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Sustainable development of mixed farming systems in a newly reclaimed area in Egypt

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SUMMARY – A linear programming (LP) technique was adopted to determine the optimum combination of crops and livestock production on small mixed farms in a newly reclaimed area in Egypt. Three locations reflected the different types of producer; traditional farmers, early retirees, and university graduates. One LP model with two scenarios was proposed. The base run (real-life situation) utilized farm available production resources of crop and livestock activities. The first scenario (LP1) was proposed to meet farmer's basic food needs and satisfy animals' requirements under the constraint of availability of Egyptian Pounds LE 10,000 as cash resources. The second scenario was the same as LP1 structure but modifying the farm size in the three studied locations to 10 feddan. It could be recommended that 10 feddan as farm size plus about 6 animal units with no less than 10,000 LE as cash resources is a reasonable structure for the development of the small mixed farm system in newly reclaimed areas in Egypt.

Keywords: Linear programming, gross margin, mixed farming, simulation.

***RÉSUMÉ –** "Développement durable de systèmes agricoles mixtes dans une zone nouvellement mise en valeur en Egypte". Une technique de programmation linéaire (LP) a été adoptée afin de déterminer la combinaison optimale pour la production des cultures et de l'élevage sur de petites exploitations mixtes dans une zone nouvellement mise en valeur en Egypte. Trois localités ont représenté les différents types de producteurs : fermiers traditionnels, retraités récents, et diplômés universitaires. Un modèle de LP avec deux scénarios a été proposé. L'exécution initiale (situation réelle) utilise les ressources disponibles à la ferme - production des cultures et de l'élevage. Parallèlement, un premier scénario (LP1) a été proposé pour répondre aux besoins des agriculteurs en aliments de base et en même temps pour satisfaire les besoins des animaux sous une contrainte de trésorerie de 10 000 livres égyptiennes disponibles. Le second scénario reprenait la même structure que LP1 mais en modifiant la taille de la ferme dans les trois localisations étudiées, pour l'amener à 10 feddans. Les recommandations ont été de 10 feddans comme taille de l'exploitation et environ 6 unités animales et pas moins de 10 000 LE comme trésorerie, comme structure raisonnable pour le développement d'un système de petites fermes mixtes dans les zones nouvellement mises en valeur en Egypte.*

***Mots-clés :** Programmation linéaire, marge brute, agriculture mixte, simulation.*

Introduction

In Egypt, about two million feddan (1 feddan = 4200 m^2) are classified as newly reclaimed area. This newly reclaimed area is sandy or saline soils recently recovered or rehabilitated for agricultural production (MOA, 2002). Mixed farming system, practicing both crop and animal production, represent the dominant farming system in most developing countries. The production of small-scale mixed farms is still low and would be raised to adequate standards to generate satisfactory income. This could be achieved by developing the skills of farmers and providing them with effective technologies to enhance the utilization of their limited resources.

The sustainability of agricultural production in newly reclaimed areas is constrained by many limiting factors. Farmers usually look for the best possible way for allocating their limited production resources among cropping and livestock activities. Moreover, farmers always seek on optimal mix of farming activities that maximizes their income. Farmers, often, follow their instinct and experience to handle this problem. Instinct and experience do not guarantee optimal results, however, linear programming models and simulation techniques offer a powerful and useful tool that can help farmers and assist the decision-maker in choosing the most efficient way to allocate scarce resources and to achieve a certain number of goals in order of their priority.

This study adopted linear programming (LP) and simulation techniques to evaluate the current small-scale mixed farming system in the newly reclaimed area in Egypt and investigate the impact of different proposed policy scenarios on the overall efficiency of the current mixed farming system.

Materials and methods

The study area

This study was carried out at South Tahreer Province. It is located in the west of Nile Delta at 120 km north west of Cairo between longitudes 30° 57' E and 30° 41' E and latitudes 29° 55' N and 29° 25' N. This area contains a variety of small-scale mixed farming systems of different farm size and type of farmers. Three locations were identified: (i) location 1, where the farmers were traditional settlers and the average farm size was 4.6 feddans; (ii) location 2, where farmers were mainly early retirees and the average farm size was 13.8 feddans; and (iii) location 3, that included university graduates and the average farm size was 15.4 feddans.

Data

A random sample of 155 farms was obtained. A questionnaire was designed to identify available production resources, animal and crop production performance, variable costs, and gross outputs. These data were collected during the agricultural year October 1995 to September 1996. Activities were wheat, berseem (*Trifolium alexandrinum*), groundnut, maize and livestock products (milk, meat and manure) named X_1, X_2, X_3, X_4 and X_5, respectively. Livestock was measured in animal unit (AU) according to Barnard and Nix (1993).

Data analysis

The data were analysed by least squares techniques using General Linear Model Procedure (SAS, 1998). The fixed effects linear model was used to analyse production resources and to develop technical coefficients of crop and livestock activities and level of inputs needed for each activity.

Farm budget was prepared (Table 1), including gross outputs, variable costs and gross margin. Variable costs for crops included labour, mechanical power, fertilization and seeds. Also, variable costs for livestock activities included labour, green fodders, concentrates, veterinary care. Technical coefficients derived from statistical and farm budget analyses were used in building up the simulation models.

Farm model structure

The general mathematical formula of the linear programming model used to simulates the behaviour of the current farming system (real-life situation) which is called base run and proposed policy scenarios in the three locations based on Quantitative System Business (QSB, 1987) software was as follows:

Objective function:

$$\text{Maximize (gross margin)} = \sum_{i=1}^{5} a_i X_i,$$

where: a_i = gross margin per unit for each variable of X_i ; X_i = number of feddans cultivated with wheat (X_1), berseem (X_2), groundnut (X_3), maize (X_4), and number of animal units (X_5).

Subject to:

- Land: $X_1 + X_2$ = average farm size (winter crops)
  $X_3 + X_4$ = average farm size (summer crops)

- Labour:

$$\sum_{i=j=1}^{5} c_j X_i \leq b,$$

where: c_j = number of units of man/day required for each commodity; b = maximum units of man/day available; and X_i as mentioned before.

- Available cash resources:

$$\sum_{i=j=1}^{5} d_j X_i \leq m,$$

where: d_j = variable costs for each variable X_i; m = available cash resources; and X_i as mentioned before.

- Non negativity:

$X_i \geq 0$, i = 1,….,5

Table 1. Gross outputs (GO), variable costs (VC) and gross margins (GM) in LE[†] (Egyptian Pounds) per feddan and per animal unit for the studied locations

Variables	GO[††]	VC[††]	GM
Location 1			
Winter crops			
Wheat	785	420	365
Berseem	720	186	534
Summer crops			
Groundnut	1165	497	667
Maize	644	378	266
Livestock	1078	309	769
Location 2			
Winter crops			
Wheat	423	202	221
Berseem	720	152	568
Summer crops			
Groundnut	478	406	72
Maize	229	130	99
Livestock	933	439	494
Location 3			
Winter crops:			
Wheat	394	330	64
Berseem	720	274	446
Summer crops			
Groundnut	645	537	78
Maize	292	359	-67
Livestock	1212	364	848

[†] 1 Euro = 7.5 LE.
[††] The marked differences in GO and VC among the three studied locations were due to the different production resources available in each location, in addition to management practices in each location.

Proposed policy scenarios

The study propose different government policy scenarios to sustain and enhance the overall efficiency of the current farming system, namely: (i) fulfil family's consumption of essential food (wheat and maize) in addition to using on-farm feeding resources to satisfying animal's requirements and an availability of 10 000 LE as cash resources (LP1); and (ii) the second scenario (LP2) was similar to LP1 in addition to adjust average farm size to be 10 feddan for each farmer in the studied area.

Results and discussion

Base run solution

Results of base run (real-life situation) that simulate the behaviour of current situation for the three studied locations are shown in Table 2. The base run solution revealed that, in order to maximize the farm income, farmers have to change their management practices of the current cropping pattern to be 3.25, 2.32 and 2.22 feddans of berseem in winter, and 2.32, 4.12 and 2.43 feddans maize in summer, along with 1.61, 1.14 and 1.37 animal units in the three studies locations, respectively. The proposed areas cultivated with berseem in winter, represented about 71%, 17% and 14% and those cultivated with maize in summer represented about 50%, 31% and 16% of farm size, in the three locations, respectively. The obtained results are not comparable with the real-life situation, this may due to high variable costs of cultivating wheat and groundnuts and higher gross margin of selected crops (berseem and maize). Livestock activity was found as a competitive activity with cropping. Herd size was small due to the limitation of cash resources.

The obtained results support the concept concluded by Bhatia and Gangwar (1981) that, farmers have different goals other than just maximizing their farm income. Also, Abdulkadri and Ajibefun (1998) suggested that farmers could have socio-economic objectives other than profit maximization like family satisfaction and diversification of strategic crops to avoid market risk. To deal with market risk problems many researchers (e.g. Charnes and Cooper, 1958; Madansky, 1962; Charnes and Cooper, 1963; Bawa, 1973; El-Shishiny and Attia, 1985; El-Shishiny, 1988; Rodríguez and Anderson, 1988) introduced various stochastic or multi-objective modelling techniques farm planning to avoid uncertainty problems.

Proposed scenarios solutions

The first scenario (LP1) was proposed mainly to reduce market risk due to cultivating only one type of crops obtained from base run solution and to satisfy farmers' basic needs, i.e. an attempt for farm self-sufficiency. Applying the LP1 scenario in the three studied locations revealed that there was no feasible solution for the location 1. This result could be due to the small farm size of location 1 (4.6 feddans).

The optimal LP1 solutions for locations 2 and 3 are presented in Table 2. The optimal LP1 solutions proposed that, farmers should cultivate 12.32 feddans wheat and 1.48 feddans berseem in location 2 and 11.53 feddans wheat and 1.86 feddans berseem and leave 2.01 feddans fallow in location 3 in winter. While, in summer, farmers should cultivate 2.43 feddans groundnuts and 11.37 feddans maize in location 2 and one feddans groundnuts, 5.6 feddans maize and leave 8.8 feddans fallow in location 3, along with 9.03 and 8.6 animal unit in the locations 2 and 3, respectively. The total crop area proposed by LP1 in location 3 is smaller than total farm size due to the limiting cash resources which led to not cultivating all farm size and leaving some fallow.

The optimal LP2 solutions for the three studied locations are shown in Table 2. The optimal LP2 solutions suggested that, farmers should cultivate 8.99, 8.5 and 9 feddans wheat and 1.01,1.5 and 1 feddans berseem in the three locations, respectively, in winter. While, in summer, farmers should cultivate 1, 7 and 1 feddans groundnuts and 9, 3 and 8 feddans maize in locations 1, 2 and 3, respectively. Moreover, the solution suggested that farmers in location 3 could leave one feddan fallow.

Table 2. Real-life situation, base run and proposed scenarios solutions of the three studied locations

Item	Real- life situation	Base run	LP1	LP2
Location 1				
Cropping pattern (feddan):				
Winter				
Wheat	1.95	---	No feasible solution	8.99
Berseem	1.65	3.25		1.01
Summer				
Groundnuts	3.05	---		1.00
Maize	1.39	2.32		9.00
Livestock production (animal units)	2.32	1.61		6.60
Location 2				
Cropping pattern (feddan)				
Winter				
Wheat	4.10	---	12.32	8.50
Berseem	2.67	2.32	1.48	1.50
Summer				
Groundnuts	4.85	---	2.43	7.00
Maize	2.33	4.10	11.37	3.00
Livestock production (animal units)	2.40	1.14	9.03	6.40
Location 3				
Cropping pattern (feddan)				
Winter				
Wheat	3.32	---	11.53	9.00
Berseem	2.35	2.22	1.86	1.00
Summer				
Groundnuts	4.41	---	1.00	1.00
Maize	1.65	2.43	5.60	8.00
Livestock production (animal units)	2.84	1.37	8.60	6.50

The result of LP2 solution for livestock activity was 6.6, 6.4 and 6.5 animal units in the three studied locations, respectively. These results show that the limitation of small farm size in location 1 in the LP1 constrained the farmers for using the high amount of the available cash resources to improve their farm income. While, in location 3, the cropping pattern was changing but as in the same trend as LP1 and the 8.8 feddan of fallow area obtained in LP1 in summer was decreased to 1 feddan in LP2. The number of animal units in this scenario was nearly the same in the three studied locations. This result indicated that livestock activity was not competitive with cropping activity, because, decreasing the farm size from 13.5 and 15.4 feddan in location 2 and 3, respectively to 10 feddan led to decrease the livestock activity. Moreover, the cultivated area in location 3 was increased from 6.6 feddan in LP1 to 9 feddan in LP2 during summer season.

Economic indicators

The gross margin per farm and return per unit of production resources (per feddan and animal unit) were used as economical indicator for the system efficiency. Base run solution revealed that the gross margin per farm was improved with value of 55%, 26% and 42% more than real-life situation in the three locations, respectively (Table 3). Gross margin in location 1 was the highest among of the three locations. This could be due to type of farmers who have more experience than the other farmers in the other two locations, small farm size made farmers use most available resources in their farms. These results in agree with other findings in previous studies as those conducted by, Siam, *et al*. (1994), Ahmed (1995), Ahmed *et al.* (1996), Mahmoud (1997) and Alsheikh *et al*. (2002).

Table 3. Economical indicators of the real-life situation and simulation models of the three studied locations (LE)

Item	Real-life situation	Base run	LP1	LP2
Location 1				
Gross margin/farm	2919	4524		12132
Return / feddan	635	983		1213
Return / animal unit	1258	2810		1838
Location 2				
Gross margin/farm	1730	2179	8638	6476
Return / feddan	128	161	640	648
Return / animal unit	720	1911	957	1012
Location 3				
Gross margin/farm	1654	2347	9361	7299
Return / feddan	107	151	608	730
Return / animal unit	582	1713	1088	1123

Applying the first scenario (LP1), the results showed that the gross margin per farm can be improved by 296% and 299% more than base run in the locations 2 and 3, respectively (Table 3). These high percentages could occur due to different available cash resources between base run and LP1. While, the difference between the two percentages indicated that farmers in location 3 were slightly more efficient than that in location 2. This difference could obtained due to slight differences on farm size between the two locations (13.8 *vs* 15.4).

The values of gross margin obtained in LP2 were improved to 12132, 6476 and 7299 LE in the three studied locations, respectively. This result confirmed that the farmers of location 1 were more efficient than the other two locations, because they used their own production resources economically and not due to small farm size only.

The return per feddan was improved about 55, 26 and 41% in base run compared to the actual situation in the three locations, respectively. While, the return per feddan in LP1 was improved about 297% and 303% compared to base run in the locations 2 and 3, respectively. This result could be supported the same result obtained in the first economical indicator. While, in the LP2, the return per feddan was improved 1% and 20% in locations 2 and 3 respectively. This result indicated that decreasing the farm size to 10 feddan did not affected strongly the return per feddan.

The return per animal unit was improved by about 123, 165 and 194% in base run compared to the real-life situation in the three locations, respectively. These high percentages could occur due to a theoretical assumption: that the farmers in the three locations already have the animals. Anyhow, these percentages indicated that there was an observed result against that obtained in the first and second economical indicators, which suggested the farmers in location 1 were more efficient than those in the other two locations, in addition to increasing farm size to 10 feddan and soft loan of LE 10,000. This result is due to the fact that farmers in the other two locations prefer livestock activities than cropping activities. While, the return per animal unit in LP1 was decreased about 100% and 57% in the locations 2 and 3, respectively. This result could occur because the farmers in location 2 cultivated 13.8 feddan in both winter and summer seasons in LP1 *vs* 2.32 feddan in winter and 4.1 feddan in summer in the base run solution. Also, this result could occur due to the small number of the animal units obtained from base run solution (1.14 animal units in location 2). The same trend was occurred in location 3. This result also supported that farmers in the other two locations could prefer livestock activities than cropping activities, because they kept high number of animal units (9.03 and 8.6 animal units in location 2 and 3, respectively) and leaves some fallow.

Applying LP2 scenario revealed that the return per animal unit decreased in comparison with results of base run to values of 1838, 1012 and 1088 LE, in the three studied locations, respectively. This result may be due to the increasing number of herd size recommended by the optimal solution. In general, the return per animal unit under both real-life situation and the proposed two scenarios was higher than the return per feddan.

It could be recommended that, 10 feddan as farm size plus about 6 animal units with not less than 10,000 LE as cash resources is a suitable structure for developing the small-scale mixed farming system in newly reclaimed areas in Egypt.

Conclusion

Results of the present study revealed that simulation and linear programming techniques provide full information about the impact of the proposed policy on farm income before implementation. It is of a great interest to notice that response of different proposed scenarios has not the same impact on farm income in the studied area. This could be attributed to the differences of production resources and management practices among the studied locations. The proposed models are a valuable planning tool formulated to assist decision-makers in evaluating alternative policy for sustainable development of newly reclaimed areas in Egypt.

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