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Spatial Organization of Marketing Facilities in Developing Countries: A Case Study of Oilseeds in Sudan

E. Dean Baldwin[1], Babiker I. Babiker[2] and Donald W. Larson[1]

[1]*Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, OH 43210 (U.S.A.)*
[2]*Department of Rural Economy, Faculty of Agriculture, University of Khartoum, Khartoum North (Sudan)*

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Abstract

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Little attention has been devoted to the study of spatial organization of marketing facilities in developing countries, even though such studies would be most useful for a wide range of marketing problems. The results of such studies could be valuable to private and public decision-makers in developing countries whose policies and decisions determine the number, size and location of marketing facilities. The spatial organization model developed in this paper for application to the oilseeds industry in Sudan demonstrates the relevance of this research technique for developing country studies of marketing facilities. A linear programming transshipment model is utilized to determine the optimal spatial organization of oilseeds in Sudan when the costs of oilseed assembly, processing and distribution of oil and cake to final destinations are considered simultaneously. The optimal spatial organization of oilseed processing plants was determined for six alternative solutions. Model results indicate that the optimal organization of processing plants would be obtained with fewer and larger plants, resulting in lower transportation costs.

Introduction

The optimal spatial organization of marketing facilities in developing or developed countries can contribute significantly to lower marketing costs that

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benefit domestic producers and/or consumers in the form of better prices. Lower marketing costs can also improve the ability of a country to compete in export markets. The number, size and location of marketing facilities are essential variables to consider when one attempts to analyze the optimal spatial organization of marketing facilities in a region or country. Private and public decision-makers in most, if not all developing countries make policy and investment decisions, on a regular basis, that influence the spatial organization of marketing facilities.

Applied research results that analyze these optimal spatial organization issues could improve the information base for public and private decision-makers and lead to better investment/disinvestment decisions that improve market efficiency and lower marketing costs. The spatial organization model developed in this paper for application to the oilseeds processing industry in the Sudan could easily be applied to a wide range of problems addressing the organization of marketing facilities. Common examples of the problems that can be analyzed with this approach are the number, size, and location of storage facilities for grain products (or any other storable commodity), processing plants for any food and fiber crop, rice milling, cotton ginning, sugar refining, and slauthering plants. The results of the analysis would be of value to private decision-makers in firms with multi-plant operations, to government decision-makers whose policies influence plant location decisions, and to managers of government-owned parastatal marketing organizations (quasi-monopolies) with multi-plant facilities. The spatial organization model can be used to evaluate the organization of existing plants or the construction of new plants.

Oilseeds production and exports in the Sudan, especially groundnuts, are undergoing critical changes in terms of production and marketing. Production of groundnuts, sesame and cottonseed has increased steadily over the last few years and more increases are expected as a result of new investments and policy changes in the agricultural sector. On the marketing side, policy measures to strengthen the country's comparative advantage in the world market and improve infrastructure are being undertaken. Efforts to increase processed oilseeds exports as a substitute for raw seed exports have also been an important policy objective. The increase in supply and the emphasis on exporting oil and cake rather than unprocessed seeds will affect the location, number, and size of processing plants needed to implement the planned strategy. Assuming that the present trend of increased production and exports of processed oilseeds continues, economic information is needed to serve as guidelines and to give more precise direction to the expected changes in marketing services. (Marketing services include the transportation, storage, handling and processing of products in the oilseed industry.)

The present marketing services of oilseeds in the Sudan are rather inefficient. Sudan is geographically a large country with several important production regions for oilseeds that are distant from demand centers (Fig. 1). Costs

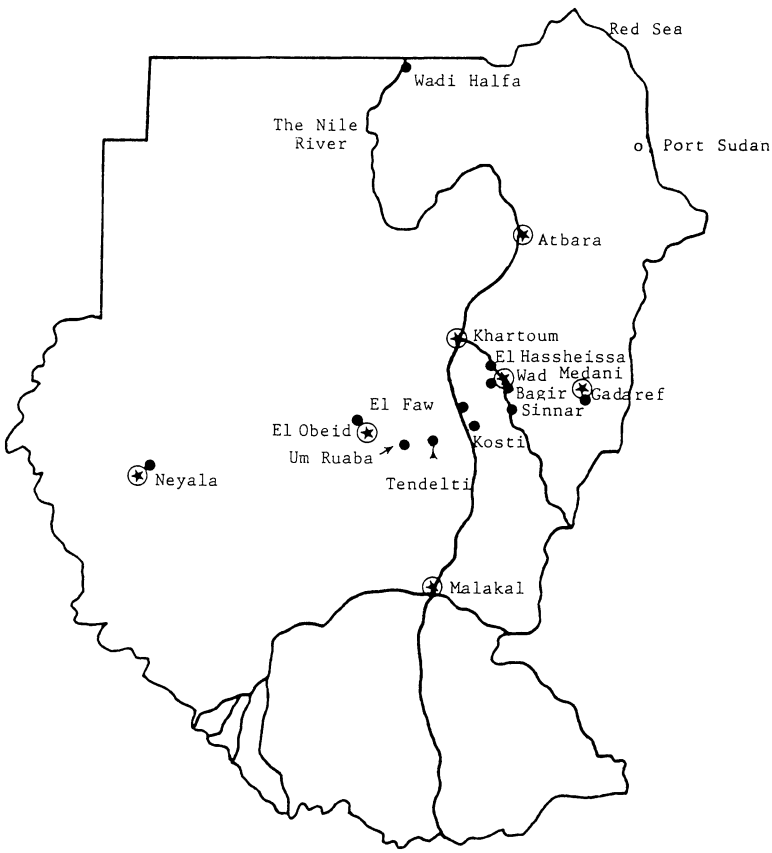

Fig. 1. The Sudan: major oilseed production (•) and consumption (⊛) centers. o = Port Sudan.

of transportation are high, the processing activity is concentrated in the capital city of Khartoum, and the processing capacity is underutilized. In 1979, Sudan had 87 active oilseeds processing plants that ranged in size from less than 2000 t (metric tonne) to over 14 000 t of oilseeds processed. Most of the plants (52 of the 87) processed less than 4000 t and only seven plants processed over 14 000 t in 1979. Another 18 plants processed from 4000 to 8000 t and the remaining 10 plants processed between 8000 and 14 000 t in 1979. These data indicate that Sudan has a large number of small oilseed processing plants. These plants had a total rated capacity* of 1 036 000 tons of oilseeds annually but processed only 456 000 tons in the 1979/80 season. If the country is to improve its comparative advantage in the world vegetable oil market, Sudan must remedy these processing and transportation inefficiencies.

*Rated capacity is defined as the number of tonnes of seeds that a properly engineered plant can process when a continuous and even flow of seeds enters the plant 24 h a day.

The present research demonstrates the applicability of spatial analysis techniques to solving industry location problems in developing countries using an example from Sudan. It outlines the potential gains from reorganizing the oilseeds processing industry. The specific objectives are:

(1) To analyze the costs of transportation, storage, and processing of oilseeds in the Sudan.

(2) To determine the optimum location, number and size of processing plants for 1979/80 and 1989/90.

(3) To analyze the impact of change in selected variables in the model on plant location, marketing costs and product flow.

Methods of analysis

To achieve the stated objectives, a linear programming transshipment model was used. This model allows for transshipment points between origins and destinations and permits storage and processing activities to be incorporated. The problem can thus be represented, using this model, as a cost-minimization problem (Dantzig, 1963). Parametric programming techniques that change the right-hand-side constraints or the coefficients of the objective function are used to simulate changes in supply, demand and plant operating capacity of the Sudan oilseeds industry. For this study, Sudan is divided into twelve producing centers, seven oil and cake consumption centers and one export port, port Sudan (Fig. 1).

The calendar year is divided into three periods to facilitate representation of the assembly, processing and distribution activities. The first period, which is the beginning of the processing season, runs from 1 November to the end of February. During this period, the groundnut and sesame crops are harvested and a large proportion is delivered from farms by trucks or animals to the auction markets. After the auction market transactions are completed, the product is transported to the processing plants, mostly by trucks but in some regions by rail. Although not all the quantities purchased are moved from auction markets during this period, enough is transported to keep the processing plants at low operating capacity. This is also the period when cotton ginning starts.

In the second period, 1 March to 30 June, the quantities purchased are assembled and transported to the processing plants and export port, storage taking place while the processing continues. In the third period, 1 July to the end of October, transportation demands are low and the stored quantities are being depleted as they are turned into oil and cake.

The distribution of finished products continues throughout the year. Pipeline storage for short periods before distribution to the ultimate consumers is performed by plant owners, wholesalers and to some extent by retailers. Storage of finished products at the plant level is considered and incorporated in the model; however, storage by wholesalers and retailers is not considered. The output of processing, oil and cake, is shipped by truck or rail to the different demand centers, to Port Sudan for export, or stored for use in a later period. The supply of finished products in a subsequent time period is thus composed of the output of processing in that particular period plus the stocks carried from the previous period.

The model

The economic value of processing any commodity is usually reflected in changing the product form which adds value and contributes to GNP through the payments for the resources used in the activity. Improvements in the organization of the oilseed processing industry as well as the infrastructure and services for the agricultural sector will have the effect of reducing marketing costs for inputs and outputs, and stimulate agricultural development.

The important economic relationships that are examined in this analysis are: (a) the cost encountered in assembling the raw materials (total assembly cost or TAC); (2) the processing cost encountered in changing the form of the product (total processing cost or TPC); and (3) the cost of distributing the final product to consumption centers and the export port (total distribution cost or TDC) (King and Logan, 1964). These three costs vary with plant numbers, plant location, density of production of the raw product, volume of raw product produced and processed and the selection of transportation routes to move the processed product to consumption centers and export port.

Assuming that the total supply of raw product is fixed and that production density and plant locations are equally distributed throughout all production regions, TAC is indirectly related to the number of plants (Fig. 2). That is, as the number of plants increases, TAC declines because the size of the supply area for the respective plants and the total distance required for assembly are reduced (Bressler and King, 1970). If, on the other hand, production of the raw product is concentrated within a sub-region of the production area, a fixed number of processing plants can be relocated to more efficiently assemble the raw product, TAC declines or the TAC function shifts to the left. Assuming that the number and location of plants is fixed and that production density is fixed, an increase (decrease) in the raw product production shifts the TAC function to the right (left). That is, total assembly costs increase with the increase in production.

Assuming that the total supply of the raw product and processing plant locations are fixed, total processing cost (TPC) is directly related to the number of plants (Fig. 2). Because of the economies of size effect, a smaller number of plants with relatively large processing capacities can process a fixed supply of raw product at a relatively low TPC. An increase (decrease) in the total supply

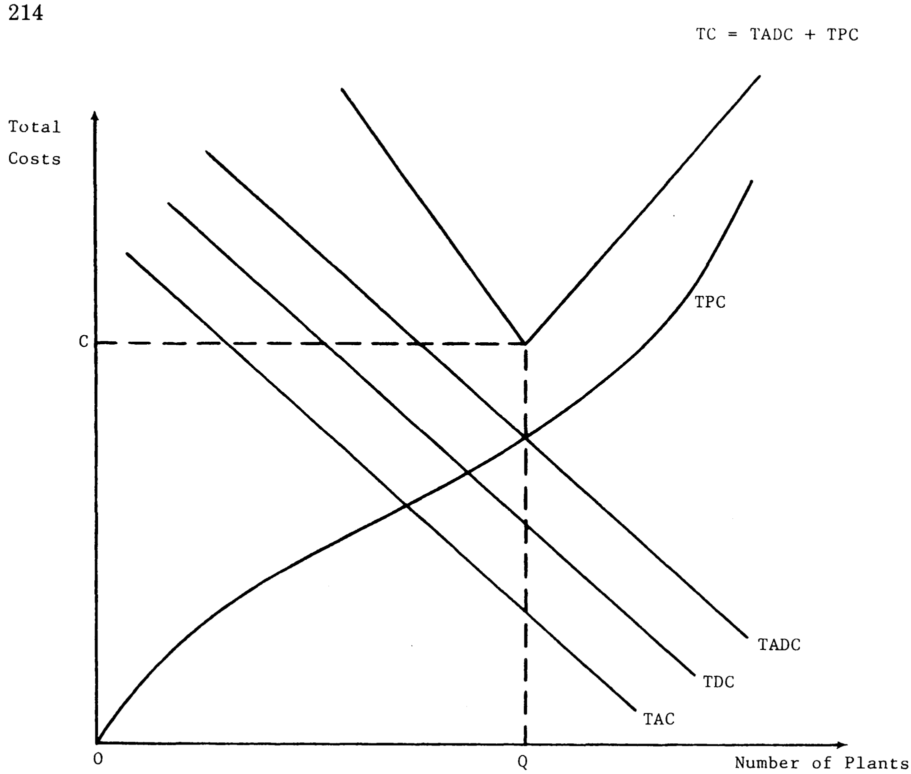

Fig. 2. Minimized total assembly cost (TAC), total distribution cost (TDC) and total plant processing cost (TPC) for a fixed volume of raw product. TADC = total assembly and distribution cost, TC = total costs.

of the raw product for a fixed set of plants shifts the TPC function to the left (right).

Assuming that the total supply of processed product, processing plant locations, consumption centers and export ports are fixed, total distribution cost (TDC) is indirectly related to the number of plants (Fig. 2). That is, the TDC will decline as the number of plants increases because the size of the market area for particular plants and the total distance required for distribution are reduced. If the total supply of the processed product increases (decreases) for a fixed set of plants, consumption centers and export ports, the TDC function shifts to the right (left). Finally, locating a fixed number of plants in the optimal position to transport the processed product a shorter (longer) distance or at a lower (higher) transportation rate shifts the TDC function to the left (right).

Since the total assembly and distribution cost functions are indirectly related to the number of firms, these functions may be added together to equal the total assembly and distribution cost function (TADC) (Fig. 2). Assuming that the total supply of raw product and plant location are fixed, the TADC and TPC functions can be summed together for the total cost (TC) to determine the optimum number and size of plants. The optimum number and size of plant are determined when the effects of reduced total assembly and distribution costs are just offset by the opposite effects of increased processing costs as the number of plants increases (Q plants and C costs, Fig. 2). Relaxing the assumptions of raw product supply and plant location permits all functions to shift to their optimum location. By summing, the TADC and TPC functions determine the optimum number, size and location of plants.

To analyze these economic relationships within a linear programming transshipment framework, the following assumptions are used:
(1) The volume of production of oilseeds is fixed for the season under consideration.
(2) Each plant location will have a transportation network to support it.
(3) Factor prices are assumed to be constant at all plant sites and to have no effect on location and size of plant.
(4) Production is assumed to be concentrated at one point in the center of the production regions and demand is concentrated at one point in the center of the consuming regions. This is to enable calculation of assembly and distribution costs for the area as a whole.
(5) The oilseed supply functions and oil and cake demand functions are price inelastic and known for each region.
(6) The surplus production over domestic consumption of oil and cakes is exported at the world market price where Sudan is considered a small exporter and price taker.

Description of the mathematical programming algorithm

The general formulation of linear programming as used in the analysis is mathematically represented as follows:

$$\text{Minimize } Q\sum_i\sum_j\sum_m\sum_k t_{ijm}X_{ijk} + \sum_i\sum_j\sum_k C_jX_{ijk} + \sum_i\sum_j\sum_k r_jX_{ijk} + \sum_p\sum_m\sum_j\sum_g\sum_k t_{pmjg}H_{pjgk} + \sum_p\sum_j f_{pjk}L_{pjk}$$

Q = Total cost of transporting the raw materials from areas of production to processing plants, cost of processing and storage of raw materials, and cost of distribution and storage of final product, expressed in Sudanese pounds (L.S.);
i = 1,...,12 (number of production locations);
k = 1,...,3 (number of time periods);
j = 1,...,87 (number of processing plants);
g = 1,...,11 (number of consuming regions for final product);
m = 1,2 (mode of transportation, rail or truck);
p = 1,2 (final product of processing, oil and cake);

D_g = total quantity of product p demanded;
D_d = domestic demand for product p;
D_e = export demand for product p;
P_s = total supply of product;
Z = level at which domestic demand for product p is fixed;
t_{ijm} = unit cost of shipping seeds from location i to processing plant j by mode m, in L.S. per tonne;
X_{ijk} = quantity of raw material (groundnuts, sesame or cottonseeds) shipped from region i to plant j for processing and storage in time k;
C_j = cost of storage of raw material at processing plant j in L.S. per tonne;
r_j = unit processing cost in L.S. per tonne of seeds;
t_{pmjg} = unit cost of shipping final product p by mode m from plant j to demand area g in L.S. per tonne;
H_{pjgk} = quantity of final product p shipped from plant j to demand area g in time k;
f_{pjk} = cost of storage of final product p at plant j in time k in L.S. per tonne per period;
L_{pjk} = quantity of final product p stored at plant j in time k;
S_i = quantity of raw material available at origin i to be shipped for storage and processing;
M_{jk} = capacity of processing plant j in period k in tonnes;
B_{jk} = raw material storage capacity at processing plant j in time k.

Subject to:

(1) Total quantity processed during the season in region i must be less or equal to the total quantity supplied:

$$\sum_j \sum_k X_{ijk} \leqslant S_i$$

(2) The quantity of raw material shipped to a processing plant must be equal to or less than the plant's processing and storage capacity:

$$\sum_i X_{ijk} \leq M_{jk} + B_{jk}$$

(3) The quantity of final product shipped must be equal to the quantity demanded:

$$\sum_j H_{jg} + D_g, \text{ all } g$$

(4) Total demand equals domestic demand plus export demand:

$$D_g = D_d + D_e$$

(5) Domestic demand is fixed at value Z. Export demand is equal to total supply of product less domestic demand:

$D_e = P_s - Z$

(6) Final product shipment equals final product equivalent of raw material processed:

$P = \infty_i \sum X_{ijk} + (1-\infty) \sum_i X_{ijk}$ for all j, k

Assembly and distribution cost estimates

Groundnuts, sesame, cottonseed and their products of oil and cakes use the same transportation facilities from auction markets and ginning factories to processing plants and from the processing plants to consumption centers. All seeds are packed in jute sacks, use the same transportation facilities, and transportation charges per tonne are the same. In the case of finished products, the cake is packed in jute sacks similar to those used for seeds, while oil is packed in 18-l plastic containers, i.e. no special transport facilities are required for them. The transport charges per tonne are the same as those for seeds.

Railroad rates and the distances between different points were obtained from the Sudan Railway Authority. Assembly and distribution costs by trucks were based on a questionnaire with a sample of 66 truckers and on interviews with 15 oilseeds merchants. Road mileages between auction markets and processing plants and between processing plants and demand centers were calculated with a map wheel using road maps and partly obtained from the Saaty study. Using the survey data of transportation rates and distances between points, a regression of rates upon actual mileage is fitted, in order to estimate transportation costs for all routes included in the model. The following estimating equation was found to fit the data:

$\log Y = 0.77 + 0.4693 \log X$

where Y = cost of transportation in L.S. per ton, and X = distance in km. (The F-value of the estimated equation was significant at the 1% level.) These assembly and distribution transportation cost coefficients are used in the linear programming model to determine the optimum spatial organisation of oilseed processing plants.

Processing cost estimates

A sample of 20 processing plant owners in different parts of the country were interviewed during the field survey to arrive at the processing cost function. Processing costs per unit are expected to vary with plant capacity because of the assumption of economics of size in processing. Given the total costs for plants with different management levels and in different locations, a scatter diagram representing the relationship between the quantity of raw material processed and processing cost was constructed. Ordinary least squares regression was then used to estimate the coefficients of the total cost function. Parameter estimates for the processing cost function were obtained using the linear and log-linear functional forms. Results in both cases are almost the same. The estimated linear total cost function is as follows:

$$\mathrm{TPC} = 45831 + 110X$$

where TPC = total cost of processing, annually, and X = quantity of seeds processed, annually. (The F-value of the estimated equation was significant at the 1% level.) The constant in the equation represents the fixed cost and the coefficient of X shows the amount by which total processing costs will increase with a unit increase in the quantity processed. The processing costs are used in the linear programming model together with the assembly and distribution costs to estimate the optimum number, size and location of processing plants.

The above information is incorporated into the linear programming transshipment model to solve the model for the optimal spatial organization of oilseed processing plants. A base model and five alternative solutions are solved. Parametric programming on the right-hand-side constraints and/or the objective function coefficients is performed to solve for the five alternative solutions. The parametric programming techniques are used to test the sensitivity of the base-model results to changes in supply of oilseeds, changes in demand for oilseeds, processing costs, plant location and plant operating capacity. The results of these alternative solutions are than compared with the results of the base model.

The model presented above was solved on a main-frame computer using an MPS (Mathematical Programming Systems) package. The model could also be solved using a similar software package on microcomputers, which are readily available to researchers in most developing countries today. Microcomputers now have the capcity to solve quite large linear programming models (Eastern Software Product, 1986). The linear programming models are solved within the framework of perfectly competitive markets.

Mathematical programming models are widely used to determine the optimum combination of plants that operate in a competitive market environment (Bressler and King, 1970). This is possible because each plant is assumed to operate on a fixed segment of its respective cost function. That is, as the total output of the industry increases the number of plants increases. Each plant has a cost coefficient that is consistent with its size category. Alternatively, cost coefficients may be changed to represent a change in the size of plant as the total volume in the industry increases. In a competitive market, economic incentives will generate the optimum number, size and location of firms, given adequate time for adjustments to occur. A government may also choose to accelerate the adjustment process by providing the appropriate economic

TABLE 1

Summary of analysis, basic solution and simulations for oilseeds industry of Sudan

Item	Optimal solution; plants at 50% of rated capacity for 1979/80	Basic solution; plants at 70% of rated capacity for 1979/80	Optimal plant location and size for 1979/80	An increase in domestic consumption of oilseeds by 20% for 1979/80	Optimal plant location and size for 1989/90	Closing of plants at the port area for 1989/90
Seeds moved and processed (t)	468 936	630 255	630 255	630 228	1 736 280	1 736 280
Total cost (L.S.$\times 10^6$)	65.6	90.5	84.7	83.8	241.5	243.0
Quantity oil distributed locally (t)	137 529	137 529	137 529	165 030	228 510	228 510
Oil exported (t)	31 761	90 000	90 000	62 490	398 250	398 250
Oil stored (t)	0	0	0	0	0	0
Cake distributed locally (t)	108 000	108 000	108 000	129 600	168 000	168 000
Cake exported (t)	192 600	294 000	294 000	272 400	945 000	945 000
Cake stored (t)	0	2010	2010	1994	0	0
Seeds exported (t)	407 064	245 745	245 745	245 772	0	0

Source: Babiker (1982).

incentives such as credit, taxes, subsidies, or infrastructure improvements. In a monopoly market situation, the firm with multi-plant facilities may choose to implement the results immediately because it has the power to do so.

Results of the transshipment model analysis

Although the model was used to obtain optimal solutions for the three time periods, this paper summarizes the results of the analysis for the whole year. Table 1 provides a summary of the analysis for the six alternative solutions that were studied. These solutions are as follows:

(1) Optimal solution for 1979/80 with plants operating at 50% of rated capacity and limited export of oil and cake. This was the situation in 1979/80.

(2) Plants operate at 70% of rated capacity with increased oil and cake exports and reduced seed exports in 1979/80. This was used as the base model.

(3) Optimal location, number and size of plants for 1979/80 compared to the base model.

(4) Domestic demand for oil and cake increases by 20% relative to the base model.

(5) Optimal location, number and size of plants based upon projections of raw material supply and final demand for 1989/90 compared to the base model.

(6) Closing of plants currently located in port area because of saline water problem at those plants with 1989/90 assumptions.

Optimal solution for 1979/80 with plants at 50% of capacity

In this solution, the 87 processing plants operate at 50% of rated capacity which is similar to the actual situation in 1979/80. This model solution shipped and processed 468 936 t of seeds, distributed 137 529 t of oil for domestic consumption, and 31 761 t for export (Table 1). For cake, 108 000 t are distributed for domestic consumption and 192 600 t are exported. The balance of the total seeds supply, 407 064 t, is exported as seeds. These are mainly groundnuts and sesame, since cottonseeds are not exported. However, the transportation and handling of unprocessed oilseeds for export are not included in the model. They are determined as the residual over the quantities processed.

The total cost as determined by the model is L.S. 65.6×10^6 or L.S. 140 per tonne*. This total cost includes the cost of handling and transporting the raw material from auction markets and ginning factories to the processing plants, the cost of processing, and the cost of handling and transporting the final products to the demand centers and the port. The processing costs include the fixed costs, charged to the first time period, and the operating costs for the whole year.

The basic solution: increasing the utilization of processing plant capacity for 1979/80

For the basic solution, the 87 processing plants operating in 1979/80 were categorized according to similarity in rated processing capacity. Twenty categories were obtained and each category was entered in the model as one processing unit. Assuming that the utilization of processing plant capacity can be increased to 70% and that unprocessed seeds can be diverted from export to processing, the model is run to evaluate the impact of increasing the utilization of processing capacity on the total cost of transportation, processing and distribution activities and on the average cost of processing. Other solutions in the following subsections are compared with this basic solution.

Column 3 of Table 1 displays the aggregate statistics for this solution. Changes in quantities processed and resulting output are evident. The total cost for the activities of transportation, processing and distribution is L.S. 90.5×10^6 or L.S. 144 per tonne compared to L.S. 140 per tonne in the previous solution. This represents mainly an increase in the total cost of transporting the raw material and distributing the final products to consumption centers because of a change in product flows. That is, the TADC and TC functions in Fig. 2 shift to the right.

To evaluate the impact of increasing the processing capacity on the average cost of processing, the total cost of processing equation is used. The average

*One Sudanese pound (L.S.) equals U.S. $2.00 at the official exchange rate in September of 1979.

cost of processing is found to be about L.S. 110 per tonne for both the 50% and 70% processing capacity solutions.

Optimal plant location, number and size for 1979/80

In contrast to the basic solution, the constraint on plant capacity for this solution was relaxed to find the optimum location, size and number of plants. The total quantity of seeds produced and processed, as shown in Table 1, is the same as in the basic solution. The quantity of seeds exported and the quantities of oil and cake distributed for local consumption or exported also remain the same as in the basic solution.

This optimal solution reduces the number of processing units from 20 to 13, yet all the domestic demand and export requirements of oil and cake as specified in the basic solution are met. To determine the optimum number and size of processing plants, the total quantity of raw material optimally assigned to any location is divided by the number of processing plants in the processing unit in that particular location. Based on this procedure, the total number of processing plants has decreased from 87 to 40, a reduction of more than 50%, as a result of the least-cost optimization procedure (Table 2). The optimum plant size ranges from 2000 to 65 000 t annual processing capacity compared to a range of 1000–26 000 t in the base solution for 1979/80. Because of the reorganization of the industry, total cost for performing the assembly, distribution and processing activities is L.S. 84.7×10^6 compared to L.S. 90.5×10^6 for the same activities in the basic solution, a reduction of L.S. 5.8×10^6 for the year. The per-unit cost, for all activities, is L.S. 134 compared to L.S. 144 for the basic solution, a 7% improvement in efficiency. The increase in the assembly and distribution costs due to the reduction in the number of plants is less than the sum of the reduction in processing costs (number of firms is decreasing) and assembly costs due to the more optimal location of plants (Fig. 2). That is, the TAC and TC functions shift to the left because processing plants have been shifted from the Khartoum region, where no raw material is produced, to regions where oilseeds production is concentrated (Fig. 1).

An increase in domestic consumption of oil and cake by 20%

For this variation, the model is used to determine the impact of an increase in the domestic demand for oil and cake by 20% on plant location and the total cost of transportation and processing for 1979/80. The quantities of oil and cake designated for export have been reduced by the amount of increase in domestic demand, since the same processing capacity is used.

The total quantity of seeds moved and processed is 630 228 t and the total quantity of oil and cake distributed in the domestic market is 165 030 t and

TABLE 2

Optimal solution for location, number and size of processing plants in Sudan, 1979/80 and 1989/90

Item	Processing unit code number locations defined for the model										
	1	2	3	4	5	6	7	8	9	10	11
Basic solution, 1979/80											
Number of processing plants in each unit	7	4	6	8	2	3	5	2	8	1	2
Average plant processing capacity (1000 t/year)	24	26	13	3	6	2	2	14	3	19	2
Optimal solution, 1979/80											
Number of processing plants in each unit[a]	1	0	0	0	2	3	5	2	8	1	2
Optimum plant capacity (1000 t/year)[a]	24	0	0	0	65	17	2	65	3	35	16
Optimal solution, 1989/90											
Number of processing plants in each unit[a]	1	0	0	0	2	0	5	2	0	1	2
Optimum plant capacity (1000 t/year)[a]	28	0	0	0	126	0	24	165	0	118	31

Item	Processing unit code number locations defined for the model									Total units selected	Total plants selected
	12	13	14	15	16	17	18	19	20		
Basic solution, 1979/80											
Number of processing plants in each unit	4	3	6	7	3	4	2	6	4	20	87
Average plant processing capacity (1000 t/year)	5	20	3	3	5	10	1	4	3		
Optimal solution, 1979/80											
Number of processing plants in each unit[a]	0	3	0	0	3	4	2	6	0	13	40
Optimum plant capacity (1000 t/year)[a]	0	28	0	0	27	14	36	6	0		
Optimal solution, 1989/90											
Number of processing plants in each unit[a]	0	3	0	0	3	4	0	6	0	10	29
Optimum plant capacity (1000 t/year)[a]	0	94	0	0	43	62	0	28	0		

[a]A zero indicates that the processing unit was excluded from the optimal solution.
Source: Babiker (1982).

129 600 t, respectively. The oil and cake quantities exported are 62 490 t and 272 400 t, respectively. The quantity of seeds exported is 245 772 t (Table 1).

The main impact of the increase in domestic demand for oil and cake is on the total cost of transportation, processing and distribution of final products. The total cost of these activities is L.S. 83.8×10^6 compared to L.S. 90.5×10^6 in the base solution, a reduction of L.S. 6.7×10^6 for the year, of a 7% decrease in costs. Total cost declines because the final product is shipped shorter distances when sold in the domestic market rather than in the export market. Shipments to the export port originate in interior areas of Sudan and must be transported long distances. This change shifts the TDAC and TC function to the left (Fig. 3). There is no significant change in plant location, number or size of plants and the percentage distribution of the processing activity among the regions.

The economic implication of the increase in domestic demand, assuming that it reduces the quantities exported, is that it will reduce the amount of foreign exchange earnings. Returns to farmers should not be affected if domestic prices are equivalent to international prices and the local currency is not overvalued. With an increase in oilseeds production and the development of processing capacity, however, production of oil and cake should be enough to satisfy domestic demand plus a surplus for export.

Optimal plant location, number and size for 1989/90

The projections of supply and demand of vegetable oil and cake were from published data that were based on certain expected relative changes in the supply of raw material and the demand for final products (Table 3). Increased investment to rehabilitate agricultural projects, currency devaluation, and measures to increase producers' incentives are the main reasons for expecting relative changes in supply. On the demand side, internal migration and different rates of population growth are reasons for the expected relative changes in domestic demand (Ministry of National Planning, 1980; World Bank, 1979). Exports are treated as the residual (supply minus domestic demand), with Sudan as a price taker in the world market. The projections of supply of raw material and demand for final products are used in the model to determine number, size and location of plants for 1989/90.

The model solution has 10 processing units comprising 29 processing plants to process the 1989/90 production compared to 87 processing plants for 1979/80 (Table 2). The average processing capacity ranges from 24 000 t to 165 000 t annually. The same procedure as before has been used to determine the optimum number and size of processing plants. Overall, the optimal solution for the 1989/90 production compared to the base model has fewer and larger processing plants. Relative future changes in the costs of processing resulting from changes in technology, for instance, may result in a different set of numbers

TABLE 3

Sudan oilseeds supply estimates and projections (in 1000 t)

	Average of 1978/79-1979/80	1989/90
Production		
Groundnuts		
Irrigated	202	564
Rainfed	310	580
Total	512	1144
Cottonseed	300	766
Sesame	230	350
Domestic disappearance[a]		
Groundnuts	255	524
Cottonseed	300	540
Sesame	171	195
Available for export		
Groundnuts	257	620
Sesame	59	155
Total	316	775

[a]Quantities used domestically for crushing, direct consumption, seeds, plus waste. See Babiker (1982) for derivation details.
Source: Ministry of National Planning (1980).

and sizes of processing plants. Due to a lack of appropriate data, however, this technology factor has not been incorporated in the model. (Should such changes occur, new input coefficients may be entered into the model to acquire a new optimal solution.)

The model required the movement and processing of 1 736 280 t of seeds with 228 510 t of oil distributed for domestic consumption and 398 250 t exported (Table 1). For cake, 168 000 t are distributed domestically and 945 000 t exported. The total quantity of seeds processed represents the total expected supply for 1989/90 with no export of seeds. The total cost of transportation, processing and distribution activities is L.S. 241.5×10^6 or L.S. 139 per tonne calculated at constant 1979/80 Sudanese pounds. This represents an upward shift in the TC function of Fig. 2.

The economic implications indicated by the results of the solution are more or less the same as those discussed for the plant location model for 1979/80. More returns are expected as a result of increased processing, since there is more value added. These returns will be reflected in increased payments for the factors of production involved, mainly processors and laborers. The reduction in transportation costs should benefit processors and farmers and/or reduce prices for domestic consumers.

The shift in distribution of processing activity to areas of production entails the development and strengthening of supporting facilities for the processing industry. Improvements in the infrastructure, such as establishing a packing materials industry, availability of spare parts, and improvement of the marketing services, are just a few of the areas where more emphasis on development is needed. The shift in processing activity also indicates that more jobs will be created in the areas of production. Again, this is expected to reduce migration from rural areas to the cappital city, especially of the young and productive members of those communities. Needless to say, this could help in solving the social and economic problems existing at the present time as a result of a very high urbanization rate (World Bank, 1979).

Closing of plants at the port area for 1989/90

The existing processing plants in Port Sudan have some technical problems, mainly the problem of saline water. These plants have so far been treated in the model as part of the Eastern region. This solution eliminates the port area as a possible location to determine the impact on processing plant location, number and size.

The solution for this model in terms of the quantity of seeds processed and the quantity of oil and cake produced and distributed or exported is the same as in the previous model. The overall processing acivity and distribution of final products are also the same.

There is no export of seeds; however, there is a change in the total cost of transportation, processing and distribution. The total cost for these activities is L.S. 243.0×10^6 when the port's processing plants are excluded, compared to L.S. 241.5×10^6 for the model with the port's plants included (Table 1). The model, including processing plants in the export port, represents the optimum plant location that minimizes the total cost of transporting the raw material, processing and distributing the final products. Logically, any diversion from that optimum solution would increase the total cost of these activities, causing the total cost curve to shift upward (Fig. 2). For this reason, there is an increase in total cost from L.S. 241.5×10^6 to L.S. 243.0×10^6 when the processing plants at the port are excluded. The increase in total cost of L.S. 1.5×10^6 could be compared to the cost of solving the saline water problem.

As expected, the solution results in a major change in the regional distribution of the processing activity. The share of the Eastern region in the total processing activity declines from 25 to 20%, while the share of the Central region increases by the same amount.

Conclusions

The optimal spatial organization of marketing facilities is a significant issue in most, if not all developing countries. Research results that identify opportunities to improve market organization that reduce marketing costs can assist public and private decision-makers in developing countries. The spatial organization model applied to oilseeds in the Sudan in the present paper is a case study example of how this technique could be applied to a wide range of marketing organization problems in developing countries.

Overall, the solution of the model has resulted in fewer and larger processing plants, lower per unit cost of transportation, and a geographical redistribution of the processing activity. A number of economic implications are indicated as a result.

For policy-makers, the redistribution of the processing activity complies with the present government policy of trying to bring together the small processing plants into larger, more economic units. Since the geographical redistribution reduces the costs of transportation, this will strengthen the country's comparative advantage, and increase exports and foreign exchange earnings. Moreover, since the redistribution gives more emphasis to processing in the areas of production, it is expected to create more employment in these areas and reduce migration of the labor force to the capital city. On the other hand, processing in the areas of production will mean establishing and maintaining the necessary supporting services for the processing industry to succeed in these areas. Marketing and transportation services, a packing industry, more availability of spare parts, banking services, etc., all need to be established and strengthened. The costs of adding this infrastructure would attenuate the benefits from a reorganization of the oilseed industry; however, all of the costs of the added infrastructure cannot be charged to the oilseeds industry, since the new infrastructure would serve the entire economy of the area. With further research, it would be possible but very difficult to estimate what portion of the infrastructure improvement costs should be allocated to the oilseeds industry and what portion should be allocated to the rest of the economy.

For processors and farmers, a reduction in transportation costs and the expected increase in exports will probably increase their returns and provide them with incentives to increase production. Consumers, on the other hand, could benefit from the increased efficiency by having reduced prices for oil.

The adjustments needed to reorganize the oilseeds industry to achieve the savings in costs and other benefits revealed by the analysis can be done in two ways. First, the older and smaller plants would close down and gradually be replaced by the optimum number, size and location of plants in a competitive market. The benefits of a full reduction in private costs would not be realized until all adjustments are completed.

Second, government policies that affect access to resources for new plants or expansion of existing plants could accelerate the adjustment process. Selection of the second alternative depends on how society as a whole values the reduced private cost relative to the required social investment.

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