

A system dynamics approach to food security: The case of Turkey



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ABSTRACT

Predicting a sustainable food safety policy for the near future is among Turkey's priority problems. In this context, this study aims to predict Turkey's sustainable food safety policies. For this reason, the system dynamics model, which is a dynamic cycle-based method with stock and flow diagrams, is used in this paper. This study supposed the six different scenarios for 2020 and 2050. Data were selected as population, productivity rate, arable land fertility rate, and annual food consumption (per capita). The purpose of creating these scenarios; To determine the most appropriate policy to ensure food safety in Turkey. In the first scenario, we assumed that the current situation continues. In the second scenario, the average productivity rate was increased by 1.5%. The third scenario assumes that annual per capita food consumption rises to 1.2 tonnes per year. In the fourth scenario, the total fertility rate is accelerated by 2%. In the fifth scenario, we assumed that the arable land loss rate decreased by 1/3. Finally, we assumed that the sixth scenario covers all the second, third, fourth, and fifth scenarios and that 2 points reduce food losses. In conclusion, the findings show that food security responds positively in scenarios 2 and 6. However, in other scenarios, food security is negatively affected. The findings show that the sixth scenario is the best-case scenario. To ensure food security, it is necessary to reduce arable land losses and food waste. Training farmers and control of the food supply chain will be beneficial for sustainable food security in Turkey. We recommend that policymakers consider these recommendations.

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1. Introduction

The concept of food security implies that human beings can access, afford, and find the food they need. A wide variety of factors affect food safety, such as civil wars, global warming, arable land, food waste, population growth rate, dietary habits, income can be counted (Maixner and Katt, 2020). According to the Food and Agriculture Organization Global Report on Food Crises, more than 113 million people across 53 countries faced acute hunger in 2018 (FAO, 2019). Specifically, due to civil wars, Yemen, the Democratic Republic of the Congo, Afghanistan, Ethiopia, the Syrian Arab Republic, Sudan, South Sudan, and northern Nigeria had encountered food insecurity in 2017 (Zougmore et

al., 2021). The world witnessed drought, flooding, erratic rains, and temperature rises because of climate shocks (FAO, 2019). Therefore, the world experienced food security because of global warming.

The main purpose of Hena et al. (2019) study is to show the possible solution for economic growth and to highlight previous work on the development and modernization of agriculture in Pakistan and China. For this reason, in this study, while the role of the agriculture sector in the development of economies is discussed in detail, the cooperation between the agricultural sector and other sectors of the economy that can alleviate poverty is discussed. Costs, assets, technology, education, unlimited investments, it is important to look at the effects of climate factors on long-term food availability. It also found that climatic factors generally have a greater impact on food availability than technologies.

Affordability, access, and availability are the three basic characteristics of food security. Food security involves continuous access to sufficient, healthy, reliable, and nutritious (Koç and Uzmay, 2015; Yang and Lin, 2019). In this context, we can define food

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safety as healthy, reliable, and affordable food. Human beings have struggled to access food due to famine and hunger throughout history (Kıymaz and Şahinöz, 2010). New technological innovations have increased the population growth rate. The food supply of a country must be able to meet the needs of its growing population.

A country that can meet its own food needs will be economically independent and self-sufficient (Pigini and Conti, 2017). Otherwise, it will encounter difficulties in both political and economic aspects. Therefore, this paper will try to predict food security for Turkey with the systems dynamic methodology to capture the circular causality in the food system (Severová et al, 2021).

The system dynamic approach is founded on feedback concepts to solve, multi-loop, non-linearity, and time-lag features of a complex dynamic system. Simulation technique developed in America (MIT) in the early 1960s and started to be used mostly in the industrial system. This technique later became widespread in the social sciences (Eştürk and Ören, 2014). It aims to strengthen our understanding of the effects of various decisions and strategies on complex socio-economic systems on the behavior of that system. The research problems are a commercial enterprise, a city, a rural society, a nation, school, family, etc (Mabhaudhi et al., 2021). The methodology is based on the "information feedback" theory (Koç and Uzmay, 2019). System dynamics approach; understanding mentally complex system behavior and making it a systematic model. It is to make the mentally analyzed system using stocks, flows, and relationships by modeling it. It is the simulation of the behavior of the embodied model structure. The main purpose of the dynamic system methodology is not to estimate the value of a certain variable at a future moment but to understand the mechanisms of change (Koç and Uzmay, 2019; Barlas, 1996; Şenaras, 2017; Coyle, 1997; Forrester, 1961).

Turkey's Current State Of Food Security: Turkey is one of the leading suppliers of the world in terms of agricultural production. Turkey is an important producer and importer of agricultural products in the agricultural market. It is estimated to be the 7th largest agricultural producer in the world. With the increase in urbanization, agriculture still occupies an important position in the country's economy, although it has decreased compared to industry, services, and other sectors. Turkey is among the top 17 countries in 119 countries. Also, in the global food security index, Turkey ranked 41 in 131 countries in 2020, and in 2014 was ranked 39, it is seen that Turkey becoming less secure, down to the lower order (Dağdur and Olhan, 2015).

On the one hand, Turkey's agricultural production is increasing. On the other hand, losses in arable land are rising. Loss of arable lands, changes in eating habits, and the upward trend of the country's population can affect Turkey's food security. It is estimated that this situation will

adversely affect the country's agriculture and food policy.

2. Literature survey

Bala and Hossain (2013) have predicted the effects of food security and climate change in Bangladesh using the dynamic system approach. They found that the gradual shifting of farmland to horticultural crops and gradual shifting of crop areas to tobacco cultivation has been the best option for food security. However, tobacco cultivation will increase the pressure on the environment. It is a better option to gradually shift the horticultural crops of agricultural land to have a beneficial effect on food security and less impact on environmental degradation as a good option considering both the impact on such environmental degradation and food security.

According to Taleghani and Yeh (2016); in the planning process for rural development, it is important to determine the structural features for the development levels and to be aware of the environmental potential of each area. In general, the level of development of the agricultural sector in different parts of the region is not the same it is seen that there is no homogeneity and heterogeneity. Identifying and exploring possibilities and capabilities and then determining the development levels of different regions is the first step in the planning process and development of such areas. The overall aim of this study is to determine the level of development of agriculture in rural areas of Guilan using numerical taxonomy. To achieve this aim, six basic agricultural indicators were used to rank the villages in the province.

Müller et al. (2020) described the foodstuffs they make to organize achievements and gaps in different spatial scales (production, trade, and consumption) in different environments (production, trade, and consumption). The solutions depend on modeling and simulating the complex interactions of the agri-food system, ranging from global to household scales and cross-disciplinary boundaries. Knowing various methodologies (from food trade balance to representative), a wide range of models tries to integrate the direct and indirect forces of land use, environment, and socio-economic change at different scales. Ensuring food for all and food and nutritional security for all, globalizing, continues to teach a crucial critical lesson. There are now examples of good practice using meta-modeling techniques, out-of-equilibrium approaches, and behavior-based modeling efforts to illustrate ways forward. They argue that greater integration of different models is necessary to explain better multi-level agency and cross-information notifications within the food system.

In Heikkinen and Pakkala's (2015) study, the state has to increase labor productivity in agriculture to regain its agricultural potential and maintain its role in agricultural production. Therefore, the solution of industrial problems related to the rural

population and the future of agriculture has become an important factor for developing modern economic policies.

Wang (2010) used Dynamic Panel Data Analysis to sample the data given in 1985 and 2007 in 27 provinces in China. Per capita, disposable income of rural residents, food retail price index, agricultural disaster zone prove that the determinants of food security expressed as an aspect of arable land are empirical. As a result, he concluded that climate change would significantly affect food security, but food prices did not affect food security that year.

According to Ali et al.(2017), this study dealt with food safety. For this, Pakistan aims to estimate costs per acre, yields, and income determinants of open-field tomato production in Punjab. Primary data were collected from 70 farmers by stratified random sampling. Cobb-Douglas model was applied for regression analysis. Education, extension agent connections, experience, seed quantity, chemical applications, and marketing cost had a positive and significant impact on revenue. Price increases and plant diseases are the main problems. The government should lower the price of agricultural inputs such as fertilizers, seeds, and chemicals.

According to Besar et al. (2020), this article aims to analyze the issues and recommendations to strengthen the socio-economic development of palm oil producers through a case study in Terengganu Darul Iman province. As a result, the problems faced by palm oil growers; low wages, lack of capital, lack of subsidies, and lack of capital Findings, the technique used to grow the palm tree, their awareness of the latest technology in palm oil, lack of capital. To overcome these problems, this study made some recommendations to strengthen the socio-economic development of palm oil growers through other efforts such as consultancy, display, and inspection of oil palm fields and downstream crops.

With the system dynamics modeling approach in Muetzelfeldt (2010) study; to solve the effects and other relationships between main and food system factors (food security, environment, and livelihoods), to solve the effects and results in time as possible and to show how the results obtained will be included, to dynamically test the results obtained in the spider diagram for the individuals, Spider The article concludes as it is suggested that it has the potential to represent their communications in a formal standardized manner with an implementation system in line with the expanded System Dynamics. These types can also serve as models. Therefore, it supports a methodology that allows for the smooth transformation of informal conceptual thinking into quantitative estimation models by stakeholders and field experts. According to Jereme et al. (2017), supporting setting up food banks in significant locations of cities could be a solution for food security

Christos et al. (2014) focused on the four pillars of food safety, namely availability, accessibility, usability, and availability, and concluded that the

probability dimension has more global interest. The analysis, in turn, involves a Systems Dynamics approach that captures the dynamic nature of the interrelationships of food issues in context and allows the evaluation of different policy reviews. Tokathloğlu et al. (2018) explained the state's role in ensuring the security of agricultural supply. They emphasized the importance of natural resources for meeting the food need of the growing population and food security. This paper evaluated the changes in global agricultural policies in Turkey. According to Şahinöz (2016), high input costs are among the significant factors which caused food insecurity. It is recommended that food policy that will be redefined by the country. To overcome the problems related to food insecurity, Saudi Arabia has been started agricultural projects such as free land distribution, according to Alreshidi (2020).

3. Data and methodology

The food security model for Turkey is investigated using the system dynamic model. System dynamics include not only micro-level behaviors but also macro-level behaviors (Noviandi et al., 2016). The data is obtained from Turkey Statistical Institute for the period between 2007 and 2018. The population data belongs to 2019, the other data, such as food, arable area, and yield to belong to 2018. The rest of the data used belong to averages of 2007 and 2018 years. The simulation model used should be able to represent the real system (Noviandi et al., 2016).

The model's functioning is based on the factors affecting the total food demand and food free of losses. The factors such as total food demand, the effects of population and per capita food consumption factors, the amount of food free from losses, arable area, yield, and food loss are set within the framework of mathematical equations, and the model is created in this way.

The food security model for 2020 and 2050 has been developed depending on six different policy scenarios. In the model, Stella software was used. Fig. 1 shows Turkey's future projection model of food safety system diagram Stella.

- Average Number of Children: Annual number of children per woman able to give birth (Base year data).
- Decrease in Number of Children: The annual decrease in the number of children per woman who can give birth.
- Child Reduction Rate: The rate of decrease in the number of children per woman who can give birth.
- Fertility Period: Age range at which a woman can give birth during her lifetime (15-49=34).
- Average Number of Children Per Year: The average number of children a woman gives birth to during her fertility period.
- Female Ratio: Female ratio in the total population
- Number of Women: Number of women in the total population.

- Proportion of women who can give birth: The ratio of women between the ages of 15-49 among all women.
- Number of Women who can give birth: Number of women between the ages of 15-49.
- Birth: Expected number of births per year.
- Death: Expected number of deaths per year.
- Death Rate: Average annual death rate.
- Cultivated Area: Total arable land in the country.
- Loss of Area: The amount of annual loss of cultivated land.
- Area Loss Rate: Annual rate of loss of cultivated land.
- Yield Amount: The amount of product per decare as of the beginning year.
- Yield Increase Rate: Annual yield increase rate per decare.
- Total Food Production: Total amount of agricultural production.
- Purified Food Ratio: The food supply ratio obtained by subtracting the loss rates in total food production.
- Amount of Purified Food: The amount of food supply remaining after losses are subtracted.
- Food Consumption: Average amount of food consumed by a person in a year.
- Food Demand: The amount of annual total food demand needed by the Total Population.

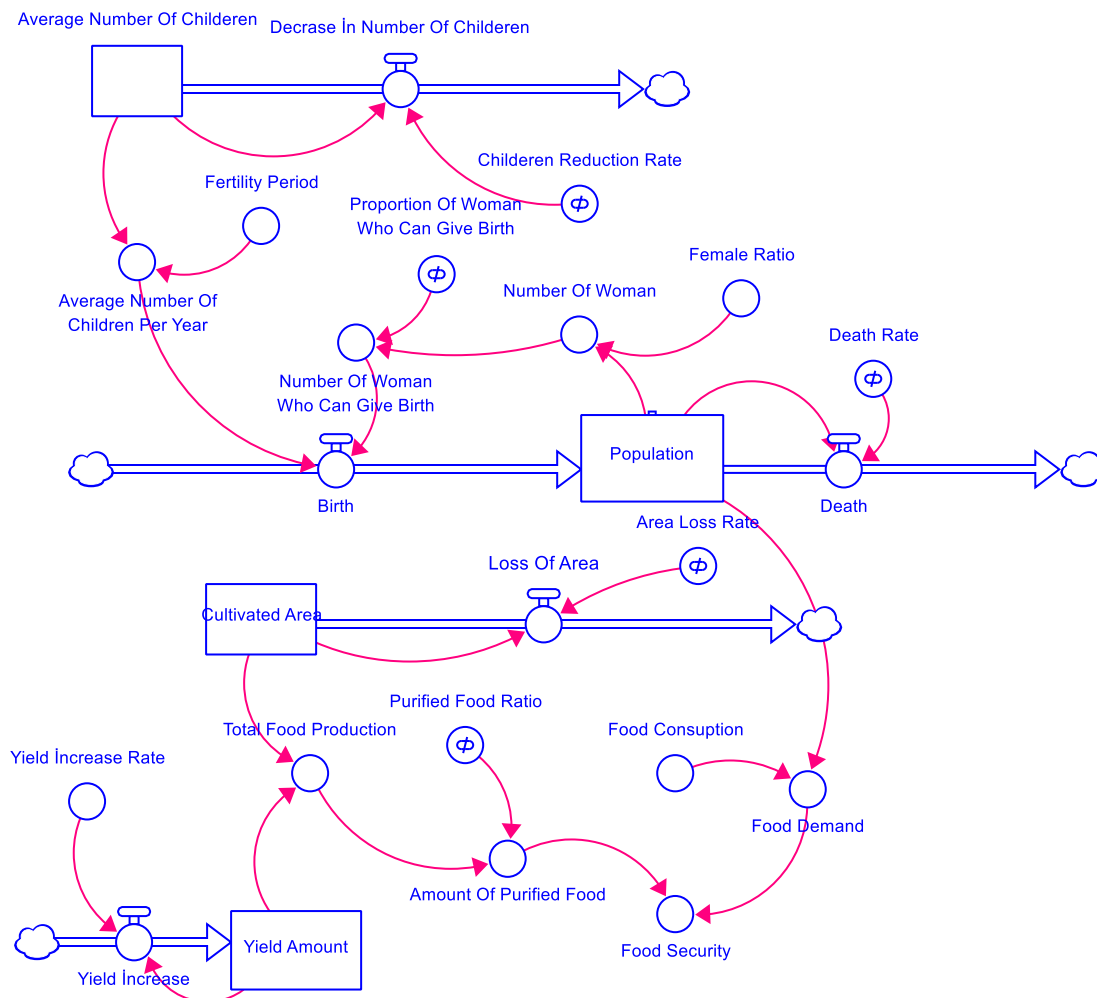


Fig. 1: Turkey's future projection model of food safety system diagram Stella

Model-generated scenarios in Turkey presents various policy options for achieving food security and the most appropriate policy for Turkey. In the model, the values and values of the stocks, flows, and transducers used and the defined mathematical equations that provide the framework for the operation of the model are defined as follows:

- $Average\ Number\ Of\ Children(t) = Average\ Number\ Of\ Children(t-dt) + (-Decrease\ In\ Number\ Of\ Children) * dt$
- $Cultivated\ Area(t) = Cultivated\ Area(t-dt) + (-Loss\ Of\ Area) * dt$

- $Population(t) = Population(t-dt) + (Birth - Death) * dt$
- $Yield_Amount(t) = Yield_Amount(t-dt) + (Yield_Increase) * dt$
- $Birth = Average\ Number\ Of\ Children\ Per\ Year * Number\ Of\ Woman\ Who\ Can\ Give\ Birth$
- $Death = Death_Rate * Population$
- $Decrease\ In\ Number\ Of\ Children = Average\ Number\ Of\ Children * Children\ Reduction\ Rate$
- $Loss\ Of\ Area = Cultivated\ Area * Area\ Loss\ Rate$
- $Yield\ Increase = Yield\ Increase\ Rate * Yield\ Amount$
- $Amount\ Of\ Purified\ Food = Total\ Food\ Production * Purified\ Food\ Ratio$

- $Average\ Number\ Of\ Children\ Per\ Year = Average\ Number\ Of\ Children / Fertility_Period$
- $Children_Reduction_Rate = 1,00296/100$
- $Food\ Demand = Population * Food\ Consumption$
- $Food\ Security = Amount\ Of\ Purified\ Food / Food\ Demand$
- $Number\ Of\ Woman = Population * Female\ Ratio$
- $Number\ Of\ Women\ Who\ Can\ Give\ Birth = Number\ Of\ Woman * Proportion\ Of\ Woman\ Who\ Can\ Give\ Birth$

- $Total\ Food\ Production = Cultivated\ Area * Yield\ Amount$

Stella software program was used for the calibration of the model (Table 1). The Powell method was applied which is the fastest and most accurate one. The values obtained as a result of calibration are the basic values used in simulations.

Table 1: Calibration results

Payoff:			Payoff			
Action			Minimize			
Kind			Calibration			
Element	Birth	Loss Of Area	Yield Increase	Decrease In Number Of Children		
Weight	auto	auto	Auto	auto		
Comparison Variable	Birth	Loss Of Area	Yield Increase	Decrease In Number Of Children		
Comparison Run	Run 1	Run 1	Run 1	Run 1		
Comparison Type	Squared Error	Squared Error	Squared Error	Squared Error		
Comparison Tolerance	0	0	0	0		
Parameter:	Children Reduction Rate	Death Rate	Area Loss Rate	Purified Food Ratio	Proportion Of Woman Who Can Give Birth	
min_value	0	0	0	0	0	
max_value	1	1	1	1	1	
scaling	1	1	1	1	1	
	Children Reduction Rate	Death Rate	Area Loss Rate	Purified Food Ratio	Proportion Of Woman Who Can Give Birth	payoff
Starting at	0.0100271022616	0.000545319305399	0.00454419645544	0.599455155572	0.501835909182	
After 187 runs	0.0100308183626	0.000559220467393	0.0045415586195	0.754547064056	0.501951633059	7.06559856991e-7

The data used in the simulation interface are yield increase rate, annual food consumption per capita, annual land loss rate, amount of food free of loss rate, the average number of children, and rate of decrease in an average number of children per year. We used six different scenarios to predict the most optimal policy: Current situation scenario, yield increase scenario, nutritional habit scenario, population targeting scenario, arable land scenario,

and mixed scenario. In the first scenario, it is assumed that the current status was kept. According to this scenario, it is predicted that there will be an increasing trend in the total food demand until 2050, and there will be a constant decrease in the amount of food free of losses. Therefore, this situation will affect food security negatively, as seen in the graph, and after a while, the supply will be unable to meet the demand (Fig. 2).

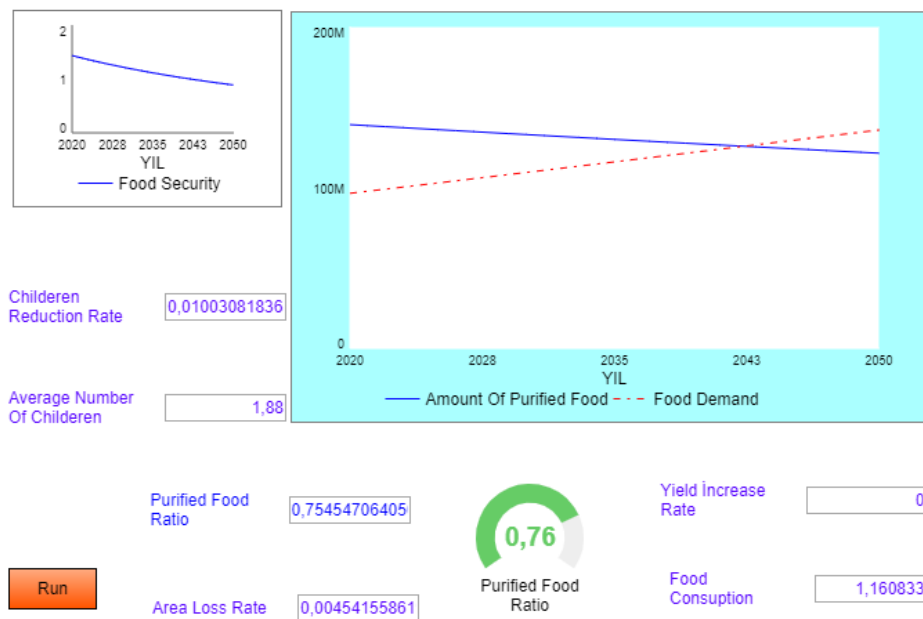


Fig. 2: Scenario 1

In the second scenario, the other variables are assumed constant, and the annual average yield increase is taken as 1.5%. As a result, it is predicted

that there will be a food supply that can continuously meet the increasing food demand, and it is expected to have a positive effect on food security (Fig. 3).

The third scenario is based on changes in consumption habits, and it is assumed that the annual food consumption per person will increase by keeping other variables constant. In this case, it is

seen that the food supply cannot meet the demand after a while. It is expected that this scenario adversely affects food security (Fig. 4).



Fig. 3: Scenario 2

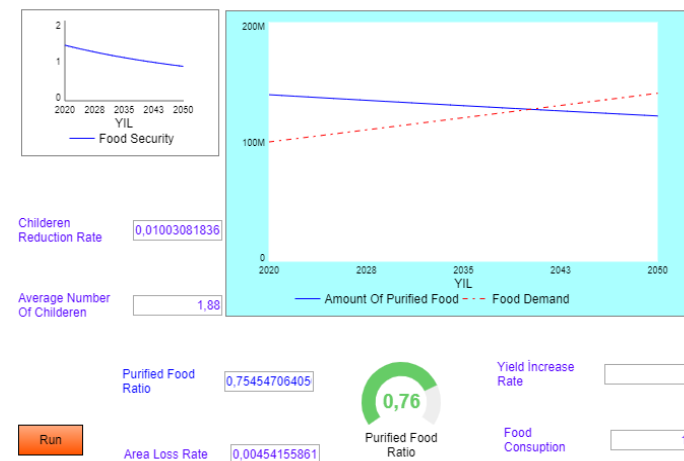


Fig. 4: Scenario 3

In the fourth scenario, population targeting has been the focus of this scenario. For the number of children per woman who can give birth, which tends to decrease continuously, 2.10 is considered the population's renewal level. Since 2017, the number of children per woman who can give birth has fallen below 2, and the decrease has continued. According

to our scenario, other variables are fixed, and the average number of children is 2. As a result, it is predicted that the food demand will exceed the production amount in the country after a while. Therefore, there will be a situation that adversely affects food security (Fig. 5).



Fig. 5: Scenario 4

The fifth scenario is based on arable land. It is assumed that annual arable land losses are reduced by 1/3 by keeping other variables constant and various conservation policies. As a result, it is seen

that it has a positive effect, extending the supply period to meet demand. However, it seems that there is an insufficient policy alone to affect food security positively (Fig. 6).



Fig. 6: Scenario 5

We obtained the best results from the sixth scenario, which consists of combining previous scenarios with a policy of food loss reduction policy.

Despite the growing population, a policy that depends on reducing food losses has positive results in food security (Fig. 7).



Fig. 7: Scenario 6

In the sixth scenario, which is the best, the importance of the population parameter regarding national security is considered the change in nutritional habits has not been neglected. In conclusion, we found that that a more effective agricultural policy with the protection of arable land. Furthermore, reduced losses and increased yield will be affected positively on food security (Fig. 8).

4. Results and discussions

In conclusion, it is found that optimal land use and reduction of food wastes will positively impact the future food security of Turkey. Turkey is one of the leading countries globally to meet future food needs in the next 20 years. Despite the reduction of the population growth rate, there has been an increase in food demand by the eating habits that change according to the development of Turkey.

Besides, failure to implement sustainable productivity growth policies that will ensure food supply in agricultural production is among the factors that negatively affect food security. Turkey's food safety of reduced and lost in providing 1/3 of arable land, the annual average of 1.5% strength, and a yield increase of 2% has been shown to reduce the loss ratio for the beneficial effects of food safety. Also, the increase in consumption to be experienced in eating habits, which changes depending on the income level, to 1.2 tons per year will negatively affect food safety.

However, it has been revealed that food safety is positively affected if a policy is created that ensures that all these factors occur at these values determined as minimal. The findings of simulation models indicate that optimal land use and reduction of food wastes will positively impact the future food security of Turkey. Turkey is one of the leading

countries in the food supply that can meet its population's future needs in the next 20 years. Despite the Reduction of Population growth rate,

there is an increase in food demand with the eating habits that change according to the development of Turkey.

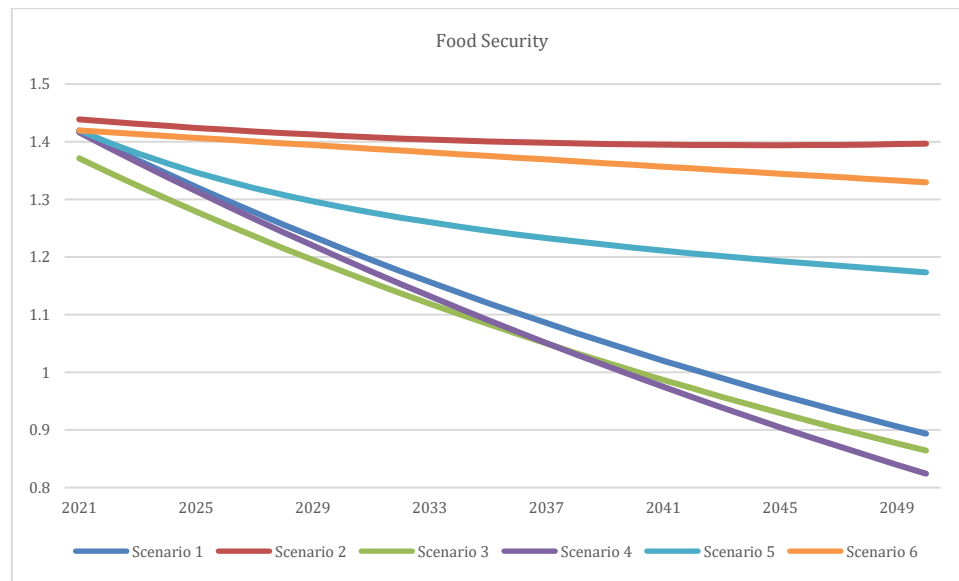


Fig. 8: Effects of scenarios on food security

Besides, failure to implement sustainable productivity growth policies that will ensure food supply in agricultural production is among the factors that negatively affect food security. Turkey's food safety of reduced and lost in providing 1/3 of arable land, the annual average of 1.5% strength, and a yield increase of 2% has been shown to reduce the loss ratio for the beneficial effects of food safety. Also, the increase in consumption to be experienced in eating habits, which changes depending on the income level, to 1.2 tons per year will negatively affect food safety. However, it has been revealed that food safety is positively affected if a policy is created that ensures that all these factors occur at these values determined as minimal. To achieve sustainable food security, for the future 30 years, Turkey should implement a holistic policy covering protecting arable lands, sustainable productivity increase policies, preventing food waste, raising the awareness of the agricultural population, and ensuring its continuity, minimizing losses, and increasing R&D.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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