THE OPTIMAL CROP ROTATION OF AI-RASHEED DISTRICT FARMS USING LINEAR PROGRAMMING TECHNIQUE

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ABSTRACT

The objectives of this research are to determine the optimal agricultural plane to achieve the optimum crop combination that maximizes the profits and the total and net agricultural income of the Al-Rasheed / Hamorabi Farm in Baghdad using L.P technique to reach the production volume that maximizes profit to choose the best plan and to increase the efficiency of the use of available resources at the farm level, to optimize the utilization of natural water resources and to protect them from the risk of attrition and to promote their use by deriving mathematical models for use in water needs assessment, including the application of an agricultural rotation to maintain soil fertility. The research has reached a number of conclusions, perhaps the most important is that the optimal solution using the linear programming method shows us the difference in the optimum crop combination of the actual crop structure of the agricultural crops and their areas. The farm has achieved a much higher income than the resulting income of the actual farm plan, as explained by the resource-based model, the LHS of the model, is less than the available resources that represent the RHS, which means that optimal plans have used fewer resources and given higher net income. From the conclusions reached, we can make a number of recommendations. The most important of these is the implementation of the linear programming technique to determine the extent to which the available resources are invested efficiently, which helps to increase the production in order to achieve the economic efficiency of the farmers and the need to generalize and apply this method in associations with similar environments to determine the optimal use of different productive resources.

Keywords: Agricultural planning, agricultural rotation, economic planning, sustainable development.

التعاقب المحصولي الأمثل لمزارع ناحية الرشيد باستخدام أسلوب البرمجة الخطية

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المستخلص

تمثل أهداف البحث تحديد الخطة المزرعية المثلى لغرض التوصل إلى التركيب المحصولي الأمثل الذي يحقق تعظيما للأرباح ولإجمالي وصافي الدخول المزرعية لمزارع ناحية الرشيد/ جمعية حمورابي في بغداد, باستخدام اسلوب البرمجة الخطية L.P للوصول إلى حجم الإنتاج الذي يعظم الربح لاختيار أفضل خطة مزرعية ذات أعلى صافي دخل, ورفع كفاءة استخدام الموارد المتاحة على مستوى المزرعة فضلا عن تحقيق الاستخدام الأمثل لموارد المياه الطبيعية وحمايتها من مخاطر الاستنزاف والعمل على تعزيز استخدامها من خلال اشتقاق نماذج رياضية لاستخدامها في تقدير الاحتياجات من مختلف الموارد الإنتاجية بما فيها تطبيق دورة زراعية من أجل المحافظة على خصوبة التربة. لقد توصل البحث إلى مجموعة من الاستنتاجات لعل أهمها أن الحل الأمثل باستخدام أسلوب البرمجة الخطية يوضح اختلافا في التركيب المحصولي الأمثل عن التركيب المحصولي الفعلي للمحاصيل الزراعية واختلافا في مساحاتها وقد حققت المزرعة دخلا يفوق بكثير الدخل الناتج من الخطة المزرعية الفعلية، كما اوضح هذا الحل أن المستغل من الموارد والذي يمثل الجانب الأيسر (LHS) من الأنموذج هو أقل من الموارد المتاحة والتي تمثل الجانب الأيمن (RHS)، مما يعني أن الخطط المثلى قد استخدمت موارد أقل واعطت صافي دخل أكبر, وبناءً على ما تقدم فإن البحث يقدم عددا من التوصيات أهمها تطبيق أسلوب البرمجة الخطية لمعرفة مدى استثمار الموارد المتاحة بشكل كفوء مما يساعد على زيادة الإنتاج بهدف تحقيق الكفاءة الاقتصادية للمزارعين وضرورة تعميم هذا الأسلوب وتطبيقه في الجمعيات الزراعية ذات الظروف المشابهة لتحديد الاستخدام الأمثل لمختلف الموارد الإنتاجية.

الكلمات المفتاحية: التخطيط الزراعي، الدورة الزراعية , التخطيط الاقتصادي، التنمية المستدامة.

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INTRODUCTION

Agricultural sector is generally suffering from underdevelopment and low unit productivity in developing countries, it is imperative for those interested in this sector to focus their attention on the stylistics and scientific methods that lead to increased production. Therefore, economic planning and the use of the scientific method in agricultural production are the basic and sufficient condition for achieving agricultural development objectives, the expansion in the agricultural production and the rise in the rate of the production components by the rational use of natural and formal resources will undoubtedly return with an increase in financial output and per capita income, so it is clear that the agricultural sector has a significant role in raising the level citizens income, and provide the local market and industry sector with theirs raw materials needs, as well as less reliance on world markets provide food and increase export opportunities . Despite the importance of the agricultural sector relative to other sectors, it is noted that the productivity of one dunum due to weak planning process of different agricultural units both at the level of the agricultural enterprise that manages and planning the production or at the level of one agricultural pattern, as well as due to the lack of optimal use of limited agricultural resources, whether land, water, human or capital which led to affecting in total agricultural production and high costs. Economic resources should therefore be reallocated which in turn contributes to achieve the productive efficiency of these resources which is to obtain more output with the same quantities of resources available or to obtain the same quantities of output but with fewer amounts of resources in an effort to balance in order to meet the needs of economic development ,so farms in general suffer from not optimally allocating of the economic resources available to them from the production elements used in the production processes, resulting low productivity and higher production costs per unit of production, and caused suffering farmers losses because of not using the scientific techniques for the use of economic resources available to them, which leads to a decline in their ability to create value added and then contribute to the composition of GDP, resulting in a slowdown in the growth of this sector compared to what can be achieved when the decision-maker in this section use the appropriate scientific technique to reallocate the available economic resources according to the scientific technique to achieve their optimal utilization. Due to the multiple aspects of economic activity within the national economy, the economic planning process has become complicated since it is difficult to develop an effective economic plan without the use of modern mathematical methods, which deals with the quantitative analysis of economic phenomena and aims to raise the total agricultural production and reduce its costs. Thus the research aims to reach an optimal farm plan to reach the optimal agricultural mix of the Al Rashid farms, using the linear programming technique to reorient agricultural production and conduct comprehensive economic planning of economic resources to increase the efficiency of the use of available resources (including agricultural resources , land and irrigation water) at the farm level to optimize the use of natural water resources ,and to protect them from the risk of attrition and to promote their use through the development of mathematical models for use in the assessment of water needs, including the application of agricultural rotation. Agricultural rotation is like any other technique that must be adopted to be effective. The adoption rate of any technology depends largely on the net yield achieved (25), in order to maintain soil fertility. The application of the agricultural rotation leads to not loss the fertility of the agricultural land as well as the improvement of its physical properties. This is the result of the succession of crops that reduce soil fertility with crops that none reduce soil fertility. The (agricultural rotation, or crop rotation) is defined as rotation of different crops on a plot of one land (14), that will enable the land to recover elements and minerals which were consumed by crops grown in the previous season(18). The agricultural rotation had been implemented through the use of two mathematical models representing two forms of linear programming. They were formulated in view of the farm productivity, which was obtained through a questionnaire distributed to the farmers of the association and compared with the farm plan applied in the farm (7), to demonstrate the optimal allocation of all components of production by increasing net farm income by optimizing the available resources. The first model is the selection of a combination of agricultural crops within the cropping structure of the farm for one year, consisting of 12 crops and 32 constraints including land, human labor, mechanical work and irrigation water as well as a constraints on growing wheat .The second model consists of the rotation of the same crops in the first model for two years (agricultural rotation) and consists of 18 crops and 42 constraints. This model contained the same constraints of the first model except the non-negative constraints with the addition of constraints to ensure the succession of crops in the agricultural rotation. The objective function of the model is to maximize the profits achieved by the farm.

MATERIALS AND METHODS

Hammurabi society and the available productive resources (7)

The total area of land owned by the Society is 4922 dunums, of which 4772 dunums are suitable for growing plants, constituting 97% of the total area, including the area of orchards of 117 dunums and 4655 dunums designated for growing winter and summer crops (2395 dunums for winter crops and 2260 dunums for summer crops). The rest of cultivated land is not reclaimed and has an area of 150 dunums and is cultivated with barley and mixtures of fodder and some types of vegetables. Table 1 show crops structure prevailing in Hamorabi farms and the quantities needed per dunum to cultivate each crop and the available quantities of production inputs of season 2015-2016. Table 2 shows costs of agricultural production inputs, gross and net income per crop at current prices per dunum for the same season.

Agricultural planning and its methods (6)

For any farming system should at least maintain the productivity of farmland at a stable and profitable level 4.The most important analytical methods that can contribute to the agricultural planning process are the following:

1. Marginal Analysis
2. Budgeting
3. Linear programming LP.

Linear programming LP technique and determination of optimal mix of production

The concept of the optimal use of the available physical and human economic resources means the rational and economical use of the resources already utilized towards improving the efficiency of the productive process and increasing the productivity of the different resources in all branches of the national economy(2).The farm Management Study deals with the methods and technique of regulating land and capital resources as well as the application of technical knowledge, expertise and skills that will maximize the net agricultural income, and among the agricultural administrative modalities is standard farm model, substitution and replacement method, direct comparison method and partial change method (1), adding to these methods LP method, a modern technique in the development of agricultural programs and plans(26) Mathematical programming refers to a set of mathematical methods that can be used to find the optimal set of solutions for economic problems that involve objective function of multiple variables with a set of constraints that are in the form of variations (smaller than or greater than or equal to), mathematical programming includes three mathematical methods (20) : (LP) method ,Non-Linear programming and Dynamic programming method. .

Table 1. Required quantities and available from the requirements of agricultural production for each crop /dunum for season 2015-2016

Quantities required \ Crops	. Quantities available	Water melon	Okra	Cucumbers	Tomatoes	Maize	Sun Flower	Autumn Potatoes	Green Onion	Broad Beam	Cloves	Beat Root	Wheat
Area / dunum	4655	50	190	100	100	1800	20	250	20	50	50	25	1500
Compound fertilizer / kg	419190	100	100	100	100	100	50	100	100	50	50	50	100
Fertilizer Urea / kg	397560	50	50	50	100	100	50	150	50	25	50	50	100
Quantity of seeds / kg		0.5	2	0.5	0.150	7	2.5	700	100	4	5	4	40
Animal fertilizer / m^3	7000	-	-	-	12	-	-	12	-	-	-	-	-
Pesticides / L	13075	1	3	2	2	2	1	3	1	1	2	1	1
Automatic work tillage / hour	103056	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Automatic work machining and adjustment / hour	103056	1	1	1	1	1	1	1	1	1	1	1	1
Mechanical work waving and milling / hour	103056	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Work for a harvester / hour	954	-	-	-	-	-	-	-	-	-	-	-	0.5
Irrigation water* January-March / m^3	20699719	100	213	133	100	0	275	0	440	430	370	355	390
Irrigation water* April-Jun / m^3	20929709	1215	1343	955	1015	188	1430	0	0	305	470	0	275
Irrigation water* July –September/m^3	21159705	1095	1748	0	1683	840	443	750	0	0	150	0	0
Irrigation water* October-December / m^3	21159705	0	0	0	0	0	0	860	210	303	305	295	300
Workman January-March/hour	50593	8	29	13	18	-	-	60	54	14	32	29	6
Workman April –Jun /hour	554800	31	77	102	50	6	22	-	-	23	17	-	2
Workman July-September/hour	562400	58	112	-	80	24	35	12	-	-	-	-	-
Workman October-December/hour	562400	-	43	-	52	-	-	22	26	34	7	8	9
Total human work / hour	2226800	97	261	115	200	30	57	94	80	71	56	37	17

Source: 1- Al-Rasheed Cultivation Division - Planning and Follow-up Section - Hamorabi Society, 2. Questionnaire form, 3. * (3)

Table 2. Items of agricultural production requirements for each crop at current prices for the agricultural season 2015-2016

Crops / Item	Water melon	Okra	Cucumber	Tomatoes	Maize	Sun Flower	Autumn Potatoes	Green Onion	Broad Beam	Cloves	Beet root	Wheat
Operational costs * (thousand dinars / dunum).	285	250	263	310	242	244	650	360	242	216	233	345
Agricultural Price(Dinar/Kg)	550	1400	400	250	375	750	400	250	750	300	300	600
Average yield(kg/dunum)	3000	2400	3500	7500	650	500	5000	3500	4000	4500	5000	750
Total Income(thousand dinars/dunum)	1650	3360	1400	1875	243.750	375	2000	875	3000	1350	1500	450
Net income ** (thousand dinars / dunum(	11365	3110	1137	1565	1750	1311	1350	515	2758	1134	1267	105

Source: The data were calculated by the researcher based on the questionnaire
*** Operational costs = variable costs + maintenance costs. (3)**
**** Net income = total income - operational costs. (3)**

The decision-making process involves selecting the optimal decision from a range of alternatives (possible decisions) to achieve a specific objective for the farm (9), and that many of the problems in the business management of the farm can be formed in the form of mathematical programming. On this basis, the problem in mathematical programming is to find optimal values for the objective function with a set of constraints, and that all these relations can be described mathematically (11), nonlinear programming (16), which emerged in 1952 represents a set of mathematical methods that can be used to find a set of optimal solutions to problems that contain nonlinear relationships for the objective function as well as constraints (12). The dynamic programming, that emerged in 1957, represents another new technique that includes a set of mathematical methods that can be used in the decision-making process for a set of sequent relationships in management(27).The objective of dynamic programming is to determine the optimal solution for a complete set of decisions(8) .

Information needed for LP (21, 22)

There are three types of information that a linear programming model needs:

A-Decision Variables

B-Objective Function

C. Constraints

Mathematical model for LP (13)

Assuming that there are(n) decision variables from the objective function(Z) and the(m) number of determinants or constraints, the mathematical form of the linear programming model takes the following form.

Min or Max $\sum_{j}^{n} = CjXj$

S.to

$\sum_{j}^{n}$ aijXj (≥,=, ≤)bi

Xj≥0

i = 1 , 2………. , m

j = 1 , 2,…………., n

Cj, bi, aij = constants

m = number of constraints

n = number of variables

Determine the optimal production plans for the Hamorabi Farm, analyze the data and discuss the results of the models.

The most important stage of LP model is formulating stage, which is based on the fact that the association aims to maximize total net income through the cultivation of several crops subject to specific constraints (6, 10). After the linear programming model was formulated, we use the quantitative system for business = QSB (5), which maximize profit by using simplex method, which is used to solve linear programming problems to achieve optimal production plan (23, 24) for season 2015-2016.

Linear programming setting

Identify the data used in the LP Form (15, 17)

A. Defining the objective function: The objective function in the linear programming model represents maximizing the total net expected income as follows:

Max $\sum_{j=0}^{12}$ CjXj = C1X1 + C2X2...... C12X12

As:

∑ CjXj = represents the total value of the objective function to be maximized (total net income of the farm).

Cj = Net income from crop j.

X = cultivated area of crop j

As (j = 1, 2 ... 12) the combination of crops cultivated.

We aim from formulating the model to determine the optimal component of crops that achieves the greatest possible net income as available

B. Identification the data of the matrix of technical transactions for the constraints that represent the crop needs of the various production inputs per dunum, which representing LHS.

C. Determine the available quantities of production inputs in the Hamorabi Society, which represents the right side RHS.

After defining the most important essential constraints and non-negative constraints, we will move on to the formulation of the linear programming models for the Hamorabi Farm for season 2015/2016 at current prices.

(First model) LP Setting for Hamorabi Farm (winter and summer crops) at current prices for season 2015-2016

The research aims to achieve the optimal exploitation of production inputs and profits maximization for crops which cultivated by the association using LP technique, and to achieve the objectives of the research, we had formulated the LP model for Hamorabi Farm for season 2015-2016 to optimize the allocation of production resources, which maximizes total net income. The target model is a mathematical model restricted to calculate the best income, best plan and best production component that maximizing incomes net. Based on the data in tables 1 and 2, the LP model can be formulated as follows:

A. Objective function data

The objective function of the model is to maximize the total net income per dunum at the current prices achieved by the various winter and summer productive activities of 12 crops cultivated during season 2015-2016, as shown in table 2, which shows selling prices, costs and returns per unit of crop. The researcher had selected the crops which had the highest percentage of total production.

B. Identification the data for the matrix of technical transactions of the restrictions

The objective function of the model is bounded by 32 constraints (c1- c32). LHS represents the required quantities of production inputs per unit of crops and the RHS represents the available quantities from production inputs per unit as shown in Table 1.

Matrix of technical coefficients and quantities available from the primary resources used in production

Technical coefficients represent inputs requirements per unit of each crop, such as agricultural land, working hours, capital, etc., and its quantities available to the farm from each of these production resources according to what was recorded in the records of the association, as shown in Table 1 during season 2015-2016.These coefficients were represented by c1-c6 (Table3).

Working time (workman and automatic) required for production

This constraint represents the time necessary for the agricultural process to produce one crop / dunum . This time dimension of the production process is limited (or restricted) by the available hours of work during the season 2015-2016. The number of work hours available annually is estimated according to the following formula: Number of workers x Actual number of working hours per day x Number of working days per year. Table 1 shows the time required from workman and automatic work to produce one crop/dunum of each product and the time available during season 2015-2016 based on the questionnaire. It observe the variation of the workman hours of the same table, which varies according to the crop and the different seasons of the year and according to the work required for each crop, and working time constraints were represented by the constraints c7-c14 (Table3).

Constraints of distributed irrigation water quantities for the seasons of the year

The quantities of water resources available on the farm had been estimated from the discharge of the channels and pumps that provide irrigation water to the association's lands. The water resource constraints include four constraints for the water needs of different crops and the quantities of water available during the months /m3, which were represented by constraints c15 -c18 (Table 3).

Capital constraint

This constraint represents the need of capital/ dunum to cultivate each crop (Table 2), which represents the operational production costs 4 which consist of variable costs + fixed costs, the total costs of the crops which shown in the plan must not exceed the capital Which was estimated at 1445855000 dinars, estimated on the basis of the agricultural season 2015-2016 at current prices. The working capital account available to the farm was estimated based on the questionnaire, because it is not possible to obtain the capital available in the folders of the

Table 3 .First model

Max (Z) = 105X1 + 1267X2 + 1134X3 + 2758X4 + 515X5 + 1350X6 + 1311X7 + 1750X8 + 1565X9+ +1137X10 + 3110X11 +11365X12

Subject to

C1 =1X1 +1 X2 +1X3 +1 X4 +1 X5 +1 X6 + 0X7 +0 X8 +0X9 +0 X10 +0 X11 + 0 X12 ≤2395
C2 =0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6+ 1X7 + 1X8 + 1X9 + 1X10 + 1X11 + 1X12 ≤ 2260
C3 = 100X1 + 50X2 + 50X3 + 50X4 + 100X5 +100X6+ 50X7 + 100X8 + 100X9 + 100X10 + 100X11 + 100X12 ≤ 419190
C4 = 100X1 + 50X2 + 50X3 + 25X4 + 50X5 + 150X6+ 50X7 + 100X8 + 100X9 + 50X10 + 50X11 +50 X12 ≤ 397560
C5 =0 X1 +0 X2 + 0X3 + 0X4 + 0X5 + 12X6+ 0X7 + 0X8 + 12X9 + 0X10 + 0X11 + X12 ≤ 7000
C6 = 1X1 + 1X2 + 2X3 + 1X4 + 1X5 + 3X6 +1X7 + 2X8 + 2X9 + 2X10 + 3X11 + X12 ≤ 13075
C7 = 6X1 + 29 X2 + 32X3 + 14X4 + 54X5 + 60X6+0X7 + 0X8 + 18X9 + 13X10 + 29X11 +8 X12 ≤50593
C8 = 2X1 + 0X2 +17 X3 +23 X4 + 0X5 + 0X6+22X7 + 6X8 + 50X9 + 102X10 + 77X11 +31 X12 ≤554800
C9 = 0X1 + 0X2 + 0X3 + 0X4 +0 X5 +12 X6 +35X7 + 24X8 + 80X9 + 0X10 + 112X11 +58 X12 ≤562400
C10 = 9X1 + 8X2 + 7X3 + 34X4 + 26X5 + 22X6 +0X7 + 0X8 + 52X9 + 0X10 + 43X11 + 0X12 ≤562400
C11 =1.5 X1 +1.5 X2 +1.5 X3 +1.5 X4 +1.5 X5 +1.5 X6 + 1.5X7 + 1.5X8 + 1.5X9 + 1.5X10 + 1.5X11 + 1.5X12 ≤103056
C12 = 1 X1 + 1X2 + 1X3 + 1X4 + 1X5 + 1X6 +1X7 + 1X8 + 1X9 + 1X10 + 1X11 +1 X12 ≤ 103056
C13 = 0.5X1 + 0.5X2 + 0.5X3 + 0.5X4 + 0.5X5 + 0.5X6 + 0.5X7 + 0.5X8 + 0.5X9 + 0.5X10 + 0.5X11 +0.5 X12 ≤ 103056
C14 = 0.5X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 + 0 X12 ≤ 954
C15 = 390X1 + 355X2 + 370X3 + 430X4 + 440X5 + 0X6+275X7+ 0X8 + 100X9 + 133X10 + 213X11 +100 X12 ≤ 20699716
C16 = 275X1 + 0X2 + 470X3 + 305X4 + 0X5 + 0X6+1430X7+ 188X8 + 1015X9 + 955X10 + 1343X11 +1215 X12 ≤ 20929709
C17 = 0X1 + 0X2 + 150X3 + 0X4 + 0X5 + 750X6 + 443X7+ 840X8 + 1683X9 + 0X10 + 1748X11 +1095 X12≤ 21159705
C18 = 300X1 + 295X2 +305 X3 + 303X4 +210 X5 + 860X6++0X7+ 0X8 + 0X9 + 0X10 + 0X11 + 0X12 ≤ 21159705
C19 = 345000X1 + 233000X2 + 216000X3 + 242000X4 + 360000X5 + 650000X6++244000X7+ 242000X8 + 310000X9 + 263000X10 + 250000X11 + 285000X12 ≥ 1445855000
C20 = 1X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 +0X10 + 0X11 + 0 X12 ≥ 0
C21 = 0X1 + 1X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 +0X10 + 0X11 + 0X12 ≥ 0
C22 = 0X1 + 0X2 + 1X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 + 0X12 ≥ 0
C23 = 0X1 + 0X2 + 0X3 + 1X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 +0 X12 ≥ 0
C24 = 0X1 + 0X2 + 0X3 + 0X4 + 1X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 +0 X12 ≥ 0
C25 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 1X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 +0 X12 ≥ 0
C26 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 1X7 + 0X8 + 0X9 + 0X10 + 0X11 +0 X12 ≥ 0
C27 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 1X8 + 0X9 + 0X10 + 0X11 + 0X12 ≥ 0
C28 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 +0X7 + 0X8 + 1X9 + 0X10 + 0X11 + 0X12 ≥ 0
C29 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 1X10 + 0X11 +0 X12 ≥ 0
C30 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 1X11 + 0X12 ≥ 0
C31 = 0X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 + X12 ≥ 0
C32 = 1X1 + 0X2 + 0X3 + 0X4 + 0X5 + 0X6 + 0X7 + 0X8 + 0X9 + 0X10 + 0X11 + 0X12 ≥ 1500

Source: The table had been sated by the researcher based on the data of tables 1 and 2

Table 4. Matrix of the second model - agricultural rotation (First year)

Variable	X11 Wheat	X12 Clover	X13 Broad Beam	X14 Autumn Potatoes	X15 Sun Flower	X16 Maize	X17 Tomatoes	X18 Cucumber	X19 Okra
Maximize	105	1134	2758	1350	1311	1750	1565	1137	3110
C1	1	1	1	1	0	0	0	0	0
C2	0	0	0	0	1	1	1	1	1
C3	100	50	50	100	50	100	100	100	100
C4	100	50	25	150	50	100	100	50	50
C5	0	0	0	12	0	0	12	0	0
C6	1	2	1	3	1	2	2	2	3
C7	6	32	14	60	0	0	18	13	29
C8	2	17	23	0	22	6	50	102	77
C9	0	0	0	12	35	24	80	0	112
C10	9	7	34	22	0	0	52	0	43
C11	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
C12	1	1	1	1	1	1	1	1	1
C13	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C14	0.5	0	0	0	0	0	0	0	0
C15	390	370	430	0	275	0	100	133	213
C16	275	470	305	0	1430	188	1015	955	1343
C17	0	150	0	750	443	840	1683	0	1748
C18	300	305	303	860	0	0	0	0	0
C19	345000	216000	242000	650000	244000	242000	310000	263000	250000
C20	1	0	0	0	0	0	0	0	0
C21	0	0	0	0	0	0	0	0	0
C22	0	0	0	0	0	0	0	0	0
C23	0	0	0	0	0	0	0	0	0
C24	0	0	0	0	0	0	0	0	0
C25	0	0	0	0	0	0	0	0	0
C26	0	0	0	0	0	0	0	0	0
C27	0	0	0	0	0	0	0	0	0
C28	0	0	0	0	0	0	0	0	0
C29	0	0	0	0	0	0	0	0	0
C30	0	0	0	0	0	0	0	0	0
C31	0	0	0	0	0	0	0	0	0
C32	0	0	0	0	0	0	0	0	0
C33	0	0	0	0	0	0	0	0	0
C34	0	0	0	0	0	0	0	0	0
C35	0	0	0	0	0	0	0	0	0
C36	0	0	0	0	0	0	0	0	0
C37	0	0	0	0	0	0	0	0	0
C38	0	0	0	0	0	0	0	0	0
C39	0	0	0	0	0	0	0	0	0
C40	0	0	0	0	0	0	0	0	0
C41	-1	0	0	0	0	0	0	0	0
C42	0	-1	-1	0	0	0	0	0	0
Lower bound	0	0	0	0	0	0	0	0	0
Upper bound	M	M	M	M	M	M	M	M	M
Variable type	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous

Source: The table had been sated by the researcher based on the data of tables 1 and 2

Supplement Table 4. Matrix of the second model - agricultural rotation (Second year)

X21	X22	X23	X24	X25	X26	X27	X28	X29	S	RHS
105	1134	2758	1350	1311	1750	1565	1137	3110		
0	0	0	0	0	0	0	0	0	≤	2395
0	0	0	0	0	0	0	0	0	≤	2260
0	0	0	0	0	0	0	0	0	≤	419190
0	0	0	0	0	0	0	0	0	≤	397560
0	0	0	0	0	0	0	0	0	≤	7000
0	0	0	0	0	0	0	0	0	≤	13075
0	0	0	0	0	0	0	0	0	≤	50593
0	0	0	0	0	0	0	0	0	≤	554800
0	0	0	0	0	0	0	0	0	≤	562400
0	0	0	0	0	0	0	0	0	≤	562400
0	0	0	0	0	0	0	0	0	≤	103056
0	0	0	0	0	0	0	0	0	≤	103056
0	0	0	0	0	0	0	0	0	≤	103056
0	0	0	0	0	0	0	0	0	≤	954
0	0	0	0	0	0	0	0	0	≤	20699716
0	0	0	0	0	0	0	0	0	≤	20929709
0	0	0	0	0	0	0	0	0	≤	21159705
0	0	0	0	0	0	0	0	0	≤	21159705
0	0	0	0	0	0	0	0	0	≤	1445855000
0	0	0	0	0	0	0	0	0	≥	1500
1	1	1	1	0	0	0	0	0	≤	2395
0	0	0	0	1	1	1	1	1	≤	2260
100	50	50	100	50	100	100	100	100	≤	419190
100	50	25	150	50	100	100	50	50	≤	397560
0	0	0	12	0	0	12	0	0	≤	7000
1	2	1	3	1	2	2	2	3	≤	13075
6	32	14	60	0	0	18	13	29	≤	50593
2	17	23	0	22	6	50	102	77	≤	554800
0	0	0	12	35	24	80	0	112	≤	562400
9	7	34	22	0	0	52	0	43	≤	562400
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	≤	103056
1	1	1	1	1	1	1	1	1	≤	103056
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	≤	103056
0.5	0	0	0	0	0	0	0	0	≤	954
390	370	430	0	275	0	100	133	213	≤	20699716
275	470	305	0	1430	188	1015	955	1343	≤	20929709
0	150	0	750	443	840	1683	0	1748	≤	21159705
300	305	303	860	0	0	0	0	0	≤	21159705
345000	215000	242000	650000	244000	242000	310000	263000	250000	≤	1445855000
1	0	0	0	0	0	0	0	0	≥	1500
0	1	1	0	0	0	0	0	0	≤	0
0	0	0	0	0	1	0	0	0	≤	0
0	0	0	0	0	0	0	0	0		
M	M	M	M	M	M	M	M	M		
Continuous	continuous	Continuous	Continuous	Continuous	Continuous	Continuous	continuous	continuous		

Source: The table had been sated by the researcher based on the data of tables 1 and 2 society. The Capital constraint represents by C19 (Table3).

Non-negative constraints

All variables in the model must be positive, they are greater than or equal to zero and represented by c20-c31 (Table 3).

Constrain of minimum land area for cultivated wheat crop

Its constraint represented by C32 (Table 3).

The final form of the LP model for the Hamorabi Farm Crops, to maximize net income for 2015-2016 at current prices showed in (table3) model 1.

Identify the optimal commodity mix in the Hamorabi Society farms, analyze the data and discuss the results

The plan represented the use of the inputs coefficients used by the Hamorabi Society during the 2015-2016 seasons at the same cultivated prices and production crops costs that could be obtained through the Society records and the questionnaire.

After finishing the mathematical form for the objective function and parameters of the LP model as in Model 1, QSB had applied according to data of model 1. The results of the optimal solution showed that the value of net income at current prices was 7930168000 dinars, an increase of 3093023 thousand dinars (63.9%) from the net farm income actually achieved at current prices of 4837145 thousand dinars for the season 2015-2016 which calculated by the researcher by multiplying the value of net income at current prices for each crop as shown in Table 2 by the quantity of production shown in the same table and then collected the multiplication results. According to the results of the analysis of the basic agricultural plan, this plan occupies an area of 4655 dunum. The wheat crop occupies 1500 dunums (32.22% of the total area), its cultivation had imposed on the farm, faba beans area was 895 dunums (19.23% of the total area).Sun flower area was 31.2 dunums (19.23% of the total area) the maize crop occupies 1226.63 dunums 26.35% of total area) ,area of okra is 1002.17 dunums and represents 21.53% of the total area. The same table shows that the agricultural plan has neglected the cultivation of the rest of the other agricultural crops, and it had been shown that the resource which had utilized from (LSH) is less than the available resources, which represents (RHS) of the model.

(Second model) formulation of (agricultural rotation) and analysis its results:

In order to maintain the soil and its fertility, we had assumed an agricultural rotation have applied in terms of the beneficial exploitation of the mutual relationship between different crops 14,15. The importance of agricultural rotation appears through solving the biggest problem of the agricultural land investment using modern scientific methods to increase production and improving soil fertility, reduction costs ,crops diversity which cultivated annually, which helps to organize the utilization of available resources and balance the consumption of nutrients in the soil because the replacement of grain crops with each other or with vegetable plants reduce the consumption of certain elements and compensation of other elements, It also compensates the farmer against the loss of one crop if the single crop system is followed . Despite the advantages of the agricultural rotation Hamorabi Farm does not follow the agricultural rotation technique. Accordingly a suitable agricultural rotation for all crops grown during season 2015-2016 has been designed for two years (Table 5). The second year represented, cultivated berseem and faba bean in the agricultural land which designed for cultivate wheat in the first year after harvest, and planting the maize in the second year after berseem and faba bean in the first year, and so the crops are rotated (Table 6). The second model also includes the following:

1. Not to include three crops of the first model which are the Beet root and green onions and Watermelon, because of, the areas allocated to these crops were small and these crops were

low profitability. The model had limited to crops which its symbols as at (Table 5).

2. The second year constraints are the same constraints which were at the first year, with the exception of non-negative constraints.

3.Add two constraints which are the constraints of the agricultural rotation (c41, c42):

A. The first constraint: cultivation of berseem and faba bean in the second year after the Wheat which had cultivated in the first year as follows:

$$C41 = X22 + X23 - X11 \leq 0$$

B. Second constraint: Cultivation of maize in the second year after the cultivation of faba bean and Berseem in the first year as follows:

$$C42 = X26 - X12 - X13 \leq 0$$

Accordingly, the number of constraints reached 42 and the number of activities were 18.

4. The same coefficients were used for all the cultivation needs of the single crop of production requirements in the first model as shown in the matrix of the second model.

5. The land has been divided into two parts, one for winter crops and the other for summer crops. The matrix of the second model can be illustrated as in Table 4

RESULTS AND DISCUSSION

Analysis of the results (agricultural rotation)

This plan represents the use of the same prices and productivity applied in the Hamorabi Farm for the season 2015-2016. The results of the analysis showed that this plan of the farm achieved a net farm income of 15714750 thousand dinar of an increase of 10877605 thousand dinars which represented of 224.9% of the net income of the actual plan applied in the same farm for the same season which was 4837145 thousand dinars. The net income of the second model includes 7930167.2 thousand dinars in the first year and 7784582.9 thousand dinars in the second year. Table 7 shows that this plan occupies an area of 4655 dunums during the first year. The wheat crop occupied an area of 1500 which represents 32.22% of the total number of dunums, the remaining area were 895 dunums and constitutes 19.23% of the total area allocated for winter crops. The faba bean crop occupies 895 dunums and constitutes 19.23% of the total area allocated for winter crops. The sun flower crop occupies 31.2 dunums and constitutes (0.67%). The maize crop occupies an area of 1226.63 dunums and represents 26.35% of total area. And the Okra crop occupies area of 1002.17 dunums, representing 21.53% of the total area allocated for the summer crops. Table 7 shows that at the second year, the plan occupied the same area of the land as the first year and the same percentage of wheat and faba bean from the total area allocated for winter crops. The table had showed that there was a change in the area occupied by some crops in the second year; the sun flower occupied an area of 362.83 dunums which represented 7.79% of total area. The maize crop occupied an area of 895 dunums, representing 19.23% of the total area. It is clear from the same table that this plan neglected the cultivation of the rest of the other agricultural crops. The optimal solution using the linear programming technique in this model has shown that the resource which used represents the left side of the model symbolized as LHS, is less than the available resources representing the side Right of the model symbolized as RHS. The optimal solution for the first and second models showed that there was a surplus in water quantities (Table 8).

Table 5. Agricultural rotation 2015-2016

1st Year	Crop	2nd Year
X11	Wheat	X21
X12	Clover	X22
X13	Broad Bean	X23
X14	Autumn Potatoes	X24
X15	Sun Flower	X25
X16	Maize	X26
X17	Tomatoes	X27
X18	Cucumber	X28
X19	Okra	X29

Table 6. Proposed Agricultural Rotation of Hamorabi Society Farms

1st Year	2nd Year
Wheat	Clover and Broad Bean
Clover and Broad Bean	Maize

. **Table 7. Analysis of the results of the second model plan (agricultural rotation)**

(%)	Unit/ Dunum	Crops
Firs year		
32.22	1500	X11 Wheat
19.23	895	X13 Broad Bean
0.67	31.2	X15 Sun flower
26.35	1226.63	X16 Maize
21.53	1002.17	X19 Okra
100	4655	Total
Second year		
(%)	Unit/Dunum	Crops
32.22	1500	X21 Wheat
19.23	895	X23 Broad Bean
7.79	362.83	X25 Sun Flower
19.23	895	X26 Maize
21.53	1002.17	X29 Okra
100	4655	Total

Table 8. Available and surplus quantities of irrigation water for the Hamorabi Farm 2014-2015

Period	Surplus quantities m3	Available quantities (m^3)	Excess) % quantities of available (quantities
Jan-Mar.	19507820	20699720	94.24
April-Jun.	18623090	20929720	88.98
July-Sep.	18363720	21159700	86.79
Oct-Dec.	20438520	21159700	96.6
Total	76933150	83948830	91.64

From the study of the reality of the farm and the discussion of the results which had obtained, emerged a number of conclusions, perhaps the most important, there is a significant difference between the actual farm plan and the derived plans using the LP technique in terms of cultivated crops and net income, there is a difference in the crop combination and their areas, and the farm has earned far more income than the resulting income of the agricultural plan. The production resource-use, which represents the left side of the model (LHS), is less than the available resources which represents the right side of the model (RHS), that's means less resources were used and farm net income was increased as a result of giving the program freedom to choose activities, in other words, there is no restriction on activities. The use of scientific management tools in agricultural planning leads to rationalization of the use of production elements and their distribution among the various productive activities in a manner that leads to achieving the highest level of profits where the farm earned much more income than the actual farm plan through the use of LP technique in planning the available resources. The value of net income at current prices amounted to 7930168000 dinars when using the same production costs and the prices of the products used by the farm plan applied in the farms of Hamorabi Association agricultural, an increase of 3093023 dinars, represented 63.9% of net farm income which had actually achieved at current prices of 4837145 dinars for season 2015-2016. The productive resources that have been fully exploited which represent limited resources, namely the land suitable for cultivation summer and winter crops, which is symbolized by (c1) and (c2) sequentially, compound fertilizer (c3) and workman hours(c7) (January-March). Adding one unit (one dunum) of (c1) will add to the value of objective function 1662.45 dinars and up to 3047.81 as maximum , while adding one unit of c2 will add 872 dinars and up to 2897.26 dinars as maximum, adding one unit of c3 will add 8.78 dinars and up to 420750 dinars as maximum, and the addition of one unit of c7 will add 46.9 dinars to the value of objective function and up to 86165.2 dinars as maximum , which is reflected the shadow prices for these resources ,the crop structure remains the same unchanged if the income of wheat(x1) will change from minimum for one unit to maximum (2821.83) dinars ,and so for the autumn potato(x4) the structure of crops will not change if change the income of x4 from minimum 1095.6 dinars for one unit to maximum (M) dinars. And so for the tomato's crop (x7) the structure of crops will not change if change the income of x7 from minimum 875 dinars for one unit to maximum (1750) dinars. So for the Cucumber (x8) the structure of crops will not change if change the income of (x8) from minimum (1311) dinars for one unit to maximum (2622) dinars. So for the Wheat(x11) the structure of crops will not change if change the income of (x11) from minimum (1750) dinars for one unit to maximum (6553.64) dinars. The optimal solution for the second model (agricultural rotation) shows: the productive resources, namely the land suitable for the cultivation of summer and winter crops, which is symbolized by (c1) , (c2) sequentially, compound fertilizer (c3) and human working hours(c7)(January-March). Adding one unit (one dunum) of (c1) will add to the value of objective function (2101.45) dinars and up to(2726.63)dinars as a maximum , while adding one unit of(c2) will add (872) dinars and up to (2244.40) dinars as a maximum, adding one unit of c3 will add (8.78)dinars and up to (420750)dinars as a maximum, and the addition of one unit of(c7)will add (46.9)dinars and up to(86165.2) dinars maximum , which reflect the shadow prices for these resources. The optimal solution in the first year shows that the crop composition remains the same if the income of X11 changes from a minimum of one unit to a maximum of 3260.83 dinars as well as to the (X13) If the income is changed from a minimum of 656.6 dinars per unit and a maximum of M dinars, and X15 will remain the composition of the crops as it is unchanged if its income changed from as a minimum of 875 dinars per unit and a maximum of 1750 dinars as well as for (X16) ,the production combination remains unchanged If its income change from a minimum of 1311 dinars per unit and a maximum of 2622 dinars, and remains the production composition as it is unchanged if the income of (X19) change from a minimum of 1750 dinars per unit and a maximum of 7463 dinars, and the optimal solution of the second year can be observed as follow, the crop composition remains the same if the income of X21 changes from a minimum of one unit to a maximum of 2261.72 dinars, as well as for (X23) the crop composition remains the same if its income changed from a minimum of 868.5 dinars per unit and a maximum (M) dinars as well as for X25 the production composition will remain the same if its income changed from a minimum of 0 dinars per unit and a maximum unit of 1750 dinars, for (X26) the crop composition remains the same if its income changed from a minimum of 1311 dinars per unit and a maximum (M) dinars. , as well as for(X26) the crop composition remains the same if its income changed from a minimum of (1720) dinars per unit and a maximum (7024) dinars. The results of the LP model showed efficiency in the optimal allocation of available resources and the decision-maker's ability to make decisions by increasing profits in accordance with the available possibilities. Crop cultivation included in the plan had required the exhaustion of all the available areas of arable land and chemical fertilizer and human working hours for months January - March. The analysis of the results showed that there are positive shadow prices for some resources. This means that the farm needs more of these resources. This scarcity led to the constricted the program by the activities showed in the analysis, and the utilization rates for the other resources were low relative to available resources at the farm. From the previous conclusions we can make a number of recommendations, the most important of which are: The use of modern methods in planning and management of farms, as the use of these tools in the planning and management of farm leads to a difference in the productive activities of the farm and this is due to the proper distribution of productive resources between the activities of the farm and achieve the highest net income. Using LP technique to determine the extent the investment for the available resources efficiently, which helps to increase production. The necessity of generalizing this method and its application in agricultural associations with similar circumstances to determine the optimal use of different productive resources available. The reformulated of the crop composition of the Assembly as indicated by the results of LP in order to achieve economic efficiency of the farmers of the association and the exclusion of agricultural crops not economically important. The necessity of applying agricultural rotation because of its economic benefits in addition to reclamation of soil and conservation of fertility. Establishing agricultural training courses and guidance for farmers to use the best methods of modern agricultural production increase the resources which its shadow prices are positive for the purpose of benefiting from surplus resources whose prices are zero to increase production.

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