LINEAR PROGRAMMING APPLICAFION TO THE PROBLEM OF DETERMINATION OF THE OPTIMUM CROPPING SYSTEM IN NORTHERN TAHREER AREA*

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The north-western end of Tahreer province is called Northern Tahreer sector, it is about 40 Kolometers. Far from Alexandria as shown in figure (I). Soils of northern tahreer are loamy and high in calcium carbonate (Ca Co_3) content (about 20-70%). Its Water holding capacity is higher than in southern tahreer sector. The organic matter content is very low (I).

Land reclamation started in northern tahreer in 1956/57 by about 1362 feddans in Nasr zone, which reached 19740 feddans in 1964/65. In 1964/65, land reclamation of the revolution zone started by about 21400 feddans (2).

In 1965/66, total area reclamed in Northern Tahreer reached about 74, 625 feddans of which 19525 feddans in Nasr zone and 28, 100 feddans in the Revolution zone as shown n table (I). Figure (2) shows the development of reclaimed and cultivated areas in northern tahreer sector in the period 1956/57-1965/66.

The objective of this article is the determination of the best cropping system in in northern tahreer sector through the application of linear programming.

(*) Mr. Taha Ahmed khalil is responsible for data collection and assistanship.

(1) El-Samny, Ali Ahmed, Studies of Tahreer Prvoince F Ao, 1959, P. 12.

(2) Northern Tahreer Sector is divided into two Zones : the Nasr and the Revolution zones.

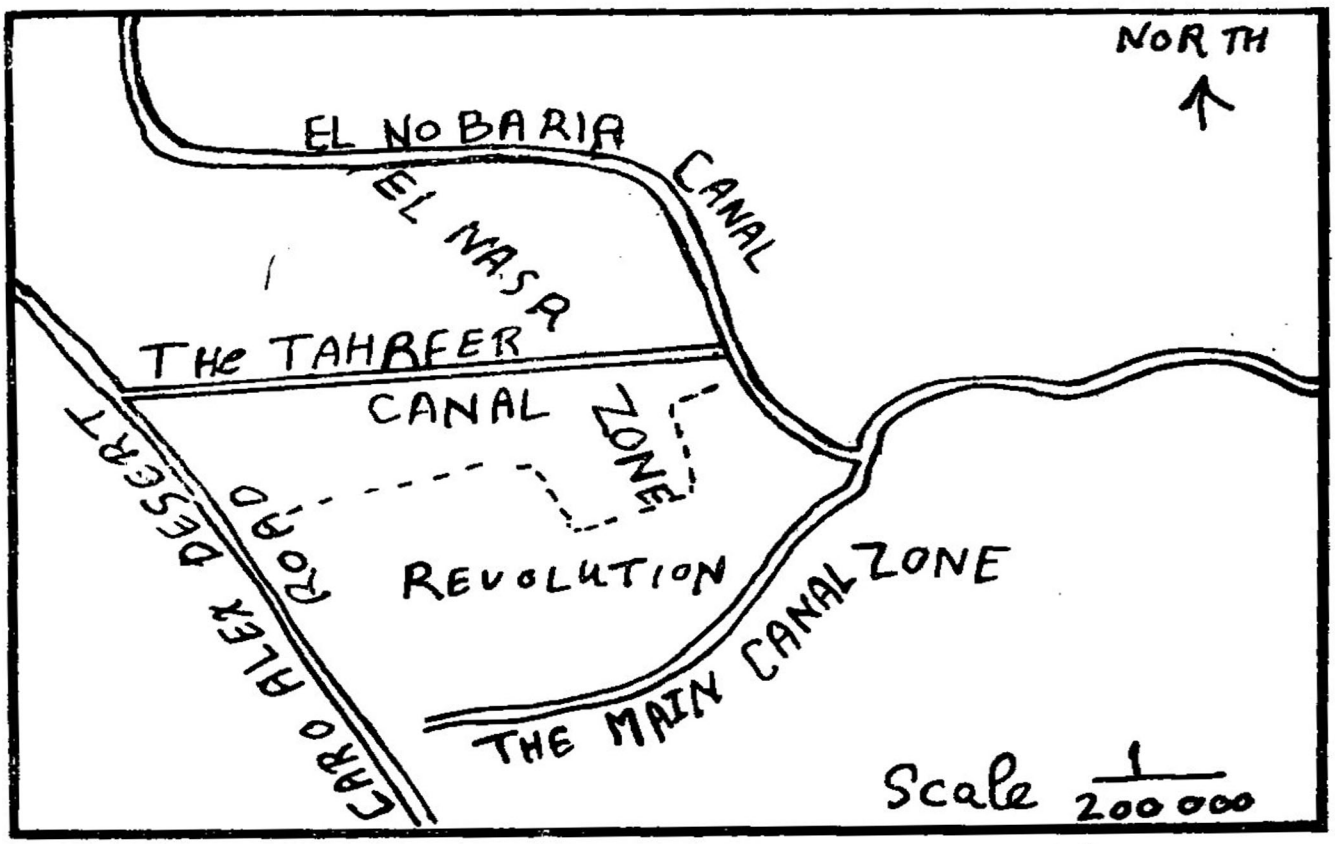

Figure (1) Northern Tahreer Map.

GRPOS AND ROTATIONS IN NORTHERN TAHREER SECTOR

Most of the field crops cultivated in the Nile delta are raised in Nasr zone as shown in table (2).(1)

There are some special crops cultivated in Nasr zone. There were about 1920 feddans is Nasr zone which is cultivated with alfalfa in 1965/66. Orchard crop area is about 4269 feddans in Nasr zone in 1965/66. Main orchard crops in northern taheer are grapes, citrus and olives. The important annual filed crops cultivated in Tahreer area are Peas, barley, barley, beans, clover, onions, wheat, watermelons, cowbeams, sorghum and maize.

Relatively small areas are devoted to Cotton, soyabeans and artichoke in Northern Tahreer.

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(1) Data are not available for the revolution zone,
The analysis is limited in this article to the Nasr zone
and to field and truck crops.

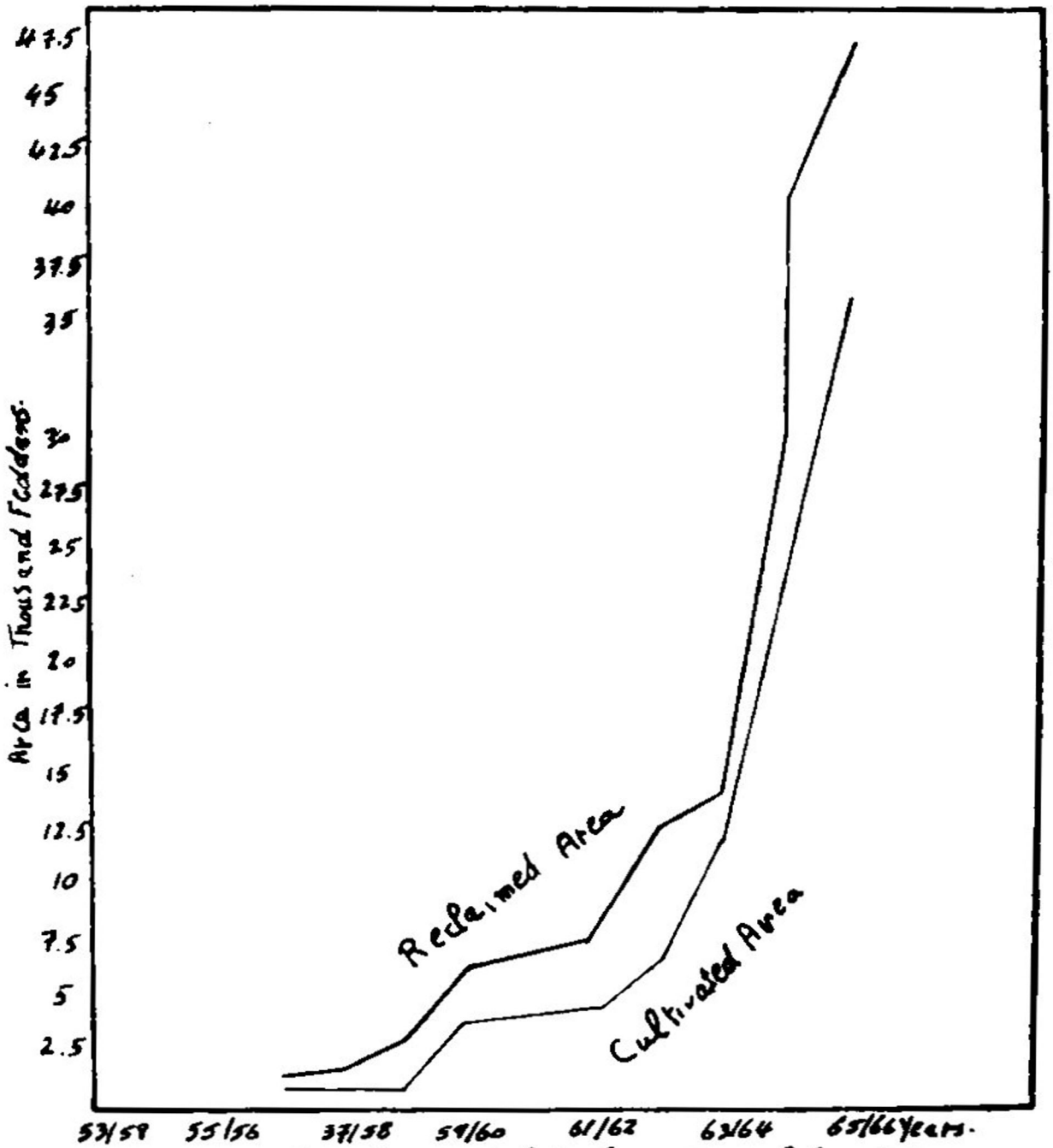

Figure (3): Development of Reclaimed and Cultivated Areas in Northern Tahreer.

TABLE 1

Reclaimed and cultivated areas in northern Tahreer sector in feddans in the period 1956/67—1965/66

Years	Nasr zone		Revolution zone		Total	
	Reclaimed	Cultivated	Reclaimed	Cultivated	Reclaimed	Cultivated
1956/57	1326	1164	...	...	1362	1164
1957/58	2116	1091	...	...	2116	1091
1958/59	3116	675	...	...	3116	675
1959/60	6681	4022	...	...	6681	4022
1960/1961	7064	4377	...	...	7064	4022
1961/1962	7659	4620	...	...	7659	4659
1962/1963	12952	7067	...	...	12952	7067
1963/1964	14293	12384	...	—	14293	12384
1964/1965	19340	10267	21400	21400	40740	31667
1965/1966	19525	12677	28100	23336	47625	36013

Source : The Egyptian Authority for Utilization and development of Reclaimed Land.

Grenerally, There is no single crop pattern or rotation for land use in Tahreer area. Table (2) shows Various crop patterns which has been used in northern Tahreer in the period 1956/57—1965/66.

YIELD, COSTS, AND RETURNS OF FIELD AND TRUCK CROPS IN NORTHERN TAHREER

There are ony diffiucultuis encountered in collecting productivity data in tahreer area which limited the time period of the analysis. Data for the years 1964/65 and 1965/66, only, are available for the Nasr zone. Yield of forage crops usually is not estimated in physical quantity. Revenue of these crops are determined at a fixed rate per feddan(I). Price per feddan for foage crops is not realistic because it is determined without regard to the out put per deddan.

(I) The price of alfalfa is 40 L.E. per reddan, clover is 52 L.E. per feddan anp cowbeans and sorghum is 18 L.E. per feddan.

TABLE 2

Development of Crop Pattern in Northern Tahreer—The Nasr Zone in Feddans

A.—Winter Crops

Crops	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	64/65	65/66
Wheat	30	100	75	—	10	100	236	855	400	1577
Barley	1065	570	200	1095	1242	945	800	2020	993	530
Tomato	35	20	—	—	320	—	160	359	—	—
Clover	—	210	400	1918	1919	1857	2769	2887	3365	1525
Peas	—	50	—	36	—	—	200	502	700	200
Alfalfa	—	—	—	277	—	300	676	727	1141	1962
Broadbeans	—	90	—	—	—	—	147	1075	400	546
Onion	—	—	—	—	—	—	63	210	138	—
Sugar cane	—	—	—	—	—	—	53	306	306	—
Garlic	—	—	—	—	—	—	—	141	—	—
Vegetables	34	51	—	20	40	—	7	171	—	—
Artichoke	—	—	—	—	—	—	120	140	110	55
Rye grass	—	—	—	—	—	—	—	—	—	202
Orchards	—	—	—	656	846	1418	1799	2674	2674	4349
Plant Nurseries.	—	—	—	—	—	—	—	—	—	91
Experiments	—	...	...	20	...	...	37	...	20	...
Distributed and Rented	...	...	...	...	...	...	...	...	...	1214
Total Area in Winter	1164	1091	675	4022	4377	4620	7076	12384	10267	12677

TABLE 2 Continued

B.—Summer Crops

Crops	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	64/65	65/66
Watermelons	82	50	50	—	—	—	495	1114	588	553
Maize	57	600	300	867	1202	981	484	1399	3173	1156
Cotton	—	—	—	400	225	207	346	666	511	611
Sorghum	—	—	—	—	—	22	200	1932	2006	1235
Sesame	—	—	—	160	43	—	50	70	—	—
Artichoke	—	—	—	—	—	100	141	—	40	65
Kenaf	—	—	—	110	33	—	—	—	—	—
Peanuts	—	—	—	—	—	—	930	—	—	—
Beans	—	—	—	—	—	—	226	138	300	—
Black eye bean.	40	—	—	110	—	—	—	542	—	—
Truck crops	19	22	10	—	—	11	45	—	33	—
Pepper	—	—	—	—	—	—	7	127	30	—
Alfalfa	—	—	—	277	300	300	676	727	1218	1791
Orchard	—	—	—	656	846	1418	1799	2674	3792	4269
Plant Nurs—Eries.	—	—	—	—	—	—	—	—	89	110
Experiments soya bean	—	—	—	—	—	—	176	120	269	147
Dstributed and Rented	—	—	—	—	—	—	—	—	1214	1611
Total Area in Summer	198	672	360	2580	2649	3039	4635	9647	12127	11248
TOTAL CROPPED AREA.	1362	1763	1035	6602	7026	7659	11702	22031	22394	23925

Source : Northern Tahreer Province Unpublished data from reiords, the Egyptian Authority for Utilization and Development of Reclaimed Land.

Generally as shown in table (3), productivity per feddan for field crops is very low relatively to the average of U.A.R. wheat yield per feddan is about 10% averese yield of U.A.R., while, watermelons yield is about 30-40% of the average yield of U.A.R. Cotton yield is about 50% of he U.A.R. average.

The following is a presentation of land productivity costs, Revenue and returns in Nasr zone (northern Tahreer) for various winter and summer crops.

Peas

Peas cultivatid area is about 100 and 200 feddans in Nasr zone in 1964/65, 1965/66 respectively yield per feddan is about 102 and 75 kilograms in 1964/65 and 1965/66 respectively which is relativeiy low, if compared with the average yield of U.A.R.

(610 Kilograms). Total variable costs per feddan are about L.E. 20 in 1964/65 and increased to about L.E. 39 in 1965/66. Total revenue per feddan is about L.E. 9 in the two seasons Losses per feddan are about II and 30 pounds in 1964/65 and 1965/66 respectively. These losses would be higher if fixed costs are considered.

Onion :

Onion is the third export crop in Egypt. It has potential export markets Northern Tahreer is located georgraphically near Alexandria, the major seaport in Egypt. Onion produced in these areas could be prepared for exportation and delivered to port at no higher total costs than in other regions in Egypt.

Yield per feddan is about 1140 Kilograms in Nasr zone in 1964/65 which is about 18% of its yield in U.A.R. costs and revenue data are not available.

Barley :

Average yield per feddan in the Nasr zone is about 402 and 257 Kilograms in 1964/65 and 1965/66 respectively which, in general, is lower than 40% of the average yield of U.A.R. Total variable costs and revenue per feddan are about 1254 and 7.73 pounds respectively in 1965/66. Total losses per feddan are about 4.81 pounds in the same seasoa as shown in table (3).

Broadbeans

Average yield per feddan amounts to about 402 and 257 Kilograms in 1964/65 and 1965/66 respectively. Cultivated area is about 993 and 530 feddans in 1964/65 and 1965/66 respectively. Total variabe costs per feddan.

TABLE 3

Yield, Costs, Revenue and returns for Various winter field and truck crops in the Nasr zone in the years 1964/65 and 1965/66

Crop	year	area feddan	Direct costs							Returns per fed. (L.E)
			Production		Direct costs		Revenue			
			total	unit	per feddaan	total	per feddan	totai	per fed	
Peas**	64/65	700		kg	102	13904	19.86	6403	9.15	—10.71
	65/66	200		«	75	7847	39.25	1833	9.17	—30.08
Onion	64/65	78	89609	»	1149					
	65/66	60								
Barley	64/65	993	398945	»	402	6646	12.54	4096	7.73	— 4.81
Breadbeans	64/65	400	16560	»	41	7834	19.57	994	2.49	—17.08
	65/66	546	7626	»	14	5973	10.94	458	0.83	—10.11
Wheat	64/65	400	103269	»	258	6230	15.57	4647	11.62	— 3.95
	65/66	1577	802589	»	509	35181	22.31	36117	22.90	0.59
Artichoke	64/65	110	877675		7979	6390	58.09	7196	65.42	7.33
***	65/66	55	367758		6687	2941	53.49	588	10.60	—42.89
Clover	64/65	3365							25.01	
***	65/66	1511				23581	15.61		25.00	9.39
Alfalfa	64/65	1141				21605	18.94		40.00	21.06
	65/66	430				6397	14.88		40.00	25.12

Source : The Egyptian Authority for he Utilization and Development of Reclaimedland, Farm ecords, unpublished data, Department of Agricultural Costs, Rowad Zone, Southern Tahreer.

(*) No available data.

(**) Peas is produced in green and dry forms. Figures indicate production in dry form through the transformation of green production to dry by a factor equal to 1/4, which represents the ratio of prices.

(***) Forage crops productionis not quantified.

are about 19.57 and 10.94 pounds in 1964/65 and 1966/67 respectively. Total revenue per feddan is about 2.49 and 0.83 pounds in 1964/65 and 1965/66 respectively, which is very low by any standard. Total losses per feddan are 17.08 and 10.11 pounds in 1964/65 and 1965/66 respectively.

Wheat

Cultivated wheat area amounts to about 400 and 1577 feddand in 1964/65 and 1965/66 respectively in the nasrzone. Wheat yield per feddan is about 258 and 509 Kilograms in 1964/65 and 1965/66 respectively. Total variable costs per feddan are about 15.57 and 22.31 pounds in 1964/65 and 1965/66 respectively. Total revenue per feddan is about 11.62 and 22.90 pounds. Total losses per feddan are about 3.95 pounds and total returns per feddan are about 0.59 pounds in 1965/66.

Artichoke :

Cultivated artichoke area is bout 110 and 55 feddans in 1964/65 and 1965/69 respectively. Yield per feddan is about 7979 and 6687 fruits in 1965/66 and 1966/67 respectively. Variable costs per feddan amount to about 58.09 and 53.49 pounds in 1964/65 and 1965/66 respectively. Total revenue per feddan is about 65.42 and 10.60 pounds in 1964/65 and 1965/66 respectively. Artichoke returns over variable costs are about 7.33 pounds per feddan in 1964/65 but it realized losses in 1965/66 amounted to about 42.89 pounds per feddan.

Egyptian clover :

Cultivated Egyptian clover area is about 3365 and 1511 feddans in 1964/65 and 1965/66 respectively which constitutes a large portion of total cropped area in the sector. No. physical yield is recorded and it is sold at a flat rate per feddan—L.E. 25.00 as shown in table (3). Total variable costs are about L.E. 15.61 per feddan, and total returns are about L.E. 9.39 per feddan in 1965/66.

Alfalfa :

Alfalfa cultivated area is about 1141 and 430 feddans in 1964/56 and 1965/66 respectively. Variable costs per feddan are about 18.94 and 14.88 pounds in 1964/65 and 1965/66 respectively. It is sold at a flat rate per feddan Net returns are about 21.06 and 25.12 pounds in 1964/65 and 1965/66 and 1965/66 respectively.

Watermelons :

Watermelons cultivated area is .bout 608 and 253 feddans in 1964/65 and 1965/66 respectively. Yield per feddan is about 4576 kilograms in 1964/65.

Total variable costs and total revenue are about 39.12 and 86.36 pounds in 1965/66. Net returns over variable costs are about L.E. 47.24 per feddans as Shown in toble (4).

Cotton :

Cotton cultivated area is about 511 and 611 feddans in 1964/65 and 1965/66 respectively. 'Yield per feddan is about 3 and 2.7 kentars. Total variable costs and revenue per feddan are about L.E. 54.93 and 26.65 pounds in 1965/66. Total losses per feddan are about L.E. 28.28 in 1965/66.

Maize :

Maize cultivated area is about 2273 and 1156 feddans in 1964/65 and 1965/66. Yield per feddan is about 638 and 980 kilograms in 1964/65 and 1965/66 respectively Total variable costs and revenue per feddan are about 30.58 and 24.72 pounds respectively in 1965/66. Total losses per feddan are about 5.86 pounds in 1965/66.

Soyabeans :

Cultivated area is about 30 and 59 feddans in 1964/65 and 1965/66 respectively. Yield per feddan is about 293 and 358 kilograms in 1964/65 and 1965/66 respectively. Total variable costs and revenue per feddan are about 51.64 and 13.49 pounds respectively in 1965/66. Total losses per feddan are about 37.97 pounds in 1965/66.

Cowbeans :

Cultivated area is about 247 feddans in 1965/66. Yield is not physically measured and it is sold at a flat rate per feddan—L.E. 18. Variable costs and net returns per feddan are about 4.35 and 13.65 pounds respectively in 1965/66.

Sorghum :

It is also a forage crop. Sorghum cultivated area is about 1565 and 925 feddans in 1964/65 and 1965/66 respectively. Variable costs and Net returns per feddan are about 5.21 and 12.79 pounds respectively in 1965/66.

In general, yield per feddan in the Nasr-zone is very low relatively to U.A.R. average yield. It is noticed also that most of the crops are realizng losses except forage crops.positive returns to forage crops is due mainly to the monopolistic situation of the organization in selling it. It should be noticed that variable costs are the only kind of costs considered, and consequently, losses will be higher if fixed costs are added.

TABLE 4

Yield, Costs, Revenue and returns for various summer field and truck crops in The Nasr Zone in the years 1964/65 and 1965/66.

Crop	year	area feddan	Production			Direct costs		evenue (L.E.)		Returns per feddan L.E.
			Total	Unit	per fed.	Total	per fed.	total	per fed.	
Water	64/65	608	2782047	kg	4576		39.12	27820	45.76	
Melon	65/66	253				9898	39.12	21848	86.36	47.24
Cotton	64/65	553	1528	ken	3			15278	29.90	
	65/66	611	1678	»	2.7	33560	54.93	16282	26.65	—28.28
Maize	64/65	2273	1449787	kg	638			30598	13.50	
	65/66	1156	1132590	»	980	35364	30.58	28578	24.72	— 5.86
Soyabeand	64/65	30	8794	»	293			450	15.00	
	65/66	59	21113	»	358	4374	51.46	1147	13.49	—37.97
Cowbeans	65/66	247				1076	3.45		18	13.65
Sorghum	64/66	1565							18	
	65/66	925			4819	4819	5.21		18	12.79

Source : The Egyptian authority for the Utilization and Development of Reclaimed land, *op. cit.*

CHOICE OF FIELD AND TRUCK CROP ROTATIONS

As mentioned above, alfalfa, cotton, peas, barley, broadbeans, clover, artichoke, watermelons, soyabeans, cowbeans, sorghum, maize and wheat are the important crops of northern Tahreer sector. Alfalfa is a perenial crop stays about four years in land.

Cotton also stays most of the year in land, i.e. no other crops coluld be cultivated with cotton or alfalfa within the year. Cotton returns per feddan are negative and equal to L.E. —28.80, while, it is positive for alfalfa and it is equal to about L.E. 25.12 Table (5) shows returns of each crop and annual water requrements.

Rotations are planned for three years, i.e., three winter crops are selected followed by another three summer or Nili Crops. All possible rotations are

TABLE 5

Returns and water requirement per feddan of field and truci crops in nor thern Tahreer Sector

Crop	Season	Returns (L. E.)	Water Requirements (CU.m.)
Alfalfa	1965/66	25 .120	6510
Onions	1965/66	— (*)	2100
Cotton	1965/66	—28 .280	3150
Peas	1964/65	—10 .710	2100
Barley	1965/66	— 4 .810	2100
Broadbeans	1965/66	—10 .110	2100
Clover (**)	1965/66	9 .390	3360
Artickioke	1964/65	7 .330	3360
Watermelons	1965/66	47 .240	2520
Soyabeans	1965/66	—37 .970	2100
Covbeans	1965/66	13 .650	1890
Sorghum	1965/66	12 .790	2100
Maize	1965/66	— 5 .860	2520
Wheat	1965/66	0 .590	2520

Source : Table (3) and (4), water requirements are computed at 10 % irrigation affi-ciency

(**) Data of 1965/66 do not represent the general trend.

(*) Unavialable data.

determined for the nasrzone (northern Tahreer)[1]. The following rotations are excludedrotations with two or three crops of the same kind. The field and truck winter crops of northern tabreer-peas, peas, barley, clover, wheat, broad-beans, and artichoke-could be arranged in the following patterns :

(1)	(2)	(3)	(4)	(5)
Peas	Peas	Peas	Barley	Barley
Barley	Barley	Barley	clover	Clover
Clover	wheaf	broadbeans	wheat	Broadbeans
(6)	(7)	(8)	(9)	(10)
Clover	Clover	broadbeans	Peas	Peas
wheat	bradbeans	Clover	Barley	Clover
Peas	Peas	Wheat	artichoke	articholce
(11)	(12)	(13)	(14)	(15)
Peas	Peas	barley	bariy	barley
wheat	broadbeans	clover	wheat	broadbeans
artichoke	artichoke	artichoke	artichoke	artichoke
(16)	(17)	(18)	(19)	(20)
Clover	Clover	Wheat	Peas	Wheat
Wheat	broadbean	broadbeans	Wheat	broadbean
Artichoke	artichoke	Artichoke	broadbeans	barley

Summer and Nili crops of nor thern tahreer-watermelons, maize, sorghums, cowbeans, and soyabeans-could be arranged in the following patterns :

(1)	(2)	(3)	(4)	(5)
watermelons	watermelons	watermelons	maize	watermelonss
Maize	Maize	Cowbeans	Cowbeans	Maize
Cowbeans	Sorghum	Sorghum	Sorghum	Sorghum
(6)	(7)	(i)	(9)	(10)
Watermelons	Watermelons	Maize	Maize	Cowbeans
Cowbeans	Sorghum	Cowbeans	Sorghum	Sorghum
Soyabeans	Soyabeans	Soyabeans	Soyabeans	Soyabeans

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(1) The equation used for determination of all possible combinations of crops and the exclusion of rotations as indicated aboveis :

$$\binom{N}{K} = \frac{N\ !}{(N-K)\ !\ \ k\ \ !}$$

where N = Number of crops.
K = Number of crops per rotatiun.

Each of the winter patterns is followed by any one of the summer and Nili patterns. This results in 200 possible farm rotations. Table (6), Shows returns and water requirements for all winter, and summer and nili patterns. Returns and water requirements for all the 200 farm rotations are calculated according to the figures in table (6). Rotations with negative returns are excluded. Table (7) shows a doubleclassification of all positive return rotations with respect to annual water requirements and returns. It shows that there are 113 rotations with positive rotations in northern tahreer. The Selection of the best rotation should be besed on three factors :First : returns, second : water requirements and third abor requirements. On the basis of Relatively high positive returns and moderat water requirements-less then 5000 M^3 per feddan annualy, there are 22 rotations could be denoted as the best rotatioqs in northern Tahreer. These rotations are shown in table (8). In the table «x_1» denotes alfalfa and «x_2» denotes cotton and so on.

TABLE 6

Returns and water requirements for Various Field and Truk Winter and Summer crop patterns in nor tharn Tahreer Area

Winter Patterns			Summer and Nili Patterns		
Number	Returns (L.E.)	Water requirement Cu. m.	Number	Returns (L.E.)	Water requirement Cu. m.
1	—2 .043	2520	/1	18 .343	2310
2	—4 .977	2240	/2	18 .057	2380
3	—8 .543	2100	/3	24 .560	2170
4	1 .723	2660	/4	6 .860	2170
5	—1 .843	2620	/5	1 .047	2380
6	—0 .243	2660	/6	4 .303	2170
7	—3 .810	2520	/7	4 .020	2240
8	...0 .043	2660	/8	...10 .060	2170
9	...2 .730	2520	/9	...10 .347	2240
10	2 .003	2940	/10	—3 .843	2030
11	...0 .930	2660			
12	...4 .497	2520			
13	3 .970	2940			
14	1 .037	2660			
15	—2 .530	2520			
16	5 .770	3080			
17	2 .303	2940			
18	—0 .730	2660			
19	—6 .743	2240			
20	—4 .776	2240			

TABLE 7

All Possible crop rotations with Positive Returns in northern Tahreer; classified according to annual Returns and annual inigation water requirement per feddan

Water M³ Returns (L.E.)	0—4	4—8	8—12	12—16	16—20	> 20	Total
4200—4400	—	—	—	—	23	—	1
4400—4600	14—184 194	—	21—22 181	11—191	13—183 193	—	11
4600—4800	6—7—46 47—64 66—67— 77—86— 87—107 114—146 147	4—44 84— 144	182	12—62 113—192	—	3—43— 63—83 —143	28
4800—5000	57—106 176	36—37 54—56 74—76 104—134 136—137 174—177	34	1—2—61 81—82 111—112	41—42— 51—71 101—131 171	31—33—54 73—103 133—173	39
5000—5200	35—55— 75—105 135— 175	96—97 127— 167	94—99— 124—164	—	52—72— 102—132 172	32—93 132—163	23
> 5200	95—165	125— 166	126	—	—	91—92 121—122 162—163	113
Total	28	22	10	15	16	22	113

OPTIMUM CROPPING PATTERN IN NORTHERN TAHREER

The optimum cropping pattern is the cropping pattern which maximizes farm returns. The problem involved is the determination of acreage which must be devoted to each production activity (crop or farm rotation), which maximizes the project returns, given the technical, econemic, and socialcondt-itions under which the project is going to be executed. The problem is a linear programing problem. The Model consists of the objective function which should be optimized ; the constraints of the production process (resources) and the technical coefficient matrix.

The objective function of northern Tahreer :

As shown above, field crops which stay the full year and cultivated in northern tahreer include alfalfa and cotton. These activities are denoted (X_1) and (X_2) respectively. Returns per feddan amount to about L.E. 25.12 and L.E.—28.28 for X_1 and X_2 respectively. Peas, barley broadbeans, clover artichoke and wheat are cultivated in winter. However, in summer and Nili seasons, Watermelons, maize, cowbeans, sorghum and soyabean are cultivated in northern tahreer. All suitable and possible rotations for this group of crops amount to 200 rotatins. These 200 rotations had been classified according to farm income and annual irrigation water requirment are shown in tables ( ) and ( ). All farm rotations with annual returns per feddan less than L.E. 16 and requiring irrigation water exceeding 5000 cubic meters per feddan are excluded. Though, only twenty two farm rotatins are considered and designated by (X_3), (X_4, (X_5), (X_6), (X_7), (X_8), (X_9), (X_{10}), (X_{11}), (X_{12}), (X_{13}), (X_{14}), (X_{15}), (X_{16}), (X_{17}), (X_{18}), (X_{19}), (X_{20}), (X_{21}), (X_{22}), (X_{23}) (X_{24}). According to 1o activity (X_3), i.e. crop rotation 3, the area has to be divided between peas, barley, and clover in winter, also between the summer crops, watermelons, (cowbean, and sorghum. Table (8) illustrates various combinations of winter and summer crops in these production activities, where winter crops, peas, barley, clover, Wheat, artichoke, and broadbeans are substituting each other, and also, the summer crops, maize, cowbeans, and sorghum.

Computation of returns per feddan for these rotations as shown in table ( ) reveals that L.E. 22.517 are expected for activity (X_3), L.E. 19.582 for activity (X_4), L.E. 16.017 for aitivity (X_5), and so on. Accordngly, the problem is to maximize the objective function. In other words, the problem is to determine the acreage which must be drvoted to each of the twenty-four rotations which maximizes total areas returns.

The Mathematical form of the objective function in northern Tahreer model is

Maximize

$$25.120X_1 + (-28.280)\,X_2 + 22.517\,X_3 + 19.583\,X_4 + 16.017\,X_5 + 22.717\,X_6 + 20.750\,X_7 + 21.830\,X_8 + 22.030\,X_9 + 17.817\,X_{10} + 19.784\,X_{11} + 13.567\,X_{12} + 13.360\,X_{13} + 13.080\,X_{14} + 19.247\,X_{15} + 20.063\,X_{16} + 13.281\,X_{17} + 20.060\,X_{18} + 26.283\,X_{19} + 24.317\,X_{20} + 24.517\,X_{21} + 23.630\,X_{22} + 25.597\,X_{23} + 23.830\,X_{24}.$$

The Constraints of Production in Tahreer area :

Naturally, there are numerous factors limiting agricultual production in northern tahreer sectoor. Among the most important, are land, water, and agricultural labor. These factors are discussed below.

Land :

Land has been used to refer to the originl and indestructible properties of the soil. In nor thern, tahreer, the limited land resource represents the area which already reclaimed and cultivated . In nor thern tahreer, cultivated area is about 12677 and 23336 feddans in Nasr and Revolntion zones respectively in 1966. This study as indicated above is concernd only with the nasr zone and its cultivated area represents the first limitation to farm production. In nor thern tahreer (nasr zone), orchard crop area in 1965/66, is composed off :

3782 feddans grapes, 409 feddans olives, 50 feddans almonds, 50 feddans pecan and 41 feddans citrus. area left for field and trucé crop rotations is about 6898 feddans which is the value of the land costiant.land constraint means that acreage devoted for all production activities must be less or equal to given area.

Mathematically, land constraint fof the nasr-zone takes the following form :

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{20} + X_{21} + X_{22} + X_{23} + X_{24} \leq 6898$$

Labor :

The term labor in this constext, means temporary agricultural labor. Agricultural labor sets an important constraint to agricultural production in nor thern

TABLE 8

Returns and water requirements for selected* field and Truce crop rotations in Nasr sone

Number of Rotation	activity	Field and truck crop rotations		Annual Returns (L.E.)	Water reqiremnets M^3 year
		Winter	Summer and Nili		
3	X 3	P ... B ... C	WM ... Cb — S	22.517	4690
13	X 4	P — B — W	WM — Cb — S	19.583	4410
23	X 5	P ... B ... Bb	WM ... Cb — S	16.017	4270
43	X 6	B ... C ... Bb	WM — Cb ... S	22.717	4690
63	X 7	C ... B — P	WM ... Cb — S	20.750	4690
83	X 8	P ... B — Ar.	WM ... Cb S	21.830	4690
143	X 9	B ... Bb ... Ar.	WM ... Cb ... S	22.030	4690
183	X 10	P — W ... Bb	WM ... Cb ... S	17.817	4410
193	X 11	W ... Bb ... B	WM ... Cb S	19.784	4410
191	X 12	W ... Bb ... B	WM ... Z ... Cb	10.567	4550
11	X 13	P ... B ... Bb	WM ... Z ... Cb	13.133	4550
12	X 14	P ... B ... Bb	WM — Z ... S	80.360	4620
62	X 15	C ... Bb ... P	WM ... Z ... S	14.247	4800
113	X 16	P ... Bb ... M	WM ... Cb ... S	20.063	4690
192	X 17	W ... Bb ... B	WM ... Z ... S	13.281	4620
31	X 18	B ... C ... W	WM ... Z ... Cb	20.066	4970
33	X 19	B ... C ... W	WM ... Cb ... S	26 283	4830
53	X 20	C ... W ... P	WM ... Cb ... S	24.317	4830
73	X 21	Bb ... C ... W	WM — Cb ... S	24.517	4830
103	X 22	P ... W ... Ar	WM ... Cb S	23.630	4830
133	X 23	B ... W ... Ar	WM ... Cb ... S	25.597	4830
173	X 24	W ... Bb — Ar	WM — Cb S	23.830	

Source : Tables 3, 4, 5, 6, and 7.

* P = peas,, B = Barley, C = clover, W = Wheat, Bb = Broadbeans
AR = Artichoke, WM = Whatermelons, Cb = Cowbean, S = Sorghurm, M = Maize

tahreer. This is due to the long distance seperating the sector from the high density populated areas in the Delta, moreover, the working conditions and climate in summer are other factors which add to the problem.

In nor thern tahreer, nearly all worlers are migrators. The monthly number of workers in northern tahreer (Nasr-zone) according to Nasr zone adminstration in 1966, are :

(b_2)	(b_3)	(b_4)	(b_5)	(b_6)	(b_7)
63820	66094	60502	73384	71182	65466
(b_8)	(b_9)	(b_{10})	(b_{11})	(b_{12})	(b_{13})
56823	62965	68324	69532	70183	69450

in months january up to December respectively. That means 12 constraints of labor in the 12 Months. The mathematical form of labor constraints are

$$\sum_{c=1}^{24} a_i \; x_i \leqslant b_j$$

Where i = 1,....., 24, j = 1, 2, ..., 12, is the + technical coefficient for final product xi and b j is the monthly labor constraint.

The twelve monthly labor constraints in Nasr zone are :

$$7 X_I + 3 X_3 + 3 X_4 + 4 X_5 + 3 X_6 + 3 X_7 + 3\tfrac{I}{3} X_8 +$$
$$3 \tfrac{I}{3} X_9 + 4 X_{I0} + 3 X_{II} + 3 X_{I2} + 4 X_{I3} + 4 X_{I4} + 4 X_{I5} +$$
$$4 \tfrac{I}{3} X_{I6} + 3 X_{I7} + 2 X_{I8} + 2 X_{I9} + 3 X_{20} + 3 X_{2I} + 3 X_{22} +$$
$$2 X_{23} + 3 X_{24} \leqslant 63820$$

$$2 X_I + 3 X_3 + I\tfrac{1}{2} X_4 + I\tfrac{2}{3} X_5 + 3\tfrac{1}{2} X_6 + 3 X_7 + 3\tfrac{2}{3} X_8 +$$
$$3\tfrac{2}{3} X_9 + I\tfrac{2}{3} X_{I0} + I\tfrac{2}{3} X_{II} + I\tfrac{1}{2} X_{I2} + I\tfrac{2}{3} X_{I3} + I\tfrac{2}{3} X_{I4} +$$
$$3\tfrac{2}{3} X_{I5} + 4 X_{I6} + I\tfrac{1}{2} X_{I7} + 2\tfrac{1}{2} X_{I8} + 2\tfrac{2}{3} X_{I9} + 3 X_{20} + 3\tfrac{2}{3} X_{2I} +$$
$$3\tfrac{2}{3} X_{22} + 3\tfrac{I}{3} X_{23} + 2\tfrac{2}{3} X_{24} \leqslant 66094$$

$$6X_1 + 8X_2 + 2X_3 + 2X_4 + 2X_5 + 1X_6 + 2X_7 + 2X_8 + 6X_9 + 2X_{10} + 1X_{11} + 1\tfrac{1}{2}X_{12} + 2X_{13} + 2X_{14} + 2X_{15} + 2X_{16} + 1X_{17} + 1\tfrac{1}{2}X_{18} + 1\tfrac{1}{2}X_{19} + 2X_{20} + 2X_{21} + 2X_{22} + X_{23} + 2X_{24} \leqslant 60502$$

$$2X_1 + 4X_2 + 3X_3 + 2X_4 + 2X_5 + 3\tfrac{1}{2}X_6 + 3X_7 + 3X_8 + 2X_9 + 3\tfrac{1}{2}X_{10} + 1\tfrac{1}{2}X_{11} + 1\tfrac{1}{2}X_{12} + 2X_{13} + 2X_{14} + 4X_{15} + 3X_{16} + 1\tfrac{1}{2}X_{17} + 2X_{18} + 2X_{19} + 3X_{20} + 3X_{21} + 3X_{22} + X_{23} + 2X_{24} \leqslant 73384$$

$$6X_1 + 5X_2 + 24X_3 + 24X_4 + 24X_5 + 24X_6 + 23X_7 + 24X_8 + 25X_9 + 25X_{10} + 25X_{11} + 26X_{12} + 24X_{13} + 26X_{14} + 25X_{15} + 25X_{16} + 26X_{17} + 23X_{18} + 22X_{19} + 23X_{20} + 27X_{21} + 24X_{22} + 21X_{23} + 25X_{24} \leqslant 71182$$

$$2X_1 + 4X_2 + 21X_3 + 20X_4 + 21X_5 + 21X_6 + 21X_7 + 21X_8 + 21X_9 + 21X_{10} + 25X_{11} + 24X_{12} + 21X_{13} + 21X_{14} + 17X_{15} + 18X_{16} + 24X_{17} + 24X_{18} + 25X_{19} + 21X_{20} + 21X_{21} + 21X_{22} + 25X_{23} + 21X_{24} \leqslant 65466$$

$$6X_1 + 7X_2 + 10X_3 + 10X_4 + 10X_5 + 10X_6 + 10X_7 + 10X_8 + 10X_9 + 10X_{10} + 10X_{11} + 18X_{12} + 9X_{13} + 9X_{14} + 9X_{15} + 10X_{16} + 9X_{17} + 9X_{18} + 10X_{19} + 10X_{20} + 10X_{21} + 10X_{22} + 10X_{23} + 10X_{24} \leqslant 56823$$

$$6X_1 + 9X_2 + 11X_3 + 11X_4 + 11X_5 + 11X_6 + 11X_7 + 11X_8 + 11X_9 + 11X_{10} + 11X_{11} + 9X_{12} + 9X_{13} + 9X_{14} + 9X_{15} + 11X_{16} + 9\tfrac{1}{2}X_{17} + 9X_{18} + 11X_{19} + 11X_{20} + 11X_{21} + 11X_{22} + 11X_{23} + 11X_{24} \leqslant 62965$$

$$2X_1 + 8X_2 + 10X_3 + 10X_4 + 10X_5 + 10X_6 + 10X_7 + 10X_9 + 10X_{10} + 10X_{11} + 11X_{12} + 11X_{13} + 11X_{14} + 11X_{15} + 10X_{16} + 11X_{17} + 11X_{18} + 10X_{19} + 10X_{20} + 10X_{21} + 10X_{22} + 10X_{23} + 10X_{24} \leq 68324$$

$$9X_1 + 5X_3 + 4X_4 + 6X_5 + 5X_6 + 5X_7 + 6X_8 + 6X_9 + 6X_{10} + 5X_{11} + 5X_{12} + 6X_{13} + 6\frac{1}{2}X_{14} + 6X_{15} + 8X_{16} + 5X_{17} + 3\frac{1}{2}X_{18} + 3\frac{1}{2}X_{19} + 5X_{20} + 5X_{21} + 6X_{22} + 4X_{23} + 6X_{24} \leq 69532$$

$$4X_1 + 2X_3 + 2X_4 + 2\frac{1}{2}X_5 + 2X_6 + 2X_7 + 3\frac{1}{2}X_8 + 3X_9 + 3X_{10} + 2X_{11} + 2X_{12} + 3X_{13} + 3X_{14} + 3X_{15} + 4X_{16} + 2X_{17} + 2X_{18} + 2X_{19} + 3X_{20} + 2X_{21} + 3X_{22} + 2X_{23} + 3X_{24} \leq 70183$$

$$9X_1 + 4X_3 + 4X_4 + 3X_5 + 4X_6 + 4X_7 + 4X_8 + 3X_9 + 3X_{10} + 4X_{11} + 4X_{12} + 3X_{13} + 3X_{14} + 3X_{15} + 2X_{16} + 4X_{17} + 5X_{18} + 5X_{19} + 4X_{20} + 4X_{21} + 4X_{22} + 4X_{23} + 4X_{24} \leq 69450$$

These Technical coefficients are calculated according to the standard labor requirements. It should be noted that the monthly labor constraints represent the actual available labor in 1966, excluding labor required for orchard and ivestock production.

Irrigation Water :

Irrigation water is one of the important constraints of agricultural production, generally in Egypt and especially in desert areas. The source of water is Tahreer is characterized by seasonality. In other words, water should enter the model with 12 monthly constraints.

In spite of the importance of irrigation water in our model, it is not included. No reliable data of monthly available quantity of irrigation water are available. There are estimates for it, but it does not represent reality.

Although water constraint is excluded from our programming model, importance of irrigation water had been taken inconsideration. All activities included in the model require less than 5000 M^3 of irrigation water annually, while activities requiring high quantity of irrigation water are exluded completely.

The Model :

The linear programmirg model consists of 24 activities and 13 constraints (pne for land, 12 for labor). The complete model is shown in table (9).

TABLE 9

The Linear Programming Model of Northern Tahreer area

Maximize

	X1	X2	X3	X4	X5	X6	X7	X8
	25 .120	— .28 .280	22 .517	14 .583	16 .617	22 .717	20 .750	21 .830
(1)	1	1	1	1	1	1	1	1
(2)	7		3	3	4	3	3	3 .3
(3)	2		3	1 .3	1 .7	3 .3	3	3 .7
(4)	6	8	2	2 .7	2 .0	1 .3	2	2 .3
(5)	2	4	3 .7	2 .0	2 .7	3 .3	3 .7	3
(6)	6	5	24	24	24	24	25	24
(7)	2	4	21	20	21	21	21	21
(8)	6	7	10	10	10	10	10	10
(9)	6	11	11	11	11	11	11	11
(10]	2	8	10	10	10	10	10	10
(11)	9		5	4 .7	6 .3	5	5	6 .3
(12)	4		3 .7	2	2 .7	2 .3	2 .7	3 .3
(13)	9		4 .7	4 .3	3 .3	4 .3	4 .7	3 .7

Model Soultion :

The optimum value of the objective finction is about L.E. 75549.46 annually. Activities selected are X_{19} and X_{20}. Activity X_{19} denotes farm rotation which includes barley, Egyptian clover, and wheat as winter crops, and watermelons, cowbean, and sorghums as summer crops. Activity «X_{20}» denotes farm rotation. which includes the same crops as in rotation «X_{19}» except the exclusion of barley and the inclusion of peas. Acreage devoted to X_{19} and X_{20} are 96 and 3002 feddans respectively.

TABLE 9 *(Continued)*

	X9	X10	X11	X12	X13	X14	X15	X16	X17
	22.030	17.817	19.784	13.567	13.360	13.080	14.247	20.063	13.281
(1)	1	1	1	1	1	1	1	1	1
(2)	3.3	4	3	3	4	4	4	4.3	3
(3)	3.7	3.7	3.3	3.3	1.3	1.7	3.3	4	1.3
(4)	6	2	1.3	1.3	2	2	2.3	2.7	1.3
(5)	2.3	2.3	2.3	1.3	2.3	4	4	3.3	1.3
(6)	25	25	25	26	24	26	25	25	26
(7)	21	21	25	24	21	21	17	18	24
(8)	10	10	10	18	9	9	9	10	9
(9)	11	11	11	9.3	9.3	9.3	9.3	11	9.3
(10)	10	10	10	11	11	11	11	10	11
(11)	6.3	6.3	4.7	4.7	6.3	6.3	6.7	8	5
(12)	3	2.7	1.7	1.7	2.7	2.7	3.3	4	1.7
(13)	3.3	3.3	4	4	3.3	3.3	3.7	2.7	4

TABLE 9 *(Continued)*

	X18	X19	X20	X21	X22	X23	X24	
	20.06	26.283	24.317	24.517	23.630	25.597	23.830	b
(1)	1	1	1	1	1	1	1	< 6898
(2)	2	2	3	3	3.3	2.3	3.3	< 63820
(3)	2.7	2.7	3	2.7	2.7	3.3	3.7	< 66094
(4)	1.3	1.3	2	2.3	2.3	2.3	2	< 60502
(5)	2.7	2.7	2.7	3	3	2.7	2.7	< 73384
(6)	23	22	23	27	24	21	25	< 71182
(7)	24	25	21	21	21	25	21	< 65469
(8)	9	10	10	10	10	10	10	< 56823
(9)	9.3	11	11	11	11	11	11	< 62965
(10)	11	10	10	10	10	10	10	< 68324
(11)	3.3	3.3	5	5	6.3	4.7	6.3	< 69532
(12)	1.7	1.7	2.7	2.3	6.3	2.3	3	< 70183
(13)	5.3	5.3	4.7	4.3	3.7	4.3	3.3	< 69450

It should be noted, that the optinum program does not inclnde cotton, alfalfa or rotations, including maize, broadbeans and syabeans. Also, it shows that agricultural labor is a limiting resource of production in northern tahreer especally in May and June.

COCLUSIONS

Land productivity and returns of most of the field and truck crops in northern tahreer are low, if campared to those in the Nil valley. This is due to the recent agricultunal land development in Northern tahreer. However, these is a possibility of increasing the economic efficiency of the sector through the selection of the best agricultural rotations. The article indicated that cotton and maiz broadbeans and soyabeans should not be cultivated at all in the sector. Crop selected are barley, Egyptian clover, Peas, wheat, watermelons, sorghums and cowbeans. Acreage devoted to each is indicated in the article above. The program suggested, secures to the country around L.E. 75549 annually as returns over variable costs, instead of negative returns. Returns could be increased if labor constiant is relaxed in May and June.

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