Developing a Systems Dynamic Model to Capture NEXUS Interactions and Help to Promote Sustainable Development in Azerbaijan

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Abstract

The objectives of this work are to investigate water, land, food, energy sectors of Azerbaijan, analyze their effect on the climate of the country, determine the key links between these sectors and understand the dynamics between them using System Dynamics Modeling (SDM). Moreover, the study aims to provide solutions, recommendations and policy insights that could be useful to make effective policy decisions to push Azerbaijan towards low-carbon and sustainable economic development.

The literature review of previous studies of the sustainability state of Azerbaijan and papers related to SDM was done and included in this report. The literature review helped to identify the state of the art and the gaps in the research areas about the sustainable development of Azerbaijan.

Thus, data collection on water, land, food, energy, and climate sectors was conducted to run the SDM and forecast the changes in these sectors until 2050 taking 2017 as a baseline year. The results of the model projected a decrease in the total available water and land resources whereas the production and consumption of food, electricity production and demand are forecasted to increase by 2050. All these sectors are determined to have a direct influence on the climate by affecting GHG emissions and their sequestration. Moreover, the comparative analysis of GHG emissions and sequestration proved an excessive amount of emissions in the considered period (2017-2050).

Finally, recommendations on energy and agricultural sectors are presented together with solutions to change the data quality issues and pollution permits in Azerbaijan.

Keywords

Sustainable Development; Low-carbon Economy; Azerbaijan; System Dynamics Modeling (SDM).

Resumo

Os objetivos deste trabalho, para os setores da água, território, alimentos e energia do Azerbaijão, são: analisar os respetivos efeitos no clima, determinar os principais elos entre esses setores e entender a dinâmica entre os mesmos através da Modelização Dinâmica de Sistemas (MDS). O estudo tem como objetivo fornecer soluções, recomendações e visões sobre políticas que possam ser úteis para tomar medidas eficazes visando um desenvolvimento económico sustentável e com baixo carbono do Azerbaijão.

Este relatório inclui uma revisão da literatura sobre o estado de sustentabilidade do Azerbaijão e artigos relacionados com a MDS. A revisão da literatura permitiu identificar o estado da arte e as lacunas nas áreas de investigação sobre o desenvolvimento sustentável do Azerbaijão.

Desta forma, a compilação de dados sobre os setores da água, território, alimentos, energia e clima foi realizada para construir a MDS e prever as mudanças nesses setores até 2050, tomando 2017 como ano de referência. Os resultados projetaram uma diminuição no total de recursos hídricos, enquanto a produção e o consumo de alimentos, produção e procura de energia elétrica devem aumentar até 2050. Esses setores terão uma influência direta no clima, afetando as emissões de Gases de Efeito de Estufa (GEE) e a sua captura. A análise das emissões e captura de GEE mostrou que deverá verificar-se uma quantidade excessiva de emissões no período 2017-2050).

Finalmente, são apresentadas recomendações sobre os setores agrícola e da energia e soluções para alterar a qualidade dos dados e as licenças de emissões poluentes no Azerbaijão.

Palavras-chave

Desenvolvimento Sustentável; Economia de baixo carbono; Azerbaijão; Modelização Dinâmica de Sistemas (MDS).

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Nomenclature

Abbreviations	
Af	Available Food
BaU	Business as Usual
CCPP	Combined Cycle Power Plant
DYNAMO	Dynamic Model
E3ME	Energy-Environment-Economy Macro-Econometric model
FAOSTAT	FAO Statistics
Fc	Food Consumption
Gas CC	Close Cycled Gas Turbine
Gas OC	Open Cycle Gas Turbine
GHG	Greenhouse Gases
LU	Land Use
MAGNET	Modular Applied General Equilibrium Tool
OSeMOSYS	Open Source Energy Modelling System
RES	Renewable Energy Sources
SAARES	The State Agency on Alternative and Renewable Energy Sources
SD	System Dynamics
SDM	System Dynamics Modeling
SIMPLE	Simulation of Industrial Management Problems with Lots of Equations
SOCAR	The State Oil Company of Azerbaijan Republic
WD	Water Demand

1. Introduction

Transition towards a low-carbon economy is a vital opportunity for every country to contribute to the transformation of the global energy market to more sustainable one and play a role in a fight against climate change. However, the social engagement, cultural and historical differences, geopolitical circumstances and significant capital requirements present an enormous challenge to act in this regard. A strong coordination between capital, technology and policy as well as cooperation between private and public sectors are required for achieving the low-carbon economy. The challenge is further exacerbated when the economic growth of the country heavily relies on fossil fuels, which is the case in Azerbaijan. This reliance became even greater when Azerbaijan got independence from Soviet Union in 1991 and used petroleum industry to boost economic growth of the country. Although fossil fuels played a great role in the economy of the country, it also exposes the country to volatile oil and gas prices. However, challenges in the country regarding the low-carbon economy should not only be associated to fossil fuels but should be analyzed by integrating several sectors that are making up the economy and investigating the dynamics between them. Thus, this study will investigate Azerbaijan's transition to a low carbon pattern as one of the 12 case studies of Sustainable Integrated Management for the Nexus of Water-Land-Food-Energy-Climate (SIM4NEXUS) project (SIM4NEXUS, 2019).

The SIM4NEXUS project, which is funded by EU and started in 2016, aims to adopt the knowledge and develop new expertise on the Nexus of energy, water, land, food and climate. Moreover, the project aspires to draw policy insights and showcase the effect of policies on resource systems. The Nexus segments are interconnected with each other and alternations in one can lead to changes in another (Domingo, 2017). The detail complexities arise due to having many components in every segment and dynamic complexities arise due to having separate segments in one system where the determination of the interconnections between them is a big challenge (Zarghami & Akbariyeh, 2011). To overcome these complexities, system dynamics model (SDM), which is an approach to understand and model nonlinear behavior of complex multi-component systems over a certain timeframe, is used in this study. Moreover, SDM is crucial for identification the links between the components/segments, investigation of resource management efficiency and giving the policy perspective on these segments.

There is much study and research conducted on water and land resources and utilization, food and energy production and consumption in Azerbaijan. However, the holistic view of economy and interconnections between these segments have not been profoundly investigated. This study fills in this gap of research area as an opportunity and aims to explore the links between water-land-food-energy-climate of Azerbaijan for more efficient use of resources and help in transitioning to low-carbon economy. The work includes literature review on computational models, studies done regarding resource use in the country and economic studies on Azerbaijan, data collection on each segments of the Nexus, population of the SDM and analysis of the model outputs.

1.1 Scope and Objectives

Azerbaijan is situated in the southern Caucasus region of Eurasia and has prominent geographical features such as the Caspian Sea coastline of 713 km to the east, the Greater Caucasus mountains to the north and flatlands in the central parts of the country. Apart from the east border with Caspian Sea, the country is bordering with Georgia and Russia to the north, Iran to the south, Turkey to the northwest and Armenia to the west and south west (Figure 1). Moreover, Azerbaijan is a country with 86600 km^2 area, 4485 m highest point (Bazarduzu) and -28 m lowest point (Caspian Sea) and the population that has reached 10 million in April 2019 (Kucera, 2019).

Figure 1 Borders of Azerbaijan Republic on the map (FreeWorldMaps, n.d.)

The territory of the Republic of Azerbaijan except the Nagorno Karabakh region, which is a disputed territory internationally recognized as a part of Azerbaijan but currently under the occupation of Armenia (European Parliament, 2010), is considered in this study.

All components of the Nexus are important to be analyzed for reaching the objectives of the study. Hence the following segments were analysis under this study:

- Water: the country has scarce water resources and 67-70% of water reserves are transboundary.
- Land: the land use of agriculture has had an increasing trend during the last years and the forestation of the country is crucial for the government after facing the challenges of deforestation due to use of wood for heating in the countryside of the country after Soviet Union.
- Food: meat is highly consumed within the country as well as bread. The balances between food production, consumption, imports and exports will be investigated.

- Energy: fossil fuels have a biggest share in the energy mix of the country, which has a biggest print on climate. However, renewable energy sources like wind, solar and hydropower are present in the mix.
- Climate: greenhouse gas sequestration (GHG) in the country is assessed together with the study on the biggest GHG emitting sectors within the country.

Considering all these segments, one of the study's objective is the determination of the key links between the segments and understanding the dynamics between them using System Dynamics Modeling. Moreover, the study aims to provide solutions, recommendation and policy insights which could be useful to make effective policy decisions to push Azerbaijan towards low-carbon and sustainable economic development.

2. Literature Review

This chapter aims to give a brief overview of the papers studied during this work for better comprehension of system dynamics modeling (SDM) and studies explored regarding Azerbaijan's economy and resource use, which are relevant to this work.

The history of SDM dates to 1950s, when Professor Jay W. Forrester and a group of graduate students from MIT started to study the shift to computer modeling from hand-simulations. The first SD modeling language was SIMPLE (Simulation of Industrial Management Problems with Lots of Equations) which was invented by Richard Bennett in 1958. Following this milestone, the early version of DYNAMO (Dynamic Models) was developed by Phyllis Fox and Alexander Pugh in 1959 (Najjar, 2013). This was followed by the first book written by Forrester in 1961 regarding system dynamics modeling under the title of "Industrial Dynamics".

The early use of SDMs facilitated the improvement of efficiency in resource management in the energy sector. In the study under the title of "The Limits to the Growth", which was conducted at MIT in early 1970s by a team of 17 researchers, system dynamics modelling was used for building the models WORLD2 and WORLD3. The aim of the project was to estimate the limits of natural resources available and its links to population growth and economic development by forecasting the future behavior of world systems (Meadows, Meadows, Randers, & Behrens, 1972). The outcomes of the work such as forecasts on the decline of population growth and industrial capacity by 2072, alternations in growth trends for successful sustainable ecology and economic stability were first presented in Moscow and Rio de Janeiro in 1971 and later were published as a book under the same title "The Limits to Growth" in 1972.

The SDMs were also used for policy analysis and design. A research team from National Cheng Kung and Providence Universities in Taiwan conducted a study under the title "A System Dynamics Model of Sustainable Urban Development: Assessing Air Purification Policies at Taipei City" in 2006 (Chen, Ho, & Jan, 2006). The study aimed at analyzing and comparing air purification policies in Taipei, Taiwan, and understanding the dynamics between air pollution, urban development and transportation. Thus, the findings of the work were a need in Taipei for deeper approach in sustainable development and the Green Land preservation policy being more important than public transportation policies.

The SDMs were used for policymaking also in Minnesota in 2010 by researchers while working on a paper titled "Using Scenario Visioning and Participatory System Dynamics Modeling to Investigate the Future: Lessons from Minnesota 2050". The project aimed at helping the decision makers to approach more sustainable communities with the help of the strategies developed by the model and identifying non-explored parts in the research done on the sustainability of the region (Olabisi, et al., 2010). Moreover, in the study scenario visioning and SDMs found to complement each other triggering sustainable systems thinking (Najjar, 2013). The most important finding of the paper was identification of controllable actions in the uncertainty of future.

The study titled “System dynamics modeling for complex urban water systems: Application to the city of Tabriz, Iran” used a system dynamic approach to model the water system of the city Tabriz. The work aimed to study the effect of utility price volatility on the water shortage as well as the influence of the wastewater system on the groundwater resources (Zarghami & Akbariyeh, 2011). The forecasts on water shortage by 2020 (45% reduction in shortage) were projected using several management scenarios. The approach and the model were acknowledged to be an effective decision support system.

Together with studying the papers done on the SDMs during the literature review, papers and work on climate change in Azerbaijan, climate plans, forecasting models for Azerbaijan and policy decision aid models were explored.

The first step in the literature review regarding studies on Azerbaijan was research about climate plans and papers discussing the impact of climate change on the Nexus components. The paper titled “Climate Change and Agriculture Country Note. The Republic of Azerbaijan” is a part of country briefs of Southern Caucasus Region mainly focusing on the exposure and the risk of the country to climate change and its’ influence on agriculture. The paper concludes that Azerbaijan is especially vulnerable to climate change with the increase of mean temperature by 1.4 °C from 2020 to 2050, increase of precipitation by 10-20% till 2050 compared to 1961 and increases of vulnerability to pests and crop diseases (Ahouissoussi, VakhidChirag-Zade, & Srivastava, Azerbaijan - Climate change and agriculture country note , 2012).

Another study by the World Bank was done in 2014 on “Reducing the Vulnerability of Azerbaijan’s Agricultural Systems to Climate Change”. In this work the important challenges for country’s agriculture due to climate change were identified, vulnerability of Azerbaijan to these challenges was assessed and adaptation and mitigation measures were discussed. The key climate hazards are identified as changes in precipitation, higher temperatures especially during key agricultural production periods, not extensive information available to people and water shortage. Thus, the paper provides several messages on need in improvement of irrigation systems, crop and livestock production, hydrometeorological data access and agricultural businesses for adaptation to these changes (Ahouissoussi, et al., 2014).

“The First Biennial Updated Report of the Republic of Azerbaijan to the UN Framework Convention on Climate Change” was also analyzed during literature review. The aim of the paper is to provide a holistic view on the greenhouse gas emissions by their source and amount (Allahverdiyev, 2014).The report covers the climate plans of the country and contains suggestions in GHG mitigation in energy, industry, waste, forestry and agricultural sectors. Moreover, the assessment of financial, technological and capacity needs for climate-change related purposes is also included in the paper. In the technology section, only need for expansion of waste-to-energy and energy efficiency practices was mentioned. In the financial needs for climate segment, the current investments in energy, transport, industry, waste and petroleum industry sectors were stated together with the future investment requirements considering climate change.

There are several studies and models that were on the economy of Azerbaijan which are also aimed to be useful for policy makers. One of these studies is “A macroeconometric model for making effective policy decisions in the Republic of Azerbaijan” which was presented in the International Conference on Energy, Regional Integration and Socio-economic Development in 2013 (Hasanov & Joutz, 2013). The paper focuses on five different sectors: real sector (household consumption, private investments, governmental expenditure and net exports), fiscal sector (governmental revenues from oil turnover), external sector (revenues from non-oil trade turnover), monetary sector and domestic prices & wage sector. The aim of the work is designing a model which describes the relationship between the covered sectors and can be used as a common tool for policymakers.

The literature review on System Dynamics Models was found to be useful in understanding how the SDMs work, their use and importance. Moreover, the papers reviewed on the studies related to Azerbaijan identified the sectors considered in the research up to now and some of the models designed for the country. To summarize, the literature review helped in understanding the gaps in the research areas and the need for the holistic study considering every segment of NEXUS using SDM.

3. Methodology

Considering the scope and objectives of the study with five NEXUS segments and the need in determination of dynamics between those, System Dynamics Modelling (SDM) is a crucial, effective and well-adjusted modeling technique to respond and achieve the study requirements.

The work was initiated with designing a preliminary model to identify the detailed structure in each segment that needs to be researched. The next step was to collect the data for each segment to populate the model which was followed by verifying and running the model. The last step of the work was to obtain the outcomes from the model and conduct thorough analysis of them to draw the conclusions fulfilling the objectives of the study.

3.1 System Dynamics Model (SDM) Structure

The SDM is designed to contain all five segments of the NEXUS and the interconnections between those.

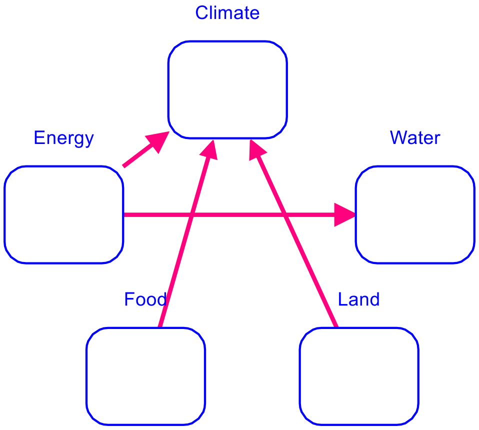

Figure 2 Structural Overview of the Highest Level SDM of Azerbaijan

As it can be seen in Figure 2, the energy, food and land segments have impact on the climate sector while energy is also interlinked with the water segment. The links between the segments and dynamics in the model are analyzed in this chapter of the report.

3.1.1 Water

The aim in designing the water segment of the SDM is to achieve a balance between the available water, water consumption and demand as shown in Equation 1. Initial balance is set to zero. The ground and surface water resources of Azerbaijan and recycled water are combined in the model resulting in available water (Figure 3).

$$\text{water\_balance}(t) = \text{water\_balance}(t - dt) + (\text{Available\_water\_1} - \text{W\_Demand}) * dt \tag{1}$$

$$\text{Available\_water\_1} = \text{Groundwater\_1} + \text{Surface\_water} + \text{water\_recycling}\ \{\text{UNIFLOW}\} \tag{2}$$

$$\text{W\_Demand} = \text{Domestic\_WD} + \text{Irrigation\_and\_agriculture\_wd\_1} + \text{Industrial\_wd\_1}\ \{\text{UNIFLOW}\} \tag{3}$$

$$\text{Domestic\_WD} = \text{Population\_1} * \text{drinking\_per\_cap\_wd\_1}\ \{\text{UNIFLOW}\} \tag{4}$$

Domestic, agricultural and industrial water demand are included on the demand side of the model using Equation 3. The population of the country and per capita water consumption are considered to compute the domestic water demand.

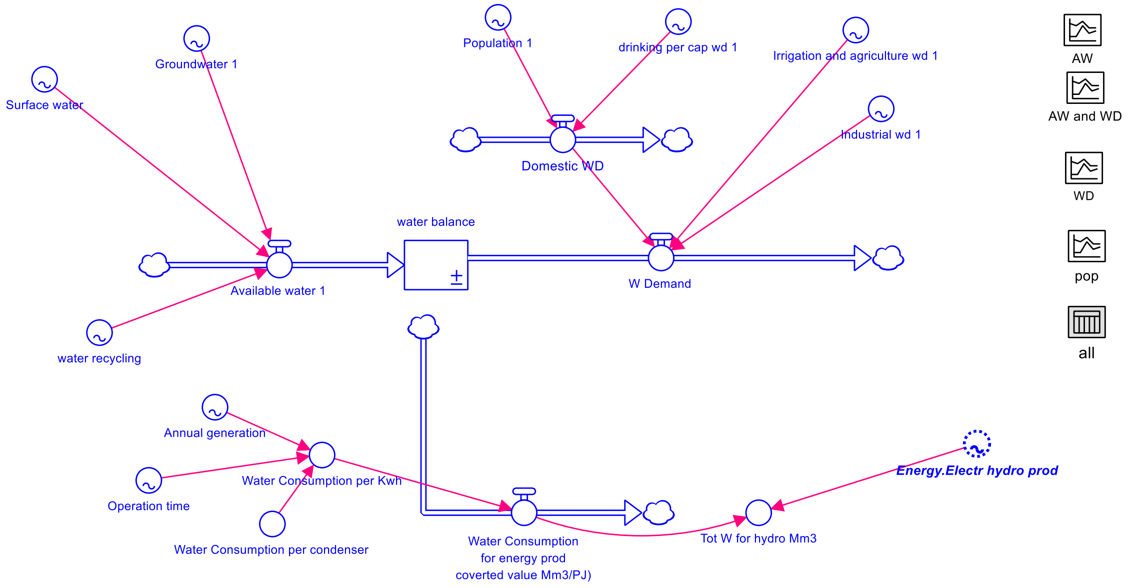

Figure 3 Structure of Water Segment of the SDM

$$\text{Water\_Consumption\_per\_Kwh} = (((\text{Operation\_time} * \text{Water\_Consumption\_per\_condenser} * 3600)/\text{Annual\_generation}))/10\text{\^{}}6 \tag{5}$$

Tot_W_for_hydro_Mm3 =
"Water_Consumption_for_energy_prod_coverted_value_Mm3/PJ)"*Energy.Electr_hydro_prod (6)

Moreover, water consumption in the cooling processes of the energy production systems are included in the SDM, expressed by Equation 5 where the annual energy production data from the Energy segment of the model is linked to this segment of the SDM as an input. Finally, the water retained in the small hydro power plants is included in the consumption part as shown in Equation 6 which is also linked to the Energy segment by accessing the hydro energy production values from that sector.

3.1.2 Land

The design of the land segment of the model is shown in the Figure 4. Here, the irrigated, non-irrigated and fallow land as well as the area covered by wetlands and forests are considered as a part of the total land use. Moreover, the land utilized for livestock is also included as an input to the total land use.

$$\text{TOT\_fertilizer\_used\_in\_irrigated\_land} = \text{Irrigated\_LU} * \text{"Fertilizers\_ton/ha"} \qquad (7)$$

$$\text{TOT\_fertilizer\_used\_in\_NON\_irrigated\_land} = \\ \text{Non\_irrigated\_and\_potentially\_irrigated\_LU*"Fertilizers\_ton/ha} \qquad (8)$$

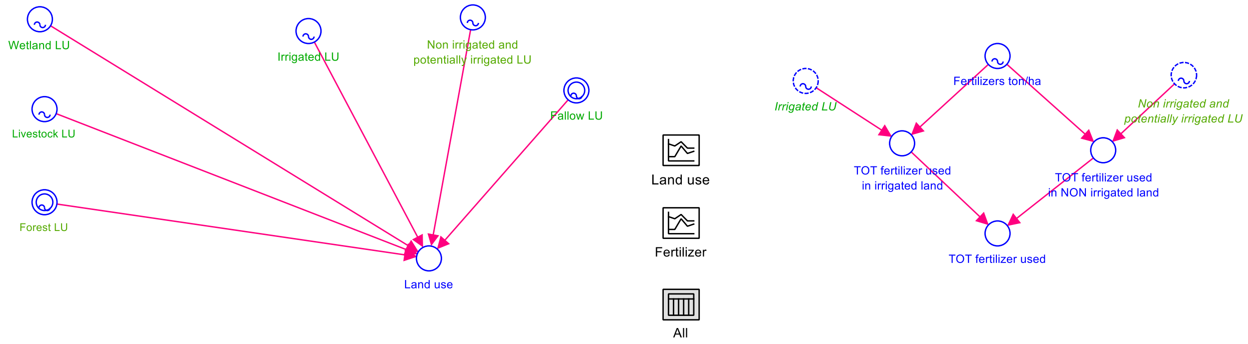

Figure 4 Structure of the Land Segment of the SDM

The fertilizer use in agricultural land is also added into the model inputs by using per hectare fertilizer consumption data and agricultural land use data to obtain the total fertilizer consumption in agriculture (Equations 7 and 8).

3.1.3 Food

The design of the food sector is based on achieving the balance between the available food resources and food consumption. On both sides of the balance food products are divided into grain, vegetable, fruit, meat, dairy and other basic food products categories (Figure 5).

$$\text{Food(t)} = \text{Food(t} - \text{dt)} + (\text{af} - \text{fc}) * \text{dt} \{\text{NON} - \text{NEGATIVE}\} \qquad (9)$$

The balance was encompassed into the model using the Equation 9 where available food and food consumption are referred as “af” and “fc” respectively.

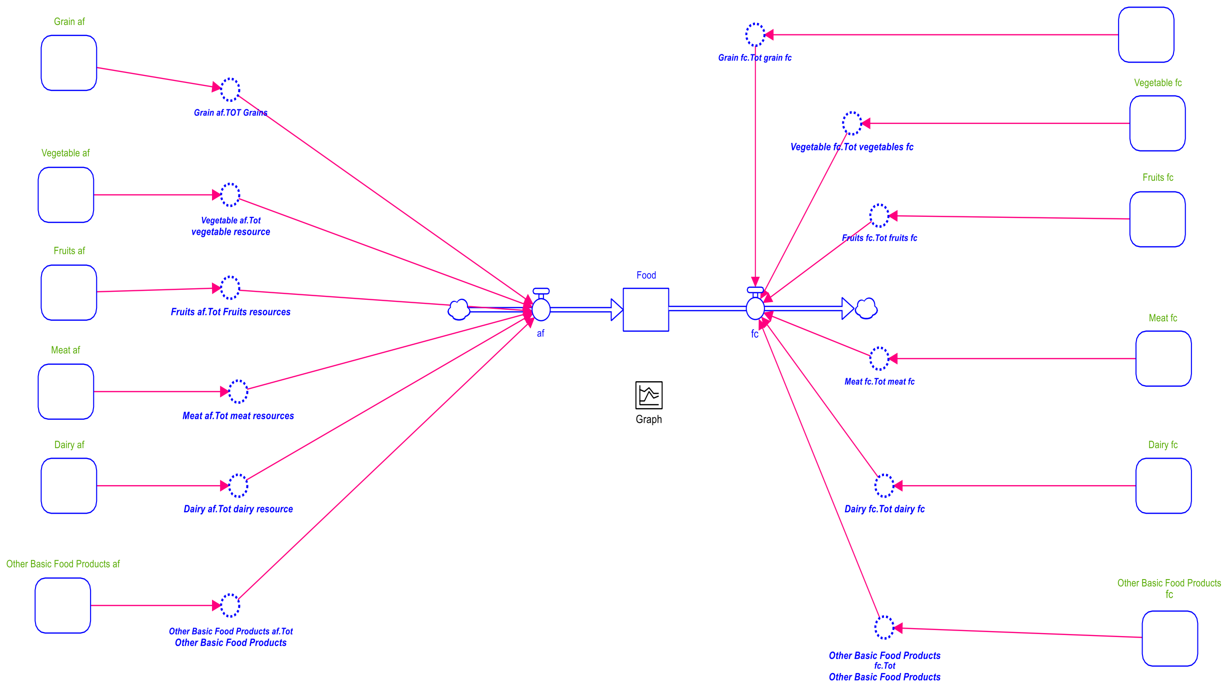

Figure 5 Structure of the Food Segment of the SDM

The detailed analysis of one food product (dairy food products) model structure will be explained in this section, which is followed in all other segments as well.

In the available food section, food stocks at the beginning of each year, the production and imports of the food products are summed to obtain the total resources for considered food products (Figure 6). Thus, in the case of dairy food section the total available dairy food resources are estimated using Equations 10, 11 and 12.

Tot_dairy_resource =
Milk_and_dairy_products_Total_of_resources+Cheese_Total_of_resources (10)

Milk_and_dairy_products_Total_of_resources =
Milk_and_dairy_products_Stocks_at_the_beginning_of_year_2+
Milk_and_dairy_products_Production_1+Milk_and_dairy_products_products_Import_1 (11)

Cheese_Total_of_resources =
Cheese_Stocks_at_the_beginning_of_year_3+Cheese_Production_1+Cheese_Import_1 (12)

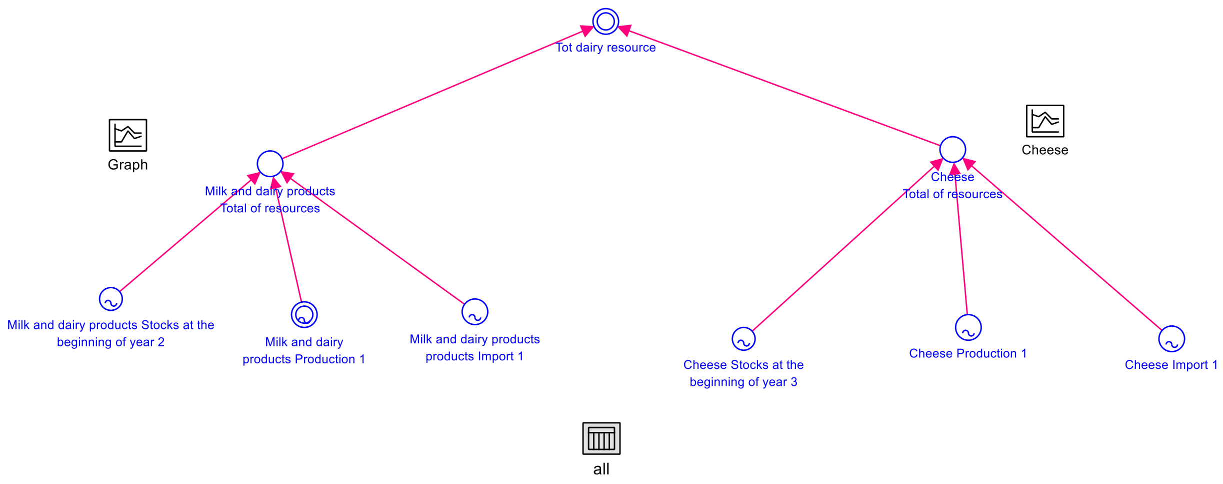

Figure 6 Structure of the Available Dairy Food section of the SDM's Food Segment

In the food consumption section, the use of food products, their exports, losses and stocks at the end of a year are accumulated. For milk products, for instance, use of milk as fodder for cattle and poultries and industrial use of milk are also added to the model using Equation 13.

Milk_and_dairy_products_Total_of_utilizations =
Milk_and_dairy_products_Used_fodder_for_cattle_and_poultries+Milk_and_dairy_products
_Industrial_purposes+"Milk_and_dairy_products_As_food_products_(without_processing)"+ (13)
Milk_and_dairy_products_Export+Milk_and_dairy_products_Stocks_at_the_end_of_year+
Milk_and_dairy_products_Losses

Finally, the total use of dairy products is encompassed as the sum of total milk and cheese products utilization.

3.1.4 Energy

In the energy segment of the model, the balance between the available energy and the energy demand is followed. Available energy is segregated into energy produced from fossil fuels (oil and gas) and renewable energy sources (hydro, wind and solar energy).

On the demand side, however, energy consumption in the residential, service, agricultural, industrial and transportation sectors are included as shown in the Figure 7.

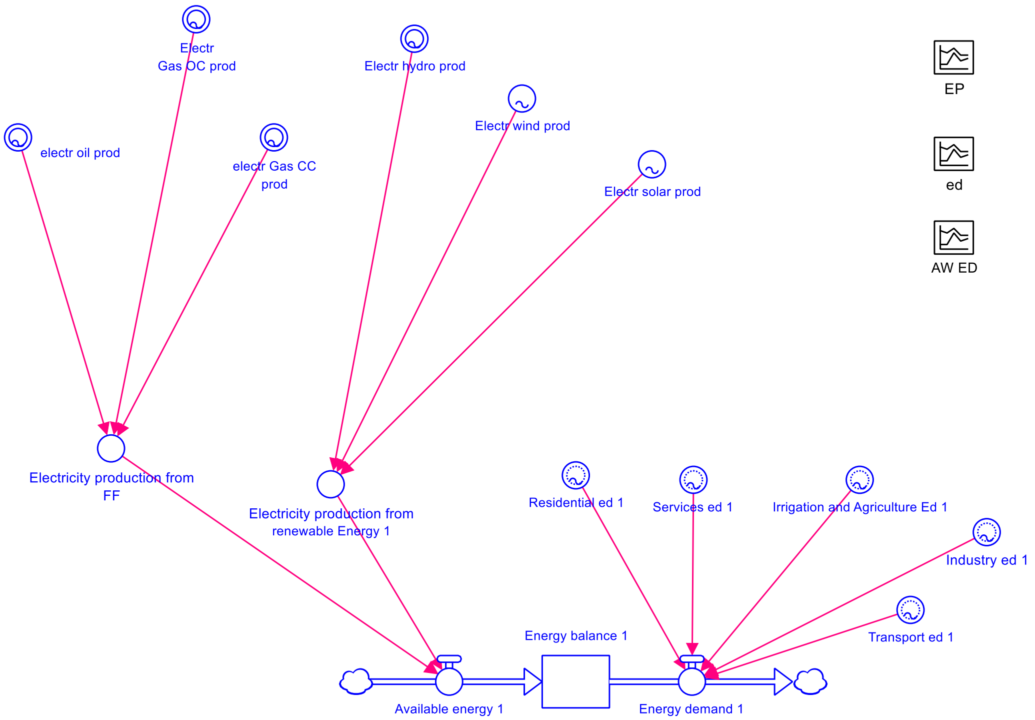

Figure 7 Structure of the Energy Segment of the SDM

3.1.5 Climate

The climate segment is the final segment of the SDM which is directly linked to water, land, food and energy sectors. As it is seen in the Figure 8, this part of the model is designed to balance the GHG emissions and sequestration.

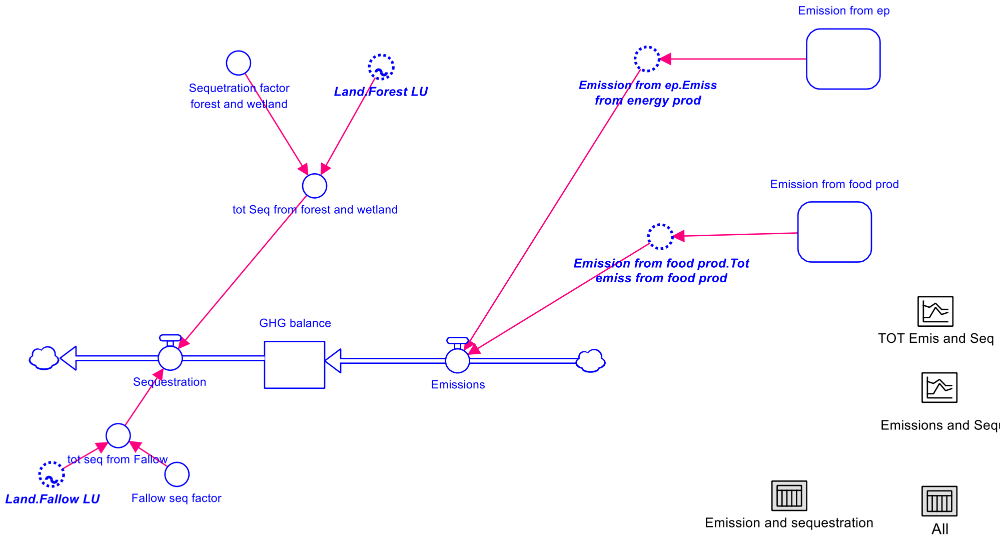

Figure 8 Structure of the Climate Segment of the SDM

The sequestration side of the balance links this section of the model with Land segment as both forests and fallow lands are sequestering the GHGs. The total sequestered GHG are obtained by using the sequestration factors and the forest and fallow land areas as shown in the Equations 14, 15 and 16.

$$\text{Sequestration} = \text{tot\_seq\_from\_Fallow} + \text{tot\_Seq\_from\_forest\_and\_wetland}\ \{\text{UNIFLOW}\} \tag{14}$$

$$\text{Tot\_seq\_from\_Fallow} = \text{Land.Fallow\_LU} * \text{Fallow\_seq\_factor} \tag{15}$$

$$\begin{gathered}\text{Tot\_Seq\_from\_forest\_and\_wetland} = \\ \text{Sequetration\_factor\_forest\_and\_wetland*Land.Forest\_LU}\end{gathered} \tag{16}$$

The emission side, however, builds a dynamic connection between the food and energy segments with the climate sector. Here, the energy and food production values from the corresponding segments are multiplied by the emission factors to estimate the total emissions.

3.2 Data Collection

After determination of the final structure of the model, the data collection for each segment had been initiated. The data was collected considering 2017 as the baseline year for all the segments with projections to 2030 and 2050.

3.2.1 Demography Data

Azerbaijan’s population in 2017 was 9.8 million, reached 10 million in 2019 and is projected to increase up to 11 million till 2050 (Figure 9) (United Nations , 2019). The population density in the country is 105 people/km^2 with highest densities observed in the Absheron Peninsula. The population growth rate is higher than the migration loss, which explains the trend of steep increase of the population (Population of Azerbaijan , 2019).

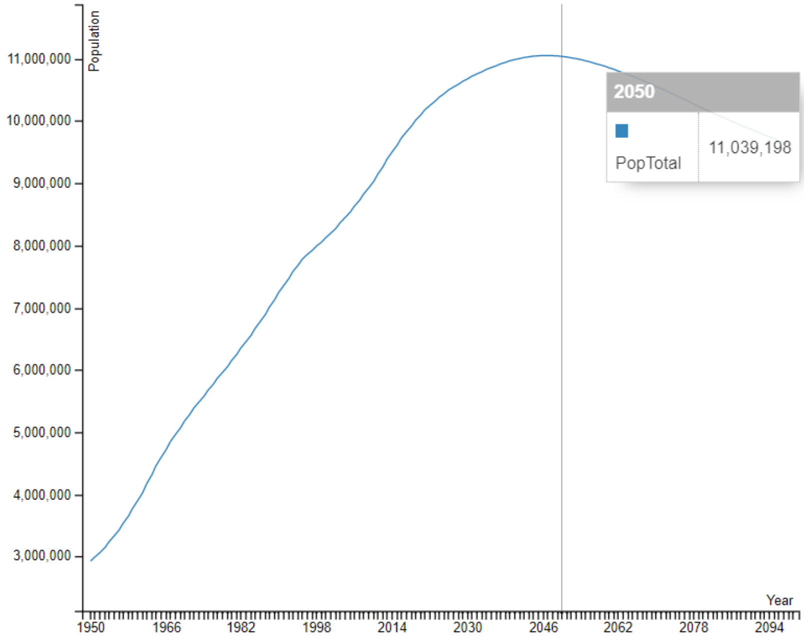

Figure 9 Population Growth in Azerbaijan via United Nations WPP

3.2.2 Water Resources, Use and Projections Data

Total water resources of the country are estimated to be about 39.9 km^3 of which 30.9 km^3 is surface and 9 km^3 is ground water (Imanov & Alekberov, 2017). The surface water, which comprises rivers, lakes, water reservoirs and glaciers, are used for the irrigation, agricultural and industrial use. However, the groundwater is not widely used.

Surface Water – Around 67 to 70% of the surface water resources of the country are transboundary and originate from the neighbor countries (Verdiyev, 2012). Per capita water consumption is 1313 million m^3/year which makes Azerbaijan one of the countries with the lowest available water resources. Irrigation and agriculture use 6570 million m^3/year of the surface waters while 2224 million m^3/year is used for industrial purposes (Water Resources , 2019). Treated and recycled water in 2017 was estimated to be 2398 million m^3.

Ground water – originates in the lowland areas such as Nakchivan AR and Talish zone, the foothill areas of Greater and Lesser Caucasus. As it was mentioned before, the groundwater is not exploited at a great rate which creates a potential for use of ground waters in dry years (Ministry of Ecology and Natural Resources of Republic of Azerbaijan, 2010).

Climate change is forecasted to stress the water resources of the country. Although no significant changes are expected in groundwaters, surface waters are forecasted to decrease by 23% compared to the baseline year. This decrease is the reflection of reduced precipitation and temperature changes, which leads to higher water shortage and reduction of per capita water consumption by 60%. (WorldBank, CLIMATE

CHANGE AND AGRICULTURE COUNTRY NOTE. The Republic of Azerbaijan , 2012) The agricultural and industrial use of water, however, is forecasted to increase by 10% and 3.39% respectively compared to 2014 (Ahouissoussi, et al., 2014) Finally, improvement in the water treatment and recycling is expected, which targets 25% increase in recycled water. (Ministry of Ecology and Natural Resources of Republic of Azerbaijan, 2010)

3.2.3 Land Use and Projections Data

In the land use section, the land used for farming, agriculture and industry and the land covered with forests and wetlands are considered. The area covered with wetlands was estimated to be 356.4 thousand hectares in 2017 (Sultanov, Sarukhanova, Kerimov, & Humbatova, 2011) and is assumed to follow the same trend with surface water and reduce by 23% by 2050. The forest areas of the country was reported to be 1213.7 thousand hectares in 2017 (Ministry of Ecology and Natural Resources of Azerbaijan Republic, 2019) which is expected to increase by 6.6% due to the forestation plan of the country (UNFCC, 2014)

The agricultural land use (LU) is divided into the livestock LU, irrigated LU, non-irrigated LU and fallow LU. The 2436.2 thousand hectares of the land is used for livestock (Agriculture, forestry and fishing, 2019) which is estimated to increase by almost 41% till 2050 (Bruinsma, 2012). The irrigated land of the country is 1445.8 thousand hectares whereas non-irrigated land is 2054.7 thousand hectares (Agriculture, forestry and fishing, 2019) The irrigation of lands is forecasted to increase by 1.5% while the areas of non-irrigated lands will reduce by 5.4% until 2050 (Bruinsma, 2012).

The agricultural sector uses fertilizers and pesticides, which was also considered in the collected data. Thus, according to the State Statistical Committee of the Republic of Azerbaijan, the use of fertilizers per ha of agricultural areas was 63 kgs in 2017 and this number is expected to almost double by 2050 (Bruinsma, 2012).

3.2.4 Food Balances and Projections Data

In the food sector, the data was collected according to the sectors identified in the model which are: grains, vegetables, fruits, meat, dairy products and other basic food products (e.g. vegetable oils, sugar etc.). The collected data covers food production, the imports, consumption, the exports and the annual forecasts of these values by both production and demand up to 2050. The balance between the total food resources and consumption was verified considering the losses as well (The State Statistical Committee of the Republic of Azerbaijan, 2019). The general increasing trend in both production and demand of the food products was identified (Bruinsma, 2012).

The forecast on the production of the grains (e.g. wheat, barley, maize, rice etc.) was estimated to be 22.3% increase by 2030 and 27.4% increase by 2050 with the annual growth rates of 0.85% and 0.2% (from 2030 to 2050) respectively. The growth on the demand side, however, is not expected to be as much as in the production. The demand for grains will increase by 14.4% till 2030 with the growth rate of 0.57% and by 15.72% till 2050 (Bruinsma, 2012)

The projections on the production and the demand of vegetables and fruits are forecasting the increase in the vegetable production by 14.4% and 24.9% in fruit production till 2050. However, the increase in the demand for both vegetables and fruits is around 30%, which is significantly higher compared to the production for vegetables (Bruinsma, 2012)

The meat products are the ones with the highest forecasted increase in both production and demand compared to other food products. The production of meat goods is estimated to increase by almost 90% till 2050 whereas the increase in demand will be 97.14% (Bruinsma, 2012) Moreover, meat is the only food product with forecasts of decreasing imports and increasing exports for the country in the following 30 years , which was provided by Modular Applied General Equilibrium Tool (MAGNET) (Fazekas, Alexandri, & Pollitt, 2017)

3.2.5 Energy Data: Current State and Projections

In the energy sector the data on energy demand, production and total annual capacities of different energy sources was collected using Energy-Environment-Economy Macro-Econometric (E3ME) and Open Source Energy Modelling System (OSeMOSYS) models (Fazekas, Alexandri, & Pollitt, 2017). The demand for energy in the agricultural, industrial, residential, service and transportation sectors was retrieved from the E3ME model whereas the OSeMOSYS model was used to forecast energy production as well as the annual capacity of wind, solar, hydro, oil, closed cycle (Gas CC) and open cycle (Gas OC) gas energy sources.

Error! Reference source not found. illustrates the energy demand in the mentioned sectors. As it can be s een, there is a general trend of increasing energy demand in every sector. The energy demand in all sector almost doubles by 2050 compared to the 2017 values except the service sector, which only increases by about 1PJ from 2017 to 2050.

Table 1 Energy Demand in Different Sectors (2017-2050)

Demand [PJ]	**2017**	**2030**	**2050**
Agriculture	3.531859	5.28303	8.843191
Industry	11.17675	13.9011	18.2179
Residential	26.15456	33.29808	42.96323
Service	18.39533	19.64158	19.4561
Transportation	15.04803	20.18377	34.7146

Table 2 Energy Production and Total Annual Capacities by Energy Sources in Azerbaijan (2017-2050)

	2017		2030		2050	
	Production [PJ]	**Total Annual Capacity (GW)**	**Production [PJ]**	**Total Annual Capacity (GW)**	**Production [PJ]**	**Total Annual Capacity (GW)**
Wind	0.982031	0.1038	0.977301	0.1033	0	0
Solar	0.019201	0.004	0.019201	0.004	0	0
Hydro	7.189766	1.13993	7.189766	1.13993	6.263113	0.99301
Oil	0	2.49	0.04676	2.49	0	0
Gas Total	84.95297	4.6857	94.36181	4.193784	131.7718	5.818331
Gas CC	43.775	1.64	61.47409	2.303084	125.6649	5.015764
Gas OC	41.17797	3.0457	32.88772	1.8907	6.106916	0.802567

3.2.6 Climate Data: Emission and sequestration factors

In this NEXUS segment, the data collection consisted of constructing the greenhouse gas (GHG) inventory considering both emissions and sequestration factors. The factors are assumed to be constant throughout the study period due to the lack of available data. This assumption considers no improvement in the efficiency and sustainability of power generation and agricultural processes, which might not align with reality of the country's future.

The sequestration factors for forests and grasslands/fallow lands of the country were determined to be 18.6 tCO2eq/ha (Ibrahimov, 2010) and 1.89 tCO2eq/ha (UNFCC, 2014) respectively.

The emission factors in power generation were segregated to emissions due to the use of oil or gas. Thus, the emission factor of power generation using gas is estimated to be 0.11 kgCO2eq/kWh which is significantly lower than the emission factor from the oil-based power generation (4.72 kgCO2eq/kWh) (WorldBank, Azerbaijan - CO2 emissions from gaseous fuel consumption (kt), 2014).

Table 3 Emission Factors in Food Sector

Products	kgCO2eq/kg product
Cattle meat	10.93
Sheep meat	19.51
Chicken meat	0.56
Pig meat	2.34

Fresh cow milk	1.17
Fresh goat milk	4.94
Fresh sheep milk	1.44
Paddy rice	2.85
Cereals excluding rice	0.12

Finally, the emission factors for food products which are shown in **Error! Reference source not found.** w ere retrieved from the FAOSTAT database (FAOSTAT, 2016). The emission factors from cattle and sheep meat production are the highest ones with 10.93 and 19.51 kgCO2eq/kg respectively whereas emission factors of poultry meat and cereals are among the lowest.

4. Limitations and Assumptions

There are several assumptions and uncertainties in the collected data, which has been used in the SDM population. These assumptions and uncertainties will be stated and evaluated in this section.

The first assumption made in the **water sector** is the constant volume of the groundwaters and no change in their use. However, this might not be the real case for the upcoming decades since groundwaters are not in current use by the state but may be used in case of water shortage in the future.

There is a big uncertainty in the industrial use of water resources in Azerbaijan. The first assumption made in this sector is in the projections of industrial water consumption. Thus, industrial water use has been assumed to increase with the same rate as in the water used for irrigation due to the lack of data. Another assumption is the constant water intake in the small hydropower plants, where some uncertainties may arise. The last assumption made in the data collected in the water sector is the water consumption per kWh in the combined cycle power plants (CCPP). The data of water consumption in CCPP was based on the Janub 760 MW plant (Azerenerji Joint Stock Company of the Republic of Azerbaijan, 2009) due to the lack of data on the other plants. Moreover, the water consumption was considered to stay constant over the year, which might not be the case if the efficiency in the process would change.

The data collected on the current values of **land sector** can be considered very reliable since the values were taken from the State Statistical Committee. Nevertheless, some assumptions in the data of this sector were also made. The first factor that can create some uncertainties in the results is the negligence of the influence of the petroleum industry of the land quality. Initially, the land spoiled by the drilling of the oil and gas wells as well as their spillage was intended to be included but confidentiality of these data made it nearly impossible to access these numbers. Moreover, although the effect of the fertilizer on land is considered in the model, the use of pesticides in the agriculture and their influence on the land were neglected. Finally, the lack of data in the projections of land use (LU) in Azerbaijan caused the trends in Caucasus and Central Asia LU to be applied to Azerbaijan case (Bruinsma, 2012).

The data collected on the **food sector** is the most reliable one compared to other segments of the NEXUS since all the current values (2017 is the baseline year for the model) were taken from State Statistical Committee. Although the data on the food sector is very detailed, the vegetable section doesn’t include all the vegetables cultivated in the country. The basic processed food products section also includes only vegetable oils and sugar, which is not the full representation of the processed food industry of the country. The cattle numbers and the agricultural data in the State Statistical Committee is also claimed to retain some uncertainties (UNFCC, 2014). Regarding the projections in the food sector, some of the projections were again aligned with Caucasus and Central Asia trends and the projections of the food imports and exports were taken from the MAGNET model (Fazekas, Alexandri, & Pollitt, 2017), which should also go under the uncertainty check.

The demand and production data in the **energy sector** was retrieved from E3ME and OSeMOSYS (Fazekas, Alexandri, & Pollitt, 2017) models respectively. The models underwent the uncertainty check.

The biggest cause of uncertainty in the **climate sector** can be the assumption of the emission and absorption factors to be constant. For instance, the emission factors from the gas electricity generation might change in the future depending on the efficiencies of the process and the plants. However, these changes cannot be foreseen and due to the complexities in the projections of these factors, they were assumed to be constant throughout the simulated period. Apart from this assumption, the determination of these emission and absorption factors is not a very straightforward procedure. Thus, the raw materials used in the food products and the variance in the processes from one factory to others makes it very complicated to find out an average carbon emission factor for each food product.

The estimation of carbon removal and absorption factors is as complicated as emission factors. The reasons for these complexities are the microclimate in the territory of the forests, soil fertility and wide range of the sorts of trees (UNFCC, 2014).

Finally, the waste segment of every sector has been neglected, which might arise some uncertainties in the results of the model. Additionally, the emissions from the construction, residential and transportation sectors were not fully accounted for in the total emissions. Of course, electricity consumption in the residential buildings was taken into account in the energy demand sector. However, the leakages and the emissions from transportation could not be calculated precisely and hence were neglected.

5. Results of the SDM

After identifying the methodology of the work, collecting the data and conducting the uncertainty analysis on the collected data, the next stage of constructing the systems dynamic model (SDM) by populating it the data has been done. The case studies of SIM4NEXUS project vary from regional to global scale; this work is a national case study of Azerbaijan where results are obtained at a national scale. Thus, this section will include the outputs from the SDM in every NEXUS section at national scale and the discussion of these results will also be covered in this section of the report. It is very important to note that the results of the SDM are given assuming the **Business as Usual** case for Azerbaijan from 2017 to 2050. It is also worth to mention that the timestep of the model was selected as one month, which provided the results of the model on a monthly basis. The outputs of the SDM were simplified to yearly values for easier discussion and comprehension of the results.

5.1 Results for Water Sector

As it was already described in the methodology part of the report, the components considered in the water section of the model are groundwater, surface water, and recycled water on the available water side, and water use for agriculture, irrigation and industries on the demand side.

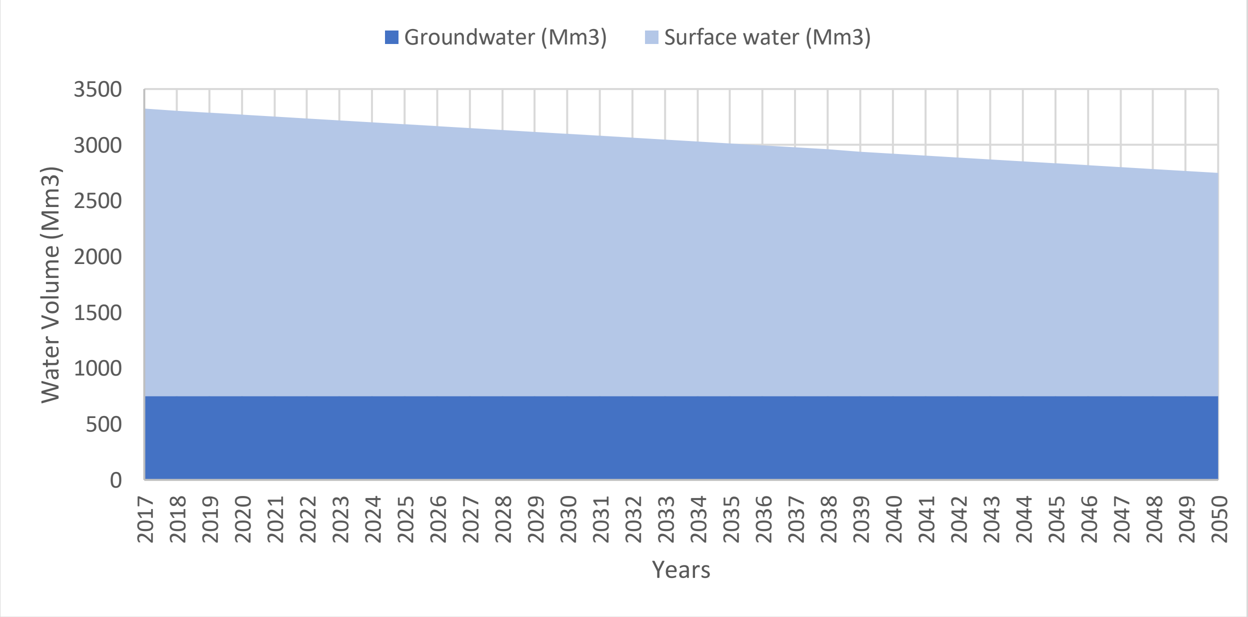

Figure 10 SDM Results for Groundwater and Surface Water (Mm^3)

As can be seen in Figure 10, there is a trend of reduction in the available surface water resources of Azerbaijan whereas the groundwater resources are not changing throughout the considered period. The results for the Groundwater resources are solely based on the conditions of the work considering the business as usual scenario for the SDM. Thus, as Azerbaijan is currently not using the groundwater resources, this trend is given as a result by the SDM for the groundwater values until 2050.

Another component of the available water side of the SDM is recycled water, which is reused to meet the water demand of the country. It is seen in Figure 11 that although there is not a significant change, there is an increase in the water recycling in Azerbaijan in the following years.

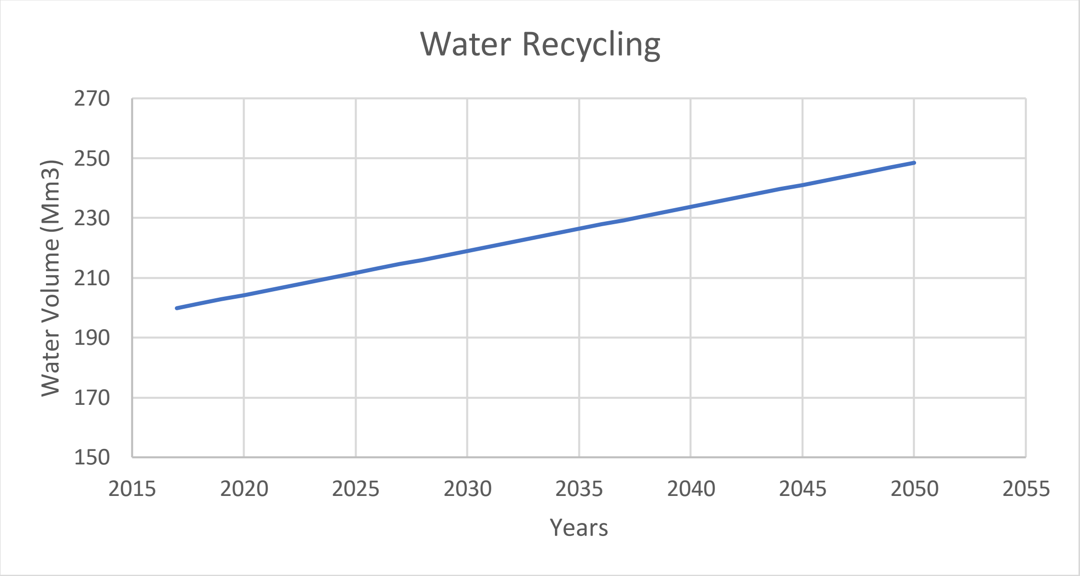

Figure 11 SDM Results for Recycled Water (Mm^3)

Additionally to the trends in the available water resources, the SDM also provides the numerical values for these components as well as the total available water in Azerbaijan from 2017 to 2050, which can be seen in the Table 4.

Table 4 SDM Results for Available Water Resources (2017-2050)

Units (Mm^3)	2017	2020	2025	2030	2035	2040	2045	2050
Groundwater	750	750	750	750	750	750	750	750
Surface water	2575	2522.61	2435.30	2348.00	2260.69	2173.38	2086.07	1998.76
Recycled Water	199.83	204.25	211.62	218.98	226.35	233.71	241.08	248.44
Total Available Water	3524.83	3476.87	3396.92	3316.98	3237.03	3157.09	3077.14	2997.20

It can be calculated from the Table 4 that the available surface water resources will reduce by 2 percent from 2017 to 2020, whereas after 2020 this value will decrease 3.5 percent every 5 years till 2030. In the next 20 years after 2030, however, the resources of surface water will reduce by almost 4 percent every 5 years. The total reduction of the surface water resources from 2017 to 2050 is calculated to be 22.4 percent.

On the other hand, the results of the SDM forecasts an increase in water recycling. Although water recycling will increase by only 2.2 percent from 2017 to 2020, the increase rate in water recycling is the highest between 2020 and 2030 being around 3.5 percent on average for every 5 years. However, the increase in water recycling will reduce to 3.2 percent every 5 years in the period from 2030 to 2050. The situation with water recycling seems to be good for the country since in total the volume of recycled water is forecasted to increase by 24.3 percent from 2017 to 2050 according to the results of the SDM.

Unlike the water recycling values, the situation with total available water in Azerbaijan seems to not have very favorable trends in the considered period. The total available water is forecasted to decrease by 2.3 percent on average for every 5 years from 2020 to 2030. Moreover, the situation is exacerbated in the following 20 years from 2030 as the total available water is forecasted to decrease by 2.5 percent every 5 years. Thus, according to the SDM results the total available water will reduce by almost 15 percent from 2017 to 2050.

After discussing the results of SDM regarding available water resources, it is also vital to analyze the forecast of the model on the water demand side. As it was described in the methodology section of the report, industrial, agricultural, and irrigation water use are considered in the demand side of the water sector of the SDM.

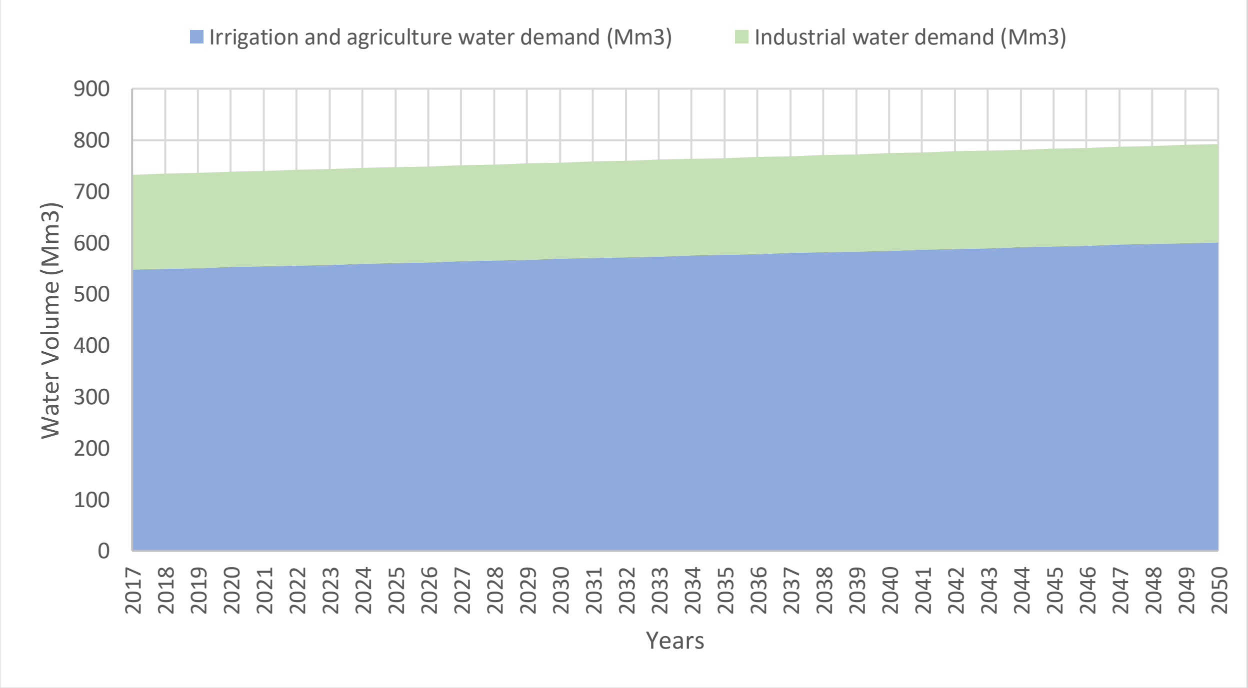

Figure 12 SDM Results for Water Demand in Irrigation, Agriculture and Industries.

It can be seen from Figure 12 that the demand for water in both irrigation and agriculture as well as industrial water use will increase from 2017 to 2050. To quantify this trend the numerical values, which are shown in Table 5, were retrieved from the SDM for water demand.

Table 5 SDM Results for Water Demand (2017-2050)

Units (Mm^3)	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Irrigation and agriculture water demand	547.50	552.34	560.41	568.49	576.56	584.63	592.70	600.77
Industrial water demand	185.33	185.89	186.82	187.74	188.67	189.59	190.52	191.45
Total Water Demand	732.83	738.23	747.23	756.23	765.22	774.22	783.22	792.22

To start with the water demand in irrigation and agriculture, the increase of the demand is not very high from 2017 to 2020 which is calculated to be only 0.88 percent. However, the increase rate is getting higher from 2020 to 2030 with 1.45 percent average increase rate every 5 years. This value will decrease to 1.39 percent for every 5 years in the period of 2030 to 2050. The increase in the irrigation and agricultural water demand in 2050 is forecasted to be 9.7 percent compared to 2017.

The change in industrial water demand is even smaller than demand changes in irrigation and agricultural water. Here, the demand is forecasted to increase by only 0.3 percent from 2017 to 2020 after which the increase rate in the demand will be relatively steady from 2020 to 2050. According to the SDM results the increase rate of industrial water demand will be around 0.49 percent every 5 years until 2050 while the total increase of the demand will be 3.3 percent from 2017 to 2050.

Regarding the trends in total water demand, the demand in water is forecasted to grow steadily by around 1.2 percent every five years from 2020 to 2050, which will account to total demand growth of 8.1 percent by 2050 compared to 2017.

Additional to the available water resources and water demand trends, the SDM also outputs forecasts on the available domestic water till 2050 by using the water per capita and population growth data as input values.

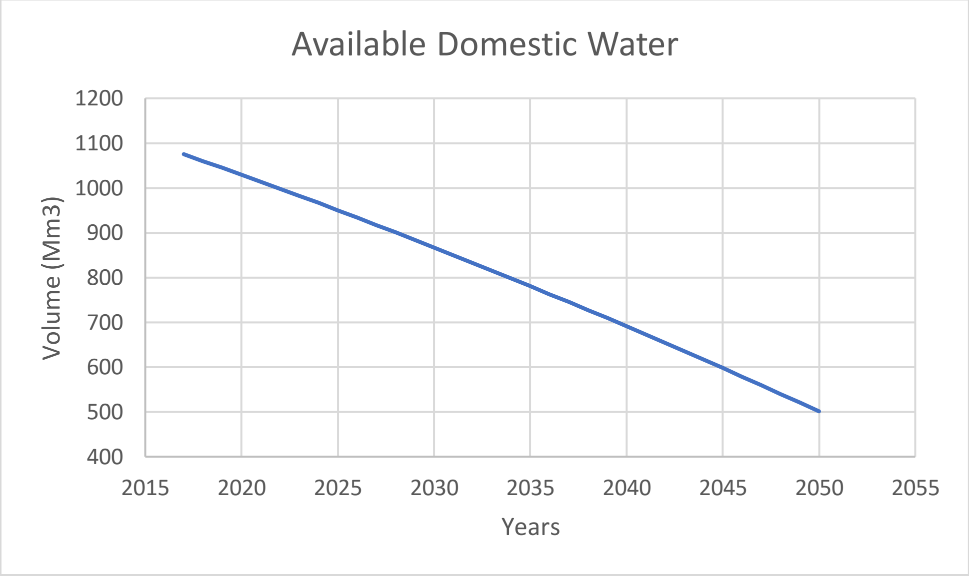

Figure 13 SDM Results for Available Domestic Water

The forecast on the available water for domestic use is shown in Figure 13, which shows a declining trend. Although the trend line seems quite steady, the decrease rates vary throughout the time from 2017 to 2050. To discuss the decrease rates, the mentioned period is divided into 3 parts as in the discussion of the previous results. The available domestic water reduces by 4.3 percent from 2017 to 2020, after which the reduction rate of this value is forecasted to be 8.2 percent on average for every 5 years from 2020 to 2030 and about 12.8 percent for every 5 years in the remaining 20 years from 2030 to 2050.

5.2 Results for Land Sector

The land sector of the model primarily focuses on the different land types of the country, how they are used and the changes in the use of land areas in the future. The subcategories of the land areas of Azerbaijan considered are forests, wetlands, fallow, irrigated, non-irrigated lands as well as the lands used for livestock. Moreover, the use of fertilizers is also incorporated into this section of the SDM.

Before starting the discussion of the results, it is worth to mention that the grouping of the plots in the results of this section is solely based on whether the subgroup has an increasing or decreasing tendency.

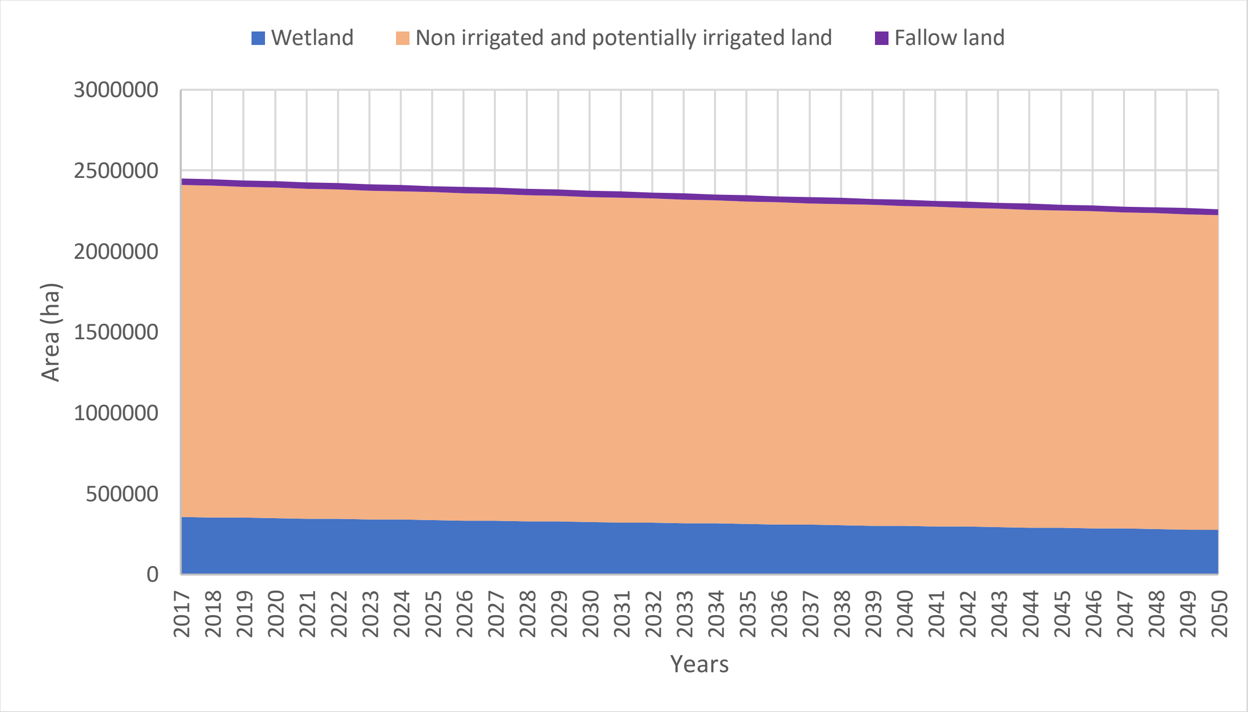

Figure 14 SDM Results for Wetlands, Non-irrigated and Fallow Lands

Thus, the first batch of results in the land sector includes wetlands, fallow lands, and non-irrigated lands together with potentially irrigated in the future. As it can be observed in Figure 14, this group is following a descending trend from 2017 to 2050. These results can be reasoned by increasing temperatures affecting the area of wetlands and a potential increase in the demand for food growing the agriculture sector, which is directly linked to the use of fallow lands. The trends in the food demand will be discussed further in the report.

Table 6 Numerical Results of the SDM for Wetlands, Non-irrigated and Fallow Lands (2017-2050)

Units (1000 ha)	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Wetland	356.36	349.11	337.02	324.94	312.86	300.78	288.69	276.61
Non-irrigated and potentially irrigated land	2054.70	2044.98	2028.77	2012.57	1996.36	1980.16	1963.95	1947.74
Fallow land	39.80	39.50	39.00	38.50	38.00	37.51	37.01	36.51

Table 6 above shows the quantitative results in the first batch of land sector results from 2017 to 2050. It is retrieved from this table that the wetland areas will decrease by only 2 percent in 3 years from the baseline year. However, after 2020 the increase rate raises up to 3.65 percent for every 5 years period from 2020 to 2040. This percentage decrease in wetland areas gets even higher after 2040, which is forecasted to be 4 and 4.2 percent till 2045 and 2050 respectively.

The downfall in non-irrigated lands is not as drastic as in the wetlands. Thus, the change in these areas is estimated to be only about 0.5 percent from 2017 to 2020. The decrease rate for every 5 years after 2020 is projected to be 0.8 percent while totally the non-irrigated lands are forecasted to decrease by 5.2 percent by 2050 compared to 2017.

The changes in the fallow lands, however, is anticipated to be neither as high as in the wetlands nor as low as in the non-irrigated lands. The overall decrease in the fallow lands will be about 8.3 percent from 2017 to 2050 with this value being 0.75 percent from 2017 to 2020 and 1.3 percent for every following 5 years after.

The next group of results from land sector of the SDM includes forests, irrigated land areas and lands used for livestock.

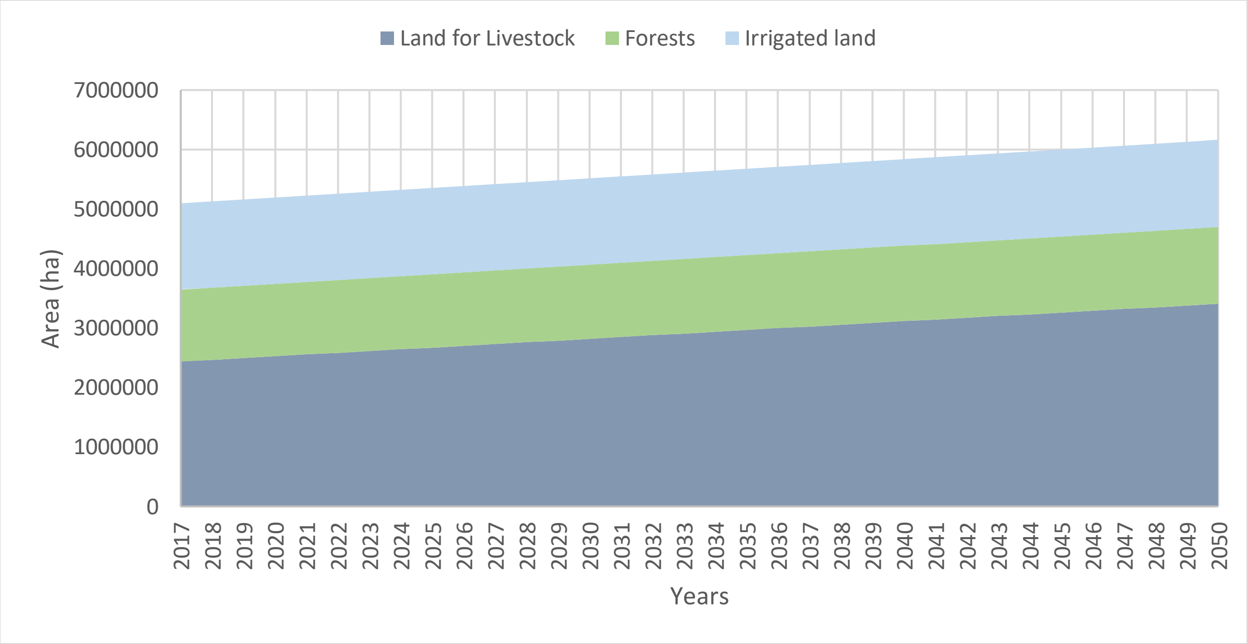

Figure 15 SDM Results for Livestock Lands, Forests and Irrigated Lands

As can be seen from Figure 15, there is a generally increasing trend in all components of this batch in the considered timeframe of the SDM. The increase in the lands for livestock and irrigated lands can again be explained by a possible increase in the food demand in the following years, which would grow farming and agriculture. The trend in the forest areas, however, can be reasoned by a favorable strategy of the country towards the forestry.

Table 7 Numerical Results of the SDM for Livestock Lands, Forests and Irrigated Lands

Units (1000 ha)	2017	2020	2025	2030	2035	2040	2045	2050
Lands for Livestock	2436.20	2524.46	2671.57	2818.68	2965.78	3112.89	3259.99	3407.10
Forests	1213.70	1220.83	1232.71	1244.59	1256.47	1268.35	1280.23	1292.11
Irrigated lands	1445.80	1447.71	1450.88	1454.06	1457.23	1460.41	1463.58	1466.76

To start with the discussion of the SDM results for the lands used for livestock, which are given in Table 7, it should be noted that the increase in this category is accounted for 3.6 percent from 2017 to 2020. The areas of land used for livestock are forecasted to increase even more by about 5.5 percent every five years in the 15 years period from 2020 to 2035. However, although the trend for this category will remain the same, the increase rate will diminish afterward to around 4.7 percent for every five years till 2050.

The change in the forest areas is not as dramatic as in the lands used for livestock since forest areas will only increase by 0.59 percent in three years from 2017 and 0.95 percent every five years afterward until 2050. The overall expansion of the forests of Azerbaijan is estimated to be 6.46 percent in the whole timeframe of the SDM.

The area of the irrigated lands is increasing even by a smaller amount compared to the ones above. Thus, the growth in irrigation is only 0.13 percent from 2017 to 2020 which increases to 0.21 percent raise on average every five years from 2020 to 2050. If the irrigated lands in 2050 are compared to the baseline year value, the increase of 1.45 percent can be observed from the results.

As it was mentioned before, in addition to the projections in the land areas, the use of fertilizers and forecasts of their utilization until 2050 (Figure 16) assuming the business as usual scenario is also included in this section of the SDM results.

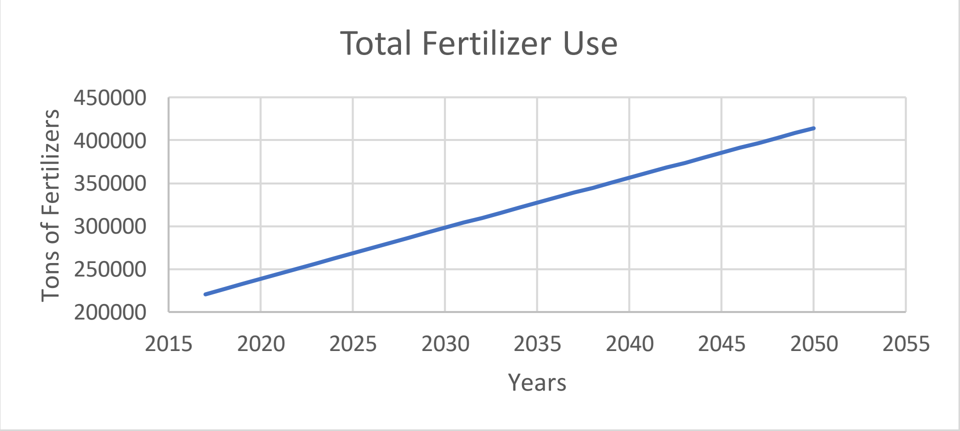

Figure 16 SDM Results for Total Use of Fertilizers

The SDM is using the fertilizer per hectare area and land areas data to output the forecast on the total fertilizers used in the country. As it is shown in Figure 16, the total use of fertilizers tends to rise from 2017 to 2050 but it also worth to see the breakdown of this trend. The total use of fertilizers is divided into fertilizers used in irrigated lands and in non-irrigated lands. Thus, the model also provides the quantitative results according to this division, which is illustrated in Figure 17.

To start with the discussion of the fertilizer use, it worth analyze the trends in both categories as well share of these categories in total use of fertilizers. The fertilizers used in the irrigated lands is estimated to increase by 8.5 percent from 2017 to 2020 and 26.4 percent from 2020 to 2030. The percentage of increase, however, reduces to 21.1 percent in the following 10 years and 17.5 percent in the last decade of the considered timeframe.

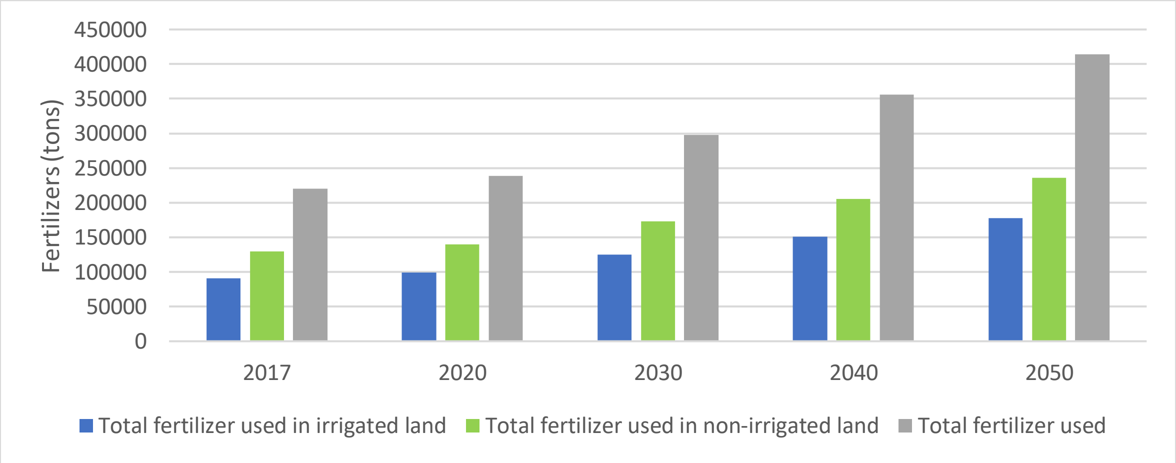

Figure 17 SDM Results for Fertilizer Use by Category

The fertilizers used in the non-irrigated lands follow a very similar path by increasing 7.9 percent from 2017 to 2020, 23.8 percent from 2020 to 2030, 18.6 and 15.1 percent in the following two decades respectively.

The increase in the total use of fertilizers is forecasted to be 87.7 percent by 2050 compared to 2017. The share of fertilizers used in irrigated and non-irrigated lands in total use is not changing significantly. However, the share of fertilizers used in irrigated lands is estimated to be 41.3 percent of the total in 2017 which will increase to almost 42 percent in 2030 and end up being about 43 percent in 2050.

5.3 Results for Food Sector

This section of the report will cover the results of the SDM regarding food production and consumption in Azerbaijan. The results in this section are more complex compared to the results for other NEXUS segment due to the initial design of the model and available detailed data. The discussion will be divided into subgroups of food products in both production and consumption as described in the methodology of the work.

5.3.1 Grain Production

The first subcategory in the food production section is grains, which includes wheat, porridge, rice, maize, barley and other kinds of grains.

As it is clear from Figure 18, the general trend for the grain production in Azerbaijan is forecasted to rise from 2017 onwards. The jumps in 2030 and 2049 are due to more detailed data input in those years which results in more precise forecasting. Moreover, it is worth to mention that apart from the production forecasts, the SDM is providing even more detailed results including the grain stocks at the beginning of each year and imports for each grain type throughout the modeled period. However, those results are not included in this section of the report.

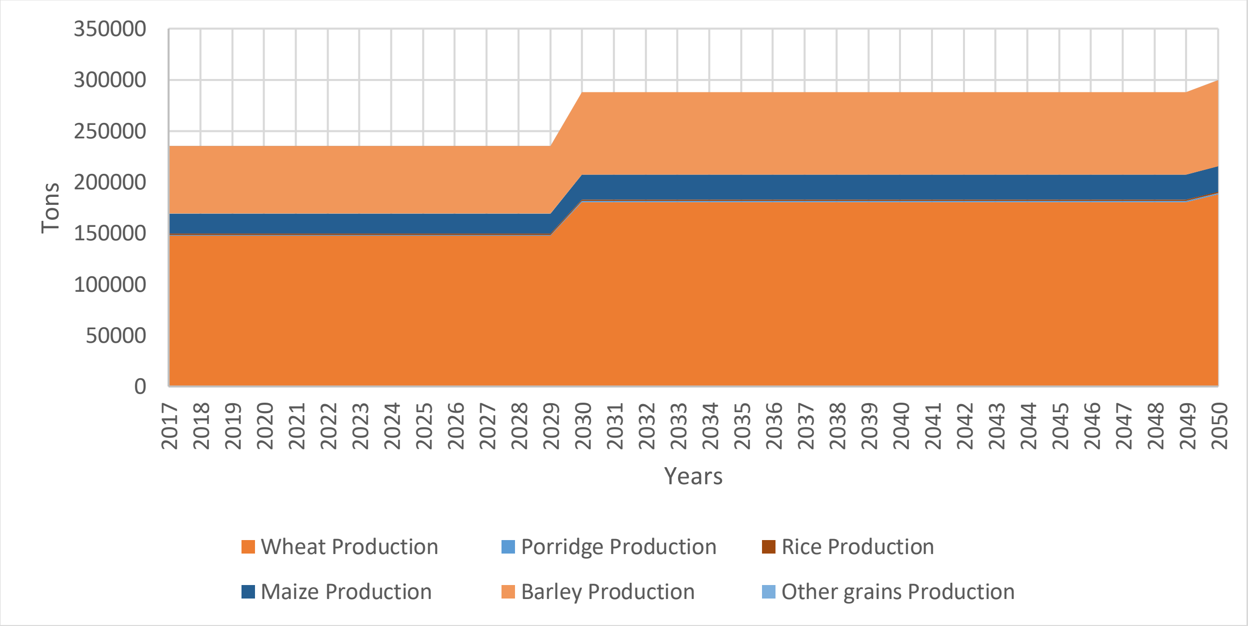

Figure 18 SDM Results for Grain Production

The quantitative results of the SDM are shown in the Table 8 for only 3 years of the modeled period. It is calculated from these results that the total production of the grains in Azerbaijan will increase by 18.2 percent from 2017 to 2030 after which this increase will only be 4 percent till 2050. The overall growth of grain production, however, is estimated to be 21.5 percent from 2017 to 2050.

Table 8 Numerical Results of the SDM for Grain Production (2017-2050)

Units (tons)	Wheat Available	Porridge Available	Rice Available	Maize Available	Barley Available	Other Grains Available	Total Grains Available
2017	339136.58	982.17	6582.75	37058.17	99067.42	758.92	483586.00
2030	414764.04	1200.87	8050.70	45322.14	121159.32	927.70	591424.78

2050	432060.01	1251.28	8386.42	47212.10	126211.89	966.86	616088.56

It is also important to analyze the breakdown of the production by the types of grains as shown in Figure 19. Wheat is having the biggest share among all the produced grain types with 70.1 percent whereas porridge is the least produced grain type. This classification is quite stable throughout the years as business as usual scenario is one of the main assumptions of the model.

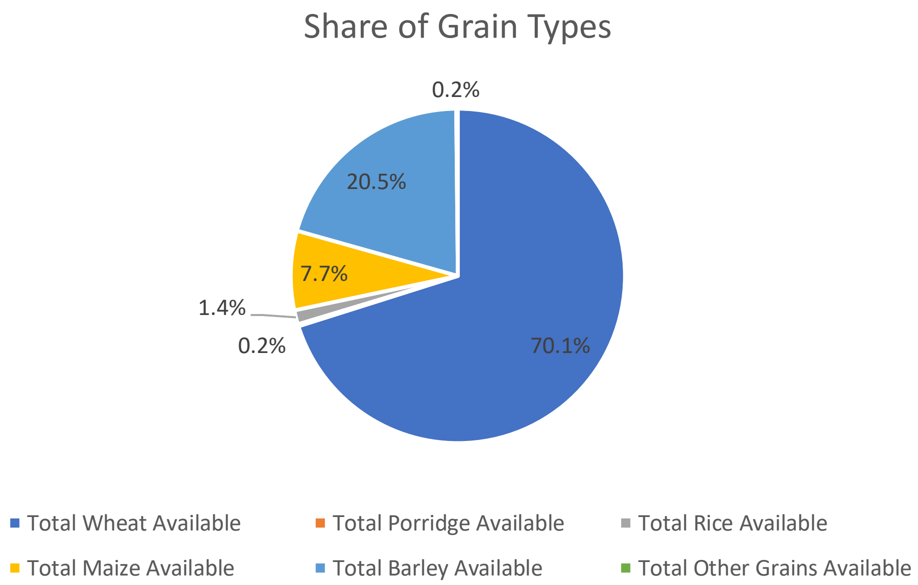

Figure 19 Share of the Grain Types Produced in Azerbaijan (2030)

5.3.2 Vegetable Production

The second subgroup of the food production section of the results is vegetable production. The results in this section include some specific values for the production of potatoes, dried onion, leguminous plants whereas other vegetable products are grouped together due to the inputs of the model and lack of detailed data on them.

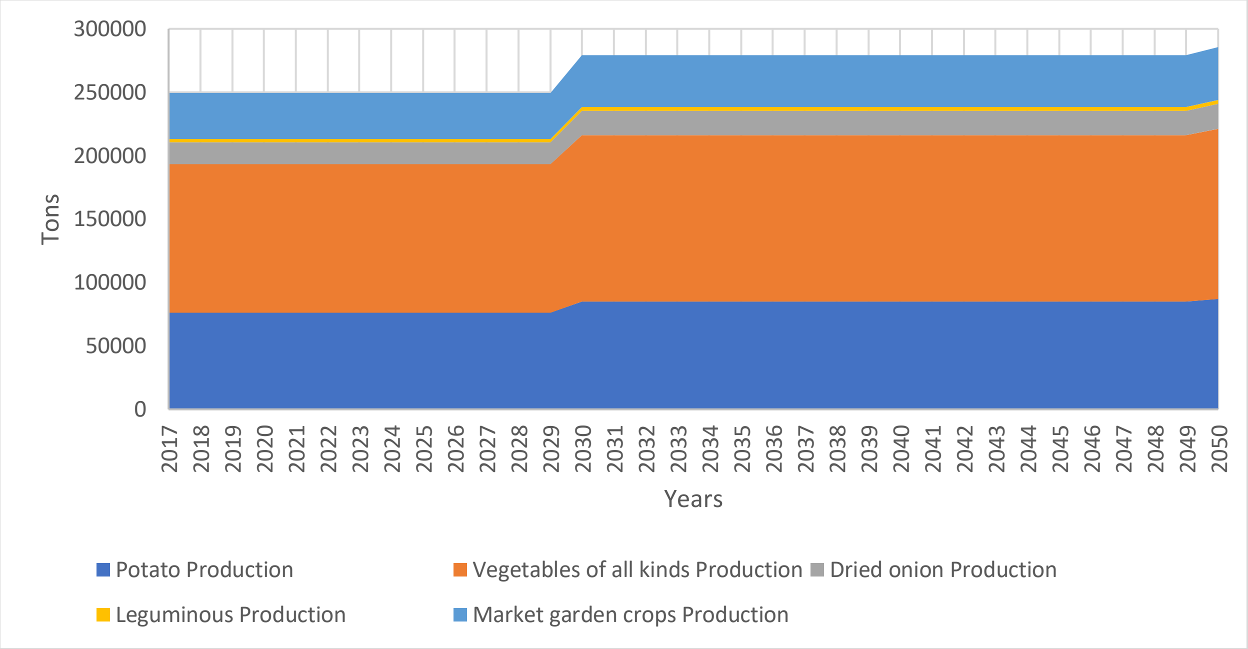

Figure 20 SDM Results for Vegetable Production

Figure 20 illustrates the forecast on the production trends on every vegetable type considered in the SDM. It is clear from this graph that all types of vegetables are projected to follow an incline in the production from 2017 onwards.

From the numerical results of the SDM for vegetable production, which is provided in Table 9, the increase in the production of total vegetables by 9.5 percent from 2017 to 2030 is calculated. It can also be estimated that 2.3 percent more vegetables will be produced in 2050 compared to 2030 and the total increase in vegetable production in the whole timeframe of the SDM is projected to be 11.6 percent.

Table 9 Numerical Results of the SDM for Vegetable Production (2017-2050)

Units (tons)	Potatoes Available	Other kinds of vegetables Available	Dried Onion Available	Leguminous Available	Garden Crops Available	Total Vegetables Available
2017	139579.25	137906.17	19675.00	7869.75	36805.17	341835.34
2030	156049.60	154179.09	21996.65	4526.32	41148.18	377899.84
2050	159678.66	157763.89	22508.20	4631.58	42105.11	386687.44

According to Figure 21, the most popular vegetable in terms of production is potato, which holds 40.3 percent of all vegetable types considered in the SDM. Leguminous plants are least produced vegetables compared to other specified ones. However, garden crops and onions have significant shares of 10.8 and 5.8 percent respectively. All other vegetables account for 40.8 percent of the total produced vegetables.

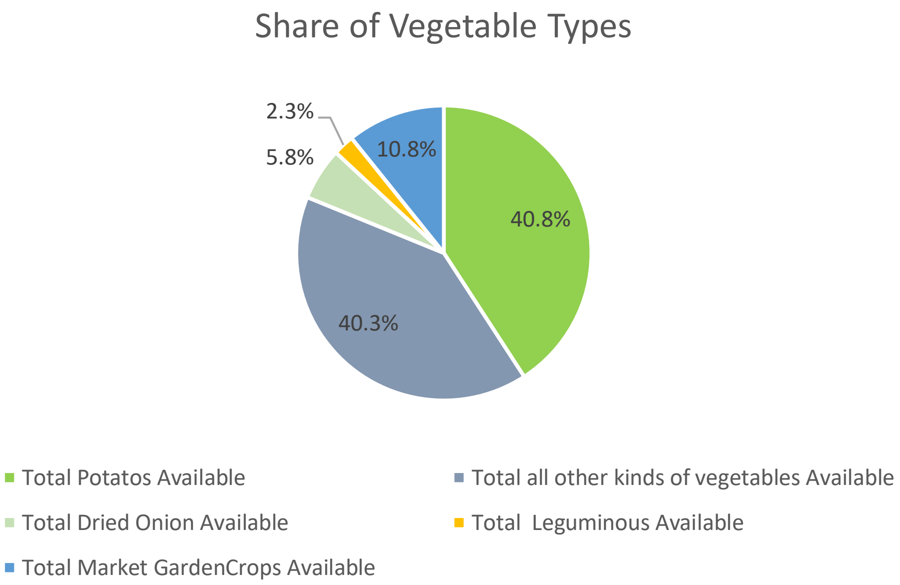

Figure 21 Share of the Produced Vegetables in Azerbaijan (2030)

5.3.3 Fruit Production

The production of fruits is not analyzed as detailed as grains and vegetables due to the lack of the input data available for every fruit type. Thus, here the overall forecasts on the fruits and berries but more specific results for grapes will be discussed.

The results for this section are summarized in Table 10. The total production of the fruits increases by 19.9 percent from 2017 to 2050 by rising 14.4 percent in the first 13 years from 2017 and 6.5 percent from 2030 onwards.

Table 10 Numerical Results of the SDM for Fruits

Units (tons)	Total Fruits and Berries Available	Total Grapes Available	Total Fruits Available
2017	91837.92	13968.92	105806.83
2030	107229.95	16309.72	123539.68
2050	114668.00	17441.91	132109.91

It can also be concluded from the table that grape production takes a significant share in the fruit production industry by accounting for 13.2 percent of the whole.

5.3.4 Meat Production

The SDM outputs very detailed results of meat production for the modeled period. The results include projections on beef, mutton and goat meat, fish and sea products, poultry and pork meat production. Moreover, the SDM also provides the forecasts of the available meat and the imports of every type of meat products mentioned. However, the latter results will not be discussed in this report.

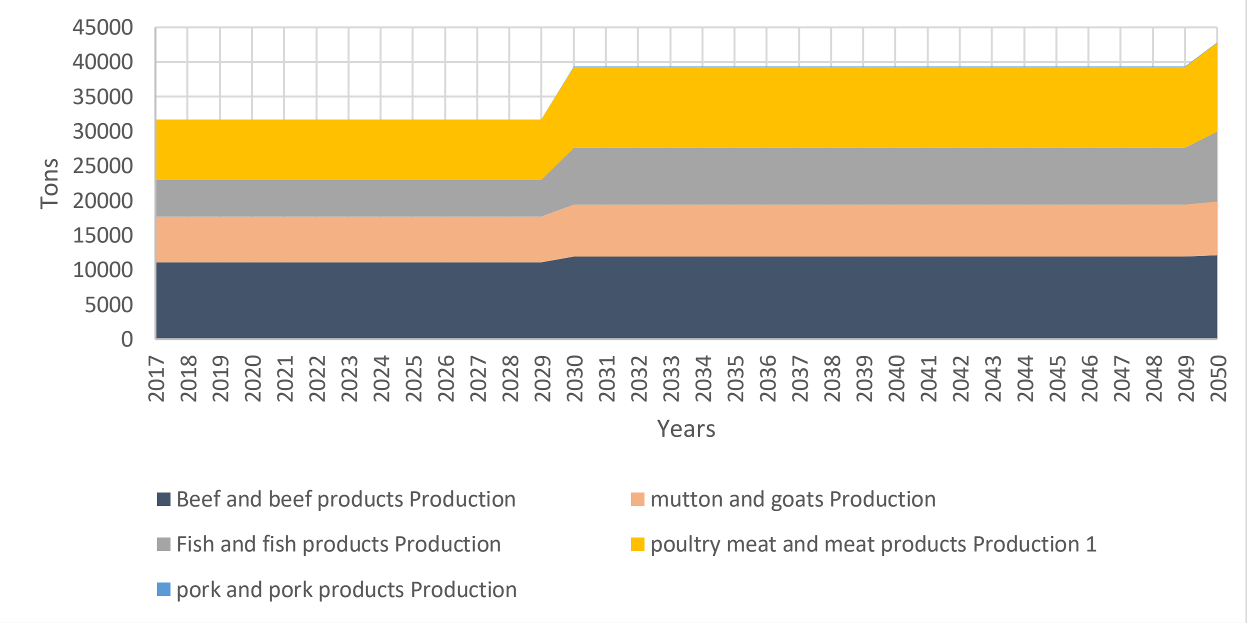

Figure 22 SDM Results for Meat Production

Figure 22 illustrates the trends in meat production for every type of meat considered. As can be seen from the graph, the meat production for every type is projected to increase in the following years until 2050. This increase could be reasoned by heavy meat-based dietary of the country, increasing the population in the future. However, there are changes in the meat-eating habits of the country, which were identified in the data collection stage of the work. These changes might also affect the results.

To start with the quantitative results of the meat production (Table 11), it is very interesting to note that beef is the meat type with the lowest increase percentage of 8.6 percent from 2017 to 2050. On the other hand, production of fish and fish products are forecasted to almost double (47.2 percent) by 2050 compared to 2017, which makes fish products the meat type with the highest increase rate. Poultry meat is projected to come second for its' increase in production as poultry meat is estimated to be produced 32.1 percent more in 2050 compared to the baseline year. The total meat production is forecasted to increase by 19.8 percent from 2017 to 2030, which is followed by 8.4 percent increase in the following 20 years. The overall increase of total meat production from 2017 to 2050 is estimated to be 26.6 percent according to the results of the SDM.

Table 11 Numerical Results of the SDM for Meat Production (2017-2050)

Units (tons)	Total Beef Available	Total Mutton and Goats Available	Total Fish and Fish products Available	Total Poultry Meat Available	Total Pork Available	Total Meat Available
2017	12974	6844.42	6829.92	11056.25	713.92	38418.50
2030	13985.97	7775.26	10490.75	14866.23	798.87	47917.09
2050	14190.96	8090.10	12935.86	16285.86	815.15	52317.93

Moreover, it is also very important to analyze the forecasts for the changes in the eating habits of people in Azerbaijan regarding different meat types. These changes are visualized in Figure 23 below.

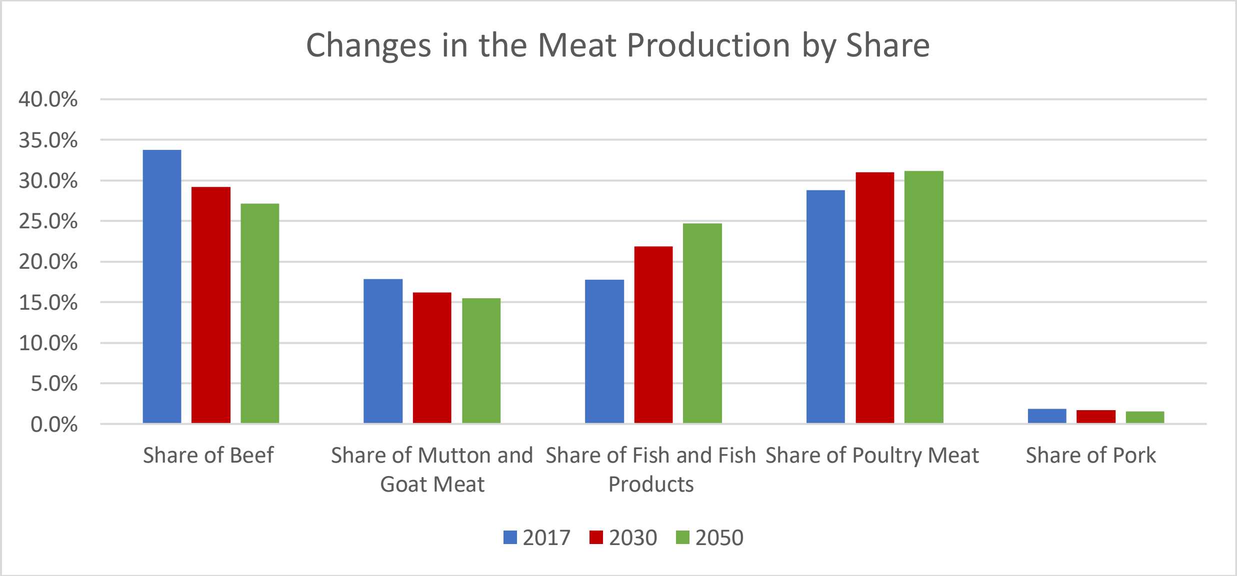

Figure 23 SDM Results for Share Changes in Production by Meat Type

As can be seen from Figure 23, beef, mutton meat and pork are reducing their importance and decrease in the share of meat production by 6.6, 2.4 and 0.3 percent respectively until 2050 compared to 2017. However, fish meat is projected to have a significant increase of 6.9 percent in its’ share in meat production by 2050 while this number for poultry meat will be 2.4 percent.

5.3.5 Dairy Production

Similar to the fruit production results, the results for the production of dairy products is not very detailed as here separate results for cheese are obtained whereas all other dairy products will be discussed grouped with milk production.

Table 12 Numerical Results of SDM for Dairy Production

Units (tons)	Total Cheese Stock Available	Total Milk and other Dairies Available	Total Dairies Available
2017	5461	197756.25	203217.25
2030	7213.98	261236.01	268449.99
2050	8296.35	300431.30	308727.65

According to Table 12, the total production of dairy products will increase by 24.3 percent from the baseline year to 2030, after which 13 percent growth in total dairy production is expected. In general, 34.2 percent more dairy products will be produced in 2050 compared to 2017. Moreover, it can also be mentioned that cheese production is accounted for 2.7 percent of the total and stays constant throughout the considered period due to working under the business as usual scenario.

5.3.6 Other Food Production

This section includes projections on the sugar and vegetable oil production since the data on these food products have been collected and they could not be integrated into other section (Table 13).

Table 13 Numerical Results of the SDM for Other Food Products Production

Units (tons)	Total Sugar Stock Available	Total Vegetable Oil Available	Total Other Products Available
2017	51836.08	21516.08	73352.17
2030	103672.17	31572.70	135244.87
2050	155508.25	34884.03	190392.28

The production of sugar is expected to increase by 50 percent till 2030 and further increase by 66.7 percent by 2050 compared to 2017 is also projected. The increase in vegetable oil production is not as high as in the production of sugar. Thus, almost 32 and 38 percent more vegetable oil is produced in 2030 and 2050 compared to 2017.

5.3.7 Grain Consumption

After the discussion of the results in the production part, the consumption of food products is also important to be analyzed. Thus, in this section, the results of the SDM for the first group of food products, which are grains, will be included.

To start with the quantitative results for grain production, it should be noted that the total consumption of the grains will increase by 12.6 percent from 2017 to 2030 according to Table 14. However, the rise in grain consumption does not follow a similarly high increase for the period afterward as this value only increases by 1.1 percent from 2030 to 2050. In total, it is projected that the grains will be consumed 13.6 percent more in 2050 compared to 2017.

Table 14 Numerical Results of the SDM for Grain Consumption

Units (tons)	**Wheat Consumed**	**Barley Consumed**	**Porridge Consumed**	**Other Grains Consumed**	**Rice Consumed**	**Maize Consumed**	**Total Grains Consumed**
2017	339136.58	99067.42	982.17	758.92	6582.75	36165.08	482692.92
2030	387972.25	113333.12	1123.60	868.20	7530.67	41372.86	552200.71
2050	392448.85	114640.81	1136.52	878.22	7617.56	41850.24	558572.21

Figure 24 illustrates the share of every grain type in the total consumption of the grains. The share does not vary throughout the years as business as usual scenario is the case in the SDM. As can be seen in this chart, the grains consumed the most is wheat, which accounts for 70.3 percent of the total.

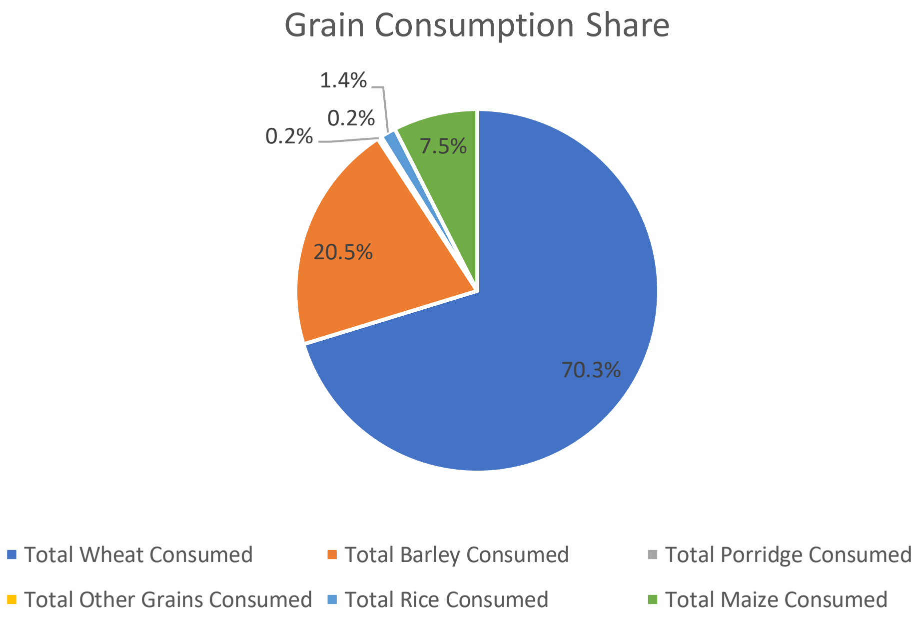

Figure 24 Share of Grain Types in Total Grain Consumption

The second most popular grain type consumed is barley with a 20.5 percent share whereas the least favorite grain type is porridge with only 0.2 percent of consumption share.

5.3.8 Vegetable Consumption

The second group in the food consumption results is forecasting of vegetable consumption. The results obtained from the model are summarized in Table 15. The estimated increase in vegetable consumption in the first 13 years is 17.6 percent followed by almost 7 percent increase in the next 20 years. The overall increase in vegetable consumption is projected to be 23.3 percent from 2017 to 2050.

Table 15 Numerical Results of the SDM for Vegetable Consumption

Units (tons)	Vegetables of all kinds Consumed	Market Garden Crops Consumed	Leguminous Consumed	Potatoes Consumed	Other Kinds of Vegetables Consumed	Dried Onion Consumed	Vegetables Consumed
2017	137906.17	36805.04	4048.58	139579.25	118231.16	19675.00	456245.20
2030	167459.46	44693.29	4916.20	169491.07	143568.11	23843.96	553972.09
2050	179774.00	47979.61	5278.14	181955.21	154126.53	25649.85	594763.35

The most used vegetable in Azerbaijan is projected to be potato with a 30.6 percent share in the total consumption whereas leguminous plants are the least favorite with only 0.9 percent of the total (Figure 25).

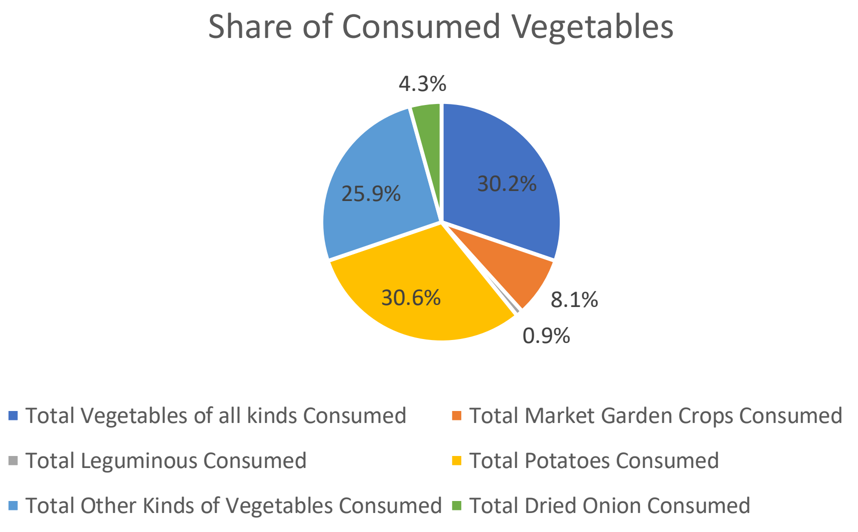

Figure 25 Share of Vegetable Types in the Total Consumption

5.3.9 Fruit Consumption

In this section, grapes are going to be projected apart from the fruit and berries as in the production section of the results. The numerical results obtained from the SDM are given in Table 16 below.

Table 16 Numerical Results of the SDM for Fruit Consumption

Units (tons)	Total Fruits and Berries Consumed	Total Grapes Consumed	Total Fruits Consumed
2017	91837.92	13968.92	105806.83
2030	111518.78	16962.46	128481.24
2050	119719.91	18209.88	137929.79

The total rise in fruit consumption is forecasted to be around 23 percent from 2017 to 2050, which can be broken down to an increase of 17.6 percent from 2017 to 2030 and 6.9 percent from 2030 to 2050. The consumption of grapes is projected to be 13.2 percent of the total fruit consumption.

5.3.10 Meat Consumption

Meat consumption will be divided into beef, mutton and goat meat, pork, poultry meat, and fish products as it was done in the production section.

To start with the quantitative analysis (Table 17), it should be noted that the type of meat which is projected to increase the most in consumption from 2017 to 2050 is estimated to be beef with 49.3 percent.

Table 17 Numerical Results of the SDM for Meat Consumption

Units (tons)	Beef Consumed	Pork Consumed	Poultry Meat Consumed	Fish Consumed	Mutton and Goat Consumed	Total Meat Consumed
2017	12974.00	713.90	11106.83	6829.92	6844.42	38469.06
2030	20415.89	1123.41	17477.71	9425.29	10770.37	59212.67
2050	25576.94	1407.37	21896.01	9425.29	13493.08	71798.69

Apart from the results on the consumption for every meat type, it is also important to analyze the changes in the shares of every meat type of meat product.

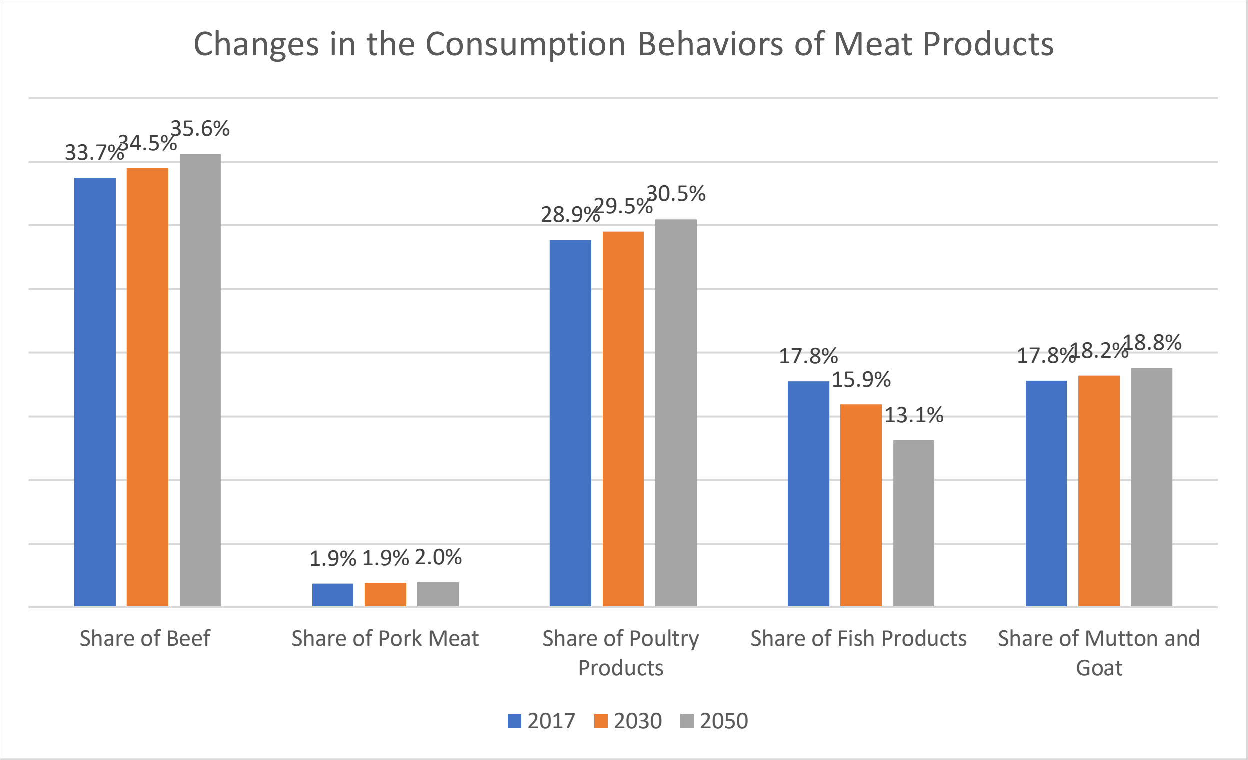

Figure 26 SDM Results for Share Changes in Consumption by Meat Type

This analysis can be conducted based on Figure 26, which portrays the variety of the shares of each meat type in the total meat consumption for 2017, 2030 and 2050. Almost every meat type follows an increasing trend in the share of total meat consumption except fish products, which reduces by 4.6 percent from 2017 to 2050. The share of beef is the figure increasing the most in the considered period, which consumed 1.9 percent more in total in 2050 compared to 2017.

5.3.11 Dairy Consumption

The dairy consumption results of the SDM are not very detailed as only cheese consumption is separated from the rest and all other dairy products are grouped with milk as in the production part (Table 18).

Table 18 Numerical Results of the SDM for Dairy Consumption

Units (tons)	Total Cheese Consumed	Total Milk and other dairy products Consumed	Total Dairy Products Consumed
2017	5461.00	1942712.42	1948173.42
2030	7406.75	2634900.85	2642307.60
2050	8635.48	3072011.15	3080646.62

The consumption of the dairy products increases in both milk and cheese making up the 26.3 percent rise of the total consumption from 2017 to 2030, followed by a 14.2 percent increase of this value from 2030 to 2050. The overall increase in the total consumption of dairy products from 2017 to 2050 is estimated to be 36.8 percent. It is also worth to mention that cheese consumption accounts for only 0.3 percent of the total consumption of dairy products.

5.3.12 Other Food Consumption

As in the production section, the other food consumption results of the SDM include the forecasts on the sugar and vegetable oil consumption.

Table 19 Numerical Results of the SDM for Other Food Consumption

Units (tons)	Total Sugar Consumed	Total Vegetable Oil Consumed	Total Other Category Food Consumed
2017	51836.08	21516.08	73352.17
2030	63354.06	32549.53	95903.59
2050	74872.04	34240.70	109112.73

As can be seen from Table 19, both sugar and vegetable oil consumption increase from 2017 to 2050. The increase in the total vegetable oil consumption from 2017 to 2050 is higher than in sugar consumption, which is projected to be 37.2 and 30.8 percent respectively.

5.4 Results for Energy Sector

In this section, the results of the SDM for the energy sector will be analyzed. It should be mentioned that due to lack of the input data, which is caused by the confidentiality of these data, for the whole energy sector of Azerbaijan only electricity production was used as an input for the model. Thus, the results of the SDM for the production side of this section only includes electricity production. However, in the results on the energy consumption side, coverage of the total scene was attempted.

5.4.1 Results for Electricity Production

In electricity production section, the results of the electricity production from oil, closed cycle (Gas CC) and open cycle (Gas OC) gas sources, hydropower, wind, and solar energy are included. It is also worth to mention that the results of this section are solely based on E3ME and OSeMOSYS models (Fazekas, Alexandri, & Pollitt, 2017), which are used in SIM4NEXUS Project.

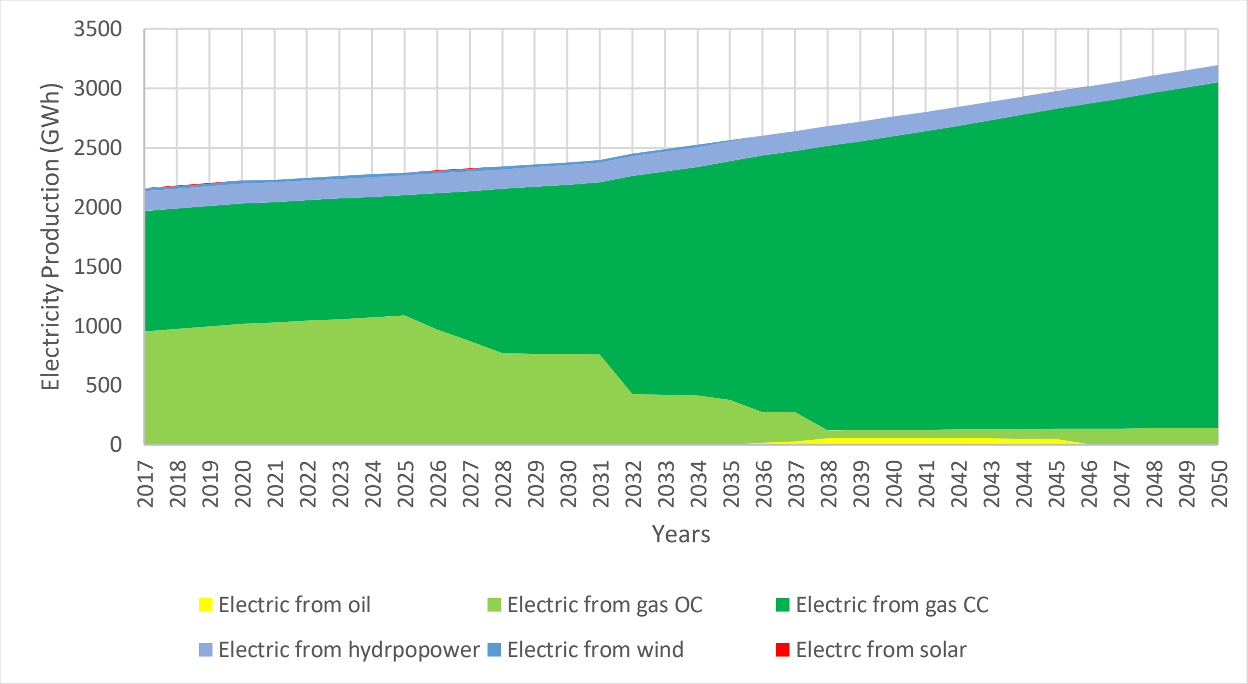

Figure 27 SDM Results for Electricity Production

As it is seen from Figure 27, electricity is not produced in the early years of the analyzed period but is projected to appear and diminish again further on. Electricity production from gas seems to become the main source of electricity for the country in the future. In terms of renewable energy sources, the results are not very promising since they are projected to have very small changes as the electricity mix is mainly forecasted to be dominated by gas sources as mentioned before.

Table 20 Numerical Results of the SDM for Fossil Fuel Based Electricity Production

Units (GWh)	**2017**	**2020**	**2030**	**2040**	**2050**
Electric from oil	0.00	0.00	1.08	53.16	0.00
Electric from gas OC	953.19	1018.40	761.29	70.22	141.36
Electric from gas CC	1013.31	1013.31	1423.01	2473.90	2908.91

Table 20 above includes the quantitative results of the SDM for electricity production from oil and gas. As can be seen from the table, oil-based electricity production is non-existing in the baseline year. However, the production of electricity from oil is predicted to appear around 2030 and contribute to the electricity mix with 1.08 GWh electricity. The use of oil in electricity production is forecasted to even increase up to 53.16 GWh by 2040. Gas CC is the dominating method of electricity production throughout the years and the production increases every year. In 2050 the production of electricity from Gas CC is forecasted to reach its' maximum by reaching 2908.91 GWh.

Table 21 Numerical Results of the SDM for Renewable Electricity Generation

	2017	2020	2030	2040	2050
Electric. from hydropower	166.43	166.43	166.43	163.22	144.98
Electric. from wind	22.73	22.73	22.62	0.00	0.00
Electric. from solar	0.44	0.44	0.44	0.00	0.00

Additional to the fossil fuel based electricity generation, production of electricity from renewable energy sources are also retrieved from E3ME and OSeMOSYS (Fazekas, Alexandri, & Pollitt, 2017), which is illustrated in Table 21. The production of electricity from wind and solar is not provided by the model after 2030. The changes in electricity generation from renewable sources are not forecasted to increase considering the business as usual scenario and the production is estimated to reduce slightly due to the domination of gas electricity production.

According to Table 20 and Table 21, it can also be concluded that the highest increase in electricity generation will be observed from 2030 to 2040 (14 percent) and the total increase in electricity production from 2017 to 2050 will be 32.5 percent.

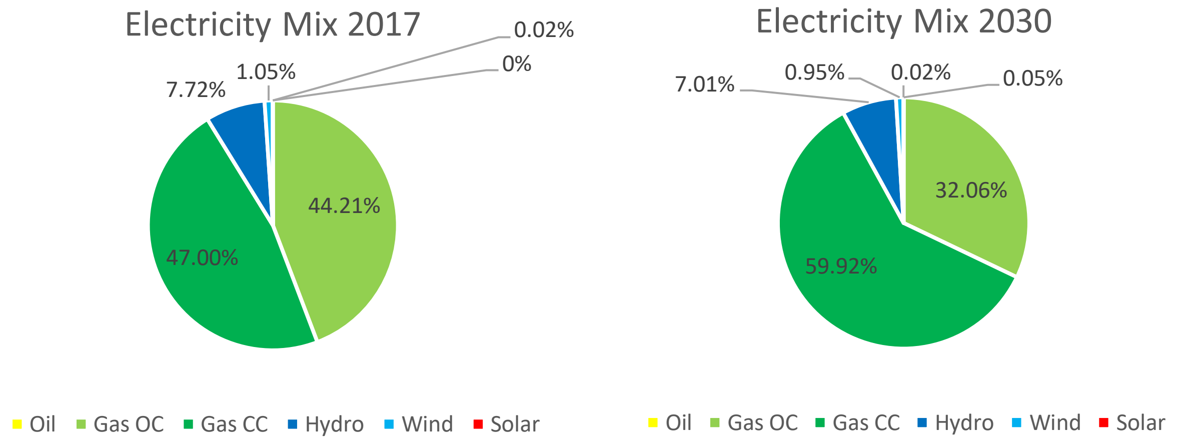

Figure 28 Electricity Mix (2017,2030)

Figure 28 illustrates the differences in the electricity mix of the country in 2017 and 2030. According to these pie charts, the oil-based electricity production will enter the mix in 2030 by 0.05 percent. Moreover, the share of gas-based electricity generation changes but still holds the biggest share in the mix. The Gas OC generation reduces its' share by 12.15 percent whereas Gas CC increases by 12.92 percent from 2017 to 2030.

5.4.2 Results for Energy Demand

After the discussion of electricity production, it is also important to analyze the demand for energy and the projection on it. Thus, this section covers residential, agricultural, and industrial energy demand as well as demand in transportation and services.

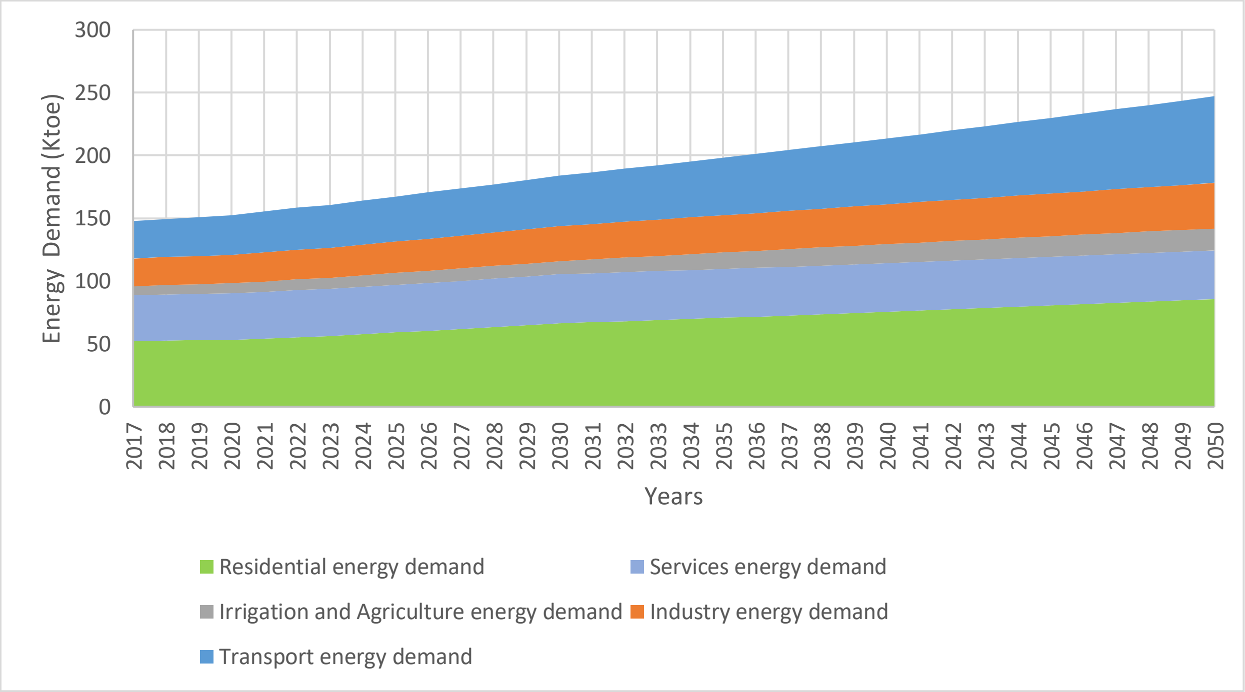

Figure 29 SDM Results for Energy Demand

It can be interpreted from Figure 29 that the demand for energy will continuously rise from 2017 to 2050 in every considered area. However, the discussion of the numerical results is necessary to fully cover the results of the SDM.

Table 22 Numerical Results of the SDM for Energy Demand

Units (Ktoe)	2017	2020	2030	2040	2050
Residential energy demand	52.06	53.18	66.28	75.53	85.51
Services energy demand	36.61	36.92	39.09	38.64	38.73
Irrigation and Agriculture energy demand	7.03	8.08	10.52	15.21	17.60
Industry energy demand	22.25	22.71	27.67	31.69	36.26
Transport energy demand	29.95	31.47	40.17	52.49	69.10
Total Energy Demand	147.90	152.37	183.73	213.56	247.20

The results of the SDM for energy demand in every considered area and forecasts of these values are summarized in Table 22. The highest increase in the energy demand is projected to be observed in irrigation and agriculture as the demand here increases from 7.03 Ktoe to 17.60 Ktoe, which is a rise of around 60 percent from 2017 to 2050. The demand in transportation comes second as here an increase of 56.7 percent is estimated. On the other hand, together with having the lowest overall increase of 5.5 percent from baseline year to 2050, energy demand in services is also the only area where a decrease in demand is forecasted in the intermediate period. This reduction of 1.2 percent in the energy demand in services is projected to occur from 2030 to 2040.

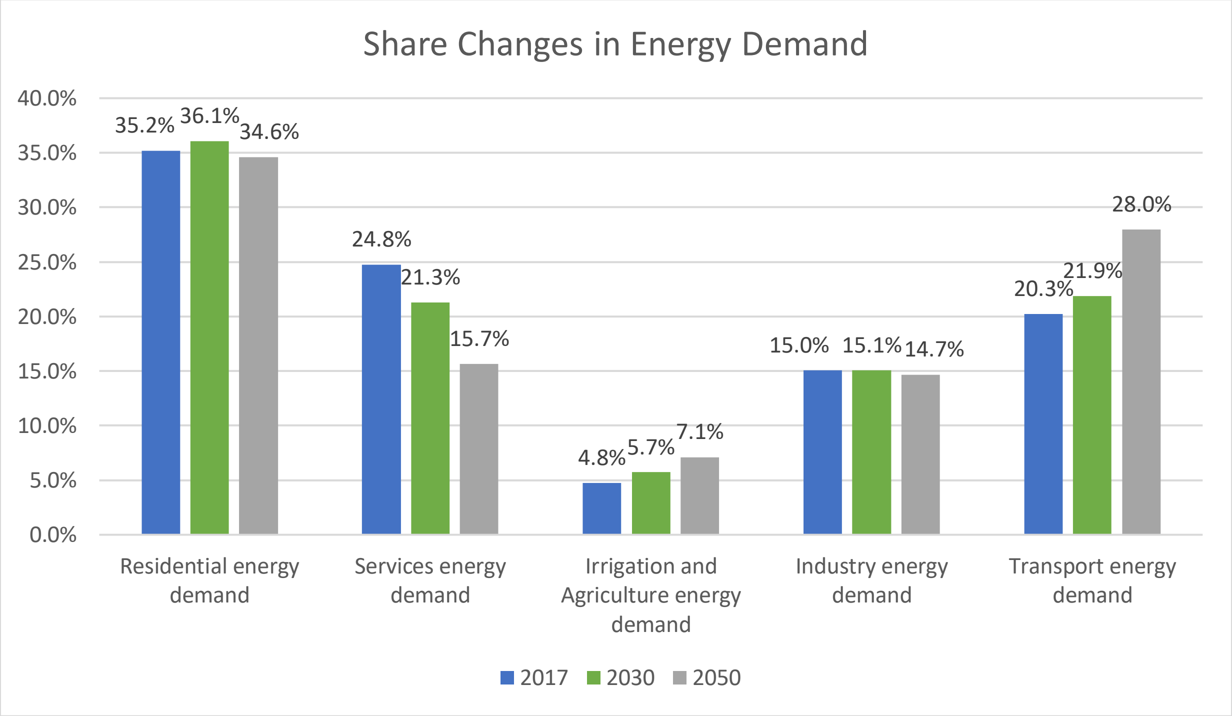

Figure 30 Changes in Share of Every Sector in the Total Energy Demand

Finally, it is also worth to analyze the changes in the shares of every sector in the total energy demand throughout the period. These changes are illustrated in Figure 30 including the share of every sector in 2017, 2030 and 2050. As can be seen from these results, the residential sector is always the dominant shareholder whereas the agricultural sector is the one with least energy demand. However, the agricultural sector is one of the sectors with increasing energy demand from 2017 to 2050 together with transportation. Thus, although the energy demand for transportation was on the third place in 2017 with 20.3 percent after services sector (24.8 percent), it is forecasted to become second-largest energy-consuming sector in 2030 and 2050 by consuming 21.9 and 28 percent of total energy respectively.

5.5 Results for Climate

The final section of the SDM results is the projections on the GHG emissions and sequestration from 2017 to 2050. The GHG results include the emissions from the energy and food sectors whereas sequestration of these gases includes absorption of GHGs by forests and fallow lands.

The results in this sector are obtained by combining the data regarding the emission and sequestration factors together with the results of the SDM for energy and land sectors. The analysis of these results for the climate sector will include a separate discussion of the emission and sequestration of GHGs. However, the comparative analyses of both emissions and sequestration will also be included.

5.5.1 Results for GHG Emissions

The projections on the emission changes throughout the years, breakdown of the total emissions by categories and forecasts of the share changes of every component will be included in this section of the report.

Table 23 Numerical Results of the SDM for GHG emissions

Units (tCO2eq)	**2017**	**2020**	**2030**	**2040**	**2050**
Total emissions from energy production	219359.57	226633.09	248765.09	534770.59	340251.96
Total emissions from food production	483.82	483.82	582.90	582.90	632.10
Total Emissions	219843.40	227116.92	249347.99	535353.49	340884.05

To start with the numerical results for the emissions shown in the Table 23, it can be noted that there is a general increasing trend in the total GHG emissions throughout the considered period. Although the emissions from energy production are estimated to increase by 35.5 percent in 2050 compared to the baseline year, the emissions from this sector significantly reduce by 57.2 percent from 2040 to 2050. This decline in the emissions could be reasoned by serious changes in the electricity mix of the country since Gas CC production was forecasted to be the dominating electricity generation method as discussed in the results for the energy sector. The increase in the emissions from the food sector is forecasted to be 17 percent from 2020 to 2030, 7.8 percent from 2040 to 2050. In total, food production is projected to emit 23.5 percent more GHGs in 2050 compared to 2017.

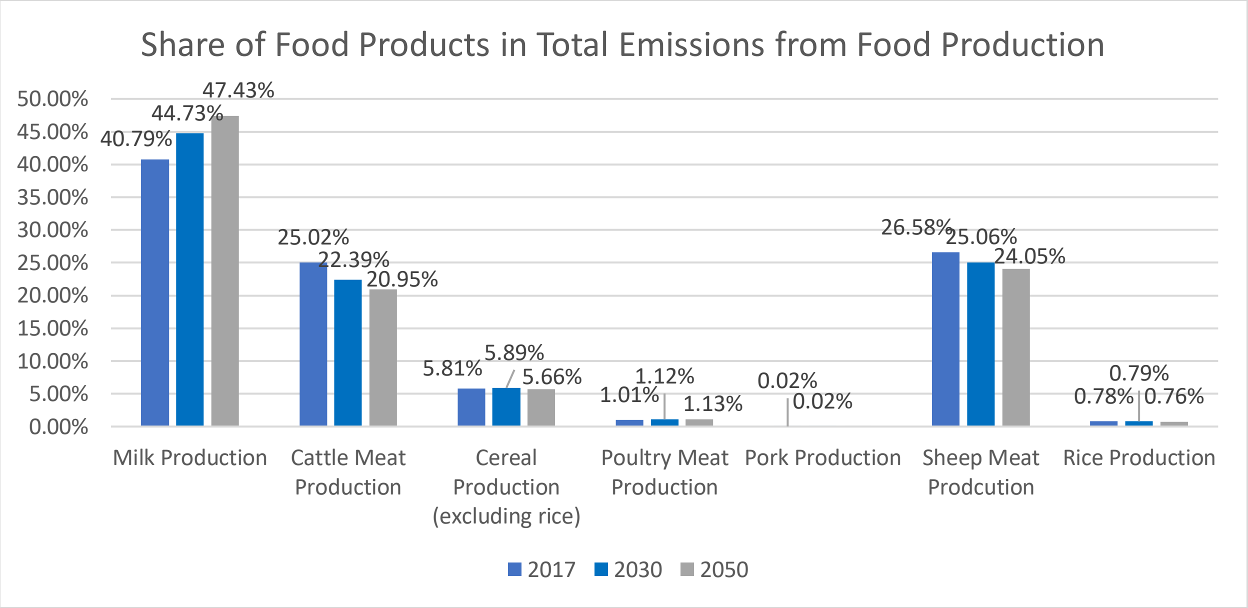

Figure 31 Share of Food Products in the Total Emissions from the Food Production

Apart from the changes in the GHG emissions, the SDM results also include the changes in the shares of the different food products in the total emissions from the food sector, which is given in the Figure 31. As can be seen from this figure, dairy production is the highest pollutant for all considered years being more than 40 percent of the total emissions from the food sector. The second highest pollutant of all time is the production of sheep meat with an average of 25 percent share in 2017,2030 and 2050. Production of pork meat is the one with the lowest constant share of 0.2 percent for all considered years, which could be reasoned by very small pork production.

5.5.2 Results for GHG Sequestration

In this section, the total sequestration of the emissions and contribution of forest and fallow lands to the total sequestration will be analyzed. The quantitative results of the SDM for GHG sequestration are given in Table 24.

Table 24 Numerical Results of the SDM for GHG Sequestration

Units (tCO_2eq)	**2017**	**2020**	**2030**	**2040**	**2050**
Sequestration by Forests and Wetlands	218708.74	219993.26	224275.01	228556.76	232838.51
Sequestration by Fallow Lands	7171.96	7118.04	6938.30	6758.56	6578.82
Total Sequestration	225880.70	227111.30	231213.31	235315.32	239417.33

It can be seen from Table 24 that while sequestration by forests and wetland is forecasted to continuously increase from 2017 onwards, fallow lands are projected to sequester less and less GHGs in the future. Thus, sequestration by forests and wetlands will increase by 6.1 percent but sequestration by fallow lands will decrease by 9 percent from 2017 to 2050. The total sequestration, however, will increase by 5.7 percent in the timeframe of the SDM.

5.5.3 Comparative Analysis of GHG Emissions and Sequestration

After discussing the GHG emissions by different sectors and carbon absorption by forests and fallow lands, it is also important to compare the emissions to sequestered amount to understand the balance of emissions and their effect on the climate of the country.

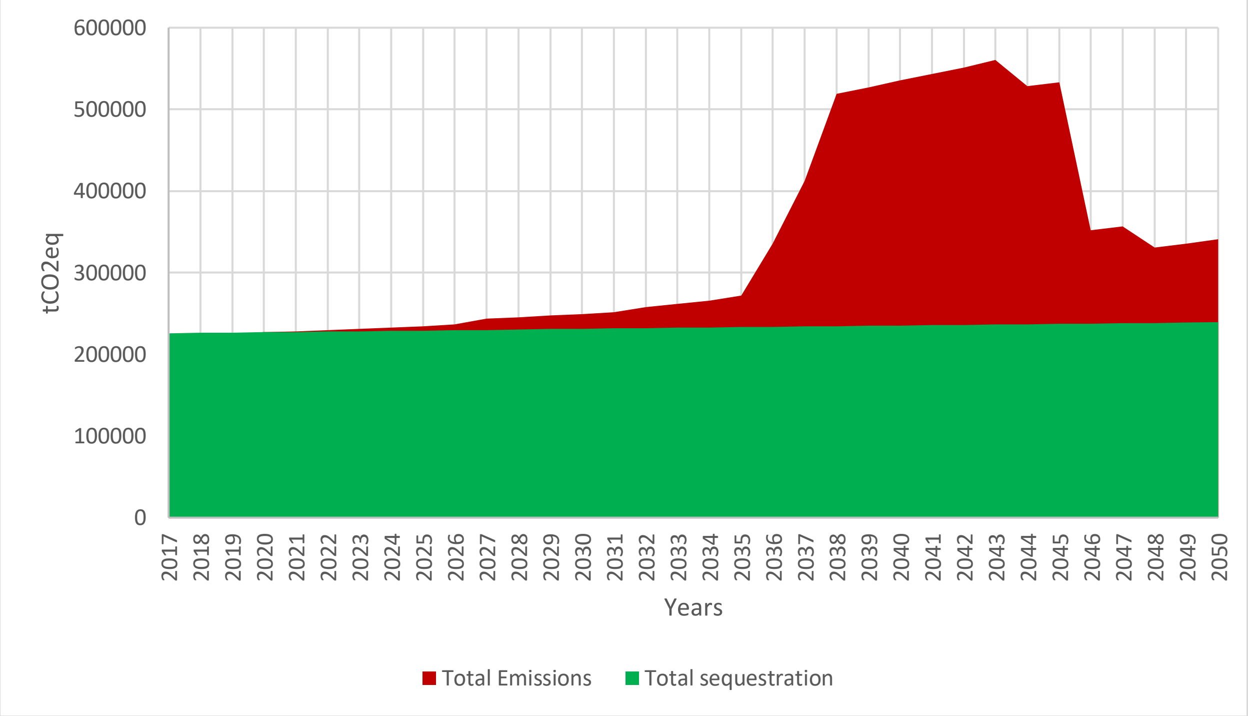

Figure 32 Comparison of GHG Emissions and Sequestration

The results for total GHG emissions and total sequestered amount are plotted in Figure 32, which projects the excess of the emissions from 2020 onwards. The gap between the emissions and sequestration is forecasted to steadily increase until 2035 after which the gap starts to drastically increase. Thus, the change in the gap reaches 86.5 percent in only 4 years after 2035. The peak of the gap will be reached in 2043 when 323.93 $ktCO_2eq$ GHGs emissions will be left non-sequestered. To sum up, despite the gap between emissions and sequestration reducing from 2044 onwards, emissions are forecasted to always exceed the sequestered amount.

6. Solutions and Recommendations

The aim of this section of the report will be to describe the possible solutions and provide some recommendations to reduce the GHGs and improve the sustainability status of the country.

Although Azerbaijan has not set certain quantitative goals regarding GHG emissions and/or climate change, there is an immense gap to be filled in these regards and need for significant changes in the approach towards sustainable development. These improvements can be done in the energy, industry, transportation, waste and agricultural sectors. Due to the scope of this work, industry, transportation, and waste sectors have been neglected but the general recommendations in these areas will also be analyzed in this section of the report.

6.1 Energy Sector

The situation of the emissions from the energy sector has been discussed in the results section of the report and it could be seen that the total emissions from the energy sector are increasing by 35.5 percent till 2050 compared to 2017. Thus, it is unquestionable to mention that vital improvements should be done in this sector. The recommendations for this development can be done by separating the sector into three subcategories, which are production, energy efficiency, and renewable energy sources.

It was already mentioned that Azerbaijan is very prominent with its petroleum reserves and produces oil and gas as primary energy sources. Hence, these energy sources are accounted for one of the main causes of the emissions in the energy sector (Table 23). The State Oil Company of Azerbaijan Republic (SOCAR) has already undertaken some responsibility in the GHG emissions, reduced associated petroleum gas flaring and venting to less than 300 million cubic meters by 2010 (WorldBank, World Bank Fact Sheet , 2010) and joined the Zero Routine Flaring by 2030 initiative (SOCAR, 2018). However, together with these achievements, the progressive emission monitoring systems should be acquired, the energy efficiency in the technologies should be improved and most importantly the leakages in petroleum/gas supply lines should be improved together with the management of the discharge of hydrocarbons in the production sites.

Apart from petroleum, Azerbaijan has also a satisfactory potential in renewable energy sources, which is shown in Table 25 (Farajullayeva, 2019). There is a big gap between the technical and economic potential of these RES and need for reduction of this gap. Thus, the State Agency on Alternative and Renewable Energy Sources (SAARES) was established under the Ministry of Industry and Energy in Azerbaijan in 2009.

Table 25 Renewable Energy Potential in Azerbaijan

RES	Total Power Potential (MW)	Technical Power Potential (MW)	Economic Power Potential (MW)
Wind Energy	84262	>15000	3000
Solar Energy	4300143	>8000	1600/1800

Biomass	1608	>900	380
Hydro energy	1600	>650	520
Geothermal Energy	800	200	40
Total	4388413	24750	5540/5740

Currently, the possible challenges that prevent the improvement of RES infrastructure and use can be:

- The lack of the legal and regulatory framework for RES development is the first one worth to mention.
- The Lack of grid regulation- Neither clear tariff methodology nor the legal basis for the grid connection of RES.
- The lack of investment in RES. The local companies have limited funds for investment; and the lack of a framework for RES results with the lack of interest from foreign investors.
- The lack of loans from the banks and financial support from the government in forms of incentives and such.

Considering these challenges, it is very important to have government involvement and support in the creation of RES share in the energy market and financing. Thus, some recommendations for solving these challenges can be:

- Policy changes supporting the positive framework for RES to enter the market and have a share in the energy mix of the country.
- Creating an independent entity for distribution grid or creating a legal basis/tariffs for grid utilization by RES
- Incentivizing the installations of renewable energy systems
- Liberalizing the alternative and renewable energy market
- Open RES market to private investments

6.2 Agricultural Sector

Agriculture and Food is another sector analyzed in this report, which proved to have a significant impact on the climate and GHGs. Thus, here some suggestions on shifting to sustainable agriculture will be discussed.

The very first step should be the education of farmers and raising their awareness of sustainable farming and agriculture techniques. Farmers in the country should be ensured of their short term and long-term benefits from the change in their practices. They should be educated about the alternative options and trained for “non-conventional” farming. For this, the agriculture and farming school staff should acquire training on sustainable agriculture for future farming trends to change and farming as well as workshops on the country level should be held for current techniques to be adjusted.

However, considering the current situation in the country, the concern of the farmers might not be the reduction in soil loss or long-term gap between food supply and demand rather the current economical profit. Thus, policymaking push in increasing the incentives for farmers and providing additional funds for aligning with the sustainable techniques should be considered.

As it is visible from Table 5 the irrigation water demand is expected to increase by 9.7 percent until 2050. Thus, it is crucial to deal with the irrigation systems in the agricultural sector to increase efficiency and reduce this demand. For instance, instead of large-scale systems that are limited to certain land types, micro-irrigation technologies can be used such as solar-powered drip, which is precise in water delivery and provides high yield and efficiency (Dobermann & Nelson, 2013).

Apart from all the mentioned recommendations, the involvement of government in the investments to R&D in this sector is important. The lack of knowledge and expertise in the field not only on the farmers' level but also on the higher levels might be one of the main obstacles in the sustainable growth of the agriculture sector. It has been proved on several scales and times that research and development investments have high profits and returns as long-term and long-lasting business and infrastructure development (Fuglie & Wang, 2012).

6.3 Pollution Permits

Azerbaijan is trying to successfully implement the pollution permits and fines for not complying with these permits. The emissions of pollutants to ambient air can only be permitted by the Ministry of Ecology and Natural Resources according to the law on the protection of ambient air of Azerbaijan Republic. According to this law, the entities that can obtain pollution permits are divided into 4 danger categories depending on their area of operations.

The first problem regarding the pollution permits in Azerbaijan is that entities producing pollutants from non-stationary sources according to production or service profile do not need "special permission" from the Ministry of Ecology and Natural Resources and their pollution is computed by the amount of the material used in these procedures of production and service activities (e.g. paint, natural gas, diesel etc.) (Aliyev, 2013).

The second problem is not very clear calculation of the emission fines as well as having too low fine prices for exceeding emission allowances. Thus, although the norms of fines for air pollution by fuel combustion were increased by ten times in 1993, there was a denomination of Azeri manat and the new national currency was 5000 times of the old one (Aliyev, 2013). This results with the very low emission prices and many entities are not pushed to reduce emissions with the pollution fines (UNFCC, 2014).

The solution here could be to reform the pollution permit system and reconsider the fines applied in case of exceeding the permitted emissions.

6.4 Emission Data Quality

There is a lack of high-quality emission inventory on the country level, which was identified during the literature review and data collection stages of the work. The monitoring and reporting of emissions are conducted by entities themselves while the Department of Environmental Protection is responsible for analyzing these data provided by entities and verifying it (UNFCC, 2014).

Therefore, it is very crucial to set up a good emission metering and verification system which would be checked by not only a very limited number of parties and would lead to transparency, accuracy and reliability of the data. The simple example could be to have the internal verification, verification by a party which has direct concerns in the emissions related to the first party (e.g. buyer or supplier), independent verification which is not anyhow interested in any party and finally the governmental verification. This would also help to acknowledge the real situation and threat to the country by GHGs, understand the opportunities in the country to mitigate climate change, and would enable policymakers to understand the priorities for ensuring more sustainable development of Azerbaijan. Additionally, this change would also boost international reliability of the country as well as improving the international performance indicators of the country.

The change in the metering and verification of GHG emissions would not be easy and fast but it could be initiated by taking small steps. The change can be subdivided into several sections such as starting to change on company level followed by corporate and sector levels, which would lead to a change on a country level.

7. Conclusions

There are several studies conducted on the economy of Azerbaijan, focusing on different resource systems. However, the literature review done as part of this study identified the gap in the research regarding the holistic view of Azerbaijan's economy, the studies of interconnections between the sectors making up the economy of the country and the studies regarding the transition of the country to more sustainable development.

In an attempt to fill this gap, this work aimed at investigating Azerbaijan's transition to a low carbon pattern by determining of the links between the NEXUS of water, land, food, energy and climate and analyses of the dynamics between them. Additionally, the work had the objective of coming up with solutions and recommendations for effective policymaking in Azerbaijan to push the country towards more sustainable development.

Hence, the work has successfully analyzed every sector of the NEXUS by investigating the dynamics in these sectors and their effect on the climate of the country taking 2017 as a baseline year and projecting these dynamics to 2050. Recommendations and solutions in the energy and agricultural sectors, which were shown to be the biggest GHG emitters according to the SDM results, as well as suggestions regarding the pollution permits and emission metering were proposed in this work to provide policy insights to policymakers.

The analysis was conducted on the results of the SDM. The general methodology for every NEXUS sector was to obtain the balance between the available resources and consumption/demand, after which in the highest level of the SDM these sectors were linked to each other.

Several challenges had been faced during the work especially in the data collection and post-processing of the results of the SDM. The determination of the baseline year was very crucial for the data collection stage due to the normalization of the data for the same year, which was selected to be 2017 due to the availability of most updated data for this year. Another challenge faced during the work was processing the results of the SDM. As the timestep of the model was initially set to one month, so did the output resolution of the model which led to the demanding processing of these results to yearly values. However, all these obstacles were successfully overcome and the results for every sector were obtained.

Although there were some favorable results of the work such as an increase in water recycling, forecasts of the forest expansion, reduction of the production of some meat types, increase in vegetable consumption, the final comparative analysis of GHG emission and sequestration showed an excess of emission in the future.

7.1 Future Studies

To summarize, it is also important to propose future studies that can follow this work to further explore the topic. Thus, this section will include suggestions for future studies regarding the topic.

Firstly, considering that this study has been done for a Business as Usual scenario only, future studies could include several cases and scenarios such as:

- Higher Renewable Energy Sources Penetration Scenario
- Permaculture Designed Farming/Agriculture Scenario

Moreover, analysis of how an increase in pollution fines and having more precise emission metering systems would change GHG emissions can be done.

Finally, after having the analysis of several scenarios, the financial and technological needs to change towards a low-carbon economy should be assessed to investigate the feasibility of these changes considering the current economic capacity of the country.

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