sum_{k=13}^{15} M_k \sum_{v=1}^{14} T_{ivk} \geqslant D_i \text{ for all i}$$

Minimum Demand Constraints for Manitoba

$$\sum_{v=1}^{14} \sum_{j=1}^{2} b_{ijk} X_{ijk} \geqslant D_k \text{ for k = 1-9}$$

Non-negativity Constraints

$$X_{ijk} \geqslant 0$$

$$T_{ivk} \geqslant 0$$

Where:

Y = Net income
r_{ijk} = Net income for the k-th crop activity in the i-th region for the j-th soil type
k = 1, wheat for export
k = 2, oats for export
k = 3, barley for export
k = 4, flaxseed
k = 5, rapeseed
k = 6, rye
k = 7, sunflowers
k = 8, potatoes
k = 9, sugarbeets
k = 10, wheat for feed
k = 11, oats for feed
k = 12, barley for feed
k = 13, wheat produced for sale as feed
k = 14, oats produced for sale as feed
k = 15, barely produced for sale as feed
j = 1, sandy soil
j = 2, clay soil
i = 1,2 . . . 14 crop districts

X_{ijk} = Level of production of k-th activity in the i-th region for the j-th soil, t_{ivk}=Cost of transportation per unit of the k-th product from (to) the i-th region to (from) the v-th region. T_{ivk} = Quantity of the k-th commodity transported from (to) the i-th region to (from) the v-th region. a_{ijk} = Amount of land needed per unit of commodity k in the i-th region of the j-th soil. L_{ij} = Soil of quality j available in the i-th region. b_{ijk} = Per unit yield of commodity k for the i-th region on soil j. $MAPR_{ik}$ = Maximum level of production of commodity k in the i-th region over the 1962-1975 period. $MIPR_{ik}$ = Minimum level of production of commodity k in the i-th region over the 1962-1975 period. M_k = metabolizable energy provided per unit of commodity k. D_i = Total amount of metabolizable energy demanded for livestock in the i-th crop district. D_k = The total demand for human food, export, industrial use and for livestock for the k-th commodity for Manitoba.

Net income per acre of different crops in various crop districts for each soil type was arrived at by deducting the cost of production from the gross income. Gross income for different crops was estimated by multiplying the yield per acre of various crops obtained at the recommended levels of fertilizers and pesticides with 1974-75 prices. These prices were used because these were the latest available.

Total land that would be available for the production of crops in each crop districts was determined by projecting the total crop and summer-fallow area over time to 1976. Area available for the production of crops for each crop district was arrived at by deducting the tame in which hay area was grown in 1976 from the total projected available land. The crop area was then partitioned into soil type 1 and soil type 2 by using the proportionate share of these two types of soils as used by Framingham *et al* [6].

Maximum and minimum production restraints were imposed in order to account for the farmer's desire for diversity and to depart from established levels of production. It was assumed that the total production of each commodity in each crop district would not increase or decrease by more than the maximum or minimum production over the period 1962-75. (For detail see 1).

Minimum feed demand constraints for metabolized energy from wheat, oats and barley were established at the normal requirement of livestock. The energy would come from either wheat or oats or barley; that is, substitution between the three is allowed. Normal livestock requirements per animal unit for each crop were first determined by dividing the projected animal requirement by the projected number of animal units in 1976 for Canada. These average requirements per animal unit were then multiplied by the availability of metabolized energy per bushel. The resulting figure was then multiplied by the projected number of animal units in each crop district. These figures were then added in order to estbalish the constraints.

Minimum constraints for wheat, oats and barley were established by adding the human food demand, export demand and industrial demand to the normal animal demand for Manitoba as a whole. Normal per capita human food demand for each of these crops was determined by projecting the human food demand for Canada to 1976 and then dividing by total population of 1976. These average requirements were then multiplied by the population of Manitoba. Industrial demand was determined by estimating the total production and total industrial use of each of these crops to 1976. It was assumed that the contribution made by each province was equal to the proportion of the total quantity used for industrial purposes to total production. The procedure used for export demand was identical to the industrial demand. The procedure used for establishing constraints for flaxseed, rapeseed, and rye demand was identical to the previous one except that there were no livestock requirements. Minimum demand restraints for sunflowers, potatoes and sugarbeets were set at the minimum level of production of those crops over the 1962-75 period (For details see 1).

RESULTS

The results were presented for the five agricultural regions and for Manitoba. The crop districts were allocated to the five regions by taking information from the Framingham *et al* study [6]. In the following sections optimal crop acreage and net income are discussed and compared with the actual acreage and net income.

Optimal Crop Acreage. The total acreage occupied by different crops in the optimal solution amounted to 9.17 million acres. Optimal acreage allocated to wheat, potatoes, and sugarbeets was lower by 13.18 percent, 19.92 percent and 19.57 percent respectively than the actual acreage in Manitoba (Appendix 1). Low acreage of these crops as compared with the actual acreage might be due to the realization of relatively higher net income from these crops in previous years because of higher prices and the expectations of the farmers that net income from these crop would remain higher for 1976.

The optimal acreage allocated to other crops was substantially higher than the actual acreage in 1976. For example, optimal acreage occupied by rapeseed, sunflower and flaxseed was higher by 192.14 percent, 161.35 percent and 119.44 percent respectively, than the actual acreage. Similarly for oats, barley and rye, optimal acreage was higher by 32.4 percent, 31.11 percent and 47.34 percent, respectively, than the actual acreage in Manitoba. From this one can conclude that an efficient organization of agriculture practised on optimum sized farms not only would lead to an increase in the total cropped area but also would substantially change the pattern of land use in Manitoba. Crops like rapeseed and flaxeed would become more important, while the share of wheat would decline in the total cropped area. Central and South-West regions were the most important in terms of the increase in crop acreage. In these two regions crop acreage increased by 65.52 percent and 53.78 percent, respectively, over the actual acreage in 1976. This was the result of higher net income per acre of most crops in these regions. In both the Eastern and North-West regions, optimal crop acreage decreased by about 23 percent as compared to the actual acreage. This was because of low net income per acre for most of the crops in these regions due to lower yield acre. There was almost no change in optimal solution acreage and the actual crop acreage in 1976 in

Appendix. 1. Percent increase or decrease of the optimal acreage over the actual acreage allocated to different crops in various regions and in Manitoba

Crop	Interlake	Eastern	Central	South West	North West	Manitoba
Wheat	–42.24	–48.10	+7.93	+24.69	–39.30	13.18
Oats	+42.25	+20.10	+72.63	+61.16	–25.20	+32.30
Barley	+64.98	–7.57	+82.21	+53.13	–17.12	+31.11
Flaxseed	–0.15	–24.24	+377.57	+111.95	+80.81	+119.44
Rapcseed	+109.57	+102.72	+470.56	+273.98	+67.72	+192.14
Rye	+44.12	–81.75	+168.54	+108.48	+63.38	+47.34
Sunflowers	+143.88	–68.46	+178.23	+186.01	169.21	+161.35
Potatoes	–13.02	–	–26.63	–19.18	–15.68	–19.92
Sugarbeets	–26.82	–	–19.39	–19.65	–14.36	–19.57
Total	+1.18	–22.86	+65.52	+53.78	–22.60	20.57

Inter-lake area. This brings us to the conclusion that certain interregional adjustments would be needed if the agricultural industry is to be organized efficiently. The Eastern and North-West regions would become less important in terms of their share to total cropped area, while the contribution of the Central and South-West regions would increase. Thus the competitive position of Eastern and North-West regions declines as compared to the Central and South-West regions with an efficient organization of crop production. This was caused by higher yields of most of the crops in the Central and South-West regions as compared to the Eastern and North-West regions. Thus the proper utilization of land in Manitoba would require that the East and North-West regions should persumably engage increasingly in pastoral farming, while the Central and South-West regions should concentrate more in crop production at the expense of summer-fallow acreage.

The percentage increase or decrease in the optimal acreage for each crop as compared to the actual acreage showed a wide deviation of the optimal acreage from the actual acreage in different regions. For example, rapessed occupied a 470.56 percent higher area in the Central region as compared with the actual one, while the wheat crop occupied 48.10 percent less area in the optimal solution as compared with the actual area in the Eastern-region. These two figures show the range by which the optimal acreage of different crops was higher or lower than the actual acreage. The increase in the optimal acreage of wheat in the Central and South-West regions over the actual acreage was the result of higher yield and consequently higher net income per acre in these regions. Similarly, the increased concentration of rapeseed acreage in the optimal solution in the Central region was the result of higher yield and resulting higher net income per acre from this crop in this region as compared to other regions. Again, consider the oat crop. Oat acreage decreased compared to actual acreage in the North-West region because of low yield in the region as compared to other regions. The Central and South-West regions experienced an increase of 72.63 percent and 61.61 percent due to the fact that these regions ranked first and second in terms of yield per acre.

The percentage distribution of total optimal and actual acreage for each crop among regions is shown in appendix II and appendix III. The Central and South-West regions were the most important in terms of their contribution to total optimal acreage. Individually both regions contributed about one-third of the total optimal crop acreage. The North-West region was next in importance followed by the Eastern region. The Interlake region contributed only 6.7 percent of the total optimal acreage. In comparison with the actual percentage distribution of total cropped acreage among regions the Central and South-West regions shared substantially more, while the other regions shared proportionately less of the total optimal acreage compared with actual acreage. The reasons for these results are as already explained in the previous discussion. This indicates the potential for development of the Central and South-West region as compared with the other regions.

With regard to the percentage contribution of each region towards the optimum acreage as compared with the actual one, it varied from crop to crop. An important observation which could be made was that the Central and South-West regions were the most important for almost all the crops in the solution as compared with the actual situation. This was the result of higher yields and net income for most of the crops in those two regions. Thus the com-

Appendix 2. The percentage distribution of optimal crop acreage among various regions

Crop	Interlake	Eastern	Central	South West	North West	Province
			Percent			
Wheat	5.38	9.65	32.14	34.93	17.90	100.00
Oats	9.01	12.84	31.31	30.98	15.86	100.00
Barley	8.55	9.57	31.30	31.56	19.02	100.00
Flaxseed	4.99	7.87	45.00	31.30	10.50	100.00
Rapeseed	4.96	16.63	29.67	32.24	16.50	100.00
Rye	5.46	4.02	34.66	38.20	17.66	100.00
Sunflower	4.58	0.91	41.02	50.71	2.78	100.00
Potatoes	6.29	0.00	42.69	47.19	3.83	100.00
Sugarbeets	11.32	0.00	62.64	24.17	1.87	100.00
Total	6.69	10.20	33.51	33.08	16.52	100.00

Appendix 3. The actual percentage distribution of crop acreage among various regions of Manitoba

Crop	Interlake	Eastern	Central	South West	North West	Province
			Percent			
Wheat	8.08	16.14	25.85	24.32	25.61	100.00
Oats	8.38	14.14	24.00	25.43	28.05	100.00
Barley	6.80	13.58	22.53	27.02	30.07	100.00
Flaxseed	10.96	22.80	20.68	32.41	13.15	100.00
Rapeseed	6.92	23.96	15.19	25.18	28.75	100.00
Rye	5.58	32.48	19.02	26.99	15.93	100.00
Sunflower	4.91	7.52	38.54	46.33	2.70	100.00
Potatoes	6.39	0.00	43.30	46.76	3.55	100.00
Sugarbeets	11.54	0.00	62.50	24.20	1.76	100.00
Total	7.97	15.95	24.41	25.94	25.73	100.00

petitive position of the Central and South-West regions would increase with an efficient organization of crop production.

Net Income. The value of net income in the analysis for 1976 in optimal solution came to $689 million whereas net income from crop production amounted to $459 million under the actual conditions. In other words optimal level of net income was higher by 50.29 percent than the actual net income.

Contribution of different regions towards the total net income is given in Table 1. This shows that the South-West and Central regions were the most important in terms of their contribution to net income in the optimal solution. Individually, both of these regions contributed more than one-third of the total net income. The North-West region was next in importance followed by Eastern region. The Interlake region shared only 6.12 percent of the total net income. In comparison with the actual percentage distribution of net income among regions, the Central and South-West regions contributed more, while the other regions contributed proportionately less of the total net income in optimal solution as compared with the actual net income. Thus one could expect that the Central and South-West regions would experience an increase and other regions decrease in share of total net income with an efficient organization.

CONCLUSIONS

A number of conclusions can be drawn from the result of this study. Some of the important conclusions are discussed here.

Table 1. Contribution of different regions towards the total net income

Region	Optimal Solution		Actual Situation*	
	Net Income in $	Percent of total	Net Income in $	Percent of total
Interlake	42,228,690	6.12	34,100,180	7.50
Eastern	57,009,448	8.27	70,104,820	15.28
Central	237,656,640	34.47	112,350,300	24.49
South-West	245,051,690	35.54	124,169,600	27.07
North-West	107,501,973	15.60	117,722,460	25.66
Total	689,448,461	100.00	458,757,360	100.00

*The procedure used in calculating actual net income is discussed in (1).

The first conclusion concerns the effect of optimal organization on the total cropped area and on the cropping pattern. The study indicated a substantial increase in the total cropped area as compared to the actual area. The model also showed a change in the cropping pattern, i.e. a decrease in the area devoted to wheat, potatoes and sugar-beets and an increase in the area allocated to other crops. Thus one could conclude that efficient organization would lead to not only an increase in the cropped area but would also substaintially change the pattern of land use in Manitoba.

The increase in cropped area in the Central and South-West regions was so strong that it not only compensated for the decrease in area in Eastern and North-West regions, but also resulted in increasing total cropped area in Manitoba. From this it can be concluded that an optimal organization of the agriculture industry in Manitoba would require interregional adjustment in land use. The Central and South-West regions would become more important in terms of their contribution to total cropped area, while the share of the Eastern and North-West regions would decline.

Finally the results show that net income from crop production was greater by 50 percent when agriculture is organized efficiently in optimal solution as compared to the actual net income. This leads to the conclusion that an efficient agricultural industry using the best techniques of production would increase the net income of the farmers considerably.

The results also indicated that the contribution of Central and South-West regions towards the total net income was higher with the optimal organization as compared to the actual one. Thus one could expect that Central and South-West regions would experience an increase and other regions a decrease in share of total net income with an efficient organization.

POLICY IMPLICATIONS

A number of policy implications can be implied from the results of this study. Foremost among these is the great potential for increased net income from the crop production sector. Given the objectives of Manitoba agriculture and the increased net income resulting from efficient organization of agriculture on the optimum sized farms, a basic question is, whether policies should be framed to convert the small farms into optimum units? Some will argue that an increase in net income from crop production is the only legitimate goal in measuring the benefits that will flow from an efficient organization of agriculture practised on the optimum sized farms. This group favours policies which would increase the total income from the agriculture sector. Others will argue the goal of maximixation of positive utility of rural life on the family farms. They also advocate that the amalgamation of family farms into optimum sized farms leads to very high social cost and destroys the human values associated with them. This group favours farm policies which would increase the viability of small and medium farms. Thus the above two objectives which emphasize on the one hand an increase in total income from agriculture and on the other enhance the economic viability of low and middle income farmers are in direct conflict with each other. Neither of the objectives can have dominance over the othe because the society's preference function is not linear and after achievement of one particular goal its further attainment involves diminishing utility relative to the other goal. Expression and quantification of a societal preference function is difficult especially with regard to an increase in income resulting from efficient use of resources in agriculture on the optimum sized farms and the existence of small family farms. Thus the decision about the extent to which the efficiency in use of resources in agriculture can be traded with the extent of existence of small family farms can be left to politicians. Assuming that the Manitobans decide on an efficient use of resources in agriculture industry which could be practised on the optimum sized farms, then one could suggest the following:

1. Efficient use of resources requires an adjustment of farms towards optimum size. This size among other things is influenced by government policies. The Government policies which are conducive towards the viability of small farms would result in greater inefficiency in the agriculture sector. If there are no programmes which support small farms and the economic forces in agriculture are allowed to work with little government interference, the farm numbers would decline rapidly and there would be an adjustment towards the optimum farm size. Changes in government policies which favour the maintenance of small farms would be needed in order to achieve the necessary adjustments in farm size.

2. Co-operative farming would be offered by some as another possible approach. Small farmers who may not be able to justify the use of heavy machinery due to higher cost to individual farmers, may take advantage of the modern, large scale methods through co-operative farming and at the same time preserve the traditional values associated with the family farms. Through co-operative ownership of machinery, small farmers may realize economics of size and lower cost per unit of output and be able to compete with the large optimum sized farms. Reduced labour demand resulting from co-operative farming could be used for livestock operations or for some other industry. The government could provide necessary technical information and credit facilities to farmers who are interested in co-operative farming.

3. In case the government is concerned with the efficiency goal along with maintaining the family farms of optimum size, then the government should attempt to fashion two or more small under-sized and inadequate family units into one large and more efficient unit (rather than to add a small unit to an already large one). Institutions like Manitoba Agricultural Credit Corporation should be strengthened. A typical arrangement will be that as land comes onto the market when an operator dies, retires or migrates, the Manitoba Agricultural Credit Corporation could purchase it. The land so obtained could be sold to an operator of a smaller unit who is able to fashion a larger and more efficient unit through special credit arrangements. This would make a non-optimum sized farm into a unit closer to optimum rather than an increment to an already very large operation. Under this arrangement, the process of converting small farms into units closer to optimum is very slow and gradual. If the Manitoba Agricultural Credit Cropora-tion paid higher than the market price, more farmers would move from farms to other industries. If in turn, the Manitobal Agricultural Credit Corporation can sell land below the market price and extended credit for a long term at a low interest rate, it may increase the demand by small farmers for land which would result in farm enlargement. The speed and effectiveness of this policy and its cost would depend among other consideration on the amount of public funds and assistance made available. If little emphasis is to be placed on the family farms then the Manitoba Agricultural Credit Corporation could sell small units to already large ones through special credit arrangements. This would assist and accelerate the process of enlargement by the absorption of those farms which are not of optimum size.

4. Optimum sized farms in Manitoba agriculture are of 760 acres and over, require machinery which is larger is size as compared to the machinery used by many farms today. This points out the adjustments which would be needed in the production of machinery in order to meet the demand on optimum sized farms.

5. In order to use the resources efficiently, optimum sized farms must use not only the better techniques of production but must also follow the cropping patterns which are most profitable to that region. These would require that necessary information about the profitability of crops and better techniques of production be provided to farmers through agricultural extension service.

6. The results indicated that the total cropped area would increase substantially in South-West and Central regions, while it would decline in the Eastern and North-West regions with an optimal organization of crop production. This would necessitate an adjustment in the cropped area. Retirement of land from crops in the North-West and Eastern regions would require the formulation of certain land diversion programs. This would involve direct high government payment to farmers to compensate for net income that could have been realized until the time it would become profitable to grow crops in these regions or to use the diverted land for grazing. Another approach would be to buy the land from farmers in Eastern and North-West regions and to make proper provision for the welfare of families which would be displaced. Increase in cropped area in Central and South-West regions would necessitate an increase in supply of fertilizer, pesticides, machinery and other agricultural input.

7. Cropping patterns changed with an optimal organization of crop production as compared with the actual one, i.e. area allocated to wheat, potatoes and sugarbeets decreased, while area devoted to other crops increased. In order to

have necessary adjustments in cropping patterns it might be required on the part of the government to formulate necessary price supports, individual crop acreage restrictions and marketing quota programmes.

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