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The Future of Food Supply in the Middle East: Case Studies of Iran, Turkey and Iraq

Ph.D. Thesis

DOI: 10.54598/001710

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2021

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1. INTRODUCTION

1.1. Introduction

Food security is one of the most important challenges of the current century specially in the developing countries as 15% of the population of developing countries face chronic hunger. However, human societies encounter crucial challenges ahead that could remarkably make the current worrying situation worse. The world population is expected to reach more than 9 billion by 2050 in which the share of developing countries in this population increase is approximately 100% (DIVISION 2020). In addition, RUANE & SONNINO (2011) argue that 70% of the world's population will be urban by 2050. Residents in urban areas are just food consumer while most agricultural activities take place in rural areas and the villagers are mainly engaged in agricultural activities and feed production and the rural areas play a vital role in food provision for the cities. On the other hand, urbanization and anti-poverty activities are expected to increase income. This increase in income and new lifestyle (urbanization) has changed people's demand for food as such demand for meat, oil and fish and dairy products increase and replaces demand for grains. Hence, FAO (2009) expects that the Global demand for food will increase by 70% in 2050.

The other challenge that affects the food security in the developing countries is the effect of climate change on the agriculture. Hazards and extreme events affect the crop yield (NOSRATABADI et al. 2020) changes the growth patterns and global warming have altered the pest distribution patterns leading to spreading disease among crops and livestock. The negative influence of climate change on food security is increasing and vulnerable areas already suffer from droughts and food insecurity in serious danger. The Global South, especially those are in Asia which are suffering from lack of land availability, experience a severe problem in both food production and food availability. It is worth mentioning that the World

Bank introduced the term of Global South, contrasts to the Global North, that refers to the low- and middle-income countries in Asia, Africa, and Latin America. According to the UN organization, however, there are sufficient food for all the current population of the world and the main problem of food security currently is in the food accessibility (RUANE & SONNINO 2011).

1.2. Food Security Issues in the Middle East

According to the FAO annual report on food security and nutrition in the world, the number of people in Western Asia facing undernourishment has increased from 20.1 million to 33.7 million from 2010 to 2018. Western Asia is the only region in Asia in which malnutrition is increasing, especially in countries experiencing a popular uprising. It is worth mentioning that in this report Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates and Yemen are categorized in Western Asia.

Globally, 2013.8 million were exposed to moderate food insecurity in 2018, an increase of 317.5 million compared to 2014, in which 704.3 of them are in severe food security, 119.3 million more than in 2014. Research shows that 80.2 million encountered with food insecurity in 2018 in the Western Asia that this number increased by 6.5 million compared with 2014. The number of people faced severe food insecurity also increased by 5.1 million from 2014 to 2018, in Western Asia.

Although the number of people encountering sever food security reported 27 million in 2018 in the Western Asia, which is only 0.03% of people in the world are at risk of severe food security, the percentage of people are exposed to moderate and severe food security in Western Asia is higher than the world. The percentage of people are in the risk of food insecurity have been always higher the world average where 29.5 percent of the population of Western Asia are exposed to the food insecurity in 2018.

There are many reasons for the increase food insecurity, one of which is urbanization. Urbanization is expected to accelerate in the next few decades, with two-thirds of the world's population living in metropolitans by 2050 (BREARS 2016). Urbanization and related demographic changes in developing countries result in problems in food insecurity. Therefore, the pressure to adjust food systems in developing countries, where urbanization is occurring faster, is increasing substantially as urbanization will occur in some of the world's most fertile agricultural land (SETO et al. 2012; D’AMOUR et al. 2017). Hence, the impacts and consequences of urban dispersion on agricultural production in developing countries have been recognized and food security issues have increasingly attracted the attention of researchers (SONNINO 2016). According to HATAB et al. (2019) population growth in developing cities is steadily increasing, leading to employment problems, urban population nutrition and environmental protection. Due to the scarcity of freshwater resources, farmers are increasingly turning to wastewater for irrigation, which in turn presents a wide range of health risks (FANG et al. 2007; GOBER 2010). In addition, one of the consequences of urbanization and economic development is the increase of demand for animal-based foods, while ranching intensifies the impact of agricultural production on natural resources (THORNTON 2010; HERRERO et al. 2009) and MAXWELL & SLATER (2003) argue that food security issues are intertwined with the loss of agricultural land.

According to MAXWELL & SLATER (2003), the food system in developing countries affected by industrialization, urbanization, and technological transformations is undergoing a change that requires new and different food policies. Therefore, they believe that new appropriate food policies are necessary to secure food and to pace with the global food system transformations.

1.3. Research Objectives

FAO (2019) introduces climate shocks, economic slowdowns, and conflicts as the main driving forces of food insecurity specially in the low and middle-income countries. To evaluate the “conflict”, FAO (2019) considers if a country has suffered at least 500 war casualties for five consecutive years. Climate variability is also defined if the cereal yield of a country affected by the climate factors. According to FAO (2019) the Economic downturns refer to the negative economic growth that a country experience. In 2018, conflict faced 74 million people with severe food insecurity and climate shocks and Economic shocks were respectively driver of severe food insecurity for 29 and 10.2 million people. Economic shocks elongate and worsen the effect of have also prolonged and ed the impact of conflict and climate events on food insecurity. Due to the high importance of food security in Western Asia, where most countries are developing and food insecurity in this area is increasing every year, the present study seeks to provide appropriate solutions to counter food insecurity in Iraq, and Turkey, which are among the Western Asian countries, and Iran, which is one of the Southern Asian countries. There are many actors in the global food supply chain, and each of them plays an important role in the production and provision of food. Innovation of business models of active businesses in the food supply chain can play an effective role in optimizing food supply and ultimately food security. For this reason, in the present study, the role of business model innovation in food security is also discussed in detail. In addition to businesses, people themselves can play a role in reducing food security. Studies have shown that the social capital created in communities can offer many benefits to members of that community. These communities can play an effective role in reducing food insecurity and providing food to their members in different ways. Therefore, the present study deals in detail with how social capital can provide solutions to reduce food insecurity. In this regards, the following research questions and hypotheses are addressed:

1. Do the machine learning models have the ability to predict domestic food production?
2. What will be the domestic agricultural production in Iran in the next ten years?

3. What will be the domestic livestock production in Iran in the next ten years?
4. What will be the domestic agricultural production in Turkey in the next ten years?
5. What will be the domestic livestock production in Turkey in the next ten years?
6. What will the domestic agricultural production in Iraq in the next ten years?
7. What will be the domestic livestock production in Iraq in the next ten years?
8. How does business model innovation contribute to the food supply chain?
9. How does social capital improve food security?

Based on the research questions and objectives, the hypotheses are:

1. Machine learning models are able to predict the food production.
2. Machine learning models have the ability to predict the future trend of domestic agricultural production in Iran.
3. Machine learning models have the ability to predict the future trend of domestic livestock production in Iran.
4. Machine learning models have the ability to predict the future trend of domestic agricultural production in Turkey.
5. Machine learning models have the ability to predict the future trend of domestic livestock production in Turkey.
6. Machine learning models have the ability to predict the future trend of domestic agricultural production in Iraq.
7. Machine learning models have the ability to predict domestic the future trend of livestock production in Iraq.

2. RESEARCH METHODOLOGY

2.1. Data

To find the most appropriate predictive model for the prediction of domestic food supply for the next two decades in Iran, Turkey, and Iran MLP and ANFIS models are applied. Agricultural production and Livestock production of a country considered as domestic food supply of the country. To measure Livestock production, three variables of livestock yield, live animals, and animal slaughtered were evaluated. And to evaluate the agricultural production, two variables of agricultural production yields and losses were considered. It should also be added that the related data collected from the FAO database, i.e., FAOSTAT, that can be accessed on http://www.fao.org/faostat/en/#home. Since this database consists only of data related to the period 1961-2017, the analysis is based on this available data.

2.2. Multilayer Perceptron (MLP)

A multilayer perceptron (MLP) is a category of artificial neural network (ANN) that benefit from a Supervised learning technique called Backpropagation in the training phase (ROSENBLATT 1961). An MLP model uses a three-layer architecture which is composed of an input layer, a hidden layer and an output layer. Hidden and output layer neurons apply a nonlinear activation function that enable the model to separate nonlinear data, which distinguishes this model from a linear perceptron. MLPs are universal function approximators (CYBENKO 1989) generating mathematical models using regression analysis. Therefore, MLP is widely used to design classifier algorithms. Hence, this model is widely used in applications such as speech recognition (Zhu et al. 2005), image recognition (CODRESCU 2014; GREENBERG et al. 1995), and machine translation (SHIMANAKA et al. 2019), Pattern-based forecasting (PEŁKA & DUDEK 2019) etc.

Equation (1) shows how the output of input variables, bias values, and input values are calculated:

$$S_j = \sum_{i=1}^{n} \omega_{ij} I_i + \beta_j \qquad (1)$$

Where *I* represent the input layer, I_i is the input variable *i*, n shows the total number of inputs, βj is a bias value, ω_{ij} is the weight of connections in *j* level. The sigmoid function is mostly used as the activation functions in MLP, and it can be calculated through Equation (2):

$$f_j = \frac{1}{1 + e^{-S_j}} \qquad (2)$$

Therefore, the ultimate output neuron j can be measured Equation (3):

$$y_i = f_j\left(\sum_{i=1}^{n} \omega_{ij} I_i + \beta_j\right) \qquad (3)$$

2.3. Adaptive Network-Based Fuzzy Inference System (ANFIS)

To enhance the performance of machine learning models, some researchers suggest hybrid models in which either two models of machine learning are integrated, or one model of machine learning is integrated with an optimization model. An adaptive neuro-fuzzy inference system, which is also called adaptive network-based fuzzy inference system (ANFIS), is a hybrid model in which a model of ANN is developed based on Takagi–Sugeno fuzzy inference system, in early 1990s (JANG 1991; JANG 1993). ANFIS is a universal estimator, as the inference system of this model follows fuzzy IF–THEN rules, the performance of this model in approximate nonlinear functions is very high (ABRAHAM 2005).

ANFIS architecture constitutes of 5 layers in which the first layer is called fuzzification layer where the input values are taken, and the membership functions are determined. The second layer is called rule layer in which the firing strengths for the rules generates here. In the third layer the firing strengths are normalized.

In the fourth layer the normalized values are defuzzificated and go to the last layer to generate the output (KARABOGA & KAYA 2019).

For example, if in an ANFIS model includes two inputs *(x, y)* and one output (f_i), the two rules for a first-order two-rule are:

Rule 1: if x is A_1 and y is B_1 then z is $f_1(x, y)$

Rule 2: if x is A_2 and y is B_2 then z is $f_2(x, y)$

Where x and y are the ANFIS inputs, A and B are the fuzzy sets, *fi (x, y)* is the outputs of the first order Sugeno fuzzy. The architecture of an ANFIS model constitutes adaptive nodes and fixed nodes. The first layer of the model includes adaptive nodes that can be calculated through Equations 4, 5 and 6.

$$O_{1,i} - \mu_{A_i}(x) \quad for\ i = 1,2 \tag{4}$$

$$O_{1,i} - \mu_{B_i}(y) \quad for\ i = 1,2 \tag{5}$$

$$\mu(x) = \frac{1}{1 + (\frac{x - c_i}{a_i})^{2b_i}} \tag{6}$$

Where *x* and *y* are the inputs, *A* and *B* are the linguistic labels, $\mu(x)$ and $\mu(y)$ are membership functions that take values between 0 and 1, and a_i, b_i and c_i are the parameter sets.

The second layer is a fixed node and can be calculated through Equation 7. It is worth mentioning that ω_i is the firing strength of a rule.

$$O_{2,i} = \omega_i = \mu_{A_i}(x) \,.\, \mu_{B_i}(y) \qquad for\ i = 1,2 \tag{7}$$

The third layer is also a fixed node. Its main goal is to normalize the firing strength by using Equation 8.

$$O_{3,i} = \varpi_i = \frac{\omega_i}{\sum \omega_i} = \frac{\omega_i}{\omega_1 + \omega_2} \qquad for\ i = 1,2 \tag{8}$$

The fourth layer is an adaptive node as well and depicted as green squares. Equation 9 is used to measure the fourth layer.

$$O_{4,i} = \varpi_i . f_i \quad for\ i = 1,2 \tag{9}$$

Rule 1: if x is A_1 and y is B_1 then $f_1 = p_1x + q_1y + r_1$

Rule 2: if x is A_2 and y is B_2 then $f_2 = p_2x + q_2y + r_2$

Where p_i, q_i, and r_i are the parameters sets.

The fifth layer is also a fixed node and can be calculated through Equation 10.

$$O_{5,i} = f_{out} = \sum_i \varpi_i . f_i = Overal\ output \quad for\ i = 1,2 \tag{10}$$

The final output of an ANFIS structure, can be calculated through Equation 11:

$$cf_{out} = \varpi_1 f_1 + \varpi_2 f_2 = \frac{\omega_1}{\omega_1 + \omega_2} f_1 + \frac{\omega_2}{\omega_1 + \omega_2} f_2 =$$

$$(\varpi_1 x)p_1 + (\varpi_1 y)q_1 + (\varpi_1)r_1 + (\varpi_2 x)p_2 + (\varpi_2 y)q_2 + (\varpi_2)r_2 \tag{11}$$

2.4. Accuracy Metrics

To compare the predictive power and accuracy performance of MLP and ANFIS two evaluation criteria namely RMSE and determination coefficient (R) are measured for both models. Equations 12 and 13 respectively show how to calculate RMSE and R^2.

Two criteria of RMSE and determination coefficient (R) were used to evaluate the predictive accuracy of MLP and ANFIS models. How to calculate these accuracy metrics is given in equations 1 and 2.

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (A - P)^2} \tag{12}$$

$$R^2 = 1 - \left(\frac{\sum_{i=1}^{n} (A - P)^2}{\sum_{i=1}^{n} A_i^2} \right) \tag{13}$$

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Training results

The results revealed that the MLP model with 10 neurons has the highest predictive power for predicting livestock production in Iran. On the other hand, this model with 18 neurons has the highest accuracy for predicting agricultural products in Iran. Similarly, for the case of Turkey, the MLP model with 18 neurons has the highest performance in both livestock production prediction and agricultural production prediction. It is also disclosed that the 14-neuron MPL model has the highest performance for both predicting livestock production and agricultural production, for the data collected from Iraq. It should be noted that the performance of these models is based on the amount of error measured by the RSME metric.

The results of the training phase show that the ANFIS model with the Trap. membership function compared to other membership functions has the lowest level of error both in the forecast of agricultural products (RMSE=987950.19) and in the forecast of livestock production (RMSE=4080579.79) in the data related to Iran. The result of the performance test of different membership functions of the ANFIS model on the data related to Turkey reveals that the ANFIS model with Gbell membership function has the lower RMSE both in the prediction of livestock product (RMSE=6643774.28) and in the prediction of agricultural product (RMSE=1920814.48) in comparison to the ANFIS model with other membership functions. The performance of different ANFIS model membership functions on Iraqi data was also tested and the results showed that the ANFIS model with Trap. membership function with a lower RMSE (RMSE=1867.43) has the highest accuracy in predicting livestock production and the ANFIS model with Gbell membership function has the highest accuracy (RMSE=8033.98) in predicting agricultural product (RMSE = 1920814.48) compared to ANFIS model with other membership functions.

3.1.2. Testing results

It is also disclosed that the MLP model with 10 neurons has the highest predictive power for predicting livestock production in Iran. On the other hand, this model with 18 neurons has the highest accuracy for predicting agricultural products in Iran. Similarly, for the case of Turkey, the MLP model with 18 neurons has the highest performance in both livestock production prediction and agricultural production prediction. It is also disclosed that the 14-neuron MPL model has the highest performance for both predicting livestock production and agricultural production, for the data collected from Iraq. It should be noted that the performance of these models is based on the amount of error measured by the RSME metric.

The results of the testing phase illustrate that the ANFIS model with the Gbell membership function compared to other membership functions has the lowest level of error both in the forecast of agricultural products (RMSE=1724426) and in the forecast of livestock production (RMSE=6052851.43) in the data related to Iran. The result of the performance test of different membership functions of the ANFIS model on the data related to Turkey reveals that the ANFIS model with Gbell membership function has the lower RMSE in the prediction of Livestock product (RMSE=5367841.52), and the ANFIS model with Tri. membership function has the higher accuracy in the prediction of agricultural product (RMSE=2201164.07) in comparison to the ANFIS model with other membership functions. The performance of different ANFIS model membership functions on Iraqi data was also tested and the results showed that the ANFIS model with Trap. membership function with a lower RMSE (RMSE=1908.30) has the highest accuracy in predicting livestock production and the ANFIS model with Gbell membership function has the highest accuracy (RMSE=2115.17) in predicting agricultural product compared to the ANFIS model with other membership functions.

Since the error level of ANFIS model have been lower than MLP in predicting of food production, the ANFIS model is selected for the prediction phase.

To ensure the predictive power of the ANFIS model, the coefficient of determination (R^2) was also evaluated for this model. It is disclosed that the R^2 for all the tested models on the database of the current study is a considerable number as R^2=0.96 for livestock products and R^2=0.76 for the agricultural products for the data related to Iraq, R^2=96 for livestock products and R^2=0.92 for the agricultural products for the data related to Turkey, and R^2=0.99 for livestock products and R^2=0.94 for the agricultural products for the data related to Iran. In other words, in addition to the fact that the predictive power of the ANFIS model is higher than the MLP model in the data of this study, the predictive accuracy of the ANFIS model is significant and considerable. That is why, the ANFIS model is applied to predict the food production in this study.

3.1.3. Prediction results

3.1.3.1. Iran

Due to the low RMSE of the ANFIS model with the Gbell membership function (RMSE=6052851.43), this model was used to predict local food production in Iran. Figure 1 illustrates that despite the decline in Iranian livestock production in recent years, the trend of livestock production in Iran is expected to increase. In other words, the output of the forecast model shows that livestock production will increase from 302028218.6 kg in 2014 to 397788163.4 kg in 2030.

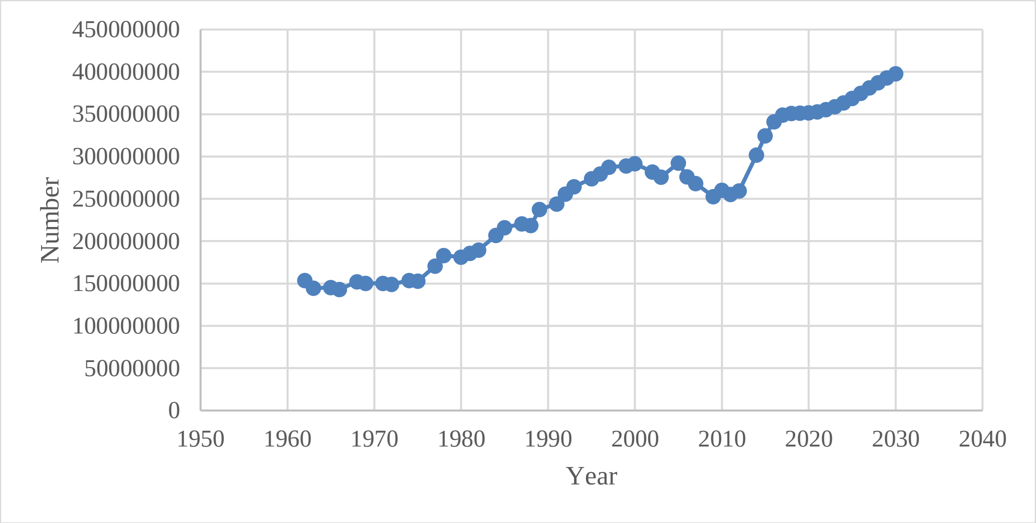

Figure 1. Livestock production in Iran, current data, and future trends
Source: Author's framework

The result of predicting Iran's agricultural production articulates that the production of agricultural products in Iran is on the rise and agricultural production in Iran will increase from 24969177 kg in 2014 to 35992727 kg in 2030 (see Figure 2).

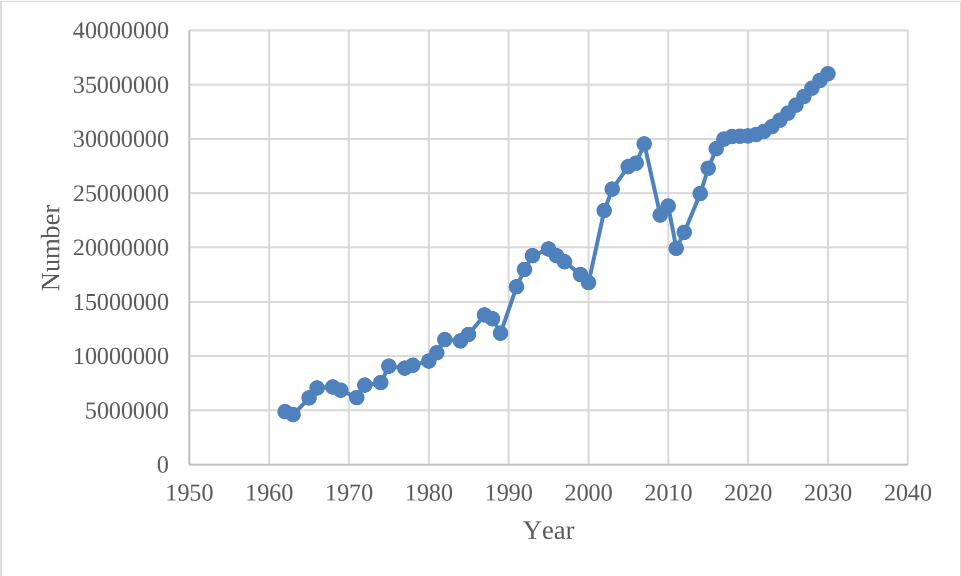

Figure 2. Agricultural production in Iran, current data, and future trends
Source: Author's framework

3.1.3.2. Turkey

Since the RMSE of the ANFIS model with the Gbell membership function was lower the other membership functions (RMSE=5367841.52), this model was used to predict livestock production in Turkey. The result of forecasting agricultural and livestock production for the next ten years in Iran is presented in Figure 3 and Figure 4

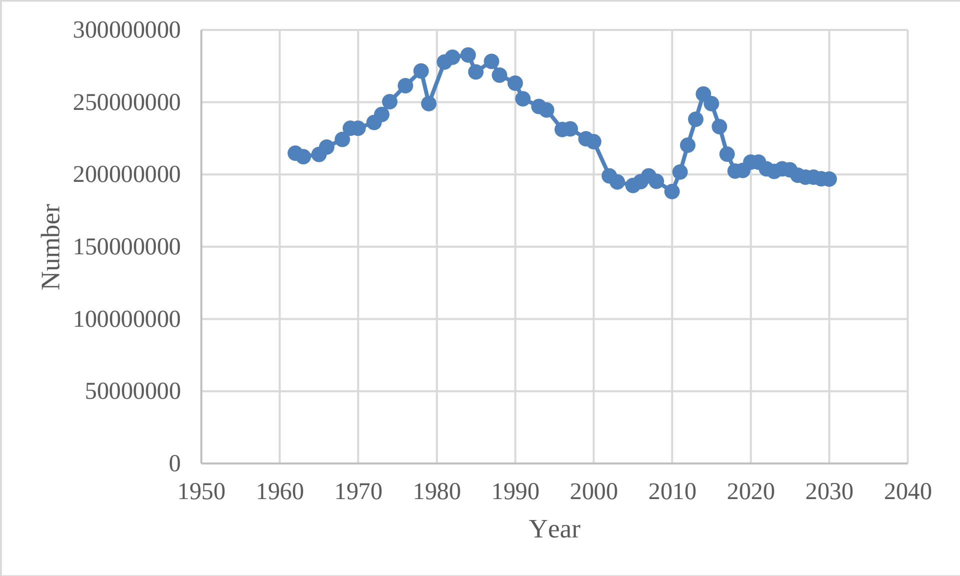

Figure 4. According to Figure 3, the trend of livestock production in Turkey is expected to decrease in the next decade. In other words, the output of the forecast model shows that livestock production will decrease from 255692892.2 kg in 2014 to 196830286.9 kg in 2030.

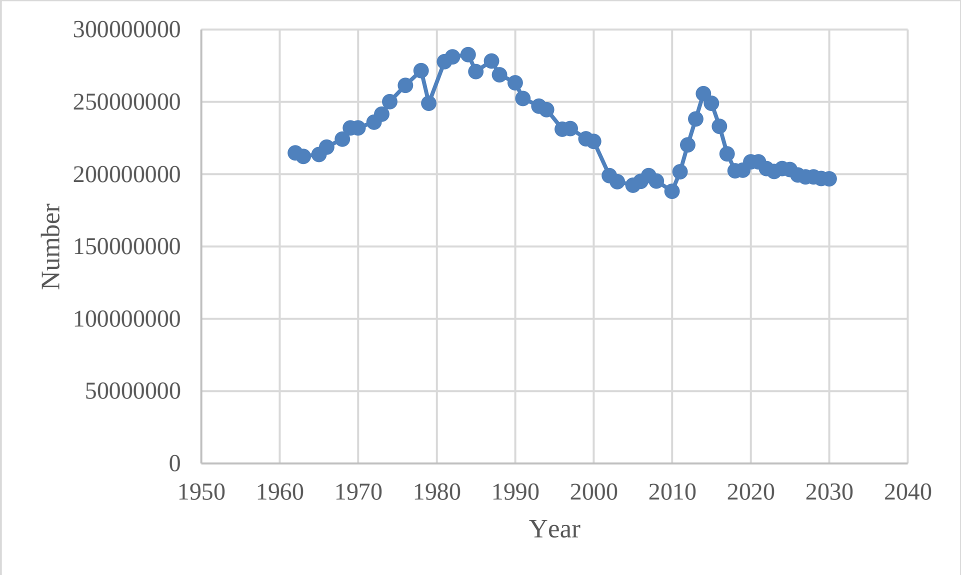

Figure 3. Livestock production in Turkey, current data, and future trends
Source: Author's framework

Since the RMSE of the ANFIS model with the Tri. membership function is lower than the other membership models (RMSE=2201164.07), this model applied to predict the Turkey's agricultural production. It is disclosed that Turkey's agricultural production is on the rise and agricultural production in Turkey will increase from 42948684 kg in 2014 to 48471123 kg in 2030.

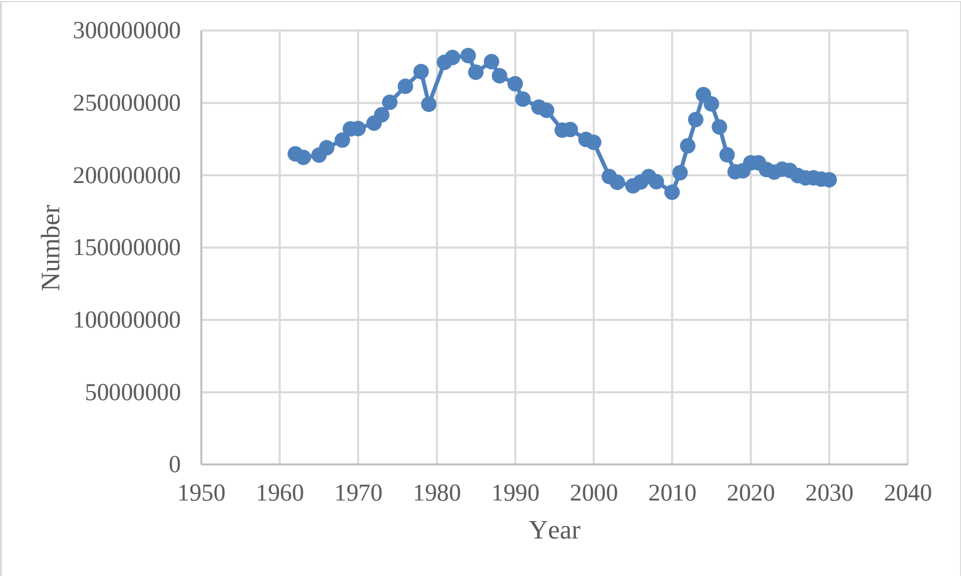

Figure 4. Agricultural production in Turkey, current data, and future trends
Source: Author's framework

3.1.3.3. Iraq

Due to the fact that the amount of RMSE of the ANFIS model with X membership function was lower compared to other membership functions (RMSE=1908.30) in predicting Iraqi livestock production, this model was used to predict Iraqi livestock production. The result of the model forecast shows that despite the fact that livestock production in Iraq has been steadily declining in the past decades, livestock production will increase in the next decade and livestock production in Iraq will increase from 552.1903 kg in 2014 to 949.6233 kg in 2030 (and Figure 5).

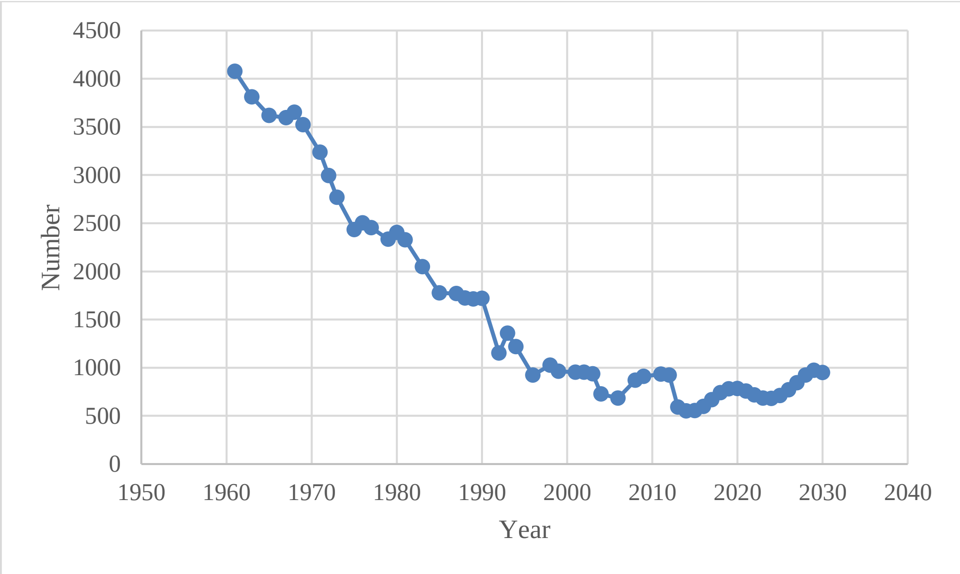

Figure 5. Livestock production in Iraq, current data, and future trends
Source: Author's framework

Since the RMSE of the ANFIS model with the Gbell membership function is lower than the other membership models (RMSE=2115.17), this model applied to predict the Iraqi agricultural production. It is disclosed that Iraqi agricultural production is on the rise and agricultural production in Iraq will increase from 146.286 kg in 2014 to 247.1713 kg in 2030 (see Figure 6).

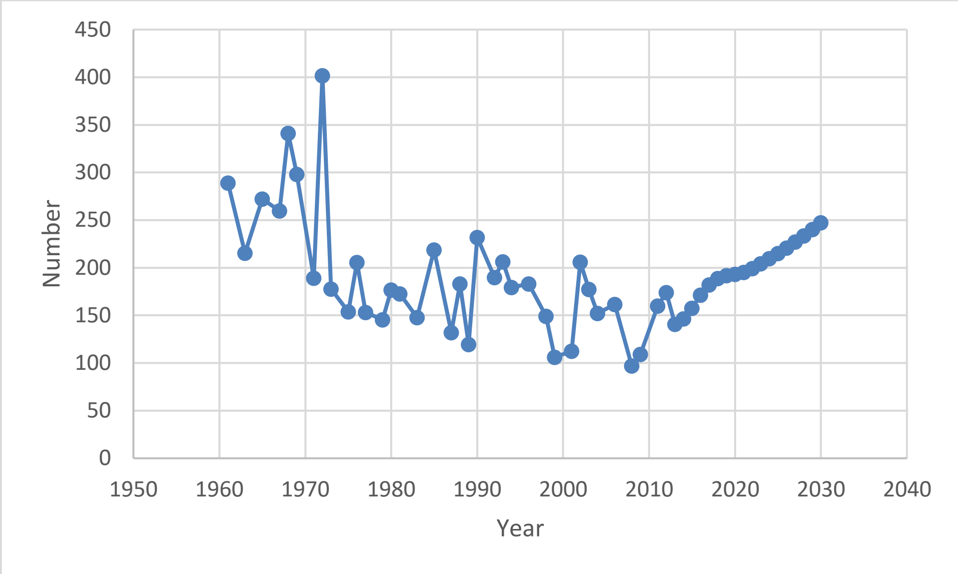

Figure 6. Agricultural production in Iraq, current data, and future trends
Source: Author's framework

3.1.4 Business Model Innovation and Food Supply Chain

The literature provides recommendations to redesign the value propositions in the business models. Where, the concept of value net is introduced which suggest collaboration among the different stakeholders to shape the value. The literature recommends that to engage the customers in the value shaping processes

In the literature, innovation is considered in value creation processes as the strategy to BMI for the food industry. There are empirical evidence proving that applying e-commerce models facilitates the value creation processes. Reconsidering the value delivering processes is another strategy are considered by the author to BMI in the FSC. It is also recommended that applying IoT to optimize the management of delivering the food production.

3.1.5 Social Capital and Food Security

Finding revealed that social capital improves food availability and food accessibility through two mechanisms: Knowledge sharing and product sharing (i.e., food sharing). Food utilization, on the other hand, is developed only through a product-sharing mechanism. It is found that social capital increases the stability of the food system. In general, the social capital and interactions of the members of a society stabilize a food system by eliminating the members' vulnerability and increasing their resilience.

3.1.5 The summary of Hypotheses testing

The results presented in this chapter showed that all the hypotheses presented in this study were confirmed and their summary is presented as follows.

H1 (Machine learning models are able to predict the food production) is supported.

H2 (Machine learning models have the ability to predict the future trend of domestic agricultural production in Iran) is supported.

H3 (Machine learning models have the ability to predict the future trend of domestic livestock production in Iran) is supported.

H4 (Machine learning models have the ability to predict the future trend of domestic agricultural production in Turkey) is supported.

H5 (Machine learning models have the ability to predict the future trend of domestic livestock production in Turkey) is supported.

H6 (Machine learning models have the ability to predict the future trend of domestic agricultural production in Iraq) is supported.

H7 (Machine learning models have the ability to predict domestic the future trend of livestock production in Iraq) is supported.

4. CONCLUSION

4.1. Introduction

Knowing the quantity of food produced in the nation may help plan and build ways to attain food security. Thus, the current work seeks to develop a machine learning model that can forecast food production in Iran, Iraq, and Turkey. The ANFIS model outperformed the MLP model in this study's dataset, therefore it was used to forecast food production in the three nations. Due to its strong predictive capacity, machine learning and deep learning models are often used to forecast data trends. The ANFIS model, a hybrid deep learning model, is able to forecast the trend of agricultural and food production based on historical data.

Iran's livestock production is predicted to rise 13% by 2030, reducing agricultural output. Because in actuality, some agricultural fields are changed into pastures, or even into sites for maintaining and rearing cattle. However, as animal production increases, a greater part of agricultural output goes to livestock consumption, removing it from the human food basket. However, the prediction model predicts an 18% growth in agricultural output in Iran over the following decade. Given Iran's vulnerability to drought, macro-management must address problems such as water supply and land use management. Other infrastructures that should be explored in Iran include technological infrastructure to optimize agricultural output and transportation infrastructure. Iran has the largest livestock output among the three nations studied, and this production is predicted to expand by 13%.

In 2030, livestock production in Turkey will fall by half a percent compared to 2020, but agricultural output will rise by 8%. As a result, Turkey's agricultural output surpassed that of Iran and Iraq in both 2020 and 2030. The data reveal that in 2030, Turkey, Iran, and Iraq will produce 48471123 kg, 35992727 kg, and 247.1713 kg of agricultural output.

The findings of this analysis reveal that agricultural and livestock output in Iraq would expand faster than in Iran and Turkey in 2030, with a growth rate of 21% from 781.9615 kg to 949.6233 kg. So, from 193.1157 kg in 2020, agricultural output in Iraq is anticipated to expand by 28% to 287.1713 kg in 2030. Although livestock and agricultural output in Iraq is predicted to grow faster than in Iran and Turkey over the next decade, it remains low compared to other nations. Iraq's food output is poor due to its large population, which is about half that of Iran and Turkey, and the country's bad environment for agriculture and livestock, as well as drought. Of course, effective water management and crop selection may maximize yield. So, in addition to water and land management, crop management should be prioritized in this nation.

4.2. Contributions

The methodology of this study and the use of deep learning models on the data of agricultural products and livestock products are of the innovations of the present study because this study is the first study that uses these deep learning models for this purpose. Since the results have been promising, it is suggested that the ANFIS model for similar datasets be used for future research. In other words, the output of this study provides a tool for policy makers and decision makers at the macro level of food security through which they can depict a possible view of the future of food production and based on it to design policies and plans related to food security.

The conceptual model of this study, which considers the agricultural and livestock production of a country as the internal potential of that country in food supply, is another innovation of this research.

The findings of this study, in addition to the conceptual model and confirmation of the predictive accuracy of the ANFIS model, have added information about the forecast of agricultural and livestock products of Iran, Turkey and Iraq for the next ten years to the research literature, which is considered as another contribution of this study.

4.3. Recommendations

The prediction model suggested in this work is used by macro-level policy makers and decision makers in food, agricultural, and animal import and export. Because this model may provide a glimpse into a country's future food production process. This graphic would help politicians plan more accurately, particularly for food security. On the other hand, the results of this research, which estimates the quantity of agricultural and animal output in the three nations of Iran, Iraq, and Turkey, may be utilized to plan and policy.

This study lays the groundwork for future investigation. Future research should evaluate the current study's prediction model on comparable data from other nations and compare the findings. However, future studies should discover independent factors determining a country's food production volume.

The domestic agriculture and animal output of a nation is critical in solving food insecurity. Thus, many nations have different assistance programs to encourage farmers and ranchers to maximize domestic production and provide food as much as feasible. Of course, governments may also import food to guarantee food security. Agriculture and animal husbandry growth in a nation not only provides food, but also contributes to regional (particularly rural) development and job creation. Government initiatives usually include agricultural, and livestock help. The current study's prediction models anticipated that agricultural output would grow in all nations, while animal production will increase in Iran and Iraq. Agricultural growth should be designed around three axes: resource conservation, farmer income, and food security. Where agricultural expansion increases food security and farmer income while remaining sustainable and non-destructive to environmental resources. Agriculture development projects in drought-stricken countries like Iran and Iraq should focus on modernisation and industrialisation to maximize water usage while protecting groundwater. Along with water management, land use management is a key factor in agricultural development choices. Land use balance is vital in sustainable development planning. In general, agricultural development may be achieved via rural development and long-term strategic objectives such as increased agricultural competitiveness, sustainable resource management, and rural economic power.

Prioritize the agriculture sector, which manages and plans voluntary agricultural-environmental-climate measures. The second goal is to boost agricultural firms, as well as other participants in the food supply chain, such as wholesalers and ultimate suppliers. To establish appealing and sustainable rural communities and villages with greater future possibilities, rural economic development should be fostered. Finally, a regional development plan involving many residents must be devised, creating a distinctive value-added area to assist rural growth.

Governments may also encourage private sector investment and participation in agricultural development programs to help achieve food security. The private sector's involvement may help improve food security and regional development by providing employment and raising people's incomes. Because, apart from food availability, affordability is a major element determining food security. That's why some governments, like Iran's, provide low-income people subsidies to help them buy food and live a healthier life.

The market for agricultural goods in developing nations is quickly expanding, creating new possibilities for agricultural and food sector players. The key problem today is to assist small farmers into this expanding market. A country's agricultural sector will become more reliant on imported food, and rural poverty reduction efforts based on agriculture will be less effective. Meanwhile, small and medium-sized businesses play a vital role in connecting small farmers to huge markets for agricultural goods at the national level, not only meeting consumer demand but also creating employment. Governments should develop infrastructure and help farmers to boost food value chains and expand smallholder farmers' access to markets. It is essential to create roads and enhance rural access to power, water, and ICT. They should also encourage the development of waste-free infrastructure, such as storage facilities, specialized agricultural terminals, and processing gear.

Agricultural infrastructure increases processing, minimizes post-harvest crop waste, and eventually brings low-income farmers into the loop. Smallholder farmers will be able to better their livelihoods by accessing global markets. Commercial agriculture and the food sector should be financed in these nations. This assistance may include advisory services in areas like as productivity, climate change adaptation, food safety, and involvement in small supply networks.

These and other studies show the relevance of entrepreneurship and innovative business models in the food supply chain. Various governments have focused on entrepreneurship for three reasons: 1) technological development, 2) social wealth generation, and 3) employment creation.

4.4. Limitations

The findings of the present study include limitations that prevent them from being generalized. One of the main limitations of this study is that the present study considers only the domestic production of a country. In other words, the purpose of this study is to examine the domestic capacity of a country to combat food insecurity, while a country's food supply can be obtained in various ways in addition to domestic production. Importing foodstuffs is one of these ways that have not been considered in this study. On the other hand, not all domestic products of a country are consumed for domestic consumption and a percentage of production is always exported, which is not considered in the present study. Another limitation of this study is the political and economic conditions of these countries are considered stable. The political and economic conditions of a country have a great impact on agricultural and livestock production. For example, economic, social or political crises or even wars can hamper a country's domestic production. Even changes in government support policies for domestic producers can affect a country's output, which is considered a constant variable in the present study.

5. NEW SCIENTIFIC RESUALTS

Countries have various hurdles in addressing food insecurity, yet current literature provides several answers. Having a full picture of what is anticipated in the future will help in planning future programs and solutions. The current research intends to fill a theoretical need by predicting future domestic food demand capacity of nations. The current study's key contribution is a model that can estimate agricultural and livestock output in a nation using machine learning. Because machine learning models are highly predictive and are being used in more and more disciplines of study. The study's contribution is shown below.

1) Innovation in the proposed model to study a country's domestic potential for food supply:

In this research, the agricultural and animal products produced in a nation are considered to indicate that country's domestic capacity for food supply. The FAO's FAOSTAT database was used to gather statistics on agricultural and animal output in three countries: Iran, Turkey, and Iraq. These figures indicate the quantity of agricultural and livestock output in each nation during the previous 50 years. As stated before, the aggregate of these goods represents a country's domestic food capacity.

2) The dissertation contributes to up-to-date analysis on business model innovation and food supply chain literature:

Using a thorough literature analysis, this research shows the relevance of business model innovation (BMI) in improving the food supply chain (FSC). This dissertation is the first to describe the current BMI-FSC link. This project will promote food security by demonstrating how BMI policies are adopted at each level of the FSC. This paper explains how BMI influences FSC and gives a conceptual paradigm.

3) The dissertation contributes to up-to-date analysis on social capital and food security literature:

This dissertation examines the significance of social capital to food security and shows how it may be produced in communities. This research uses a comprehensive literature review to demonstrate how social capital might promote food security by sharing knowledge and products (namely, food availability, food accessibility, food utilization, and food system stability).

4) This dissertation presents food security analyzes in the context of three countries:

The current research examines the state of food security in Iran, Turkey, and Iraq, as well as the literature suggestions for enhancing the four pillars of food security (food supply, accessibility, usage, and system stability). This phase's contribution is fresh for the food security literature and notably for the three nations studied. This portion of the study revealed that improving family food security and water management are the most essential measures to improve food security in Iran. Meanwhile, Turkey's food security solutions concentrate on yield control, land use management, and water management. Finally, this study's findings demonstrate that food security research in Iraq focuses on macro-agricultural and land management.

5) This dissertation provides information related to the future of food supply on the content of the three countries:

This dissertation predicts the domestic food supply potential of three nations, Iran, Turkey, and Iraq, using time series data of agricultural and animal products (until 2030). In other words, this research estimates how much agricultural and animal goods each of these three nations will produce over the next decade. The analysis found that agricultural output in all three countries (Iran, Turkey, and Iraq) would rise in 2030 compared to 2020. The ANFIS forecasting model also predicts an increase in livestock output in Iran and Iraq in 2030 compared to 2020, but a decline in livestock production in Turkey.

6) The methodology of this study and the use of deep learning models on the data of agricultural products and livestock products are of the innovations of the present study because this study is the first study that uses these deep learning models for this purpose. The positive findings recommend using the ANFIS model for comparable datasets in future study. In other words, the study's findings help policymakers and decision-makers see the future of food production and create policies and strategies around it. This study's conceptual approach views agricultural and animal output as a country's internal food supply capacity. Aside from the conceptual model and validation of the ANFIS model's predicted accuracy, this study's results have provided information about the forecast of agricultural and animal products in Iran, Turkey, and Iraq for the next 10 years to the research literature.

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