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Estimation of Risk in Egyptian Agriculture in The Light of the Current Variables: An Analytical Study Using MOTAD Model Approach

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Abstract
The present study introduces a mathematical description of the risk models in the cropping pattern to determine the scientific basis for estimating it. We evaluated two mathematical models based on linear and non-linear programming methods for estimating the associated risks. The first model dealt with maximizing the net return per acre for various crops under certainty, taking risk into account. The second model considered the maximum potential level of productive risk in light of constraints and limitations, achieving high self-sufficiency rates for strategic crops. The results of solving these models using MOTADindicated that the application of the first model was preferred because it took the risk element into account for both the net yield and the water requirements of the crops. In this model, the net return could be maximized by 6.7%, estimated at 4.2 billion L.E. as a surplus, and the irrigation water was estimated at 1.053 billion meters cubic(m^3) after optimization. According the water saving, 412 thousand feddans could be added in new lands. Following this model, it was also suggested to expand the cultivated areas for some crops, such as wheat, under different irrigation systems (such as sprinkling and drip), which contributed to raising the self-sufficiency rates (SSR) of many important crops, including wheat, Baladi beans, and maize in 2019.

Keywords: *Agriculture-associated risks, optimization, cropping pattern, programming model*

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I. Introduction

The agricultural sector is considered one of the most important productive and economic sectors in Egypt. Agriculture contributed by 14% to Gross domestic product (GDP, Dhehibiet al.,2016)with the value of agricultural production standing at EGP 469.202 billion L.E. (Egypt State Information Service, 2018). This sector also accounts for about 25.8% of the total employment, and it is one of the elements of achieving food security, meeting local needs of food commodities, and providing production requirements for other sectors.However, Egypt lags in achieving self-sufficiency in strategic food products. The self-sufficiency ratios for Wheat, Maize,and Beans in 2018 were 42 %, 50 %, and 52%, respectively. Making Egypt a Net Food Importer (Ministry of Agriculture and Land Reclamation (MALR 2017- 2018)). In the same year, imports of agricultural products amounted to 269.481 billion L.E, (Food and Agriculture organization FAO, 2018).

Despite the importance of this sector, many risks affect the agriculture sector, including but not limited tothe fluctuations in crop production and prices, the production factors, rapid change in population and urbanization, limited landand water resources. In addition to the risks that growers may be exposed to, either in the decrease in the return or the increase in the prices of production inputs, which leads to a rise in both the burden and the cost of risks. The difficulty in predicting these risks mentioned above leads to increased concerns among producers and limits investment in the agricultural sector.

The problem to which the current study is seeking solutions is that the agricultural production faces many natural and economic risks that is caused by exogenous factors related to the nature of agricultural production, which must be taken into account when planning for the optimum crop pattern, and how the impact of risk could be minimized and agricultural income could be stabilized and returns could be maximized.

Hence in agriculture, it is crucial to evaluate and manage agricultural risks and select the best management methods.Integrated risk assessment helps to identify more than one risk and leads to greater decision-making efficiency.Subsequently, crop optimization has received extensive attention in recent years, and mathematical models have been developed to determine the optimal use of the available resources for maximizing the net benefits subjected to some constraints.

Liner programming (LP) models that are based on either profit maximization or cost minimization disregard uncertainty. LP is one of the best and simple techniques for optimizing an irrigated area where various crops compete for a limited quantity of land and water resources (Abdou and Frag, 1993). The MOTAD model measures risk as absolute deviations from a target goal. The model is transformed into a LP problem that minimizes the mean absolute income deviations.

Several researchers have applied LP models to develop an optimal cropping pattern within the available resources and constraints of their study areas(Maqsood et al. 1994;Guptaet al.,2000;Bajalinov, 2004;Aghajani et al. 2013). Among those previous studies, Sarker et al. (1997) developed LP model to determine the area to be used by different crops for their maximum contributions taking into account the land types, alternative crops/crop combinations, and investment.

The objective of the current study is to formulate a linear programming model to determine the optimal use of productive resourcesin Egypt based on the available data from 2013 to 2018, aiming to i) reach a crop composition that is low in the associated risks, ii) achieve the maximum possible profit margin from the available agricultural land, and iii) minimize the consumption of irrigation water to achieve water savings that can be redirected for the purposes of horizontal expansion and achieving food security, thus maximizing the net profit of cultivation.

II. Risk Assessment in Agriculture

Agriculture is a risky activity mainly because agricultural production occurs in a risky environment, such asbiological risks, climatic changes; price-associated risks such as uncertainty in the prices of inputs and outputs; financing risks such as unavailability of credit in time and fluctuations in interest rates there is a need to make decisions on how to manage the risk. For this reason, risk can be defined as choosing among alternatives that reduce the financial effects of the uncertainties of weather, yields, prices, government policies, global markets, and other factors that can cause variations in farm income (El-Maghazy, 2004; Abraham, et al., 2004)

While that as all actions that might be taken by a farmer are subject to risk, there is no distinction between farm management and what is historically called risk management. In many ways, all decisions made in agricultural systems are made with imperfect knowledge about the outcomes. A crop is selected, sown, managed, and harvested in weather conditions that are uncertain at sowing. A yield of unknown quality is harvested, and after which, the product is then sold at what may be an unknown price. These unknowns make efficient resource allocation decisions difficult. Therefore, risk management at the farm level is extremely important because the inability to adapt would lead to lower incomes and loss of livelihoods for millions in developing countries.

The currentstudywill provide analysis for the majorrisks in agriculture and reveal their relation to variousscientific theories.There are two categories of risks; direct risks and indirect risks(Figure 1).The direct risks include the natural risks and the risks associated with encroachment by building on the agricultural areas, the steady population increase, the decline of the financing role, and the climate changes that lead to negative changes in production, crop composition, agricultural transactions, price levels. Whereas the indirect risks include the decline of the agricultural extension role, the lack of adequate information and statistics, the diminishing role of the cooperative societies as well as the weakness of the institutional, structural, organizational and legislative reform of the institutions and national associations (Benli and Kodal,2003; Collette and Siarry,2003). The aforementioned risks are also coupled with many other general risks such as production risks, marketing risks, credit risks, political risks, personal risks, and environmental risks.Each of these risks plays a role in the decision-making process bythe government, the farmers, and the agriculture sector producers in general. Since these risks are overlapping/interacting and influencingeach other's, therefore,it is difficult to isolate different types of agricultural risks in the processes of the analysis, evaluation, or management. For instance, the production risk is related to the economic, political, and personal risks, and the economic risk depends on the country's political situation and the existing legislation and regulations.

Also,the credit risk depends on the regulation, which is part of the political risk, and on the country's general economic situation.All the risks that are facing the agriculture production in Egypt are concluded in (Figure 1).

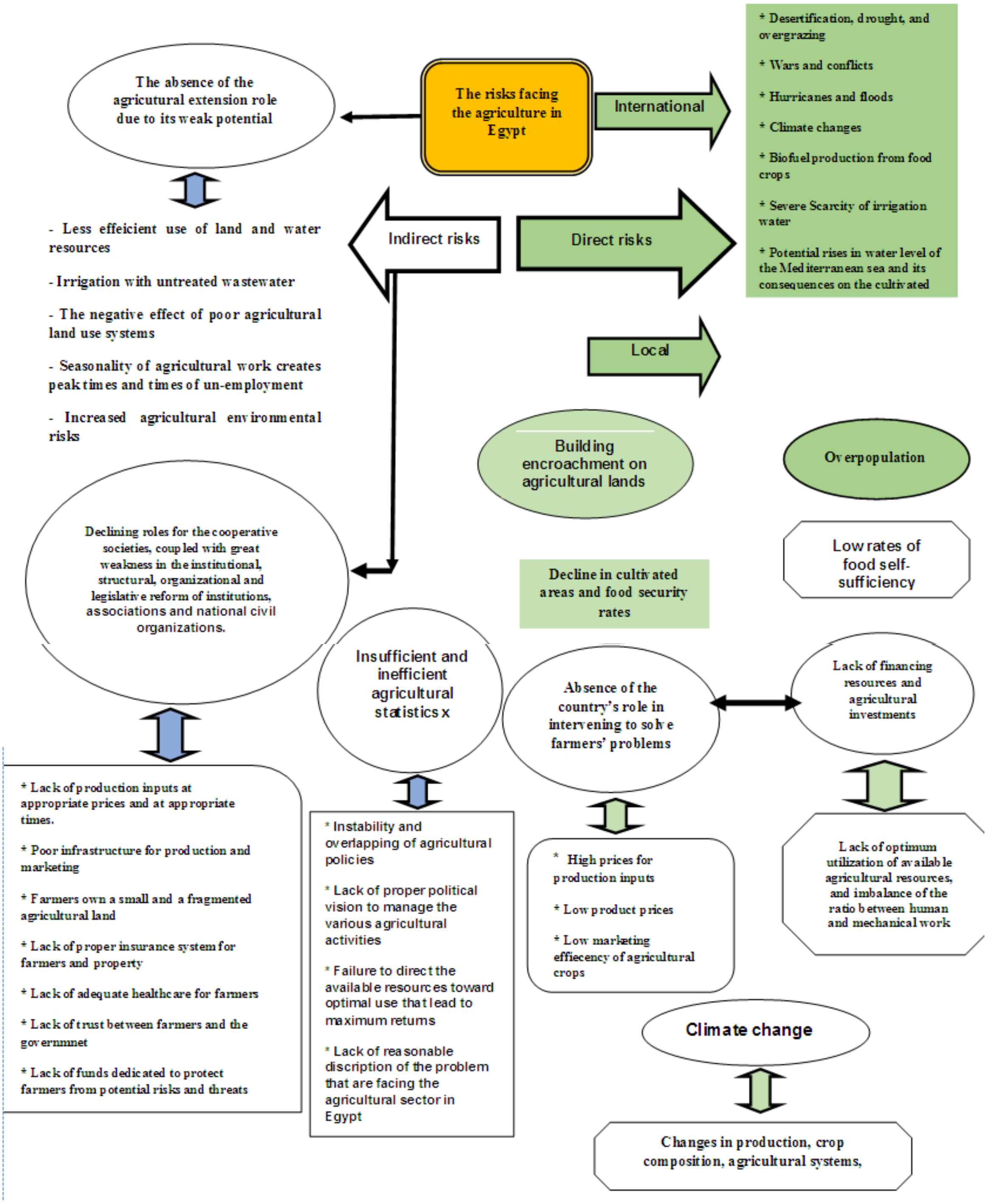

Figure 1. A diagram for the risks that are facing the agricultural sector in Egypt

III. Materials and Methods

The analysis and the results presented in the current article were mainly based on the published statistical data obtained from the Ministry of Agriculture and Land Reclamation (MALR) and the Ministry of Water Resources and irrigation (MWRI) in Egypt(the period from 2013 to 2018). The technical coefficients that quantify resource requirements are determined as a weighted average for real values of the most recently available data during six years (2013-2018). Moreover, individual crops are subject to organization constraints, which are the upper and lower limitations.

Linear programming(LP) is considered one of the most analytical methods used to determine the optimal crop pattern of agricultural production units. in our cases risk estimation is adopted by (LP) for MOTAD model to minimize the absolute differences in the net return.In order to achieve the aims of the current study,our analysis depend on three parts: objective function; linear constraints; and non-negativity constraints. Also, the used model is subjected to different constraints, includingthe water availability, land area restrictions for different seasons and achievingself-sufficient rates in strategic crops.

The objective function: minimize the risks in Egyptian agriculture and determine the optimum cropping pattern. The model was applied in two possible future scenarios in accordance with the objective function as the following:

1st scenario: LP model is formulated to suggest the optimum cropping pattern with maximizing net return per unit under certainty in light of the model's constraints and conditions, which is subjected to take the risk into account over the study period.

2nd scenario: The model is employed to take the maximum possible level of risks and maximizes net return in light of the model's constraints and conditions, taking into account the increasesin the SSR of the strategic crops.

A typical specification can be written as follows (Hazel, 1971):

$$MinimizeZ = \sum_{h=1}^{s} \bar{y}_h \quad (1)$$

Subject to :

$$\sum_{j=1}^{n} (\mathrm{ch}_j - \mathrm{g}_j)\mathrm{x}_j \pm \bar{y}_h \geq 0 \ (forallh, h = 1, \ldots, s) \quad (2)$$

and

$$\sum_{j=1}^{n} f_j x_j = \lambda \ (\lambda = 0 \text{ to unbound}),$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \ \ (foralli = 1, \ldots, m)$$

$$Z = x_j, \bar{y}_h \geq 0 \ \ (forallh, j) \quad (3)$$

$$\sum_{j=1}^{n} (\mathrm{ch}_j - \mathrm{g}_j)\mathrm{x}_j = sumoftheabsolutevaluesfornetreturnyearly, j = 1$$

Where:

$\bar{y}_h$ = is the absolute value of the negative deviation in gross margin from its mean at h^{th} year.

ch_j= is the expected gross margin of j^{th} crop or activity

x_j = is the activity level

a_{ij} = is the technical coefficient

λ= constant

b_i = is the available resource

$\sum_{j=1}^{n} f_j x_j =$

is the expected total gross margin which parametrically changes from 0 to Emax. wile, m, n, t= are respectively number of activities, constraints, and sample years.

1.1 Linear constraints: The previously mentioned objectives are subjected to sets of constraints that are to be satisfied within the model, which include the following:

a. **Land area constraints in different seasons**: this implies that the sum of areas allocated to crops in a certain season must not exceed or equal the total land area available for that season.

$$\sum_{j=1}^{ns} x_j \leq A_s \quad (4)$$

where the subscript s refers to the season (s= 1, 2 and 3 for the winter, summer and Nile crops, respectively). ss is the sum of the available area for cultivation in feddan in different seasons of a year.

In setting up the LP problem, the assumption is that series of linear constraints including the 47 crop activities. The total available cropped areas for the modeling was about 11.4 million feddan, representing about 80% of the total cropped area of about 14 million feddan as an average of the years (2013-2018) in Egypt. It is distributed over the three seasons of the year: 6.052 million Feddan for the winter season, 5.425 million Feddan for the summer season and Nile seasons, and 1.066 million Feddan for fruits representing land restrictions. Due to the limitations of the data on other field crops, they are excluded from this study.

b. **Water requirement**: this constraint represents minimization of the use of irrigated water. The total water requirement for different crops should be less than or equal to the total water available at the field during the year. around 41.4 billion cubic meters.

$$\sum_{j=1}^{n} CWR_j \; x_j \leq W_j \qquad (5)$$

where CWR_j is the water ration for the ith crop in m^3/ fed, and W_t is the total water available for irrigation at field in m^3.

3.2**The non-negativity constraint** where all the area should not be less than zero.

IV. Results

4.1. Ranking the agricultural crops in Egypt for the degree of related risks

There are numerous mathematical models used for risk analysis and uncertainty in economic activities in general and agricultural production activities in particular as important analytical models (Hardaker,[20]. The production risks of the most important crops were estimated in Egypt during the average period of 6 years (from 2013-2018).The data in the current article is mainly based on published statistical data from the (MALR and MWRI in Egypt). The technical coefficients that quantify resource requirements are determined as a weighted average for real values of the most recently available six years (2013-2018). Moreover, individual crops are subjected to organization constraints, which are the upper and lower limitations.

The agricultural crops in Egypt were ranked for the degree of related risks by taking the average values of the net return for the cultivated areas.Risksare expressed by amount of variance (V), standard deviation (Sd) and coefficient of variation (CV, Table 1).

Table 1. Ranking the agricultural crops in Egypt for the degree of related risks. The data represents the net return per unit from the years 2013 to 2018.

	Low risk				Medium risk				High risk		
Crops	AV	SD	CV %	Crops	AV	SD	CV %	Crops	AV	SD	CV
Carcadeh	19.6	975	4.96	Summer Pepper	2.9	595	20.3	Nile White Maize	2.6	1311	50.0
Clover	11.7	786	6.67	Green Peas	7.8	1596	20.4	Potatoes Summer	3.5	1867	52.8
Basil	11.7	794	6.76	SummerSoybeans	3.2	687	20.9	Barley	2.2	1203	52.8
Coriander	21.9	1971	8.97	Flax	3.1	794	26.3	Potatoes Summer	5.3	3150	58.5
Clover Thresh	5.1	711	13.90	Squash	4.2	1128	26.5	Sugar Cane	4.9	3633	73.1
Pepper	15.5	2260	14.56	Eggplant	3.5	952	27.0	Cotton	5.1	3878	76.3
Summer Sorghum	7.9	1256	15.75	Summer Watermelon	8.2	2234	27.1	Fennel	1.7	1670	93.5
Summer Eggplant	4.1	644	15.83	Nile Cabbage	3.6	984	27.2	Sunflower summer	3.5	3649	102.4
Henna	3.4	563	16.15	Rice	2.4	681	27.6	Caraway	4.9	5087	102.7
Summer Tomato	4.9	808	16.43	Summer Tomato	5.8	1642	27.9	Lupine	741	1005	135.7
Wheat	3.8	650	16.95	Sugar Beet	4.1	1166	28.9	Chick Peas	3.1	4555	148.1
Squash Summer	3.3	603	17.79	Garlic	11.9	3634	30.3	GreenMarjorm	4.8	7598	157.5
Wormwood	4.3	786	17.92	Lentil	2.7	888	31.8	Green Mint	536	1003	187.2
Bardacoch	13.5	2594	19.18	Aniseed	6.5	2082	32.0				
Cantaloupe	3.2	625	19.26	Sesame summer	12.5	4117	32.8				
Tomato	8.2	1610	19.41	Peanuts Summer	1.5	501	33.0				
Cabbage	7.2	1401	19.43	Broad Beans	2.4	884	36.2				
				Summer Okra	12.5	4671	37.1				
				Onion	11.3	4533	39.9				
				Summer Maize	1.9	819	41.2				
				Summer Cucumber	10.3	4333	42.0				
				Fenugreek	1.8	841	46.6				
				Cumins	7.5	3691	49.2				

Average of net return/unit in Egyptian pound (L.E), standard deviation, and coefficient of variance are shown. AV, average of cultivated area; SD, standard deviation, CV, coefficient variance.

The results indicated that, the crops-related risks could be divided into the following three groups; crops with a net return value of 0-20% represent the low risk; crops with value of 20-40% represent the medium risk; and crops with value of > 40% represent the high risk.

The analysis of risks that arefall under low-risk category, through the application of this approach, has resulted in thatTomato and Cabbage are exposed to high risks due to the fluctuation of the farm price. Whereas the summer Cucumber, Fenugreek and Cumin have been more exposed to risks under medium risk, regardless of being non-strategic crops. It may be because the observedreductionin the net return per feddan through the same period as shows in (Figure 2A and 2B**)**. The net return of maize, potatoes, barley, sugar crops, cotton, sunflower, caraway, fennel, chickpea, lupine, and municipal mint has fall in the high-risk category, due to the fluctuation of the farm price and the total costs, and consequently the fluctuation in the net return per feddan during that period. Moreover, the response of farmers to cultivation of maize, potatoes, sugar crops and cotton depends on the farm price and net return was expected(Figure 2C).

Hence, the absence of complete information and a fair price policy diel to encourage farmers to make the decision to cultivate such a cropor not. Therefore,it is necessary to positionthe crops under high risk under the umbrella of insurance compulsory, whereas the crops under low risk must be positioned under the voluntary insurance scheme. Given the characteristics of agriculture in Egypt, the obtained results presented in Table 1 coincide with the previous reports by (El-Refaie et al.,2019; Osama et al,2017).

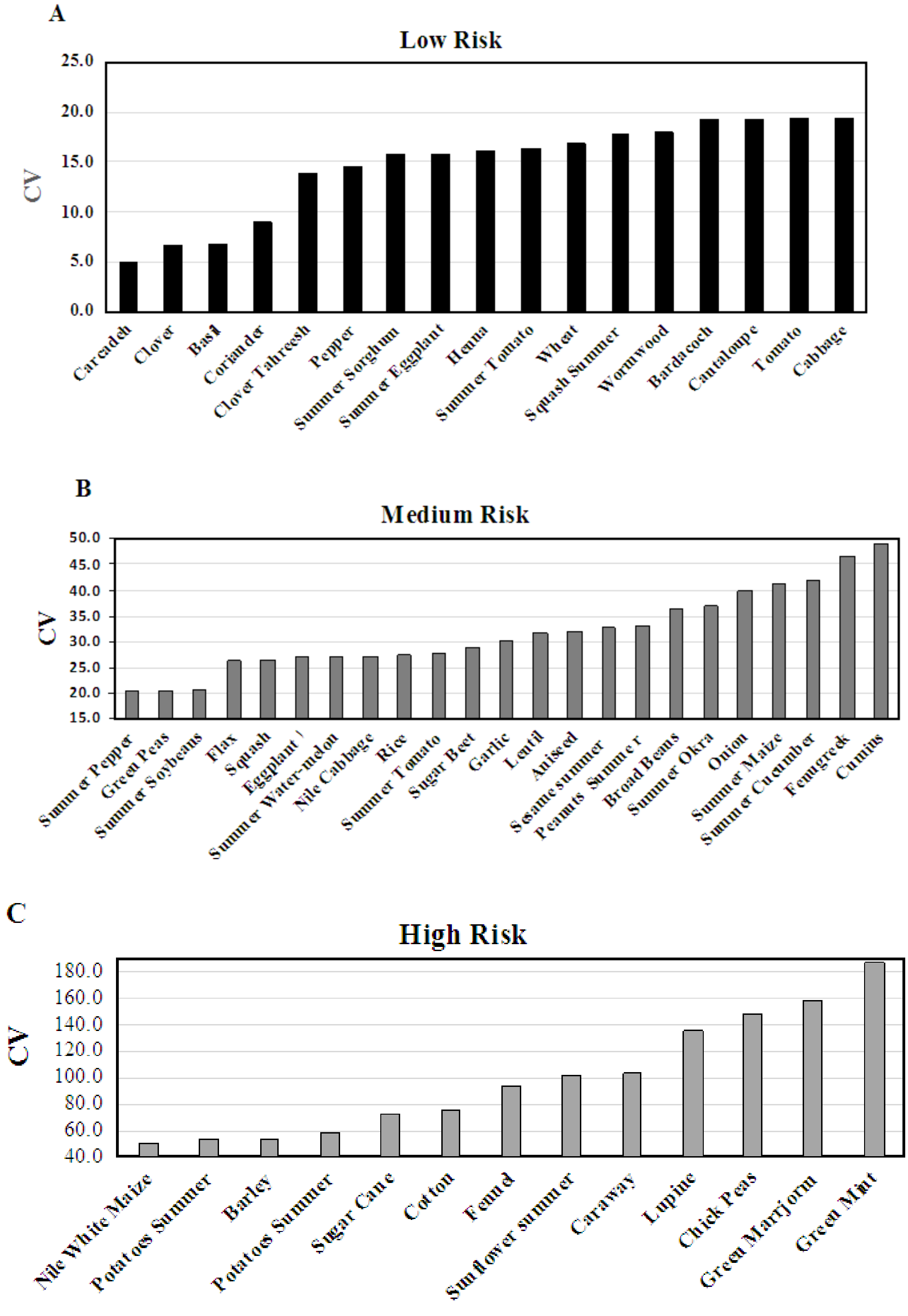

Figure 2. CV for (A) **Low Risk**, (B) **Medium Risk**, and (C) **High Risk**

4.2. Results of the LP model

The percentage of change in cropping area after optimization from years 2013 to 2018 is shown (Table 2). The results were estimated based on the MOTAD approach for the cultivated areas in Egypt.Table 2 showedthe output of maximizing the total net return after optimization as well as the change in cropping area after optimization, including areas under risks and certaintyin comparison with the current cropping patterns. The increases and decreases in the cultivated areas of crops are highlighted in Table 2which are represented by up and down arrows, respectively.The arrows pointing to the right represent no changes in the cultivated areas. Based on the results obtained from Table 2,we suggest two differentscenarios as seen below:

a) 1st scenario

The aim of the 1stscenario is to maximizethe net return per unit under certainty, which is subjected to take the risk into account over the study period. Through analyzing the results of this scenario after optimization, it can be seen that the net return has became 68.062 billion L.E. under certainty compared to 58.412 billion L.E. under risks,that it has increased by 9.65 billion L.E, represent about 14.17 %. This mean that the risk ratio in the 1st scenario is up to 14.17%, while at the same time the net return has increased by 6.3% which is about 4.3 billion L.E compared to current cropping pattern.

According to the availability of water resources,based onTable.2, it is observed that the water requirements for planted areas under certainty were 40.366 billionm^3, whichare less than the current water requirement by approximately 1.053 billionm^3, that is equivalent to 2.5% of the water needs. Thus, it became clear that approximately412 thousand feddans could be added in new lands under the different irrigation system.

Furthermore, it is shownthat after optimization the cultivated area of strategic crops, includingwheat, broad beans, sugar beet, rice, maize, sorghum, and soybeans has increased by approximately 16%, 44%, 32% 13%, 1%,8% and 98%, respectively, to reach to their lower limit that satisfiesSSR. It is obvious that there is a positive impact for the strategic crops area after optimization. Moreover, the cultivated area of non- strategic crops barley, chickpeas, fenugreek, lupine, wormwood, fennel, and bardacoch has also increased by 240%, 257%,76%, 389%,169%, 178%, and 43%, respectively.

On the other hand, the cultivated areasformany other crops, including clovertahreesh, flax, onion, cumin, green mint, caraway, coriander, squash, cabbage, green peas,pepper, sesame, sunflower, sugarcane, cotton, potatoes, and cantaloupe crops,did not changein both categories; however, these crops have been increased after optimization compared to current cropping pattern as shown in **Table 2.**Nevertheless, some crops have decreased after optimization under risk category, while increasing under certainty, and most of them were vegetable crops having negative impact under risk.

b) 2nd scenario

The objective of the 2ndscenario is to take the maximum possible level of risks and maximizes the net return in light of the model's constraints and conditions, taking into account the increase in the SSR of the strategic crops. As shown in Table 2, the total net return after optimization has increased from 65.001 billion L.E. under certainty compared to 63.763 billion L.E. to current cropping pattern, which represent an approximate of 1.238 billion L.E. increased(1.9%). As for the water requirements it has found to be decreased to 39.8 m^3 after optimization compared to the current cropping pattern which is 41.4 billionm^3, declining by approximately 1.520 billion m^3(3.6% less).

However, the cultivated area of wheat crop showed no changes in both categories; under certainty and under risk, despitethe noticeableincreasesthat exceed the current cropping pattern. This was not the case in the other two strategic crops, rice and maize, that they showedmuch stability and similar cultivation area totheir estimations from the1stscenario. as shown in Table 2.

The results of the linear programming reflect an increase in the estimated net return compared to the current crop pattern, and an excess of water needs, which are estimated at about 1.05 billion m^3 that can be directed to the horizontal expansion and the addition of new areas, through scenarios that are compatible with the available water resources under modern irrigation systems.

Table 2. Percentage of change in cropping area after optimization from years 2013 to 2018.
Crop area (Million/fed)

		1nd scenario				2nd scenario		
		Cu	CER	Risk	Cu-CER	CER	Risk	Cu-CER
	Total revenue	63.76	68.062	58.412	4.299	65.001	55.866	1.238
	%in risk	14.17				14.05		
		Water requirement				Water requirement		
		41.419	40.366	-	1.053	39.899	-	1.52
	Change in cropping area after optimization							
	Crop areas	Cu	CER	Risk	%	CER	Risk	%
X1	Wheat	3.292	3.008	3.476	↑ 16	CER	Risk	→ 0
X2	Barley	0.123	0.058	0.196	↑ 240	3.80	3.80	↑ 240
X3	Broad beans	0.104	0.088	0.126	↑44	0.06	0.20	↑ 44
X4	Chickpeas	0.003	0.001	0.005	↑257	0.09	0.13	↑ 257
X5	Fenugreek	0.005	0.003	0.006	↑76	0.00	0.00	↑ 76
X6	Lupine	0.001	0	0.002	↑389	0.00	0.01	↑ 389
X7	Lentil	0.002	0.005	0.005	→0.0	0.00	0.00	↑ 522
X8	Sugar Beet	0.504	0.424	0.56	↑32	0.00	0.01	↑ 32
X9	Clover Tahreesh	0.224	0.323	0.323	→ 0	0.42	0.56	→ 0
X10	Clover	1.182	1.496	0.707	↓-53	0.32	0.32	↓-61
X11	Flax	0.01	0.014	0.014	→0	1.01	0.40	109
X12	Onion	0.171	0.203	0.203	→0	0.01	0.01	↓-6
X13	Garlic	0.028	0.031	0.022	↓-29	0.20	0.19	↓-29
X14	Cumin	0.002	0.003	0.003	→0	0.03	0.02	→ 0
X15	Green Mint	0.003	0.004	0.004	→0	0.00	0.00	→ 0
X16	Wormwood	0.01	0.006	0.015	↑169	0.00	0.00	↑ 169
X17	Fennel	0.003	0.002	0.004	↑178	0.01	0.02	↑ 178
X18	Bardacoch	0.003	0.003	0.004	↑43	0.00	0.00	↑ 43
X19	Green Marjoram	0.006	0.015	0.002	↓-83	0.00	0.00	↓-83
X20	Caraway	0.007	0.015	0.015	→0	0.01	0.00	↑ 317
X21	Coriander	0.004	0.006	0.006	→0	0.00	0.01	↑ 56
X22	Tomato	0.191	0.208	0.169	↓-19	0.00	0.01	↓-19
X23	Squash	0.024	0.028	0.028	→0	0.21	0.17	↑ 40
X24	Cabbage	0.029	0.033	0.033	→0	0.02	0.03	↑ 20
X25	Green Peas	0.044	0.047	0.047	→0	0.03	0.03	↑ 13
X26	Pepper	0.033	0.038	0.038	→0	0.04	0.05	↑ 40
X27	Eggplant	0.043	0.047	0.042	↓-11	0.03	0.04	↓-11
X28	Rice	1.344	1.216	1.372	↑13	0.05	0.04	→ 0
X29	Summer Maize	2.069	2.232	2.26	↑1	1.22	1.22	↑ 1
X30	Sorghum	0.348	0.335	0.361	↑8	2.25	2.26	↑ 8
X31	Soybeans	0.027	0.017	0.034	↑98	0.34	0.36	↑ 98
X32	Peanuts	0.147	0.156	0.134	↓-14	0.02	0.03	↓-14
X33	Sesame	0.066	0.084	0.084	→0	0.16	0.13	→ 0
X34	Sunflower	0.016	0.018	0.018	→0	0.08	0.08	→ 0
X35	Sugar Cane	0.328	0.326	0.326	→0	0.02	0.02	→ 0
X36	Cotton	0.299	0.132	0.132	→0	0.33	0.33	118
X37	Carcadeh	0.012	0.014	0.011	↓-23	0.13	0.29	↓-23
X38	Basil	0.007	0.008	0.006	↓-34	0.01	0.01	↓-34
X39	Summer Tomato	0.241	0.266	0.198	↓-26	0.01	0.01	↓-26
X40	Nili Tomato	0.041	0.049	0.029	↓-40	0.27	0.20	↓-40
X41	Summer Potatoes	0.137	0.158	0.158	→0	0.05	0.03	→ 0
X42	Nili Potatoes	0.05	0.062	0.037	↓-41	0.16	0.16	↓-41
X43	Summer Squash	0.032	0.04	0.026	↓-34	0.06	0.04	→ 0
X44	SummerEggplan t	0.056	0.06	0.051	↓-16	0.03	0.03	↓-16
X45	Summer Pepper	0.052	0.055	0.048	↓-11	0.06	0.05	↓-11
X46	Summer Watermelon	0.109	0.14	0.084	↓-40	0.05	0.05	↓-40
X47	Cantaloupe	0.045	0.058	0.058	→0	0.14	0.08	→ 0

Cu, current cropping pattern; CER, cropping pattern under certainty; Risk, cropping pattern under risk

Collectively, based on the obtained resultsfromthe model used herein,we also suggesttwo scenarios to implement horizontal expansion policies in Egypt:

a) 1st scenario

This scenario depends on the expansion of about 80% of wheatabout 10% for the cultivation of municipal beans, and about 10% of the remainder for planting vegetables, in the winter season.In the summer season, corn and yellow corn is grown in an area of 80%, while 10% for vegetables and about 10% for green fodder(Table 3). As show in in Table 3, according to the water regulations of crops under the sprinkler irrigation system, it became clear that about 206 thousand feddans could be added in the winter season, and about 206 thousand feddans could be added in the summer season, due to the application of the first alternative, and with a total crop area of approximately 412 thousand feddans in the two seasons together. It is recommended cultivation of about 164.8, 20.6, 10.3, 10.3, 82.4, 82.4, 20.6, 20.6 thousand feddans of wheat, municipal beans, eggplant, beans, maize, yellow corn, vegetables, and green fodder, respectively.

Table 3. Potential scenarios to implement horizontal expansion policies in Egypt

Scenarios		1st scenario					2nd scenario				
		Areas that could be added			Expected production		Areas that could be added			Expected production	
Season	Crops	% for suggested area	Area 1	Area 2	Production 1	Production 2	% for suggested area	Area 1	Area 2	Production 1	Production 2
Winter	Wheat	0.8	164.8	192	461.44	537.6	0.5	111.5	132	312.2	369.6
	Municipal beans	0.1	20.6	24	26.574	30.96	0.15	33.45	39.6	43.1505	51.084
	Eggplant	0.05	10.3	12	145.436	169.44	-	-		-	-
	Beans	0.05	10.3	12	36.359	42.36	-	-		-	-
	Vegetables	-	-	-	-	-	0.35	78.05	92.4	931.917	1103.26
Summer	Maize	0.4	82.4	96	273.568	318.72	0.3	66.9	79.2	222.108	262.944
	Yellow Maize	0.4	82.4	96	276.04	321.6	0.2	44.6	52.8	149.41	176.88
	Vegetables	0.1	20.6	24	611.82	712.8	0.3	66.9	79.2	1986.93	2352.24
	Green forage	0.1	20.6	24	659.406	768.24	0.2	44.6	52.8	1427.646	1690.13
Crop area			412	480				446	528		

Data for expected areas and expected production under i) sprinkler irrigation system; ii) drip irrigation system was calculated using this formula:
Areas that could be added= water saving from linear programming (LP) results (Table 2) / suggested area factor.
Suggested area factor = water requirement per feddan * % suggested cultivated area.

As for the use of drip irrigation systems, it became clear that approximately240 thousand feddans could be added in the winter season and similar number of feddans in the summer season,with a total crop area equal to 480 thousand feddans.By distributing the proportions of the areas proposed from the first alternative according to the area that can be expanded, it was found that it is possible to expand cultivation. Thatapproximatelyof 192, 24, 12, 12, 96, 96, 24, 24 thousand feddans of the same crops could be added.

Whereas the area that could be added from the water abundance under the sprinkler irrigation systems due to the application of the first alternative, estimated at 206 thousand feddans in the winter season and the same in the summer season, it was also found that the amount produced from the same crops could increase by about 461.4, 26.5, 145.4, 36.3 , 273.5, 276, 611.8, 659.4 thousand tons, on the same order, while the expected production volume under drip irrigation systems was estimated at about 537.6, 30.9, 169.4, 42.3, 318.7, 321.6, 712.8, 768.2 thousand tons.

b) 2nd scenario

This scenariois proposed to reduce the area of wheat and corn to half, that in the winter season, 50% of wheat is cultivated, around 35% of vegetables, and around15% with municipal beans, while in the summer season, maize and yellow corn couldbe cultivated in 50% of the area, withabout 30% of the area with vegetables, and about 20% would be grown with forage. Based on the previous estimate, it was found that about 223 thousand feddans could be added in the winter season and the same in the summer season, with a crop area of about 446 thousand feddans, sufficient for the cultivation of 111.5, 33.45, 78.05, 66.9, 44.6, 66.9. 44.9 thousand fed of wheat, beans, winter vegetables, maize and yellow corn, summer vegetables, and green fodder in the winter and summer season, respectively.

As seen from the data in Table3, under the drip irrigation systems and according to the previous estimate, it became clear that it is possible to expand the addition of about 264 million feddans in the winter season and the same in the summer season, with a crop area of about 528 thousand feddans sufficient to cultivate about 132, 39.6, 92.4, 79.2, 52.8, 79.2, 52.8 crops of wheat, beans, winter vegetables, summer and yellow maize, green and green fodder respectively .While the expected production quantity was estimated to be added, it was found that the quantity produced from the same crops could increase by about 312.2, 43.1, 931.9, 222, 149.4, 1986.6, and 1427.6 thousand tons under the sprinkler irrigation systems, and it was estimated at 369.6, 51, 1103.2, 262.9. 176.8, 2352.2, 1690.1 thousand tons under drip irrigation systems.

Through the research results, new areas have been added in each alternative, as indicated by the preferences of the results under the drip irrigation system, therefore the self-sufficiency rates of field crops (wheat, municipal beans, maize, Table.4)would be calculated as a guide. Moreover, it was observed that the self-sufficiency rate of these crops increased by about 45.1%, 13.3%, 52.1%, with an increase of about 2.7%, 2.8%, and 1.8%, respectively. This confirms the need to change the patterns of Egyptian cultivation of strategic crops, benefit from irrigation development projects, and mitigate the aforementioned risks.

Table 4.Achieving food security.

Crops	Expected production	Current production	Total production	Consumption	Gap	SSR	SSR**
Wheat	537.6	8349	8886.6	19714	-10827.4	42.3	45.1
Municipal beans	30.96	116	146.96	1104	-957.04	10.5	13.3
Maize	318.72	8543	8861.72	16988	-8126.28	50.2	52.1

** %SSR Expected.

V. Discussion

Analyzing the previous results in both scenarios, it may be concluded that the total net returns after optimization has increased by 6.7 % ,1.9% respectively. It is worth to mention here that the first scenario has increase exceed by 4.299 billion L.E. compared to the current cropping pattern. On the other hand, with regard to the water needs for crops, it was found that the water saved after optimization in the second scenario has been less than about 0.467 billionm^{3}that it was in the first scenarios, it may be because the reduce area of rice by 13 % in the second scenario. Which means that they are to a large extent similar.By estimate the income variations for each activity and taking the average values of the cultivated areas under risk over the study period. It became clearly that after optimization is the cultivated area of crops in the first scenario are almost the same crops that fall under the medium risk category as shown in table 2 above. but the crops that fall under high risks category it is found that these stable and no change as (mint, caraway, sunflower, sugar cane, Cotton and potato. While, the cultivated area of Green Marjoram and potatoes has reduced by 83%, 41% respectively in both scenarios.

A linear programming shows that the risk had a positive effect on increasing the cultivated area of crops that fall under high-risk category namely, rice, corn, sorghum, soybeans, wheat, barley, chickpeas, lupine, lentils, sugar beet, it can be see that these crops were fall non risk in the model. which indicates that with 1% reduce the risk in the 1% leads to an increase in cultivated area of strategic crops such as wheat, rice, maize, sorghum, soybeans by 16%, 13%, 1%, 8%, 98%, respectively. Also contributes in raising self-sufficiency rates, reducing imports and improving the balance of payments.The results of both scenarios are observed that the vegetable crops are fall more at risk, and that non-strategic crop cultivation will limit the expansion of food-and export-crop cultivation as it will give a high yield that will later help import what is already needed, with the need to use aquifers under modern irrigation systems to conserve limited water resources. finally, it can see that in either approaches, first scenario achieved the highest increase the total net return which is due to its highest area for strategic crops among other crops and its requirement of irrigation water is not as high as well. It should be noted that achieving such a proposed crop composition based on risk analysis according to changes in farm prices for wheat and rice crops depends on the effectiveness and synergy of policies, tools, and mechanisms to implement an indicative crop composition that meets the national interest, both in terms of achieving food security and rationalizing the use of irrigation water on the one hand. At the same time, it ensures the achievement of the farmer's interest and goal who implements and cultivates that crop composition towards maximizing his farm income on the other hand.

Since both scenarios give almost the same results, we prefer the first scenario for several reasons, the most important of which are: achieving the highest net return and saving water needs, in addition to achieving state policies in increasing self-sufficiency of wheat as a strategic food crop, corn as animal feed, and oil crops as import crops.

VI. Conclusions

The currentarticlepresents an application of MOTAD risk programming model in the agriculture sector in Egypt. The model was employed with various constraints to explore the effects of agriculture-attributed risks on cropping pattern and net return. Risks effect on resource and water requirement as well as the actual areas of crops under current cropping pattern were revealed. A total of 47 crops were analyzed during the period from 2013 to 2018, utilizing the available data from the Ministry of Water Resources and irrigation in Egypt. The analysis results indicated that variability of crops gross margins or outcomes have significant effect on cropping pattern. Further the data showed positive effect of the tested risks on the crop areas, but their effect were shown to vary over different farmers and regions with various conditions. Finally, thecurrent study recommendshigh needs to change the cropping pattern in Egypt in order to increase the gross net return and highlights the availability of new policy crucial to support planning for water resources' development and management in Egypt.

Declarations

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MMN andHMA conceived the study and oversaw its design and coordination. MMNcollected and analyzed the data. HMA helped with data collectionand analysis, results interpretation, and drafting the manuscript. All authors have been involved in drafting the manuscript and/or revising it critically for important intellectual content. All authors have read and approved the final manuscript.

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