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A Simulation Model of System Dynamics Reality and Future Food Security of Wheat in Egypt

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Abstract

The aim of this study is to propose a vision on how to achieve high level of food self-sufficiency in light of the available resources, expect ed future changes and future needs. This study defines the major driving forces that will improve the food security in Egypt based on data and economic indicators of wheat during the period (1995- 2015-16). A system dynamics model was built to present the process of imports, demand and consumption of wheat in Egypt, through monitoring the increase in population undernourishment, and filling the gap between the desired quantity and the supply of wheat. Finally, sets of policies were formulated and suggested to improve food security in 2030, which are presented in the improvement of land management and productivity, increase of individual income, decrease of population growth, and building a strategic inventory of wheat for solving the problems of local supply.

Keywords: Food security; Consumption; Imports; System dynamics.

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1. Introduction

Egypt, like other countries in world is faced with Food shortages and poverty, these problems are becoming worse, So, as the same time Agriculture accounted for 70 % of the labor force, 25 % of the total GDP, 60 % of export earnings, 75 % of raw materials for the industrial sector and 45 % of government revenue (FAO STAT, 2015). Food security is one of the most important problems in Egypt. It holds political, social and economic impacts for the entire country. Indeed, a large number of population in the country and its stable growth rate makes food preservation a priority for Egypt. However, the relationships between grain consumption patterns and resources requirements to maintain this consumption have frequently been disregarded. Although, statistics indicate that recent Egyptian agricultural production and productivity remain inadequate and have not made any progress on the food security front. Yields have not improved and, consequently, Egypt remains food-insecure and is increasingly reliant on food supplies and commercial food imports To meet their needs for local products, due to a wide gap between the production and consumption occurred in the light of the increasing population, rising standards of living, declining of trade in food grains and high prices in the market, The main problem in the study is identified by increasing food deficit in Egypt as a result of the population increase, given the decline in self-sufficiency rates, the widening gap between production and consumption of food commodities year after year (Abdo, 2013).

2. Research Methodology

The objective of modeling is simulation as mentioned above, simulation of dynamic systems models is more obvious when considering the assumptions about how they interact with each other. It also allows to identify the critical variables that affect the phenomenon and how to cope with the induced changes and their behavior over time, thus encouraging the development of more likely scenarios. The model was built using Vensim Software. To simulate and explore the food security of wheat by studying of availability, accessibility and stability of food by analyzing land production and population needs, market sectors and expenditures.

3. Model Structure

The model is subdivided into four main sub-models: cultivated wheat area productivity and production, population undernourishment, imports and market sectors.

3.1. Population Sub-Model

In Egypt, the population growth is considered a unique case by all standards, a an equally unique approach Predictable including the situation in the future, in Egypt Population grows at an annual rate of about 0.21 in contrast, the population projected to grow at an average about 117 million people by 2030, thus Egypt will face food shortage in light of the limited resources of fertile land, fresh water and food supplies. Figure 1 below illustrates the structures of the population model. Key to understanding the current situation and future demand for food: births and deaths Which illustrates the relationship between births and death we define the growing population by the Birth Rate which is estimated through the population increase yearly, and the death fraction is used to define the Death

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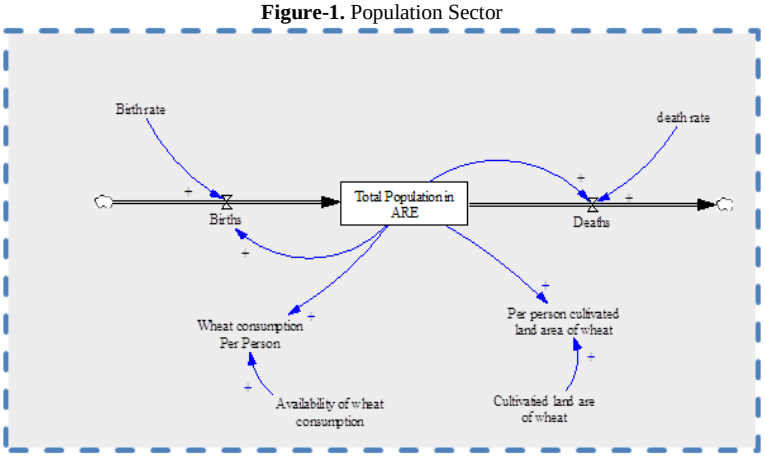
Rate which is estimated from 1995s to be a small fraction affected by the prevalence of undernourishment. Account for the effect of food security on mortality, we assumed a positive nonlinear relationship between food consumption per person and life expectancy at birth. In other words, as food consumption per person decreases, it is assumed that mortality rate associated with inadequate food will increase, causing life expectancy at birth to decrease beyond normal life expectancy (Hafez, 2011).

Figure-1. Population Sector



3.2. Evolution of Cultivated Wheat area, Productivity and Production Sub-Model

As a result of a multiplicity of situations of instability in the domestic market of wheat, The food gap in Egypt is clearly represented through the inability of domestic production to meet domestic consumption of the wheat. Thus, there is a need to enhance and increase wheat production. Studies show that the cultivated area of wheat increased during the period and recorded its highest level in 2015, The productivity of Egyptian wheat acres also increased slightly during the period (1995-2016) which lead to the rise of wheat production during the same period, However, because of the high rates of population led to the decline in average per capita. The cultivated Area is represented as a stock in figure 2 and is increased by a cultivation rate of an average 1.9 % each year, which was estimated from the rate of increase of land yearly. The amount of wheat produced each year is also calculated through productivity of cultivated area yearly. As shwoed in figure 2, a reinforcing loop of the cultivated process is used to represent the gradual increase of cultivated wheat land yearly. The model assumes that the cultivated area is not lost and only increases with reclamation activities. Future research will consider the effect of desertification on the size of cultivated area (Gamal and Hoda, 2011).

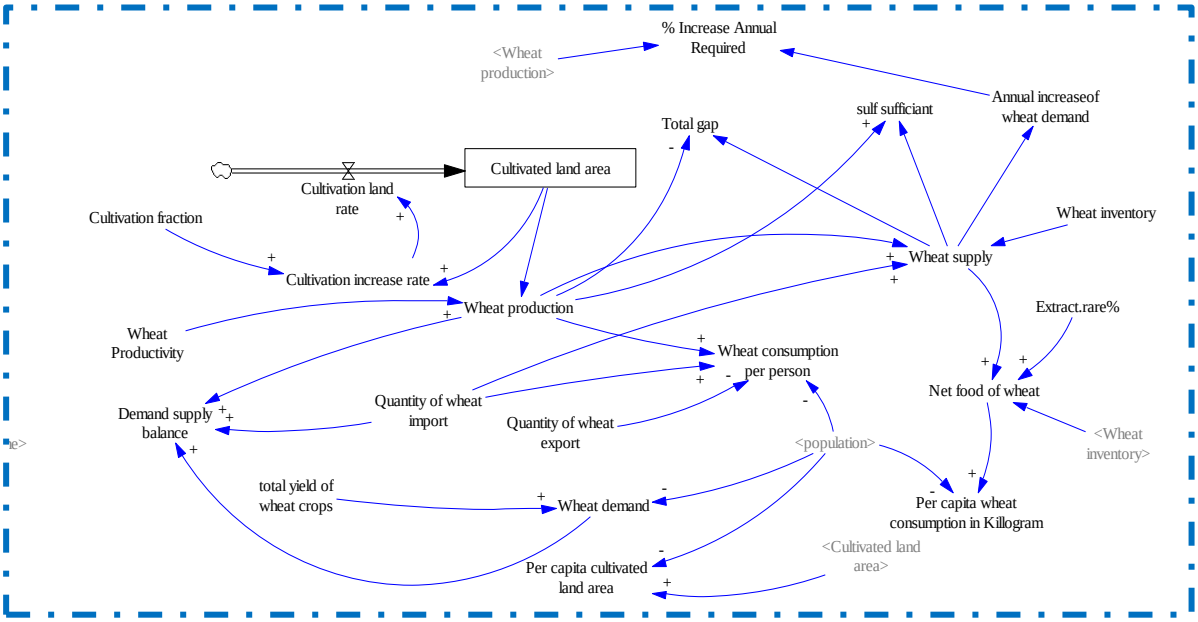
3.2.1. Demand side

Demand for wheat is determined by population and per capita wheat demand. The impact of wheat import on wheat demand was captured by the effect of demand supply balance on per capita wheat demand to demonstrate the negative relationship between quantity of wheat import and wheat demand. As population increases, demand for food is postulated to increase (Malr, 2011).

3.2.2. Supply side

The structure of the wheat production sector shows wheat production as a process of productivity per unite physical and human to cultivate land area for wheat production. As a quantity of wheat production change over time represented in the model as cultivate land area, productivity per unit of land is postulated to change; assuming a positive association. The model defines wheat consumption per capita from the combined food security index as the amount of food available for wheat production minus food export in addition to food imports divided by the population, while the availably supply of wheat is estimated as the same equation did not take into account the number of population, but per capita Wheat consumption in kilogram is already estimated by net food of wheat and population the structure of the wheat production model is depicted in figure 2 below (Kasem, 2013).

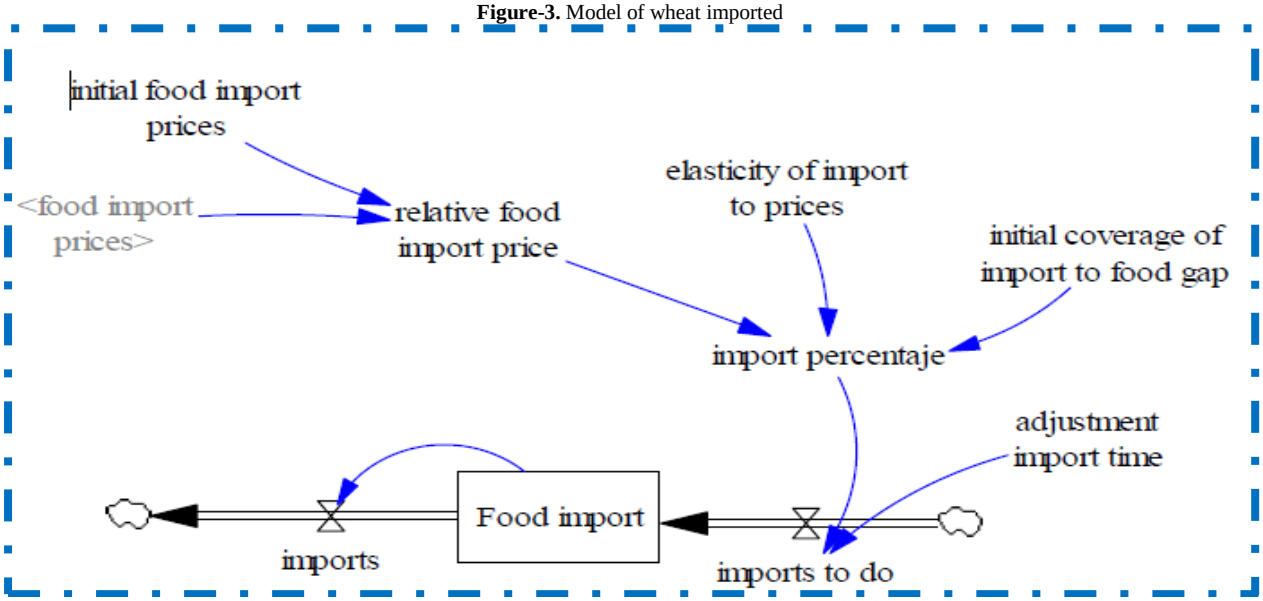
Figure-2. food security of wheat in Egypt



3.3. Imports and Consumption Shipment Sub-Model

Dependence on imports from the external market has become a source to coverage of increased consumption, Egypt had to be a major importer of wheat in the world, to maintain a stock that covers the gap between wheat production and population demand. the model was built to represent the stock of wheat import is incorporated into the model as a way of increasing the food supply, the import of wheat depends on a wheat gap; after determining the required amount of wheat imports, a simple sub-model is created to calculate wheat imports that the government should cover. Giraldo *et al.* (2011). The sub-model in figure 3 showed that the initial of import presentage yearly, as shown in the reinforcing loop import to do (Malr, 2011).

Figure-3. Model of wheat imported



4. Model Validation

It is important to test and validate the model to help in building the right product as per the customer's requirement and help in satisfying their needs after entered the data, for the purpose of identity is commensurate results with reality and can be represented in the community for assisting decision makers or not. From the output of the models have been tested and validated by comparing historical data with the results of the models, Sources of Information for Modelling adopted the announcements made to divide and Experts from three governmental agencies in Egypt,(1) Ministry of Agriculture and Land Reclamation; (2)The Information and Decision Support Center, (3)The Egyptian Cabinet and Ministry of Supply and Internal Trade approved the adequacy of the model through comparing it with the real system subjectively. In addition to the assumptions of the researcher, the model succeeded in achieving the goal of improving wheat production and food security in Egypt. The model also agreed with other researches on the shortage of wheat in Egypt and the future crisis in covering population needs, it also succeeded in predicting the future demand, consumption, imports and expenses of wheat. The model has been

validated during the period (1995-2015-16) by comparing the model results with the historical data gathered and then setting forecasts of the year 2030 (Gerber, 2014).

5. Results and Discussion

5.1. Simulation Results and Forecasting Projection

Through the built system dynamic model, and setting data from 1995 to 2030 as the forecasting period, we got the forecasting results to available time series data selected of variables represent the validation of different endogenous variables in Figures 4,5 and 6, its projection for the next 15 years until 2030. Figures 4 indicates the yearly increase in population of the model compared to the historical data. Its accuracy reaches 99%. Figure 5 showed the yearly wheat production given the productivity of agricultural land compared with the historical data. Its accuracy is 93%. Figure 6 determines cultivated Area increased by a cultivation rate and reclamation activities compared with the historical data (Abdel and Albahloul, 2009).

Figure-4. Population growth yearly in thousand People

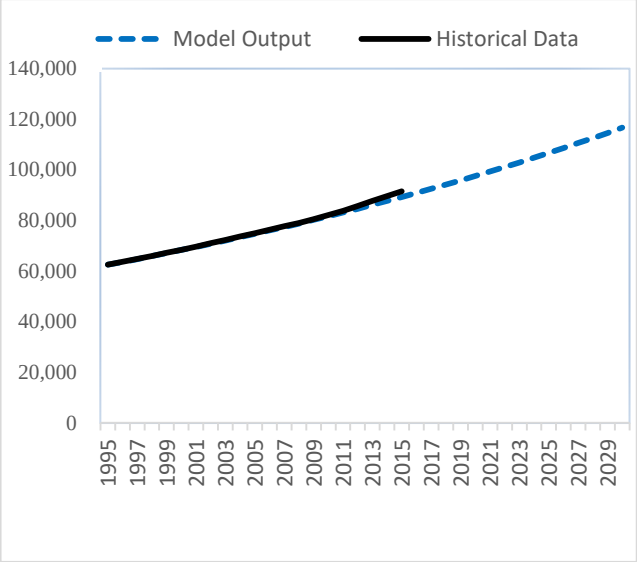


Figure-5. Production of wheat yearly in thousand tons

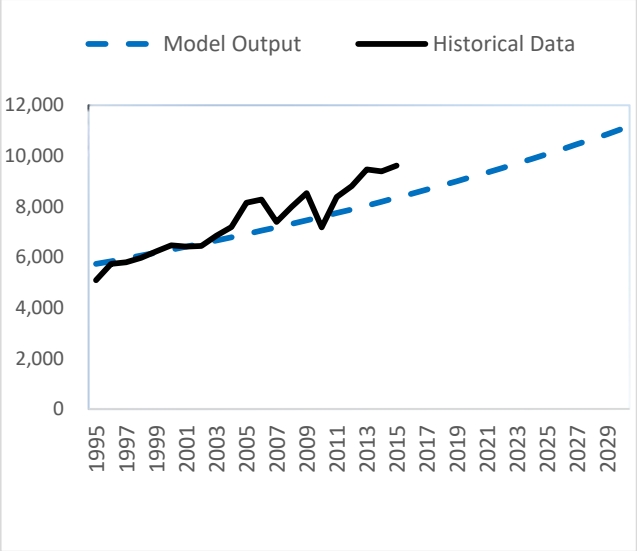
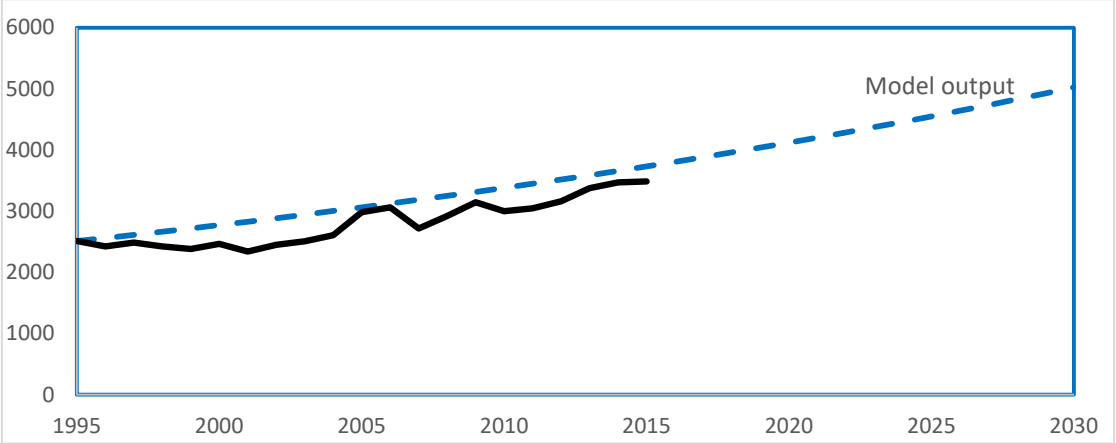


Figure-6. Cultivated land area of wheat in thousand acers



To overcome the challenges that faces the producers of wheat in Egypt, and access to the best ratio in wheat self-sufficiency must determine a fair and just price guarantee to encourage farmers to expand the country's isolation wheat plus throughput capability of the planned areas of the state to ease the burden on the balance of payments and reduce the quantities imported from abroad. In order to predict future supply and demand and production. The figures 4 and 5 the gradual increase in the number of population as a result of the large number of births fraction, which affects the annual demand of wheat. Also, the projection of cultivated area will be expected reach to 5 million tons in 2030 years. Figure 7 showed that the amount of wheat available for consumption depending on local production and inventory, the amount of wheat bought in from 1995 until 2015, In the absence of rising imports from 2016 and then increased gradually even less because of inadequate income to meet the gradual increase in the price of the quantity purchased would decrease slightly while there is a gradual increase in consumer demand. Through the Comparing model output with historical data showed the results of model deslienc compared to historical data, this represents the amount of flour waste which provides for consumption either flour or bread.

Figure-7. Amount of wheat consumption yearly *quantity of wheat in output without flour of wheat

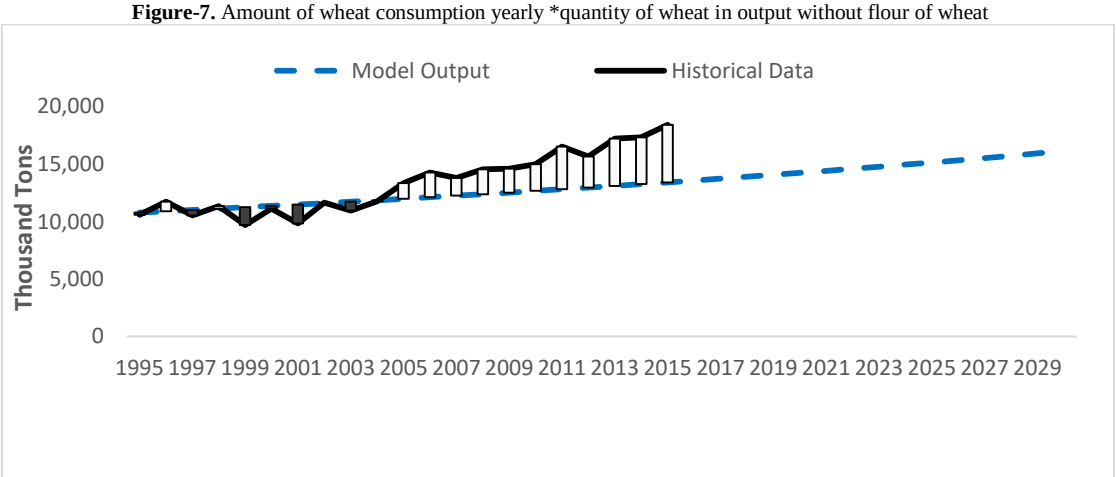


Figure 8 Indicates the amount of wheat supplied to cover population needs, and the amount of desired wheat demand by the population. It determines the undernourishment ratio, which is the ratio of people who received their desired amount and those who did not, which is approximately 7.5% of the whole population (Giraldo *et al.*, 2011; Naseri *et al.*, 2018).

Figure-8. Fulfilling the needs of wheat for the population

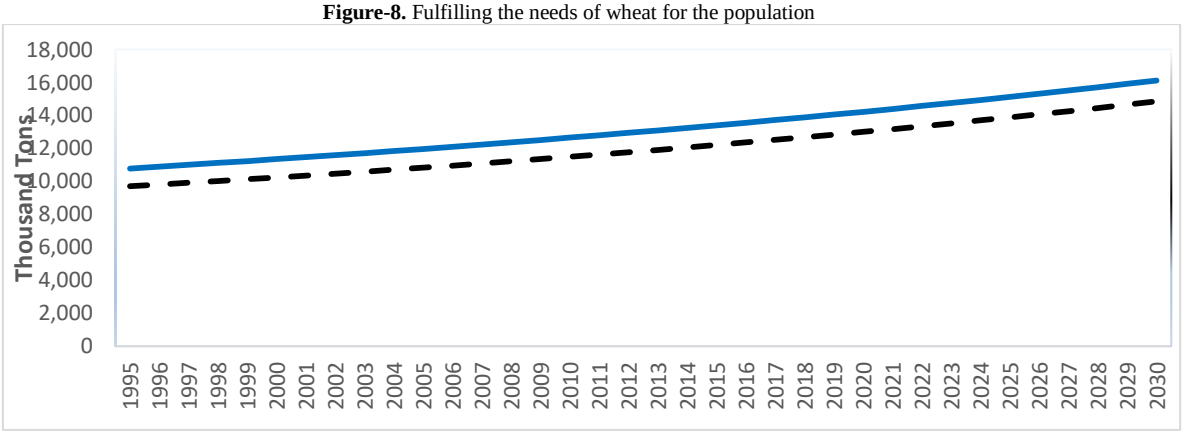
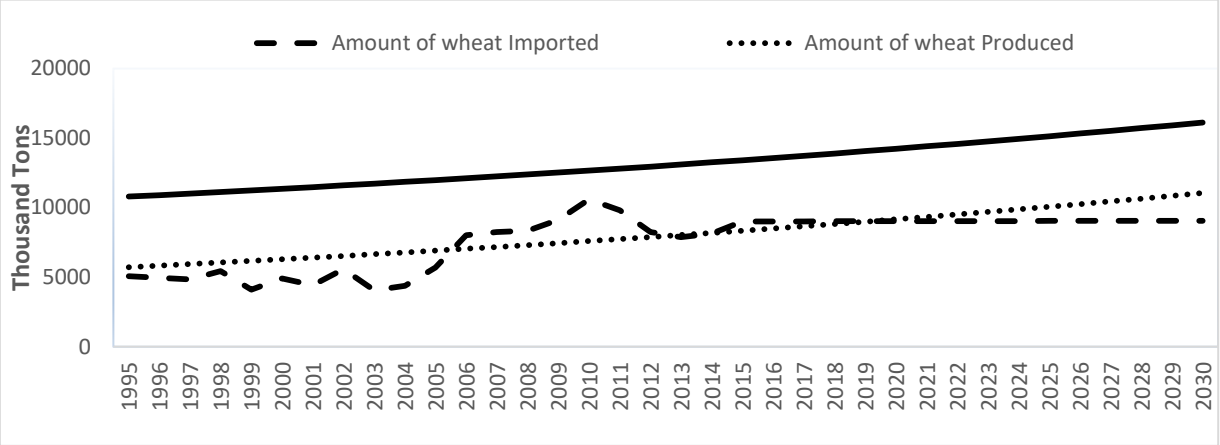


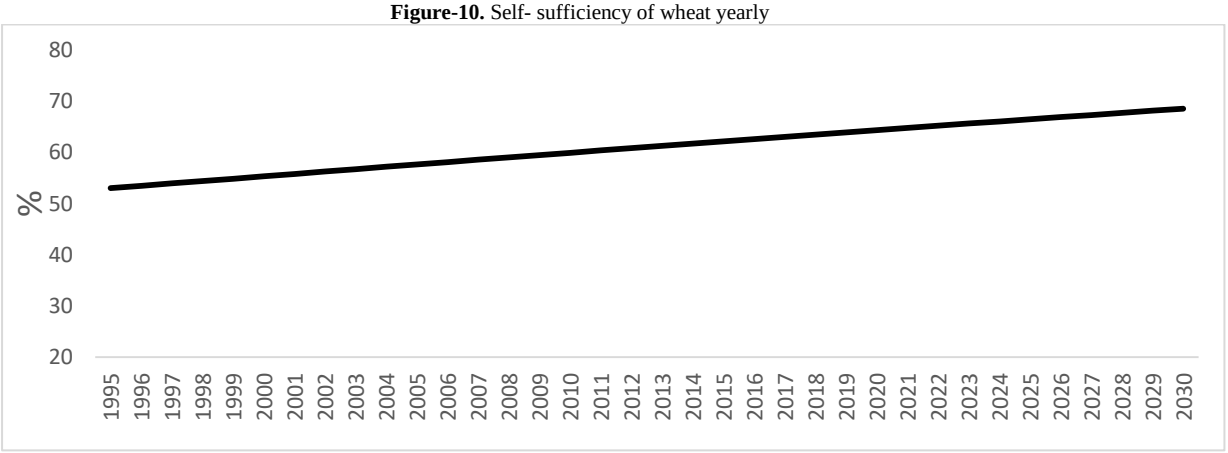
Figure 9 indicates the domestic supply of wheat which is increased gradually due to the increase in the productivity and cultivated area, while the imports increase gradually also to cover the needs of population (Capmas, 2014; Villalobos and Bello, 2014).

Figure-9. Amount of wheat produced and imported and amount of wheat consumed yearly



In the light of the results of the measurement of spatial variations in the yield of wheat during the average period (1995-2015 to 2030). Figure 10 represent The rate of self-sufficient that was predicted in 2030 where increased to nearly 70 %, compared to 1995 it was about 53%, Which he asserts that there is a light improvement during the coming disclosure ,due as a result of expansion in new areas or improvement in productivity.

Figure-10. Self- sufficiency of wheat yearly



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Based on the results of the prediction, it has been found that the average size of the food gap of wheat, may increase from 8.717 million tons as and average during 1995-2016 to about 10.3 million tons as an average during (2016-2030). To cover the gap, it was necessary to follow the means possible either through horizontal expansion, vertical and reduce consumption, since there are quantitative patterns related to reality and other cultures of society was the only one way for the study is to estimate the quantities can be expanded in the future depending on the local resources and production elements. Therefore, two alternatives were proposed to cover the wheat gap. The implementation of these alternatives depends on the availability of reclaimed areas and the necessary resources through two alternatives.

Alternative 1: The proposal covers 50% of the volume of the wheat gap.

Alternative 2: The proposal covers 25% of the volume of the wheat gap**.**

The study was predicted during the period 2016-2030 In order to cover the food gap using the average productivity, were estimated the required area and local resources to be equivalent to that of local production. As mentioned before, the increase in local production has been through three level:

- Increasing the cultivated area with constant productivity
- Increased cultivated area with increased productivity
- Increase the productivity of acres with the stability of the cultivated area.

In case it is impossible to allow the reclamation and cultivation of agricultural land to cover100 % of the gap. It is possible to cultivate an area of 1.9 million acres that contribute to reducing the gap size by 50%, and about the 0.988 million acres Covering 25% of the gap size in the wheat crop.

Table-1. Alternatives proposed to increase wheat production

Forecast		Forecasting of Area		Forecasting of Production	
Years	Total gap	50%	25%	50%	25%
2016	8.717	1.453	0.726	4.358	2.179
2017	8.941	1.49	0.745	4.47	2.235
2018	9.165	1.528	0.764	4.582	2.291
2019	9.389	1.565	0.782	4.694	2.347
2020	9.614	1.602	0.801	4.807	2.403
2021	9.838	1.64	0.82	4.918	2.459
2022	10.062	1.677	0.838	5.031	2.515
2023	10.286	1.714	0.857	5.142	2.571
2024	10.511	1.752	0.876	5.255	2.627
2025	10.735	1.789	0.894	5.367	2.683
2026	10.959	1.827	0.913	5.479	2.739
2027	11.183	1.864	0.932	5.591	2.795
2028	11.408	1.902	0.95	5.7041	2.852
2029	11.632	1.939	0.969	5.815	2.908
2030	11.856	1.9767	0.988	5.928	2.963

Notes: Data of alternative Calculated according to the Acre needs.
Resource: Calculated Based on the result of simulation model.

The main features for cover the food gap of wheat, the agricultural production in general and the production of wheat from the grain sector serves as the activities of the various problems and challenges, where he faces the wheat crop significantly many of the challenges and problems, including with regard to production and consumption and imports which eventually lead to contrast and the instability of the crop from one year to another, and the impact of these challenges and problems depends on the size of the cultivated area, competing with other crops in the winter season, climatic conditions and agricultural policies and funding, and the nature of the role of existing institutions in the agricultural sector in the national economy. The main objective is to increase crop production in an attempt to cover the food gap followed many axes, which would raise the self-sufficiency rates as shown in figure 11.

Through the axis of vertical expansion: In this aspect, the supply of the wheat crop can be increased by providing the private sector with the opportunity to invest in agriculture in new and rehabilitated lands after providing suitable and encouraging investment, or through agreements with some neighboring countries (Sudan) as a geographical extension and breeding ground In order to benefit from these areas and promote agriculture in Egypt and a means of international cooperation between the two countries. On the other hand, attention is given to expanding the cultivation of modern varieties and genetically engineered plants, to modern breeding programs and to resistance to fungal infections, as well as to rationalizing the use of production inputs in order to ensure that farms adopt these technologies while working to improve the economic climate and increase the role of the private sector which seeks to profit. With a view to ensuring the efficient use of these resources, and also to ensure that farmers apply appropriate technologies, while attempting to increase investment in land reclamation and high-quality improved seed production projects as one of the National Program

Through horizontal expansion: The horizontal agricultural expansion is one of the main and important indicators on which the Arab Republic of Egypt relies to overcome the danger of the growing food gap. This requires increasing the crop area in light of the available resources to cover the size of the gap in Egypt in the coming years. Where the area of agricultural land is one of the most important constraints facing the planning process in agricultural production, so it is necessary to search for the best combination of field crops that can be grown in the old lands and the expansion of crop cultivation, which suffer from a lack of new land has (Akhpanov et al., 2018).

Special axes to waste minimization and rationalization of consumption: crop losses and agricultural commodities have a significant impact on the size of the food gap, because of the lack of supply of food commodities, the wheat of food gap is reduced by rationalization consumption.

6. Conclusion and Future Work

The research highlighted the current status of wheat economics in the Egyptian food security by studying the evolution of consumption volume, production gap and the consequent development of the volume of wheat imports and its impact on the national economy, which will contribute to the format.ion of food security in Egypt, taking into consideration the following points studied in the model. Further studies will be conducted out focusing on the sources of production efficiency, and the amount of irrigation water for agriculture that could help to convert farmland from uncultivation to a cultivated land.

Acknowledgements

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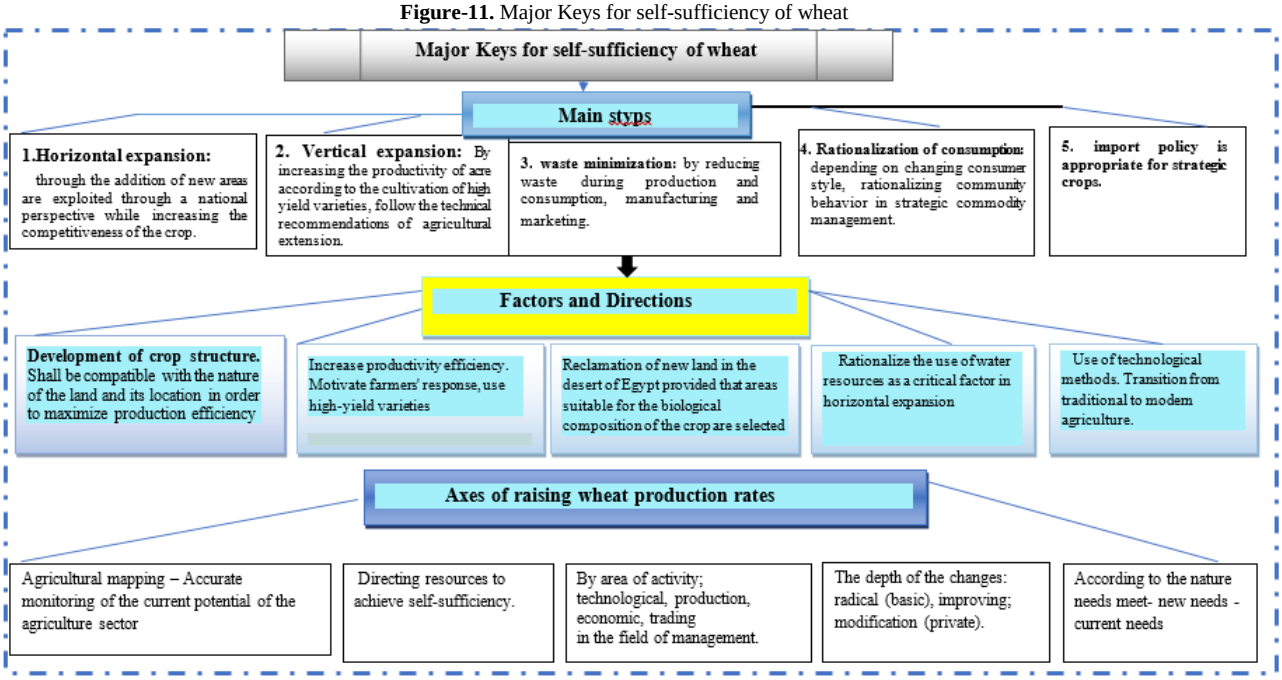
Figure-11. Major Keys for self-sufficiency of wheat



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