The Optimal Distribution of Arable and Non-Invested Lands for Irrigated Crops by Using Linear Mathematical Programming / Swaida Governorate

Maya Al-Abdala* (1), Safwan Aboassaf (1), and Afraa Sallowm(2)

(1). General Commission for Scientific Agricultural Research (GCSAR), Syria

(2). Faculty of agriculture, department of agricultural economics, Damascus University, Syria

(*Corresponding author: Dr. Maya al-abdala: mayaabdala6@gmail.com)

Received: 6/ 12/ 2023 Accepted: 9/ 3 /2024

Abstract

The research aims to determine the optimum-cropping pattern that maximizes the net unit return in the case of increasing the cultivated area, which is represented by agricultural lands that are not invested by farmers and are arable in Swaida governorate/Syria by using Linear Mathematical Programming. Through a questionnaire targeting 106 farmers during the 2020 agricultural season. The results after solution of the proposed linear programming model showed: An increase in the actual cultivated area by 21.14% an area estimated at 1715.7 Dunums. As a result, the total net return of the proposed alternative increased by 111.75% over the net return of the actual cropping, as the total achieved revenue amounted to about 611.46 million SP, compared to 288.76 million SP net return actual cropping. The study recommends the need to use the linear programming technique, as one of the quantitative research methods in management, which achieves the case for the optimal use of economic resources.

Keywords: Linear Programming. Optimal Cropping. Maximization. Net Return. Constraints**.**

Introduction:

Optimal crop composition has always expressed the optimal combination of crops that achieve the largest possible profit margin, based on input prices and outputs of the production process, and the productivity of the area. This is with the existence of a competitive relationship on agricultural land between different crops in one agricultural season. The increase in the area of one crop is always at the decrease of the area of other crops, especially if the total supply of agricultural land is fixed and limited (Al-Shazly *et al.*, 2009). Policies to achieve self-sufficiency through land reform and increasing the area of arable land require optimal distribution of this increase so that it achieves the best possible return on crop composition within the constraints of existing water, land and regulatory resources.

The methodology of mathematical linear programming is one of the sciences that helps make decisions in a more accurate manner and away from the randomness resulting from trial and error. Among the studies that have used the linear programming methodology to achieve the optimal cropping pattern: In The study (Saman *et al.*, 2014) in determining the optimal cropping pattern using mathematical programming and focusing on sustainable agriculture in the city of Boroujerd in Iran during 2010-2011. The results showed that to reach the value of the optimal crop pattern, must increase the wheat, beet Sugar, fodder corn compared to the actual pattern, and reduce the barley area, and stability in bean area. In the study of (Igwe and Onyenweak, 2013), the linear programming technique was applied to thirty farms to maximize the profit margin from different mix of crops and livestock projects, the proposed model increased about 61.35% over the current gross margin, with planting and allocating: 0.31 hectares for potatoes Sweet/maize/melon, 0.33 ha to cassava/maize/sweet potato and 1.30 ha to cassava/maize/sweet potato/legume crop, the study recommended that farmers mix crop cultivation with poultry and fish farming to improve the gross profit margin. Farmers have to choose among a variety of complex ways of production. Crop planning may involve choices about varieties, planting dates, fertilizer, and pesticide treatments. Linear programming has proved a very flexible tool for modeling these kinds of complexities and it was developed to determine the optimal crop pattern for a rural farmer. Crops considered maize, soya beans and cotton. The proposed model produced an optimal crop combination that gives higher income than that obtained from the farmer's plan. The income difference was 72.79 percent. (Majeke *et al.*, 2013). With the aim of maximizing net profit, from ten current agricultural crops by using linear programming in one region of India, based on constraints related to: (costs of seeds, fertilizers and pesticides), crop yield, labor wages, machinery expenses, and selling price during 2009-2010.The proposed model included 21.49 %, 13.47%, 15.97%, 18.08%, 14.8% of the lands for cotton, legumes, green chickpeas, soybeans, millet respectively and there is no allotment for wheat (Wankhade & Lunge, 2012).

Research problem: Population density and the increase in demand for agricultural products motivated farmers to increase the cultivated area in order to cover food needs and in pursuit of self-sufficiency. Various agricultural mechanization has facilitated agricultural investment in increasing the cultivated areas and diversifying crops. This was accompanied by farmers' tendency to produce highly profitable crops, which led to an uneconomic depletion of the most important agricultural productive resource, which is the land. Therefore, with the possibility of increasing the agricultural areas of crops, this requires the optimal distribution of the composition of irrigated vegetables in Swaida governorate that based on a scientific approach in management and away from randomness in decision-making, which is the mathematical linear programming to achieve the highest possible return.

Research objective: The main objective of this research is to determine the optimum cropping pattern that increases the net unit return in the case of increasing the cultivated area, which is represented by agricultural lands that are not invested by farmers and are arable.

Materials and Methods

The study was conducted in Swaida governorate, southern Syria during 2020 agricultural season. The research was based on primary data through a questionnaire targeting irrigated vegetable farmers. And it included questions related to the composition of crops approved by farmers in the study area. Secondary, data were also relied on the number of irrigation wells that have been operating for at least three consecutive years to irrigate vegetable crops. the sample size is consisted of (106) observations, and according to the following formula (Glenn, 1992; Yamane, 1967):

$$n = \frac{N}{1 + N(e)^2}$$

Where: N: The studied community, which identified as owners of these wells, which amounted to 221 wells (Department of Agricultural Extension, 2020)

e: Precision Level %7± Where Confidence Level is 95%. n: size sample.

Statistical methods: Descriptive analysis methods: to describe the study variables such as means and percentage. Quantitative analysis in management: to one of the models of operations research is a Linear Programming Model. The LP model takes the following mathematical form: (Vanderbei, 2001)

$$\text{(Maximization) or (minimization) } Z = \sum_{J=1}^{n} C_j X_j$$

$$S/C:$$

$$\sum_{j=1}^{n} a_{ij} X_j \geq\leq b_i \qquad \text{for } i = 1, 2, \dots \dots, m$$

$$X_j \geq 0, \quad \text{for } j = 1, 2, \dots, \dots, n$$

Where:

Max z: The objective function in Maximization, which is the sum of the net returns from different crops of the crop pattern, (Syrian Pound).

X_j: Decision variables of the linear program to be defined, representing the areas of the crops constituting the crop pattern (Dunums).

C_j: the variables' parameters that effecting on the function, representing the net yield of a Dunum of the different crops (S.P/Dunum).

$a_{11} \dots a_{1m}$: The parameters of a linear program's variable used by each resource and are known.

$b_1 \dots b_m$: represents the available resources that are known and specific.

And all xj are ≥ 0: are non-negativity constraint.

Results and Discussion

1. Characteristics of the study sample:

1.1. Settlement zones:

The studied sample randomly covered Settlement Zones, the second Zone represented the highest percentage by about 84.91%, and Swaida administrative region represented the highest percentage by about 60.38%. Table (1).

Table (1): Distribution of sample according to administrative regions and settlement Zones.

Administrative Regions	Settlement Zones			Total	%
	First	Second	Third		
Salkad	10	22	2	34	32.08
Swaida	4	60	0	64	60.38
Shahba	0	8	0	8	7.55
Total	14	90	2	106	100
%	13.21	84.91	1.89	100	

Source: Questionnaire, 2020.

1.2. Geographical:

Table (2) shows the minimum and upper limits of the rainfall and the altitude, where the average rainfall amounted to 292.8 mm, and the average height above sea level was 1010.47 m in the sample.

Table (2): Rainfall and the altitude in studied sample.

Item	Minimum	Upper	Average	S. D
Rainfall/mm	125	380	292.83	78.58
Altitude/m	650	1470	1010.47	306.78

Source: Questionnaire, 2020.

1.3. Cultivated area characteristics in the study sample:

Table (3) shows the distribution of the actual cultivated. It was noted that the actual cultivated irrigated area was 8116.3 Dunums. Summer cultivated exceeded an area of about 6065.9 Dunums, compared to 2050.4 Dunums of total winter cultivated area. While the total cultivated area invested and not invested in the study sample was about 9832 Dunums, that is, there are about 1715.7 Dunums of land that can be invested in the sample but have not been introduced into the production process.

Table (3): Minimum and maximum limits of the area of the actual cultivated irrigated areas approved by farmers for the 2020 season. Dunum

	Min	Max	Sum	Mean	Std. Deviation
Total Actual Cultivated Irrigated Area	1.00	310.00	8116.3	77.55	79. 9
Total summer Cultivated area	1.00	285.00	6065.90	61.9	62.6
Total winter Cultivated area	.50	165.00	2050.40	35.8	39.85
Total Cultivated area planted and not planted	4.00	1000.00	9832.00	92.76	116.18
Investment able Cultivated area	.00	910.00	1715.7	35.35	92.31

Source: Questionnaire, 2020.

By comparing the averages between the actual cultivated area and the Total Cultivated area planted and not planted in the study sample, One Way ANOVA showed statistical significance of the differences between the mean areas at the 1% level, as shown in Table (4).

Table (4): Significance of differences between the actual and investable area averages.

			Sum of Squares	df	Mean Square	F	Sig.
Actual Cultivated Irrigated Area * Total Cultivated area	Between Groups	Combined	266468.380	31	8595.754	16.19	<.001
	Within Groups		39289.176	74	530.935		
	Total		305757.557	105			

Source: The results of IBM SPSS 28.

2. Alternative model (increasing the area):

The area of arable lands that are not invested by farmers in the study sample amounted to 1715.7 Dunums. By about 21.14% of the actually cultivated area. The reasons for not investing are different. An analytical framework was built to reach the optimal crop composition, provided that none of the crops and vegetables are excluded from the actual crop composition, whether summer or winter, and within the constraints of the land resources available for each crop, and for the total cultivated area. The following is the mathematical form of the proposed alternative model in the event of benefiting from the increase in the agricultural area to maximize the net return.

2.1. Mathematical form:

– **objective function:**

max: $z = 1936.4 * X1 + 207911 * X2 + 350619 * X3 + 1928 * X4 + 101921 * X5 + 29939.2 * X6 + 159908 * X7 + 22687.2 * X8 + 32526.2 * X9 + 13209.5 * X10 + 78421.2 * X11 + 101728 * X12 + 1.89305e + 006 * X13 + 16812.5 * X14 + 45562.5 * X15 + 38966.7 * X16 + 1254 * X17 + 149082 * X18 + 12879.1 * X19$

Max Z: Maximizing the net return per area unit for all crops.
C_i: net return per area unit for each crop.
X_i: Crop. Tomato, Eggplant, Pepper, Watermelon, Melon, Cucumber, Squash, Armenian cucumber, Okra, Beans, Potato, Onions, Garlic, Cabbage, Cauliflower, Peas, Broad Beans, Parsley, Wheat.

– **Constraints:**

i. Land constraints: which includes three constraints:

- The total area of irrigated winter crops equal or greater than the total irrigated winter area.

$$X13 + X14 + X15 + X16 + X17 + X18 + X19 <= 2050.4$$

- The total area of irrigated summer crops equal or greater than the total irrigated summer area.

$$X1 + X2 + X3 + X4 + X5 + X6 + X7 + X8 + X9 + X10 + X11 + X12 <= 6065.9$$

- Total irrigated area equal or less than the Total investable irrigated area.

$$X1 + X2 + X3 + X4 + X5 + X6 + X7 + X8 + X9 + X10 + X11 + X12 + X13 + X14 + X15 + X16 + X17 + X18 + X19 = 8116.3$$

ii. Structural constraints: The minimum and upper limits have been set for the area of each crop:

- The minimum limit for each crop equal or greater than 50% of the total area of the crop.

Minimum limit tomato	X1 >= 1770.7	Min. lim. potato	X11 >= 158.5
Min. lim. eggplant	X2 >= 135.8	Min. lim. onion	X12 >= 50
Min. lim. pepper	X3 >= 80.25	Min. lim. garlic	X13 >= 14
Min. lim. watermelon	X4 >= 597.25	Min. lim. cabbage	X14 >= 80.05
Min. lim. melon	X5 >= 50.25	Min. lim. cauliflower	X15 >= 176.55
Min. lim. cucumber	X6 >= 98	Min. lim. peas	X16 >= 162.95
Min. lim. squash	X7 >= 38.7	Min. lim. Broad Beans	X17 >= 74.95
Min. lim. Armenian cucumber	X8 >= 23	Min. lim. parsley	X18 >= 13
Min. lim. okra	X9 >= 8	Min. lim. wheat	X19 >= 504.95
Min. lim. beans	X10 >= 22.5		

- The upper limit for each crop equal or less than the total area of the crop planted except (tomatoes, wheat, potatoes, and watermelons) to direct them to the excess area because they are very important and related to self-sufficiency in the region.

maximum limit eggplant	X2 <= 271.6	Max. lim. onion	X12 <= 100
Max. lim. pepper	X3 <= 160.5	Max. lim. garlic	X13 <= 28
Max. lim. melon	X5 <= 100.5	Max. lim. cabbage	X14 <= 160.1
Max. lim. cucumber	X6 <= 196	Max. lim. cauliflower	X15 <= 353.1
Max. lim. squash	X7 <= 77.4	Max. lim. peas	X16 <= 325.9
Max. lim. Armenian cucumber	X8 <= 46	Max. lim. Broad Beans	X17 <= 149.9

Max. lim. okra	X9 <= 16	Max. lim. parsley	X18 <= 23.5
Max. lim. beans	X10 <= 45		

- Non-negativity constraint. $x_{ij} \geq 0$

2.2. Area distribution:

Table No. (5) Shows the distribution of additional arable and non-invested areas (1715.7) Dunum according to Alternative model. In order to achieve the best crop pattern that increases the net return per unit area, the cultivated area of potatoes and wheat, respectively, increased by 4209.15 , 100.95 Dunums. And fixing the area of: eggplant, pepper, melon, Squash, onion, garlic, cabbage, flower, peas, parsley. And reduce the area of watermelon, cucumber, ajjour, okra, beans, broad beans and tomatoes by about 597.25, 98, 23, 8, 22.5, 74.95, 1770.7 Dunum respectively, i.e. a reduction of the actual area by 50%.

Table (5): Area Distribution according to Alternative Model.

Code	Crops	Area/ Dunums		The difference between the actual and the proposed / acres	The difference Ration %
		Actual	Proposed		
x11	Potato	317	4526.15	4209.15	1327.81
x20	Wheat	1009.9	1110.85	100.95	10.00
x2	Eggplant	271.6	271.6	0	0
x3	Pepper	160.5	160.5	0	0
x5	Melon	100.5	100.5	0	0
x7	Squash	77.4	77.4	0	0
x12	Onion	100	100	0	0
x13	Garlic	28	28	0	0
x14	Cabbage	160.1	160.1	0	0
x15	Cauliflower	353.1	353.1	0	0
x16	Peas	325.9	325.9	0	0
x19	Parsley	23.5	23.5	0	0
x4	Watermelon	1194.5	597.25	-597.25	-50
x6	cucumber	196	98	-98	-50
x8	Cucumber Ajjour	46	23	-23	-50
x9	okra	16	8	-8	-50
x10	Beans	45	22.5	-22.5	-50
x17	Broad Bean	149.9	74.95	-74.95	-50
x1	Tomato	3541.4	1770.7	-1770.7	-50
Total		8116.3	9832	-	-

Source: The results of Solver Program

2.3. Net Return from Alternative Model:

The total net income increased by 111.75% over the net return of the actual pattern, reaching a total of about 611.46 million SP, compared to 288.76 million SP net income of the actual pattern. Table No. (6) Shows the distribution of this increase on crops whose returns have increased, crops that have not changed, and crops whose returns have decreased.

Table (6): Net return from Alternative Model.

Code	Crops	Actual Return per D / SP	Total Return for all area/ SP *million		The difference/ SP *million	The difference ratio %
			Actual	Proposal		
x11	Potato	78421.2	24.86	354.95	330.09	1327.81
x20	Wheat	12879.1	13.01	14.31	1.30	10.00
x2	Eggplant	207911.2	56.47	56.47	0	0
x3	Pepper	350619.1	56.27	56.27	0	0
x5	Melon	101921.2	10.24	10.24	0	0
x7	Squash	159908.2	12.38	12.38	0	0
x12	Onion	101728.3	10.17	10.17	0	0
x13	Garlic	1893052	53.01	53.01	0	0
x14	Cabbage	16812.5	2.69	2.69	0	0
x15	Cauliflower	45562.5	16.09	16.09	0	0
x16	Peas	38966.7	12.70	12.70	0	0
x19	Parsley	149081.9	3.50	3.50	0	0
x17	Broad Bean	1254	0.19	0.09	-0.09	-50
x9	Okra	32526.2	0.52	0.26	-0.26	-50
x10	Beans	13209.5	0.59	0.30	-0.30	-50
x8	Ajjour	22687.2	1.04	0.52	-0.52	-50
x4	Watermelon	1928	2.30	1.15	-1.15	-50
x6	Cucumber	29939.2	5.87	2.93	-2.93	-50
x1	Tomato	1936.4	6.86	3.43	-3.43	-50
	Total		288.76	611.46	322.70	111.75

Source: The results of Solver Program.

Conclusion.

The study applied the linear programming method to Suggesting an optimal cropping pattern that maximizes the net return in the event of the possibility of increasing the irrigated area using the cultivable and not invested area, provided that none of the crops of the actual crop pattern, whether summer or winter, are excluded. The result shows the distribution of additional arable and non-invested areas 1715.7 Dunum according to Alternative model. In order to achieve the best crop pattern that increases the net return per unit area, the cultivated area of potatoes and wheat, respectively, increased by 4209.15, 100.95 Dunums. And reduce the area of watermelon, cucumber, ajjour, okra, beans, broad beans and tomatoes by about 597.25, 98, 23, 8, 22.5, 74.95, 1770.7 Dunum respectively, i.e. a reduction of the actual area by 50%. The total net income increased by 111.75% over the net return of the actual pattern, reaching about 611.46 million SP, compared to 288.76 million SP net income of the actual pattern

The study recommends:

- The need to use the linear programming technique as one of the quantitative research methods in management, which achieves the case for the optimal use of economic resources.
- The necessity of investing all arable land that has not been included in the production process within investment plans that work to increase the return per unit area on the one hand, and the possibility of providing an increase in production for export.

References:

Al-Shazly, F.; M. Mahmoud; A. Musa; and Sh. Imad (2009). Egyptian crop composition in light of local and international risk and changes, working paper at a conference on new policies to promote the agricultural sector in Egypt, October 4, 2009

Glenn, D.I (1992). Determining Sample Size. Florida Cooperative Extension Service. University Of Florida. Fact Sheet Peod-6.

Igwe, K.C. and C.E. Onyenweaku (2013). A Linear Programming Approach to Food Crops and Livestock Enterprises Planning In Aba Agricultural Zone of Abia State, Nigeria. American Journal of Experimental Agriculture. 3(2):412-431.

Majeke, F.; M.T. Mubvuma; K. Makaza; and J. Mutambara (2013). Optimum Combination of Crop Farm Activities: Application of a Linear Programming Model to a Rural Farmer in Zimbabwe. Greener Journal of Economics and Accountancy. 2(2):58-61.

Ministry of Agriculture and Agrarian Reform. Directorate of Agricultural Extension0 unpublished Data 2020. Swaida, Syria.

Saman Z.; K. Hadis; K. Elham; and S. Samira (2014). The Determination of Optimal Cropping Pattern Using Mathematical Programming with an Emphasis on Sustainable Agriculture (Case Study: Boroujerd City). Journal of Applied Environmental and Biological Sciences. 4(3):21-25.

Vanderbei, R. J. (2001). Linear Programming: Foundations and Extensions. (2nd ed.). department of operations research and financial engineering, princeton university, princeton.

Wankhade, M.O.; and H. S. Lunge (2012). Allocation of agricultural land to the major crops of saline track by linear programming approach: a case study. International journal of scientific & technology research. 1(9):21-25.

Yamane, T.; (1967). An Introductory Analysis 2. Nd Ed., New York: Harper and Row.

التوزيع الأمثل للأراضي الصالحة للزراعة وغير المستثمرة للمحاصيل المروية باستخدام البرمجة الخطية الرياضية/ محافظة السويداء

مايا العبد الله*[1] و صفوان أبو عسّاف[1] و عفراء سلوم [2]

(1). الهيئة العامة للبحوث العلمية الزراعية، إدارة بحوث الدراسات الاقتصادية والاجتماعية، سوريا

(2). كلية الزراعة، قسم الاقتصاد الزراعي، جامعة دمشق، سوريا

(*للمراسلة: د. مايا العبد الله Mayaabdala6@gmail.com)

تاريخ الاستلام: 2023/12/6 تاريخ القبول:2024/3/9

الملخص

يهدف البحث إلى تحديد التركيب المحصولي الأمثل الذي يزيد من صافي عائد وحدة المساحة في حالة زيادة المساحة المزروعة والمتمثلة بالأراضي الزراعية غير المستثمرة من قبل المزارعين والمزروعة في محافظة السويداء / سورية باستخدام أسلوب البرمجة الخطية الرياضية، من خلال استبيان استهدف 106 مزارعين خلال الموسم الزراعي 2020. أظهرت النتائج بعد حل نموذج البرمجة الخطية المقترح: زيادة المساحة المزروعة الفعلية بنسبة 21.14٪ وتقدر المساحة بـ 1715.7 دونم. ونتيجة لذلك، ارتفع إجمالي العائد الصافي للبديل المقترح بنسبة 111.75٪ عن صافي عائد المحصول الفعلي، حيث بلغ إجمالي الإيرادات المحققة حوالي 611.46 مليون ل.س مقابل 288.76 مليون ل.س صافي العائد المحصول الفعلي. أوصت الدراسة بضرورة استخدام تقنية البرمجة الخطية كأحد أساليب البحث الكمي في الإدارة والتي تحقق حالة الاستخدام الأمثل للموارد الاقتصادية.

الكلمات المفتاحية: البرمجة الخطية. التركيبة المثلى. تعظيم. العائد الصافي. القيود.