Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Master's Thesis

Economic Exploration of Climate Change Impacts on Agriculture and Food Security in Tajikistan

Bc. Shafe Davlatzoda

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Shafe Davlatzoda

Economics and Management

Thesis title

Economic Exploration of Climate Change Impacts on Agriculture and Food Security in Tajikistan

---

Objectives of thesis

This diploma thesis aims to explore how different factors and climate change impact food security in Tajikistan through their effects on the agriculture sector of Tajikistan. This study intends to offer useful insights for successful climate change adaptation and mitigation methods in Tajikistan by looking at the effects on local populations, economic activity, and policy implications.

Methodology

This study employs advanced statistical methods to investigate the intricate relationships between climate change, agricultural dynamics, and daily calorie supply per capita in Tajikistan. Through multiple regression modeling and descriptive statistics, author explore the connections between the dependent variable and key independent variables. The dataset spans from 2000 to 2021, offering a comprehensive view of evolving trends. SAS Studio serves as the primary platform for regression analysis, facilitating the extraction of valuable insights. Additionally, Excel aids in descriptive analysis and data visualization, enhancing our ability to effectively present and interpret results. Qualitative analysis plays a pivotal role in shaping the literature review, supporting the quantitative findings. The Agency on Statistics Under the President of the Republic of Tajikistan and the World Bank will be used as a source of data collection for time series analysis in the 2000-2021 years.

The proposed extent of the thesis

60 – 80

Keywords

: Climate Change, Food Security, Agriculture, Economic Resilience, Regression Analysis, Climate Variability, Daily Calorie Supply, Sustainability, Time-Series Data, Wheat Production, Tajikistan.

Recommended information sources

Agency on statistics under the President of the Republic of Tajikistan [online]. Available at: https://stat.tj/en

Hydromet of Tajikistan, A. f. (2018). THE FIRST BIENNIAL REPORT OF THE REPUBLIC OF TAJIKISTAN ON INVENTORY OF GREENHOUSE GASES UNDER THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE. Dushanbe: Tajikistan, Agency for Hydrometeorology under the Committee on Environmental Protection under the Government of the Republic of tajikistan.

JAMES, G. – WITTEN, D.- HASTIE, T.- TIBSHIRANI, R. An introduction to statistical learning with application in R.New York,USA: Springer, 2013. ISBN 987-1-4614-7137-7.

NISBET, R. – ELDER, J. – MINER, G. Handbook of statistical analysis and data mining applications. Amsterdam, Netherlands: 2009. ISBN 978-0-12-374765-5.

Smutka, L., Čechura, L., Krepl, V., Čábelková, I., Procházka, P., Malec, K., Akhmedov, S., Kotyza, P., Mach, J., Davlatzoda, S., Kasimov, F., Hakimov, F., Zabirov, M., Kulhánek, A., Messana, D., Činčera, P., Němec, L., Homidov, A., Gaforzoda, B., Saidzoda, M., Kamolov, J., J., (2022). Assessment of the Costs and Benefits of Climate Change Adaptation in Agriculture, Forestry, and Water Management Sectors of Tajikistan; Deliverable 1. Report on existing and forecast future changes in climate in six target districts and observable impacts of agriculture, forestry, water resources. Faculty of Economics and Management, Czech University of Life Sciences Prague & Dekonta under the UNDP project 115-2021-RFP.

Tajikistan, A. f. (2022). FOURTH NATIONAL COMMUNICATION OF THE REPUBLIC OF TAJIKISTAN UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE. Dushanbe: Agency for Hydrometeorology of the Committee for Environment Protection under the Government of the Republic of Tajikistan.

World Bank and Asian development Bank (2021), Climate Risk Country Profile: Tajikistan. 1818 H Street NW, Washington, DC 20433: The World Bank Group and the Asian Development Bank.

Expected date of thesis defence

2023/24 SS – PEF

The Diploma Thesis Supervisor

Ing. Karel Malec, Ph.D.

Supervising department

Department of Economics

Electronic approval: 21. 2. 2024

prof. Ing. Lukáš Čechura, Ph.D.

Head of department

Electronic approval: 27. 2. 2024

doc. Ing. Tomáš Šubrt, Ph.D.

Dean

Prague on 17. 03. 2024

Declaration

I affirm that I worked alone to complete my master's thesis, "Economic Exploration of Climate Change Impacts on Agriculture and Food Security in Tajikistan," using just the references listed at the end of the document. I thus declare, in my capacity as the master's thesis' author, that no copyrights are violated.

In Prague on 28.03.2024 Shafe Davlatzoda

Acknowledgement

My profound appreciation goes out to my thesis advisor Karel Malec for all of his help and support during this process. His knowledge and support were very helpful in determining the course of this thesis. I also want to express my gratitude to my friends and family for their steadfast understanding and support throughout this difficult yet worthwhile experience.

Economic Exploration of Climate Change Impacts on Agriculture and Food Security in Tajikistan

Abstract

Changes in temperature and precipitation patterns brought about by climate change increase the frequency of extreme weather events, which is a serious danger to global agriculture and food security. The agricultural communities who depend on agriculture for their survival are more vulnerable as a result of these changes that upset conventional farming techniques and have an impact on crop yields, animal productivity, and total food production.

The purpose of this diploma thesis is to investigate how food security in Tajikistan is affected by various factors and by climate change on the agriculture sector of Tajikistan. The study used descriptive and regression analysis on secondary data based on annual time series data from 2000 to 2021 from different sources, such as the Food and Agriculture Organization, the World Bank, and the International Fund for Agricultural Development.

The study showed that bread products are the most important food item consumed in Tajikistan, followed by melons and vegetables, meat, and dairy products. The study also showed that climate change represents a serious risk to the country's agricultural production, especially for crops such as barley, cotton, maize, rice, soy, sunflower, and wheat. The study further showed that the daily calorie supply per capita in Tajikistan is positively influenced by the total population and the imports of wheat and meslin flour. The diploma concluded that Tajikistan's food security depends on maintaining and enhancing its agricultural output, diversifying its food consumption, and ensuring adequate food imports. The study also proposed some suggestions to enhance the food security condition in Tajikistan, such as investing in agriculture sector and improving regional cooperation and trade and increasing food quality and safety standards.

Keywords: Climate Change, Food Security, Agriculture, Economic Resilience, Regression Analysis, Climate Variability, Daily Calorie Supply, Sustainability, Time-Series Data, Wheat Production, Tajikistan.

Ekonomický průzkum dopadů změny klimatu na zemědělství a zajišťování potravin v Tádžikistánu

Abstrakt

Změny teplot a srážek způsobené změnou klimatu zvyšují četnost extrémních povětrnostních jevů, což představuje vážné nebezpečí pro globální zemědělství a potravinovou bezpečnost. Zemědělské komunity, jejichž přežití závisí na zemědělství, jsou zranitelnější v důsledku těchto změn, které narušují konvenční zemědělské techniky a mají dopad na výnosy plodin, produktivitu zvířat a celkovou produkci potravin.

Cílem této diplomové práce je prozkoumat, jak je potravinová bezpečnost v Tádžikistánu ovlivněna různými faktory a změnou klimatu na zemědělský sektor Tádžikistánu. Studie používala deskriptivní a regresní analýzu sekundárních dat založenou na ročních datech časových řad od roku 2000 do roku 2021 z různých zdrojů, jako je Organizace pro výživu a zemědělství, Světová banka a Mezinárodní fond pro zemědělský rozvoj.

Studie ukázala, že chléb je nejdůležitější potravinou spotřebovanou v Tádžikistánu, následuje melouny a zelenina, maso a mléčné výrobky. Studie také ukázala, že změna klimatu představuje vážné riziko pro zemědělskou produkci země, zejména pro plodiny, jako je ječmen, bavlna, kukuřice, rýže, sója, slunečnice a pšenice. Studie dále ukázala, že denní přísun kalorií na hlavu v Tádžikistánu je pozitivně ovlivněn celkovou populací a dovozem pšeničné a soražové mouky. Diplom dospěl k závěru, že potravinová bezpečnost Tádžikistánu závisí na udržení a zvýšení jeho zemědělské produkce, diverzifikaci spotřeby potravin a zajištění adekvátního dovozu potravin. Studie také navrhla některé návrhy na zlepšení stavu potravinové bezpečnosti v Tádžikistánu, jako jsou investice do zemědělství a zlepšení regionální spolupráce a obchodu a zvýšení standardů kvality a bezpečnosti potravin.

Klíčová slova: Změna klimatu, potravinová bezpečnost, zemědělství, ekonomická odolnost, regresní analýza, proměnlivost klimatu, denní přísun kalorií, udržitelnost, údaje z časových řad, produkce pšenice, Tádžikistán.

Table of content

1. Introduction 9

2. Objectives and Methodology 10

2.1 Objectives 10

2.2 Methodology 10

3. Literature Review 14

3.1 Glimpse into Tajikistan climate and geographical conditions 14

3.1.1 Geographic Position and Administrative Structure 14

3.1.2 Climate conditions in Tajikistan 15

3.1.2.1 Changes in climate conditions and observable trends in the climate 19

3.1.2.2 The predicted climate change, threats 21

3.2 Tajikistan Economy 25

3.2.1 Key economic metrics and features. 25

3.2.1.1 Recent economic developments 28

3.3 Agriculture Sector in Tajikistan 29

3.3.1 Characteristics and development of agriculture 29

3.3.2 Recent trends 31

3.3.3 Projections 34

3.3.4 Climate change impact in the agriculture sector of Tajikistan 35

3.3.4.1 Effects on Crops 38

3.4 Food security in Tajikistan 42

4. Practical Part 48

4.1 Descriptive and Trend analysis 48

4.2 Regression model 57

4.2.1 Model 1 with all independent variables 58

4.2.2 Model 2 without wheat production variable 59

4.2.3 Final model 60

5. Results and Discussion 63

5.1 Comparison with other author findings 64

6. Conclusion 67

7. References 69

8. List of pictures, tables, figures, and abbreviations 72

1. Introduction

As the world struggles with the extensive effects of climate change, nations like Tajikistan have particular difficulties in sustaining their agricultural systems and guaranteeing the food security of their people. Tajikistan, in the center of Central Asia, is facing risks to its crucial agricultural industry due to changing climatic trends. With the title "Economic Exploration of Climate Change Impact in Agriculture and Food Security in Tajikistan," this diploma thesis sets out to explore the relationships that exist in this area between agriculture, food security, and climate change.

In the first section, author examine the body of literature to comprehend how Tajikistan's shifting climate is affecting the nation's agricultural sector. Author examine the complex issues that the country's food security face, from changed precipitation to rising temperatures. The context of Tajikistan's food security provides context for appreciating the seriousness of the problem.

Moving from the theoretical to the practical, author concentrate on a critical component of food security: the daily calorie supply per capita. Regression analysis is a powerful statistical technique that author will use to examine the complex aspects influencing Tajikistan's food supply. Author looks at factors including per capita income, imports of wheat and meslin flour, wheat output, and population size in order to get insights that might help stakeholders and policymakers come up with plans for a resilient and food-secure future for Tajikistan. The goal of this investigation is to provide meaningful and practical information while maintaining its originality and authenticity.

2. Objectives and Methodology

The goals and strategies used in this study to accomplish the research objectives are described in this section. This thesis's principal aim is to identify how Tajikistan's agriculture and food security are affected by climate change. A thorough methodology was developed to do this, incorporating a range of research methods and analytical instruments. The technique used, including data collection techniques, research design, and analysis protocols, is covered in detail in the ensuing chapters.

2.1 Objectives

The thesis examines how Tajikistan's agriculture and food security are affected by climate change. The goal of the thesis is to present a thorough grasp of the intricate dynamics of food security in the context of climate change, particularly as they relate to the Tajik agricultural industry and to assess the economic impact of climate change on Tajikistan's food security and agricultural output, identify practical adaptation strategies, and suggest legislative changes to increase the sector's resilience.. Through an analysis of the relationships between many elements and their consequences for the nation's food security, the research aims to offer helpful insights on strategies for a resilient and food-secure future.

1. How may agricultural productivity be impacted by climate change, and how can this impact Tajikistan's food supply?
2. What is the relationship between the total population, per capita income, wheat and meslin flour imports, and wheat output and the number of calories supplied daily per person in Tajikistan?

2.2 Methodology

A thorough evaluation of academic journals, scientific literature, and internet resources served as the foundation for the investigation and analysis carried out in this diploma thesis. Carefully selecting data from reliable sources, such as the World Bank, FAOSTA, World Data, the Agency on Statistics under the President of the Republic of Tajikistan, and World Data, was necessary for the time series analysis covering the years 2000 to 2021. The thoughtful selection of a wide range of reliable sources enhances the research's strength and guarantees a comprehensive analysis of the topic.

Four key variables were included in the analysis since the goal was to comprehend the elements that affect the daily calorie supply per capita in Tajikistan. These variables are "Total Population," "Wheat and Meslin Flour Import," "Income per capita," and "Wheat production." The careful choice of these variables demonstrates the methodical approach taken in the study, guaranteeing a comprehensive investigation of the complex dynamics affecting food security. Well-known programs like Microsoft Excel and SAS Studio were used to process the data that was supplied in a computational and analytical manner. Methodically integrating reputable data sources and analytical tools supports the uniqueness and originality of the study while also bolstering the analysis's credibility.

Formula 1: Multiple regression model

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta p X p + \varepsilon} \quad \textbf{(1)}$$

The variables in the regression equation, Y = b0 + b1X1 + b2X2 +... + bpXp + ε, stand for the following: The dependent variable's projected value is represented by Y, the unique independent or predictor variables are represented by X1 to Xp, the estimated regression coefficients are b1 to bp, Y's value when all independent variables are zero is represented by b0, and ε is a random variable that represents the error term. The change in Y corresponding to a one-unit change in the corresponding independent variable is shown by each regression coefficient (b1 to bp). When using multiple regression, b1 shows how much Y changes when X1 changes by one unit while all other independent variables remain constant. It is necessary to estimate the unknown coefficients β0, β1,, βp (Nisbet, Elder and Miner, 2009). Using the given equation, predictions may be formed with these estimations.

Formula 2: Estimating regression coefficients

$$\mathbf{Y = b_0 + b_1 X_1 + b_2 X_2 + \cdots + bpXp} \quad \textbf{(2)}$$

The Ordinary Least Squares (OLS) technique is used to estimate the parameters, and it is dependent on the following conditions:

Formula 3: OLS

$$\sum_{i=1} (y_i - a - b_x x_{1i} - b_x x_{2i})^2 \;\dots min \quad \textbf{(3)}$$

The computed parameters' statistical significance is evaluated using the t-test. The steps in the hypothesis testing process are developing the null and alternative hypotheses, selecting a significance level (1%, 5%, or 10%), computing the t-value, figuring out the critical value, and comparing the t-values to decide whether to reject or not.

The following is the formulation of the t-test hypotheses: H0 = βi, H1 = βi ≠ 0. Finding the variables' statistical significance is the last step.

- If a variable's P-value is greater than the significance level (alpha) of 0.05, it is deemed statistically insignificant.
- On the other hand, if the P-value is smaller than the designated significance level of 0.05, a variable is considered statistically significant.

Multiple coefficients of determination are used to assess the fitness of the generated multiple regression equation, as shown by following formula:

Formula 4: Multiple coefficient of determination

$$\mathbf{R^2 = SSR / SST} \qquad \mathbf{(4)}$$

SSR refers for the sum of squares resulting from regression in this method, whereas SST stands for the total sum of squares (James, 2021).

When examining a model's assumptions and potentially significant data, regression diagnostics are essential. Several important assumptions are assessed in the context of linear regression. According to the first, the model correctly depicts a linear connection between the variables. This is known as linearity. For non-linear data, departing from this assumption suggests a less-than-ideal fit. When met, homoscedasticity, another requirement, optimizes parameter estimates by emphasizing a uniform distribution of scores for the criterion at each predictor level. Independence guarantees the validity of the analysis by indicating that model faults are unrelated.

When estimating the optimum parameters, the normality assumption states that the population's residuals should have a normal distribution. Testing the robustness of the model requires identifying leverage points—places where x values deviate considerably from the mean of x—and outliers, which are defined as observations with high residuals. Significant effects on the regression model can be attributed to influential data, or observations that are far from the centroid. When these observations are removed, the parameter estimations may alter significantly. The validity and precision of the linear regression model in the analysis are ensured by these diagnostic tests, as described by James (2013).

Relative analysis becomes an essential technique in regression diagnostics to evaluate the validity of the previously given assumptions. In this assessment, residuals—which are expressed as the difference between observed and projected values—are essential. This difference is captured by the residual equation, which is written as Residual = Observed value - Predicted value (e = y – Þ). Notably, zero is predicted for both the average and total residuals (Σ e = 0). Plotting residual values on the Y-axis and the independent variable on the X-axis is a frequent graphic representation. This methodical residual analysis guarantees the robustness of the regression analysis and helps assess how well the model adheres to important assumptions.

3. Literature Review

The literature review begins with a detailed examination of the complex relationships between climate change and agricultural sustainability in Tajikistan, followed by a description of the approach and goals. This review attempts to integrate current knowledge, identify gaps, and highlight key discoveries relevant to understanding the complex processes defining the agricultural sector in the face of changing climatic circumstances by a thorough investigation of existing scholarly works and empirical studies.

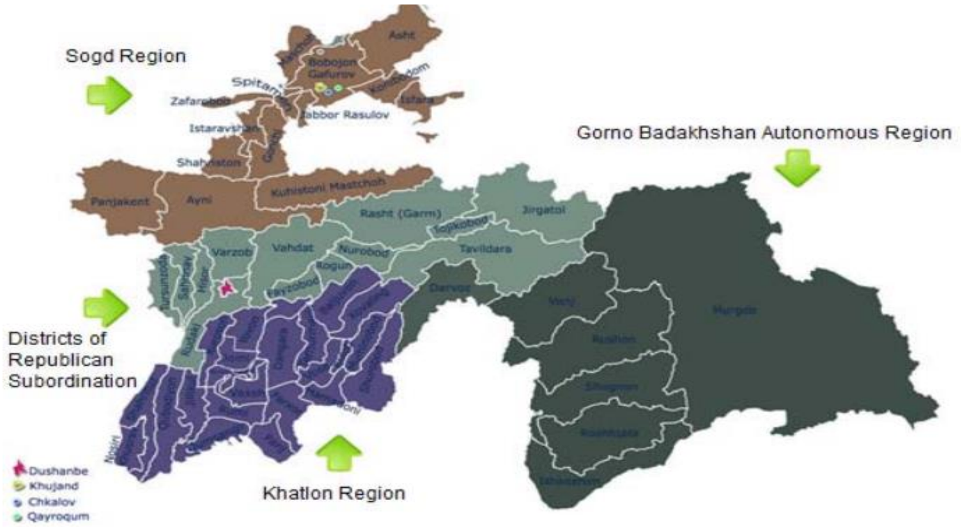
3.1 Glimpse into Tajikistan climate and geographical conditions

The author provides a brief overview of Tajikistan's climate and geographical characteristics in this part, which is crucial background information for comprehending the country's agricultural environment and susceptibility to the effects of climate change.

3.1.1 Geographic Position and Administrative Structure

In the southeast of Central Asia, between 36°40' and 41°05' north latitude and 67°31' and 75°14' east longitude, is the landlocked and mountainous republic of Tajikistan. With a length of 700 km in the west and 350 km in the south, the nation is home to 142,100 km2. Tajikistan borders Kyrgyzstan to the north (987.5 km), China to the east (495 km), Afghanistan to the south (1374.2 km), and Uzbekistan to the west and north (1332 km). Tajikistan is geographically divided from India and Pakistan in the southeast by a 15–65 km wide sliver of Afghan land (Hydromet, 2018).

Figure 1 : Map of Tajikistan



Source: Hydromet,2018

The country of Tajikistan is divided into many administrative-territorial regions, such as the Khatlon Region, the Sughd Region, and the Gorno-Badakhshan Autonomous Region. In addition, it consists of 370 jamoat dekhot, or rural administrative divisions, 62 districts, 18 cities, and 57 urban-type towns. Thirteen districts in Tajikistan's central area are classified as Districts of Republican Subordination (DRS). Notably, Dushanbe, the capital city, has four districts and a distinct administrative structure (Hydromet, 2018).

The country's structure is made up of a series of mountain ranges with intermountain depressions between them, each crowned by a multitude of glaciers and snowfields. These depressions contain deep valleys that support agriculture and operate as the sites of cities and communities housing industrial businesses. Remarkably, 93% of the nation's area is made up of mountains, with peaks reaching heights of 300 to 7495 meters. With more than half of its landmass over 3000 meters above sea level, the republic's severe climate and physical-geographical features—which include a preponderance of rocks, glaciers, and highlands—make it unsuitable for cultivation. Oases make up around 7% of the total land area (Hydromet, 2018).

3.1.2 Climate conditions in Tajikistan

Tajikistan's principal characteristics, strong continentality and aridity, are influenced by its geographical location inside the vast Eurasian continent, far from the main sources of ocean moisture. During the lengthy summer months, the arid environment results in minimal precipitation in the lowlands and foothill areas. The summer dryness is partly mitigated in mountainous locations, but the overall aridity of the environment remains. Tajikistan's climate is influenced by a multitude of elements, the most important of which are solar radiation, air circulation, and orography. Solar radiation plays a crucial impact in defining the republic's climate. Due to the republic's southern latitudes, high solar altitude, lengthy days, and absence of clouds in the valleys during the summer months all contribute to an enormous amount of solar radiation, which is used to heat the earth's surface and surface air because of the more dry soil. As a result, the valleys experience extremely high summer temperatures (Hydromet, 2018)

The influence of atmospheric circulation on climate is crucial, and Tajikistan is no exception. Tajikistan, which is located in the northernmost region of the subtropical zone, is characterized by a regular seasonal change in air masses. Warm tropical air to the south and chilly arctic air to the north indicate the dominance of middle latitude air masses. The arctic and polar fronts' constantly shifting locations aid in the dynamic interplay of these air masses. As a result, frigid and hot tropical fronts alternately affect Tajikistan's area. Summertime brings with it the dominance of continental tropical air, which means that hot, dry weather is common. The complex interaction between these air masses greatly influences the regional climate patterns (Hydromet, 2018).

Tajikistan is subject to the effect of middle-latitude continental air throughout the winter season. When cyclones move throughout Central Asia, Tajikistan sees significant weather variations, including increasing winds, a temporary spike in temperature followed by a significant decrease, and precipitation. When cold arctic air penetrates a valley, precipitation first appears as rain and then changes to snow. Unlike winter, springtime brings a noticeable heightened level of cyclonic activity along with stormy rain as precipitation. Reduced temperature differences between middle latitude and tropical air are thought to be the cause of the cyclonic activity along the polar front lessening in the fall. This results in the warm, dry weather that Tajikistan experiences, which is ideal for agricultural activity. Due to their exposure to moisture-laden western air masses, mountainous regions experience the bulk of precipitation, whereas high mountain regions in the east receive less rainfall. Remarkably, the winter months account for 75% of the yearly precipitation. There is significant regional variance in the average annual precipitation, which can vary from 100 mm to 1,800 mm (Hydromet, 2018).

The climate is greatly influenced by orography, which has a multifaceted effect based on a variety of characteristics including the exposure, steepness, and diversity of relief forms, as well as the height of mountain systems. There are situations when mountain ranges impede the flow of air masses. These mountains operate as barriers to keep out cold air masses, which affects humidity, temperature, and circulation. A unique vertical zonal climate is produced by this complex interplay, varying from a very hot environment in lowlands that is ideal for the growth of various subtropical crops to a frigid zone in highlands covered in snow and ice (Hydromet, 2018).

The atmospheric temperature varies significantly around the nation. Wide valleys, foothills, mountains, intermontane depressions, and high-altitude areas show the most notable variations. From 17 degrees in the southwest to minus 7 degrees in the Pamirs, the average yearly temperature varies greatly. The severe weather of the Eastern Pamirs has known to cause minimum temperatures to drop as low as -63°C. In contrast, the southern region of the nation has the highest absolute maximum temperature of +47°C. The considerable influence of orography on the dynamics of temperature across Tajikistan is highlighted by this climatic variety (Hydromet, 2018).

The dry climate of Tajikistan's region is typified by a lot of heat and notable intra-annual variations in almost every aspect of the environment. The temperature range, moisture content, rainfall patterns, and solar radiation intensity of Tajikistan's climate are all quite varied. Average annual temperatures vary greatly depending on altitude; in the southern parts, they may be as high as +17°C, while in the Pamirs, they can be as low as -6°C. The highest temperatures are usually reached in July, while the lowest are usually reached in January. In the Eastern Pamirs, where the lowest possible temperature might be as low as -63°C, the weather is particularly harsh. On the other hand, the southern region of the country experiences extremely high temperatures up to +47°C. The average annual precipitation in the frigid highland deserts of the Eastern Pamirs and the hot lowland deserts of Southern Tajikistan is between 70 and 160 mm. On the other hand, Central Tajikistan experiences more than 1,800 mm of precipitation annually. The extensive interactions between environmental elements that shape the weather patterns in Tajikistan's many areas are highlighted by this climatic variety (Smutka et al., 2022).

The summer thermal depression and the Siberian anticyclone are two powerful atmospheric phenomena that have a significant impact on Tajikistan's geography. These atmospheric phenomena influence a substantial portion of the Eurasian continent in addition to defining the climate of Central Asia. The predominance of north and northeast winds characterizes both systems, despite their differing thermal consequences. The complex morphology of mountains causes significant distortions in air circulation, which in turn leads to a variety of local circulation patterns that further modify the climate (Smutka et al., 2022).

Tajikistan's diverse climate has led to the identification of discrete zones that have comparable physical and geographical characteristics, all of which contribute to the country's overall thermal regime (Smutka et al., 2022).

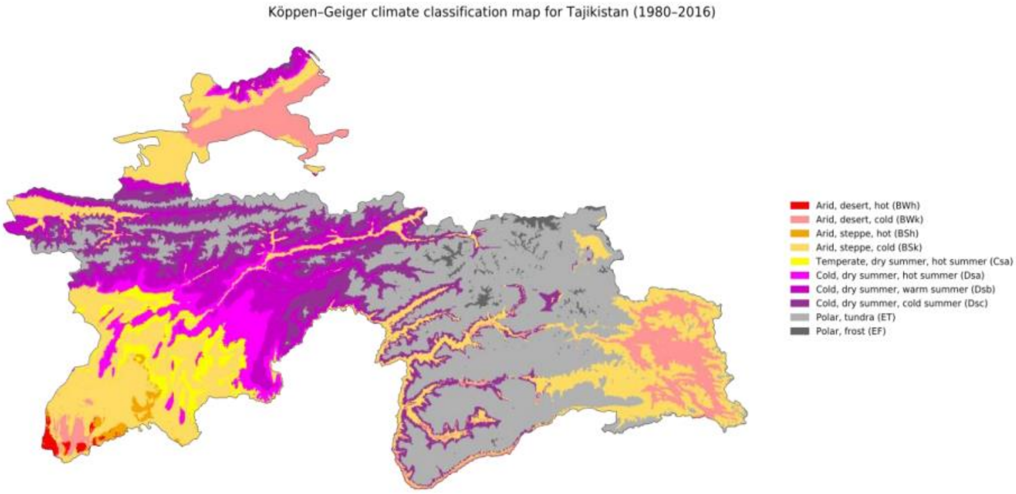
At elevations of up to 1,000 meters, the broad plains and valleys play a crucial role in agricultural and cotton production. These include the Fergana valley, the Lower Kafirnigan, the Kulob, the southwest, Gissar, and the Vakhsh valleys. These regions, which are typified by scorching summer temperatures when the summer thermal depression is dominant, enjoy clear, hot weather with maximum temperatures that may reach remarkable 43–47°C. The summer heat peaks in July, when average monthly temperatures range from 28 to 30°C (Smutka et al., 2022).

At elevations between 1,000 and 2,500 meters, the transition zone includes places like the Zeravshan Valley, hilly parts of Central Tajikistan, and a portion of the Western Pamirs. Although the temperatures are lower, this zone has dry, low-cloud summers. In this zone, a steady drop in temperature with height is seen. In the Zeravshan Valley, the average monthly temperature is 25°C, whereas in the Central Tajikistan highlands, it is 18°C. During this time, the temperature can reach an absolute high of 36–40°C (Smutka et al., 2022).

Areas at high altitude, exceeding 2,500 meters, include mountain ranges and the Central and Eastern Pamirs. These regions are distinguished by exceptionally severe weather, with protracted, chilly winters. January temperatures can dip as low as -14°C to -26°C on average. In the Eastern Pamirs, there are very low temperatures, as low as -63°C. These high-altitude areas experience brief, chilly summers, with typical July temperatures seldom rising beyond +15°C. The range of absolute maximum temperatures is +20°C to +34°C (Smutka et al., 2022).

There are two main zones for Tajikistan's precipitation conditions. With an annual precipitation range of 50-300 mm, the dry climatic zone includes the broad highland region of the Eastern Pamirs, the foothills of the Turkestan Mountain range, and the lowlands in the southwest and north. On the other hand, the remaining portion of the region is in the zone of inadequate moisture, where 900 mm of precipitation falls every year. There are notable outliers, such as humid climatic areas with precipitation exceeding 1800 mm on the windward southern slopes of the Gissar Ridge. While the yearly precipitation cycle varies by location, in general, it follows a pattern of minimal precipitation in the summer and maximum precipitation in the foothills and valleys in March and April, which shifts to April and May in the highlands. Precipitation varies in number of days; the Eastern Pamirs' highland desert experiences the least amount of precipitation, at 50 days. The distribution of snowfall is likewise variable. In the foothills, 15–25% of precipitation falls as snow on average; at higher elevations, this percentage rises to 50–70%, peaking in the Pamirs at 85–90%, including 100% of the Fedchenko glacier. In the lowlands, there are 50–80 days with precipitation of 0.1 mm or more; in the foothills, there are 80–100 days, and at altitude, there are 125 days (Smutka et al., 2022).

Figure 2: Köppen – Geiger Map of Tajikistan

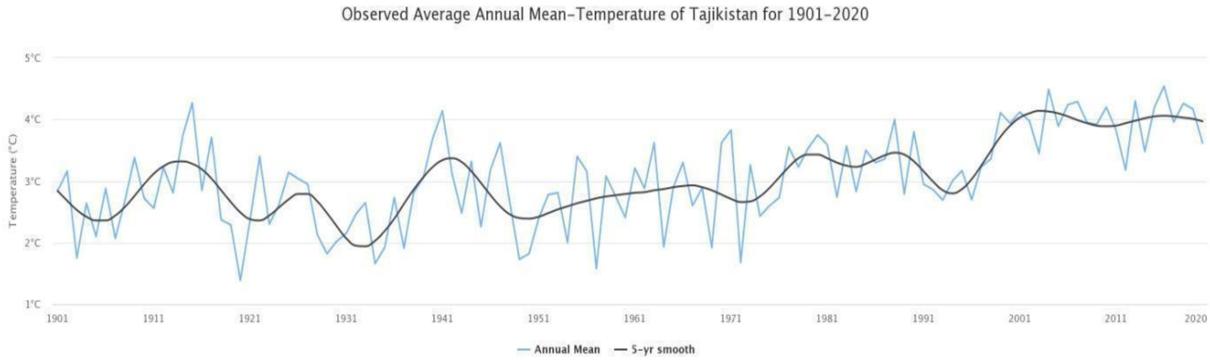


Source: Smutka (2022)

3.1.2.1 Changes in climate conditions and observable trends in the climate

The country, which is on the boundary between the subtropical and temperate zones, is known for its high levels of sunshine, dry, dusty weather, little cloud cover, and dramatic daily and monthly temperature swings. Tajikistan is situated at the meeting point of two major air circulation routes, one from Siberia to the north and one from the tropics to the southeast. This results in substantial regional and annual climatic fluctuation, desertification, and high temperatures. The southern Pamirs experience 17 °C on average annually, whereas the lower Pamirs experience -6 °C. The normal maximum and lowest temperatures are recorded in July and January, respectively. The Eastern Pamirs have recorded minimum temperatures as low as -50 °C, while the southern region may have maximum surface air temperatures higher than 40 °C. Rainfall in the lowlands, hot deserts of northern Tajikistan, and cold mountain deserts of the eastern Pamirs ranges from 70 to 160 mm annually, with the highest amounts occurring in central Tajikistan. Droughts occur most frequently in July, August, and September since these months get the least amount of precipitation. Figure 3 shows that the ten years 2001–2010 were the hottest since Tajikistan started keeping track of its temperatures using instruments in 1901. The temperature rose by almost 1oC over the long-term average in the lowland regions, 0.8oC in the center, and 0.2oC in the hills. The average annual temperature increases between 1930 and 2010 was 0.1 °C. Every year, the weather remains incredibly unpredictable, mostly because of atmospheric circulation mechanisms that bring in unusually hot or cold air.

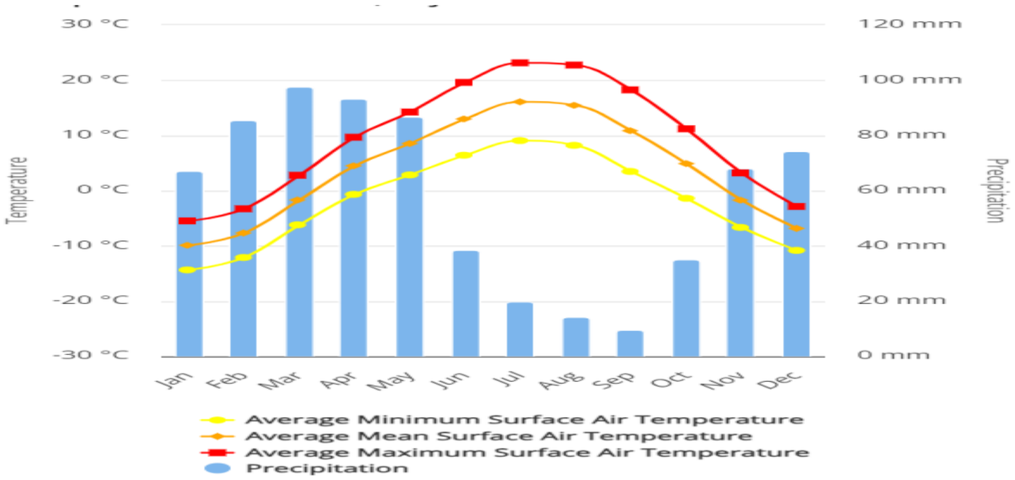
Figure 3: Observed average annual mean – temperature of Tajikistan for 1901–2020



Source: (Smutka et al., 2022).

As observed in Figure 4, temperature increases over the past century have been greatest in the fall and winter and lower - less noticeable - in the spring and summer. The microclimate of the location affects the precipitation trend, which is quite variable. Generally, there was a 5–10% rise in the average annual precipitation. The frequency of rainy days has actually reduced in certain places, and this rise is mostly linked to occurrences with higher intensities. Due to this, there have been several exceptionally dry years recently, most notably in 2000, 2001, and 2008, when rainfall was 30–50% below average. The 20th-century variations in the precipitation regime are consistent with worldwide patterns. There is a positive correlation between temperature and extreme rainfall, as supported by data from several Asian nations. Future projections indicate that this tendency will persist (Smutka et al., 2022).

Figure 4: Monthly Climatology of Min Temperature and Mean Temperature, Max Temperature and Precipitation 1991-2020 for Tajikistan



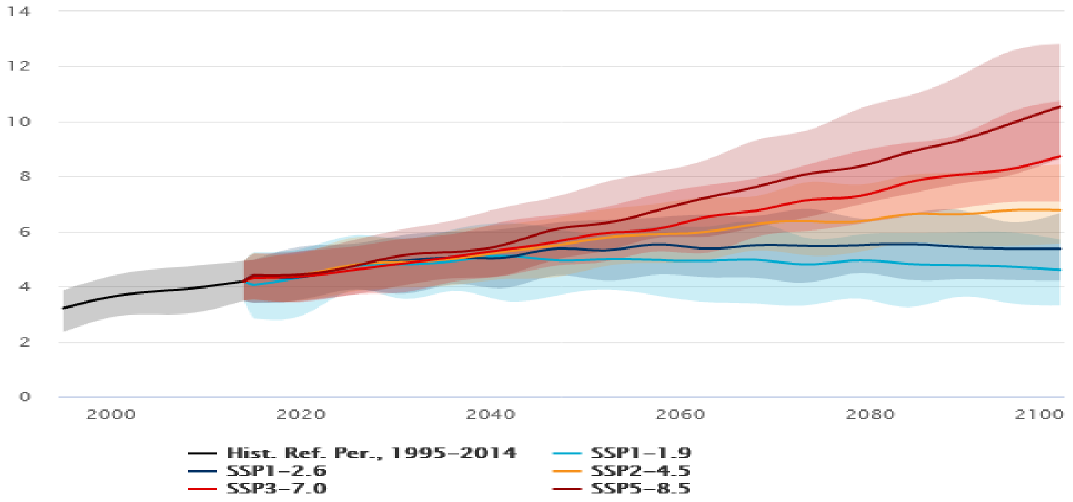
Source: Climate change knowledge portal (2022)

3.1.2.2 The predicted climate change, threats

Climate change poses significant challenges to Central Asia, a region characterized by diverse ecosystems and vulnerable socio-economic structures (Kummu et al., 2016). This region, comprising countries such as Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, faces various climate-related threats, including water scarcity, desertification, and the melting of glaciers. Central Asia heavily relies on water resources from rivers originating in glaciers and snowpack in the mountains, making it particularly vulnerable to changes in precipitation patterns and glacier retreat (UNDP, 2020). The projected increase in temperature and altered precipitation regimes exacerbate water stress and heighten the risk of conflicts over water resources, especially in transboundary river basins (UNEP, 2021). Additionally, the region's agricultural sector, a vital source of livelihood for many, is at risk due to decreased water availability, soil degradation, and increased frequency of extreme weather events (UNDP, 2020). Moreover, climate change impacts in Central Asia intersect with other socio-economic challenges, such as poverty, political instability, and limited access to technology and resources, further complicating adaptation efforts (ADB, 2017).

Most projections of Tajikistan's climate change indicate a significant increase in average yearly temperatures. The amount of this rise depends on several aspects, including the carbon dioxide (CO2) production scenario, the particular climate model that is used, and the time period that is selected. By 2080, Tajikistan's average annual temperature is predicted to rise by 1.3–6.3 °C relative to the baseline period of 1986–2005, with variances driven by different emission scenarios. The Climate Risk Country Profile for Tajikistan (2021) offers a corresponding forecast that is consistent with the general agreement that temperatures will rise. This curve indicates that by 2080, average temperature increases might range from 1.5 to 5.8 °C. These projections highlight how urgent it is to combat climate change and put in place efficient mitigation and adaptation strategies in order to manage any potential effects that rising temperatures may have on Tajikistan's ecosystems and climate (Smutka et al., 2022).

Figure 5: Projected Mean Temperatures, Tajikistan. Reference period 1995-2014, Multi-Model Ensemble

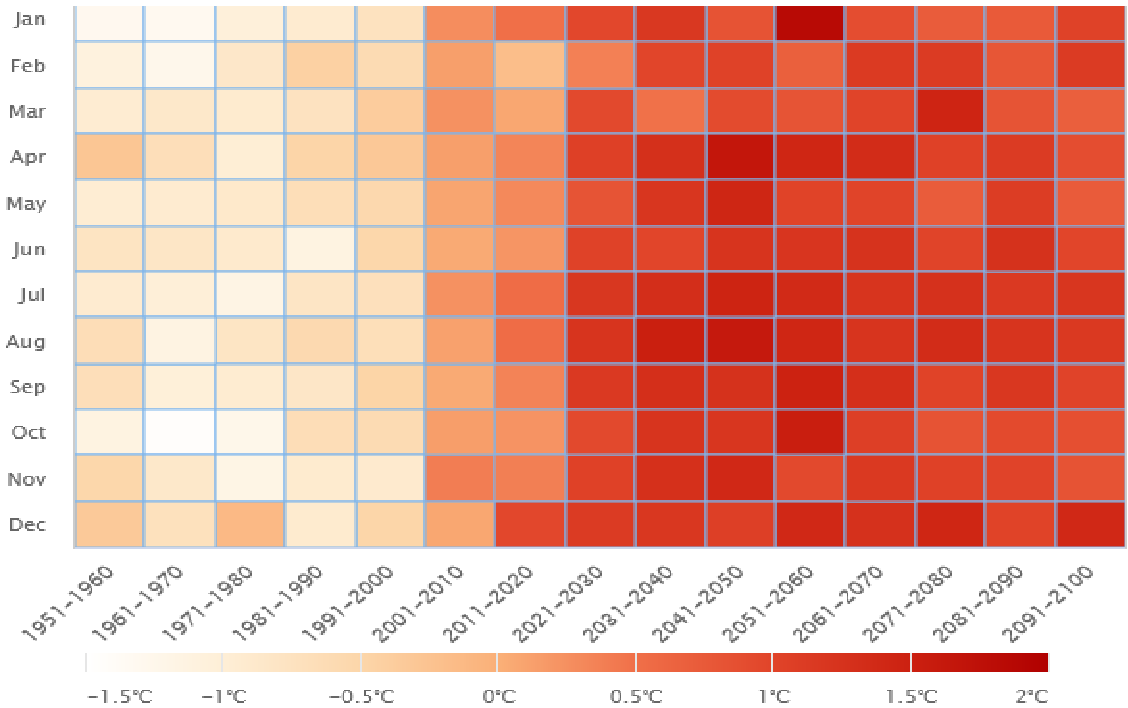


Source: Climate change knowledge portal (2022)

According to several models, Tajikistan's temperature would rise steadily until around 2040. After then, there will be significant swings in temperature until 2100, as shown in the Climate Change Knowledge Portal (2022, Figure 5). Interestingly, a few of these scenarios even consider a drop in mean temperatures, provided that additional positive developments occur in variables like greenhouse gas emissions. This draws attention to the inherent uncertainty in long-term climate forecasts and emphasizes how crucial it is to take proactive steps to reduce emissions and promote sustainable practices in order to affect how Tajikistan's climate develops in the future (Smutka et al., 2022).

According to the projections, the impact of particular climate models or scenarios on rising temperatures becomes more noticeable after 2040. The effects of emission models may be successfully avoided from the research since this study concentrates on the period up to 2040, enabling a concentrated emphasis on trend forecasts. Furthermore, there are no appreciable differences in the geographical distribution of the temperature increase by 2040, with an average increase of around 1 degree Celsius (Smutka et al., 2022).

Figure 6: Projected Mean-Temperature Anomaly, Tajikistan Reference period 1995-2014, Multi-Model Ensemble.



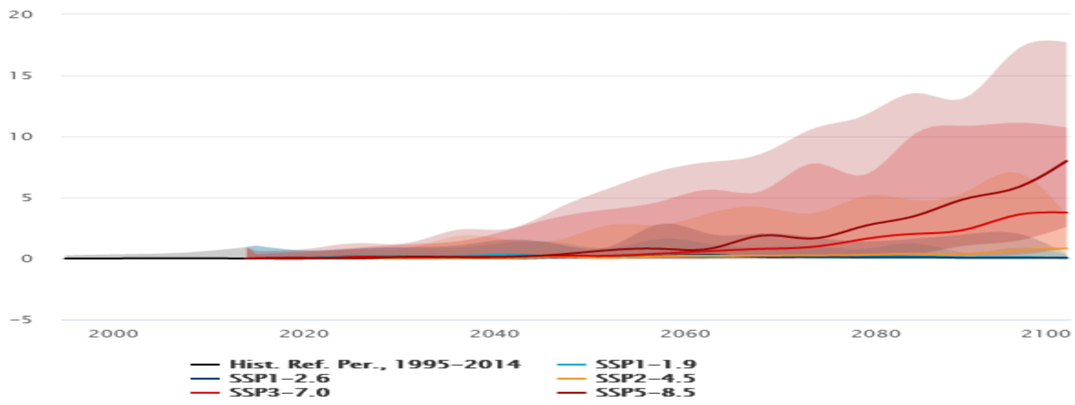
Source: Climate change knowledge portal (2022)

The predicted shift in average temperatures by 2040 is that the most significant changes are likely to occur during the summer, up to 1.2 °C, with the least noticeable shifts occurring in February (+0.37 °C) and, rather surprisingly, in May (+0.81 °C) (Figure 6, ibid). Tajikistan's agricultural output is challenged by this temperature variation, especially in areas where summers are already marked by high temperatures. The increased heat is bad for a lot of different types of crops, makes irrigation more important, and makes people worry about possible health risks. For Tajikistan's population to be safe and agricultural techniques to be managed sustainably, it is imperative that the implications of these temperature shifts be taken into consideration (Smutka et al., 2022).

A unique set of difficulties arises from the very little increase in mean temperature that is predicted for February, especially for farmers who frequently move forward the planting season from March to February. The possibility of unexpected frosts during this change in planting dates might significantly harm crop productivity. However, it is possible that this specific issue might be reduced by the additional temperature rises predicted beyond 2040. Controlling these little differences in temperature becomes essential for agricultural planning and emphasizes the necessity for adaptive techniques that take into account Tajikistan's long-term climatic patterns in addition to its immediate problems (Smutka et al., 2022).

Like average temperatures, the number of days anticipated to have a heat index higher than 35 °C (Figure 7) indicates the frequency of heat waves, which increases from 2040 onward and is outside the purview of this research. There are notable differences in the expected number of such scorching days per area. By 2040, there shouldn't be a rise in the number of days in the Sogd region—which includes districts like Kuhistoni Mastchoh and Kanibadam—where the heat index would be higher than 35 °C. The anticipated increase in the central part of Tajikistan, which includes districts like Gissar and Fayzabad, is 0.32 days. On the other hand, the Khatlon region—which encompasses areas like Muminabad and Shaartuz—expects a significant increase in the number of hot days of 3.53 days. It's important to note that Kuhistoni Mastchoh and Fayzabad are located on the boundary between two zones, indicating that the degree of change in these transitional places may vary (Smutka et al., 2022).

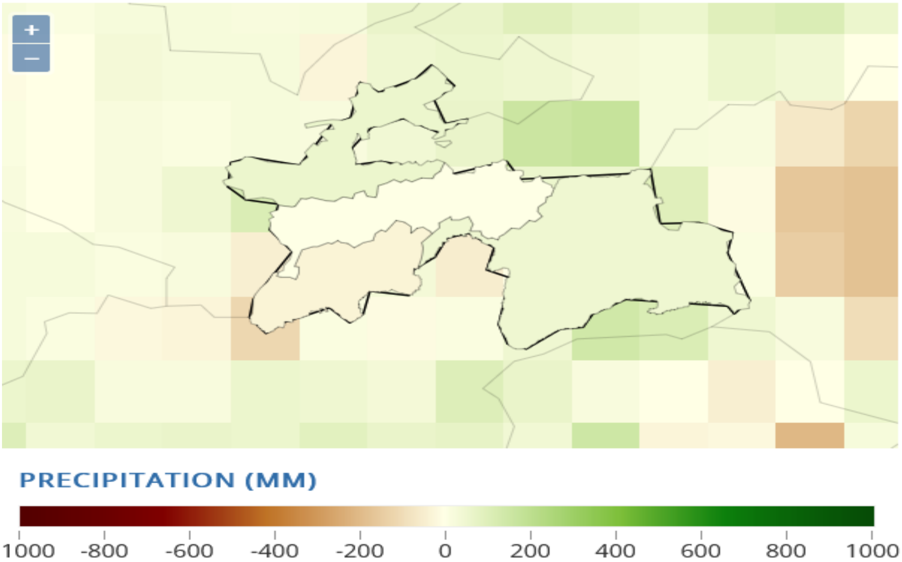
Figure 7: Projected days with heat index >35 °C, Tajikistan, Reference period 1995-2014, Multi-Model Ensemble



Source: Climate change knowledge portal (2022)

Figure 8 clearly shows significant intra-regional differences in precipitation forecasts. By 2040, there will likely be a significant 53 mm rise in total precipitation in the Sogd area. On the other hand, the anticipated growth in the central area of Tajikistan is expected to be quite low, totaling just 0.51 mm throughout the same time frame. By 2040, precipitation in the southern Khatlon region is expected to drop by -31 mm, presenting a different picture. The aforementioned geographical variances highlight the intricate nature of precipitation patterns, underscoring the necessity of employing customized and refined strategies in the management of water resources and agricultural planning throughout Tajikistan.

Figure 8: The projected precipitation anomaly 2020-2040, Tajikistan, Reference period 1995-2014, Multi-Model Ensemble



Source: Climate change knowledge portal (2022)

3.2 Tajikistan Economy

The author analyzes Tajikistan's economic situation in section 3.2, providing details on the nation's main industries, trading patterns, and economic difficulties.

3.2.1 Key economic metrics and features.

In addition to overcoming major economic obstacles since attaining independence in 1991, Tajikistan also survived the 1990s civil conflict. The country emphasised the concepts of sustainable development by promoting a democratic society and a market economy as it moved from a post-conflict state to an economically viable nation after the civil war ended in 1997. The start of economic reforms in Tajikistan was accompanied by a convoluted political environment. Between 1991 and 1996, Tajikistan's real GDP fell by around 68%, an extreme dip. Indicators for industry fell by 14.3% and those for the transportation sector fell by -2.1% between 1992 and 1994, according to the GDP's sectoral breakdown. Compared to 1990, industrial production in 1994 was just 41.9%. Following these difficult years, the economy stabilized somewhat between 1997 and 2007 thanks to advantageous external circumstances. During this time, exports doubled and global prices rose, especially for cotton and aluminium. As a result, production capacity grew and total factor productivity climbed. At the same time, there was a noticeable surge in domestic demand for goods and services, especially for agricultural products. Between 2000 and 2013, Tajikistan's international trade turnover increased by more than 3.8 times, while the economy of the nation grew at yearly rates of 7–8% throughout this time. The average annual GDP increase per person from 1990 to 2013 was $21.7 US dollars, or 4.1%. GDP increased by 49% throughout this time, from $536 in 1990 to $1,051 in 2013. With 8.5 million inhabitants as of 2016, Tajikistan is still the poorest nation in the Commonwealth of Independent States (CIS) notwithstanding these efforts. The GDP per capita is just over $800, and more than 70% of people live in rural regions. Moreover half of the people live in poverty, with a daily income of less than $2.15. Despite these obstacles, the economy of the whole country has grown dynamically in recent years, with an annual growth rate of more than 7%, offering promise for an improvement in the difficult economic conditions (Hydromet, 2018).

Three major short-term strategic objectives guide Tajikistan's economic policy. The country's present economic growth objectives are centered on eliminating transportation isolation, guaranteeing food security, and establishing energy independence. The Tajikistani government is actively seeking out international investment to support these industries and establishing the framework for further industrial growth. Tajikistan hopes to improve its economic resilience, lessen its reliance on outside forces, and promote a more sustainable and independent economic environment by pursuing these strategic goals. The nation's active participation in foreign investment demonstrates its dedication to utilizing outside resources for domestic development and fostering an atmosphere that supports industrial expansion (Hydromet, 2018).

The economy of Tajikistan is mostly agro-industrial, with a basis in agriculture that includes agricultural production, animal husbandry, and cotton cultivation. The economy is also influenced by industrial sectors such consumer products, mineral fertilizers, mechanical engineering, aluminum manufacturing, textile and light industries, and energy. The nation's overall situation is impacted by economic and geographical constraints, including as relative remoteness, communication isolation, high-altitude topography, and limited access to the sea. The GDP of Tajikistan increased by 43.8% between 2010 and 2019, with growth in agriculture accounting for 45.2%, industry for 70%, construction for 24.2%, transport and communications for 15%, and services for 51%. 2019 had an overall GDP of 8.1 billion US dollars, or 840 US dollars per person. With 19.8% going to agricultural goods, 17.4% going to industry, 8.8% going to construction, 34.7% going to the service sector, 8.9% going to transport and communications, and 10.4% going to net tax on products, the GDP structure shows substantial contributions from a number of sectors. By the end of 2018, Tajikistan's public external debt had increased significantly from 24% of GDP in 2014 to $2.9 billion, or 40% of GDP (Hydromet, 2022).

Table 1: Dynamics of the main macroeconomic indicators of the Republic of Tajikistan for 2010-2019

Indicators,	**Years**					
Mln. dollars, %	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Total GDP	5642,2	7852,8	6952,8	7157,9	7765	8116,9
Agriculture	1105,1	1722,3	1416,7	1458,5	1535,3	1604,9
% to GDP	19,6	21,9	20,4	20,4	19,8	19,8
Industry	831,8	1042,5	1055,2	1086,3	1642,6	1415,3
% to GDP	14,7	13,3	15,2	15,2	21,2	17,4
Construction	577,3	872,8	838,4	863,2	1028,5	717,0
% to GDP	10,2	11,1	12,1	12,1	13,2	8,8
Transport and communications	629,8	977,5	882,7	908,7	467,4	723,6
% to GDP	11,2	12,4	12,7	12,7	6,0	8,9
Service sector	1863	2243,4	1975	2033,2	2324,2	2812,6
% to GDP	33,0	28,6	28,4	28,4	29,9	34,7
Net tax on products	635,2	994,3	784,8	807,95	767,0	843,4
% to GDP	11,3	12,7	11,3	11,3	9,9	10,4

Source: (ASUPRT, 2021)

The President of Tajikistan emphasized in his 2021 address to the Parliament of the country the ongoing harm that the COVID-19 pandemic has caused to the world's economies, as well as the growth of the country's economy, the state budget, international trade, exchange rates, and the functioning of businesses and service organizations. Tajikistan's GDP reached 8.25 billion US dollars at the end of 2020, indicating a 4.5% growth rate, however 3% less than the 7.5% growth rate recorded in 2019. Based on preliminary data, the inflation rate in 2020 was reported to be 9.4%, which is a 1.4 percentage point increase over the 8% rate in 2019. The President emphasized in his speech the persistent difficulties caused by the epidemic and its ripple effects on other facets of the nation's economic environment (Hydromet, 2022).

3.2.1.1 Recent economic developments

In 2022, Tajikistan experienced an unusually low inflation rate and achieved outstanding economic development despite global inflation and regional insecurity. Remittances from abroad and the growth of the industrial and service sectors propelled the nation's economic activities. In 2022, the real GDP increased by 8%, indicating a significant improvement over the year before. Because to the country's strong exchange rate and smart monetary policies, Tajikistan has the lowest inflation rate in the area. The consumer price inflation rate was 4.2% at the end of 2022 and remained low in the first half of 2023, indicating a persistently strong economy and prudent budgetary management in the face of international economic difficulties (World Bank, 2023).

By sustaining a current account surplus for the third year in a row and achieving a record-breaking surplus of 15.6% of GDP in 2022, Tajikistan has proven its remarkable economic resilience. But increased imports and the government's calculated choice of saving more gold domestically led to an increase in the trade imbalance and a decline in exports. Fortunately, the country's significant remittance inflows—which make up about 50% of GDP—helped to successfully balance this deficit. The mining sector has grown to be a significant draw for foreign direct investment, supporting the stability of the national economy. Significantly, overseas reserves rose to cover more than nine months' worth of imports, demonstrating Tajikistan's prudent fiscal management and resilience in the face of economic difficulties (World Bank, 2023).

In the years 2021–2022, Tajikistan successfully decreased its total fiscal deficit from more than 3 percent in 2020 to about 1.2 percent. A number of strategies, such as improved development partner grants, expenditure control policies, and more non-tax income, were used to attain this goal. But the implementation of a new tax system had a negative impact on revenue from taxes, which dropped by 1.5% in comparison to pre-pandemic levels. In spite of this setback, the administration emphasized capital investment in the energy and transportation sectors, particularly the Rogun hydropower project (HPP), and gave public sector salary hikes and social payments first priority. The amount of national debt demonstrated a significant reduction from 46.5 percent of GDP in 2020 to 34.8 percent in 2022, which may be attributed to strong economic expansion and the strengthening of the Tajik somoni. However, Tajikistan continues to be very vulnerable to financial trouble, especially given the impending Eurobond repayment in 2025–2027 (World Bank, 2023).

The rate of poverty in Tajikistan decreased in 2022, and labour migration became an essential source of income for many households who were previously vulnerable. Under the US$ 3.65 (2017 PPP) international poverty threshold, the rate of poverty dropped to 13.4%. In contrast to previous predictions, labour migration increased significantly; according to sources, between one-third and half of families had at least one member who was employed overseas as a migrant. Remittances were crucial in reducing poverty; more than 80% of remittances were used for food consumption, with the remaining 10% going toward other necessities including housing, healthcare, and education. This emphasizes how important labor migration and remittances are to raising Tajikistani households' economic standing. At now, Tajikistan's social assistance program covers just around 15% of the population, making it the smallest in the Europe and Central Asia area. As a result, in order to improve benefit levels and promote greater justice among social transfer users, authorities have started a reform of social assistance. Enhancing the identification of underprivileged households is another goal of the reform, highlighting Tajikistan's dedication to increasing the scope and effectiveness of social assistance. These initiatives are in line with more general goals to combat social injustice and offer more thorough assistance to disadvantaged populations (World Bank, 2023).

3.3 Agriculture Sector in Tajikistan

The author analyses Tajikistan's agricultural industry in section 3.3 of the literature review, looking at academic publications and current research to clarify the industry's economic significance, difficulties, and opportunities for sustainable growth in the face of changing weather patterns.

3.3.1 Characteristics and development of agriculture

One of the most important economic sectors of Tajikistan is agriculture, which is essential to accomplishing the strategic objective of guaranteeing food security. Because it continuously boosts and strengthens agricultural production, this industry currently accounts for 20–23.5% of the GDP. This expansion in turn promotes social employment and higher earnings, which in turn promotes economic development and the systematic provision of food supplies to the populace. Furthermore, the focus on environmentally friendly farming methods helps to protect natural resources. When compared to 1991, Tajikistan's agricultural production increased significantly by

69.1% to 22.2 billion somoni in 2016. This expansion highlights the industry's tenacity and crucial position in the country's economy (Hydromet, 2018).

Throughout its history, Tajikistan has been primarily an agrarian nation, with a stronghold on agricultural output even while industry flourished under the Soviet era. About one-third of the nation was covered by agricultural land in the late 1980s, with state and collective farms serving as the main production sites, however homestead plots produced a sizable amount of the fruits and vegetables. In 2011, the total area of arable land in Tajikistan was 14,255.4 thousand hectares, of which 3,746.0 thousand hectares were used for agriculture, or 77.6% of pastureland. 1,317.8 thousand tons of grain, 372.7 thousand tons of cotton, 1,549.5 thousand tons of vegetables, 545.7 thousand tons of melons, 328.5 thousand tons of fruits, and 175.3 thousand tons of grapes were produced in the nation in 2014. Notably, up to 90% of the fiber from cotton is exported, making it a significant revenue crop. Cotton fiber exports from the country decreased somewhat from 132.9 thousand tons in 2005 to 95.3 thousand tons in 2010 (ASUPRT, 2021).

Although Tajikistan harvested around 850,000 tons of raw cotton in 1990, the production of all agricultural products fell precipitously in the early 1990s political and economic crises. The Ferghana, Vakhsh, and Hissar valleys were the main cotton-growing regions; these valleys also produced melons, grapes, and lemons. During the Soviet era, food crops were reduced in order to expand cotton farming. Tobacco, potatoes, and grains were farmed in the higher alpine areas. A few state and collective farms focused on raising cattle, as well as sheep, goats, pigs, and poultry. Currently, the nation's economy still greatly benefits from cattle breeding; as of 2013, there were 2,099.1 thousand cattle and 4,738.4 thousand sheep and goats registered (ASUPRT, 2021).

The people of Tajikistan possess the majority of animals, which include 92.3% of cattle and 83.1% of sheep and goats. State and communal ownership are the most common types in agriculture; nevertheless, as of 2010, Tajikistan has five state farms and one collective farm. communal farms function under numerous names. 87,594 farms made up the republic's agrarian sector in 2014; these included 6 agrofirms, 15 joint-stock companies, 499 subsidiary farms of agricultural enterprises and organizations, 350 state farms, 119 associations of private (dekhan) farms, 690 collective dekhan farms, and 73,806 dekhan farms. By 2003, state and collective farms accounted for around 80% of cotton output, with schoolchildren harvesting 40% of the crop. After 400 state farms were converted, 2.7 thousand big private farms with an average of 75 hectares of arable land were established. Plans were in place by 2005 to privatize and reorganize the 225 state farms that remained (ASUPRT, 2021).

The implementation of agricultural reforms in 2016 in Tajikistan has resulted in notable improvements in diverse agricultural outputs, therefore advancing the country's trajectory towards self-sufficiency. A total of 1,435.8 thousand tons of grain, 898.0 thousand tones of potatoes, 1,748.2 thousand tons of vegetables, 594.1 thousand tons of melons, 364.7 thousand tons of fruits, 214.7 thousand tons of grapes, 233.3 thousand tons of meat, and 917.9 thousand tons of milk were produced. 168.4 kg of grain, 105 kg of potatoes, 204 kg of vegetables, 69.4 kg of melons, 42.5 kg of fruit, and 24 kg of grapes are produced per person in this way. With 118 poultry firms in 2016 compared to just 8 in 2007, the poultry sector has experienced significant expansion. 357.2 million eggs and 5,143 thousand birds had been grown as of January 1, 2016. Positive changes have also been observed in the livestock sector, as evidenced by growth in the numbers of sheep, goats, and horses (from 3,355 thousand in 1991 to 5,456 thousand in 2016), as well as cattle (from 1,390.7 thousand in 1991 to 2,278 thousand in 2016). Beekeeping has also prospered, with 210.3 thousand bee colonies and 3,852.8 tons of honey produced as of January 1, 2016, up 29.7 thousand bee colonies and 2,652.8 tons of honey from 2011. There has been a notable increase in the number of fish farms, which has increased from 8 in 2008 to 220 in recent times. In comparison to 2008, fish output has climbed to 2,023.3 tons, with a total area of 5,961.01 hectares for fish farms and 2,720.19 hectares for water planes. This represents increases of 222.6% and 173.4%, respectively (Hydromet, 2018).

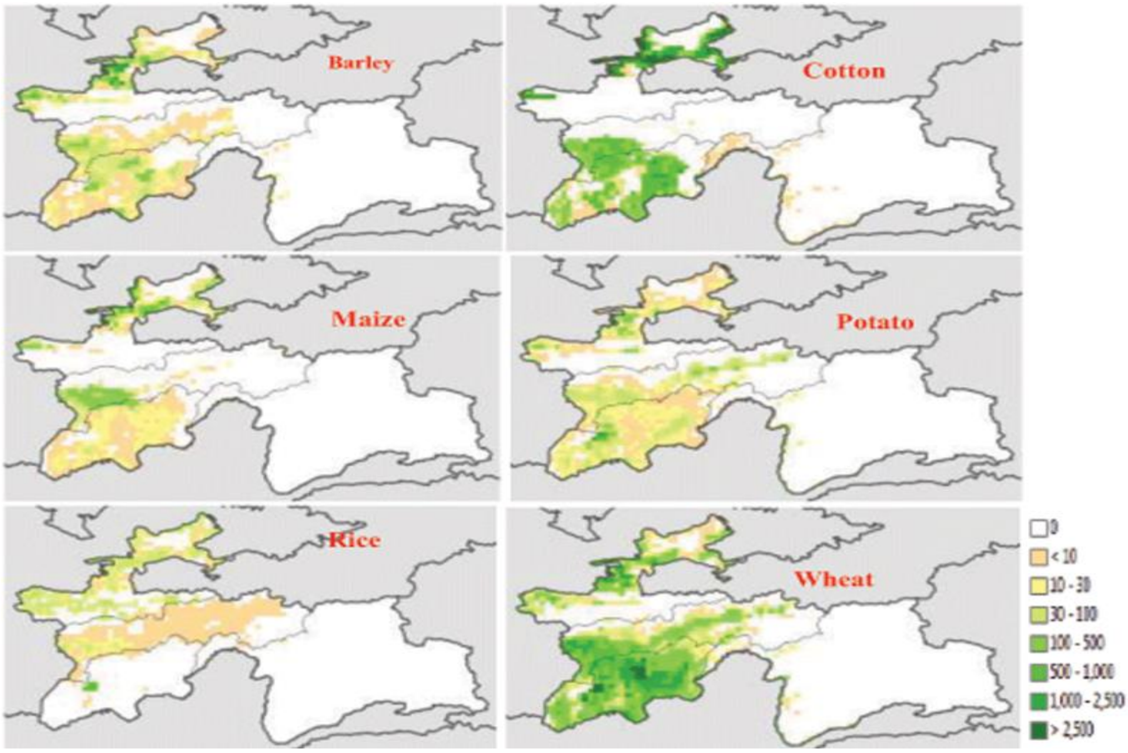
3.3.2 Recent trends

As of the end of 2019, crop production accounted for 69.1% of Tajikistan's gross agricultural output, with animal husbandry contributing 30.9% of the total. The following was how this output was distributed: 56% of homes, 39% of dehkan farms, and 5% of the public sector. Remarkably, 39% of agricultural output and more than 93% of livestock products were produced on the population's subsidiary farms. Between 2011 and 2019, the extent of agricultural land did not significantly change in terms of land use. In 2019, there were 3,669,411 hectares of total agricultural land. Of that, 76.8% was grazing land, 4.1% was permanent plantations, 0.7% was deposits, and 0.4% was hayfields. Arable land made up 18% of the total agricultural land (Hydromet, 2022).

According to data from the Republic of Tajikistan's State Committee for Land Management and Geodesy, as of 2018, agricultural enterprises accounted for around 30% of the country's total agricultural land area. KDF (2.7%), state farms (14.4%), inter-farms (1.8%), and other agricultural businesses (10.7%) were among the agricultural firms in this category. The bulk, or 70.3%, was owned by dehkan farms, which comprised 7.4% of the population's home plots. When the 659 thousand hectares of arable land were analyzed, agricultural firms accounted for 18.6% of the total, while dehkan farms claimed 81.4%, with home plots comprising 27.4% of the area. In 2018, just 70% of the arable land was classified as being under irrigation. There were 182,756 dehkan farms in Tajikistan in 2019, which is more than twice as many as there were in 2013. Dehkan farms typically occupied 15 hectares of agricultural land, of which 3.1 hectares were arable, 0.7 hectares were planted with permanent crops, and 11 hectares were pastures (Hydromet, 2022).

Crop production accounts for a large 69 percent of sectoral value-added in Tajikistan's agricultural environment. The main agricultural zones, which are located in the DRS, Sughd, and Khatlon, determine the agricultural production of the country. But much of the nation's hilly landscapes are not ideal for farming. The majority of crop production occurs in valleys, which are made possible by irrigation—including pump irrigation—and zones that receive rainfall that falls downward. Notably, 90% of the world's gross agricultural production comes from irrigated land (GAO). The distribution of particular crops indicates regional specialty for example, Khatlon is well-known for cultivating cotton and wheat, whereas Sughd produces a sizable amount of barley, maize, and rice (figure 9). Water consumption has decreased recently compared to 1990, mostly as a result of less area being used for cotton farming. Furthermore, irrigation accounts for more than 80% of the nation's total freshwater consumption, demonstrating the vital function that water plays in Tajikistan's agricultural methods (Khakimov et al., 2020).

Figure 9: Allocated land under main crops in Tajikistan, in hectares.



Source: (Khakimov et al., 2020)

The predominant crop in Tajikistan's crop output is grain, which accounts for 45.4% of all seeded lands. Industrial crops come in second at 26%, with a sizeable share (22.5%) going to cotton. Potatoes, vegetables, food melons, and fodder crops make up the remaining noteworthy contributions to the seeded lands, with 6%, 8.3%, and 12% of the total. 58% of grain harvests came from dehkan farms in 2019, with subsidiary farms of the people producing 33.5% of the overall volume of grain crops. In a similar vein, 22% of rice came from population houses and 60% from dehkan farms. Potato production was split 33% in homes and 60% in dehkan farms. The amount of raw cotton produced in 2018 was 300.3 thousand tons, a 23% drop from 2017. Dehkan fields generated more than 80 percent of the volume of raw cotton produced overall (Hydromet, 2022).

With animals accounting for more than 30% of all agricultural output, animal husbandry is an important part of Tajikistan's agricultural industry. Notably, the volume of gross livestock output increased by a significant 40% between 2013 and 2019. It is important to emphasize that homes play a major part in this industry, producing 94% of the meat, 95% of the milk, and 40% of the eggs. Over 93% of families actively participate in the production of cattle. The number of cattle in Tajikistan increased by 18.5% between 2011 and 2019, demonstrating the significance and expansion of this essential sector of the country's agricultural economy (Hydromet,2022).

3.3.3 Projections

The agricultural industry in Tajikistan is strong and varied, focusing on important crops including potatoes, wheat, melons, onions, and other vegetables. The main aim of agricultural production is to fulfil the demands of domestic consumption. However, the consequences of climate change, which may have both direct and indirect effects on vital agricultural growth processes, provide major concerns for the sector. Changes in temperature regimes, precipitation patterns, and carbon dioxide availability are examples of direct consequences. The availability and seasonality of water resources, changes in soil organic matter, increased soil erosion, changes in pest and disease profiles, the introduction of exotic species, and the loss of arable land due to desertification are some of the factors that mediate indirect consequences. These diverse effects draw attention to how susceptible Tajikistan's agricultural environment is to the intricate interactions between changing climate conditions (Smutka.., 2022).

Tajikistan's agricultural production is expected to have a mostly negative trend. Important crops like wheat, barley, maize, vegetables, and fruits are predicted to see output reductions of between 5% and 10% by 2050, according a research. Conversely, small growth of less than 5% may be seen in rice, potatoes, and cotton. Crop yield shifts like this one have the potential to put at risk community well-being and national food security. Interestingly, opinions on wheat, a vital staple crop, differ significantly. According to some research, temperatures rising may eventually improve growing conditions for wheat, perhaps leading to a 12% increase in yields. However, the stability of agricultural production is threatened by the anticipated rise in the likelihood of heatwaves and droughts, and there may be losses in net productivity overall. It is critical to proceed with care when making these estimates since climate models sometimes evaluate ordinary circumstances without accurately accounting for the effects of climatic extremes. In the farther future, worries are raised over the melting glaciers and decreasing snowpack, which might result in a big decrease in the amount of water that is accessible and increase the likelihood of severe water shortages for agriculture (Smutka., 2022).

3.3.4 Climate change impact in the agriculture sector of Tajikistan

Climate change (CC) and variability continue to be major global challenges for humanity. The negative consequences are especially dangerous for developing countries whose economies rely on climate-sensitive livelihoods with limited adaptation capacity (Belay et al, 2023).

The agriculture industry of Tajikistan is expected to be significantly impacted by climate change. Reduced agricultural output and increased vulnerability to natural disasters are the two main categories of issues that are predicted to result from the predicted changes in temperature, precipitation, and related hazards. The country's capacity to maintain and increase agricultural output is seriously threatened by these changes, which emphasizes the urgent need for adaptive methods to reduce any possible negative consequences on food security and the general well-being of the populace. In order to strengthen resilience in Tajikistan's agricultural environment, proactive measures and sustainable farming practices are vitally important given the country's combined challenges of declining production and an increased risk of natural catastrophes (Hydromet, 2022).

It is believed that a decline in water availability will be the main cause of Tajikistan's predicted drop in agricultural production associated with climate change. This decrease is also expected to be attributed to the direct stress that high temperatures place on animals and crops, as well as a possible spike in bug populations. Reduced water availability, especially in the country's driest areas, can have severe economic consequences, especially for small-scale farmers who are already struggling with the effects of climate change and related extreme weather. This emphasizes how critical it is to use sustainable water management techniques and adaptation methods in order to strengthen Tajikistan's agriculture sector's resilience to changing climatic trends. The decrease in water availability, which is a major contributing element to Tajikistan's declining agricultural output as a result of climate change, is expected to be impacted by a number of interrelated issues. First, it is anticipated that a decrease in precipitation across the nation would lead to dry conditions, which will lower animal and agricultural harvests. Second, the water cycle is about to be upset by faster and more severe glacier melting, which will result in greater flooding during the rainy season and longer droughts during the dry season. Finally, the anticipated rise in temperature of 1.8–2.9°C by 2050, along with an increased rate of evaporation, is anticipated to raise water consumption by 20–30% throughout this time frame. Comprehensive solutions are required to limit the impact on water resources and ensure agricultural sustainability due to the intricate interaction of climate-related variables. The expected increase in mean temperature as well as an increase in the frequency of high temperatures is expected to have an immediate impact on Tajikistan's agricultural systems. Increased heat stress and increased heat-related mortality in animal husbandry are major challenges to animal productivity. This stress affects crop output as well as pastures, raising the possibility of crop failure quickly owing to heat-related issues and perhaps causing pasture deterioration. Moreover, high temperatures may exacerbate crop quality deterioration and increase susceptibility to pests and illnesses. Even with possible benefits like an extended growing season and fewer frigid days, most farmers in the area will probably continue to suffer from the current economic consequences (Hydromet, 2022).

It is clear from evaluations and research already in existence that Tajikistan's socioeconomic landscape is vulnerable to several threats from climate change. Climate change has the potential to negatively impact the interrelated problems of food security, health, livelihood assets, food production, and distribution networks. This includes the possibility of poverty getting worse due to lower agricultural output and higher food costs. Forecasts about the effects, vulnerability, and adjustments in Asia, which includes Central Asia, emphasize the approaching difficulty of water shortage in the area. The main agricultural valleys in Tajikistan show signs of being especially vulnerable to climate change, raising questions about the availability of water. It is projected that the effects of climate change on Tajikistan's agricultural revenues would be crop-specific, highlighting the complex issues that the country confronts. To comprehend the possible effects of climate change on agriculture and food security in Tajikistan, analytical evaluations have been carried out (Smutka.., 2022).

As of 2016, Tajikistan's agricultural sector employed over 43% of the country's workers, making it a sizable and varied industry. The core of the country's agricultural activity is the production of important crops including wheat, potatoes, vegetables (especially onions), and other fruits. Although meeting local consumption demands is the main goal, the nation also exports around 120,000 tons of food items a year, or 2% to 3% of total exports by volume. Climate change has the potential to cause disruptions in this industry, directly affecting agricultural development processes through changes in temperature, precipitation patterns, and carbon dioxide availability. Furthermore, seasonality and availability variations in water resources, changes in soil organic matter, erosion, changes in pest and disease profiles, introduction of alien species, and the loss of arable land owing to desertification are examples of indirect consequences. Tajikistan's agricultural activities face problems in terms of sustainability and production due to climate-related variables (World Bank and Asian Development Bank, 2021).

Even in the case of lower greenhouse gas emissions, the effects of climate change are expected to have a negative worldwide impact on the yields of important staple crops. Tebaldi and Lobell (2018) predict that even if the goals of the Paris Climate Agreement are met, limiting warming to 1.5°C, there will be notable drops in world wheat and maize yields of 5% and 6%, respectively. The ideal and practical geographical ranges for some crops will inevitably change; however, the rate and extent of these changes depend on the trajectory of emissions. Particularly, Tajikistan, which imports a significant amount of wheat (650,000 tons in 2017, more than 50 kg per person), is vulnerable to the problems caused by interruptions in the global supply chain brought on by climate change. This vulnerability highlights how crucial it is to take proactive steps to strengthen Tajikistan's food security's resilience to shifting climate dynamics (World Bank and Asian Development Bank, 2021).

Climate change is expected to increase the likelihood of heatwaves and droughts, which might threaten Tajikistan's agricultural output stability and lower net production. The country's dry parts may see a reduction in income security, while more humid regions may see increases; nonetheless, when taking into account the many ecological zones that make up Tajikistan, the total net revenue change is predicted to be negative. The population's weakest segments, those with less access to agricultural technology, inadequate infrastructure, and reduced ability for adaptation, are expected to be disproportionately affected by this general decline. Most importantly, it becomes clear that adopting adaptation strategies is severely hampered by a lack of access to loans and agricultural supplies, which exacerbates the susceptibility of marginalized populations to shifting climatic trends. It is critical to remove these obstacles in order to strengthen resilience and protect the livelihoods of Tajikistan's most vulnerable citizens (World Bank and Asian Development Bank, 2021).

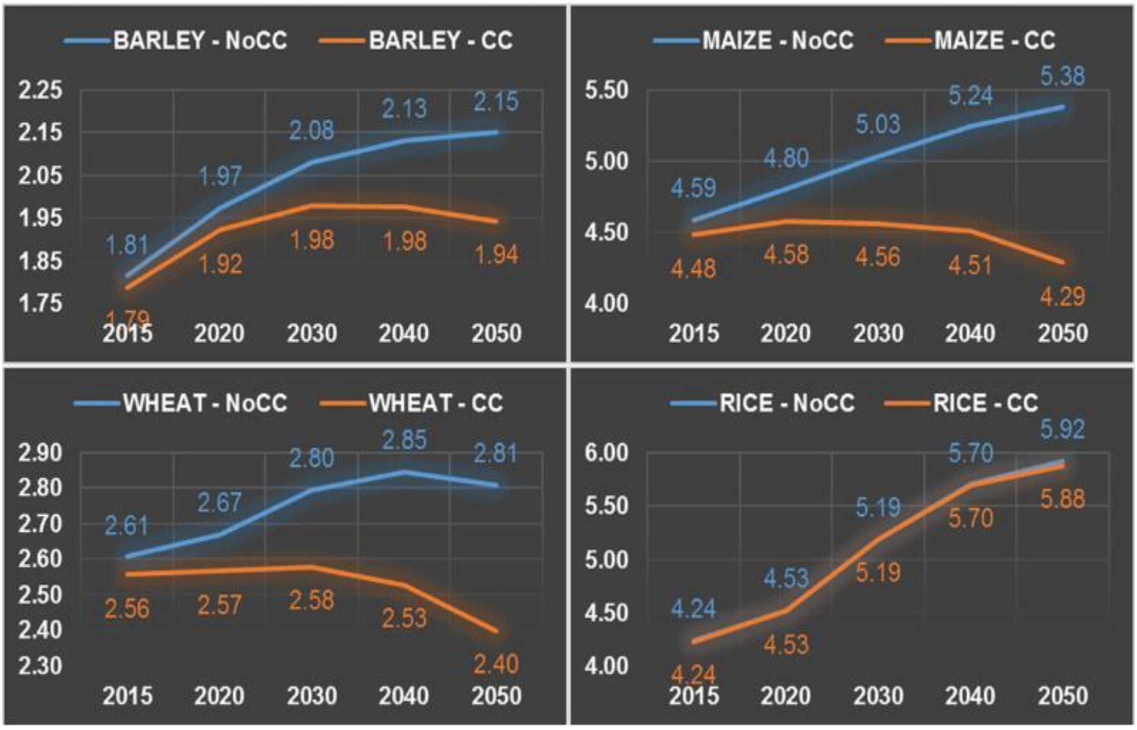
More than 33,000 hectares of formerly farmed land have been abandoned in Tajikistan, a clear indication of the country's vulnerability to climate change. Notwithstanding this obstacle, Tajikistan has the capacity to utilize around 800,000 hectares for farming. With an astounding 300 days of sunlight a year, the country can meet its own food needs and perhaps become a food provider for the surrounding area. However, achieving this potential will require adopting cutting-edge technologies and making large financial expenditures.

Reviving irrigation on 800,000 hectares of parched land with the help of contemporary pumping equipment and solar energy might be a game-changer. This large-scale project might guarantee food self-sufficiency and, as a result, achieve import substitution, which would be a big step in the right direction for Tajikistan's agricultural future CISPM (n.d.).

3.3.4.1 Effects on Crops

In Tajikistan, the effects of climate change on specific crops are closely linked to their water and heat tolerance. While spring crops may be more susceptible to heat stress in reaction to warming trends, winter crops in temperate areas often show enhanced output in warmer temperatures. In addition, changes in seasonal rainfall patterns and the incidence of extreme weather events may cause disruptions to the conventional planting and harvesting schedules, posing further obstacles to agricultural production. The intricate interactions between climatic changes and agricultural outcomes are highlighted by the diverse reactions of various crops, highlighting the necessity of customized adaptation techniques in the face of changing environmental conditions (Khakimov et al., 2020).

Figure 10: Crop yields from irrigation in metric tons/ha for barley, maize, wheat, and rice under climate change and non-climate change scenarios.

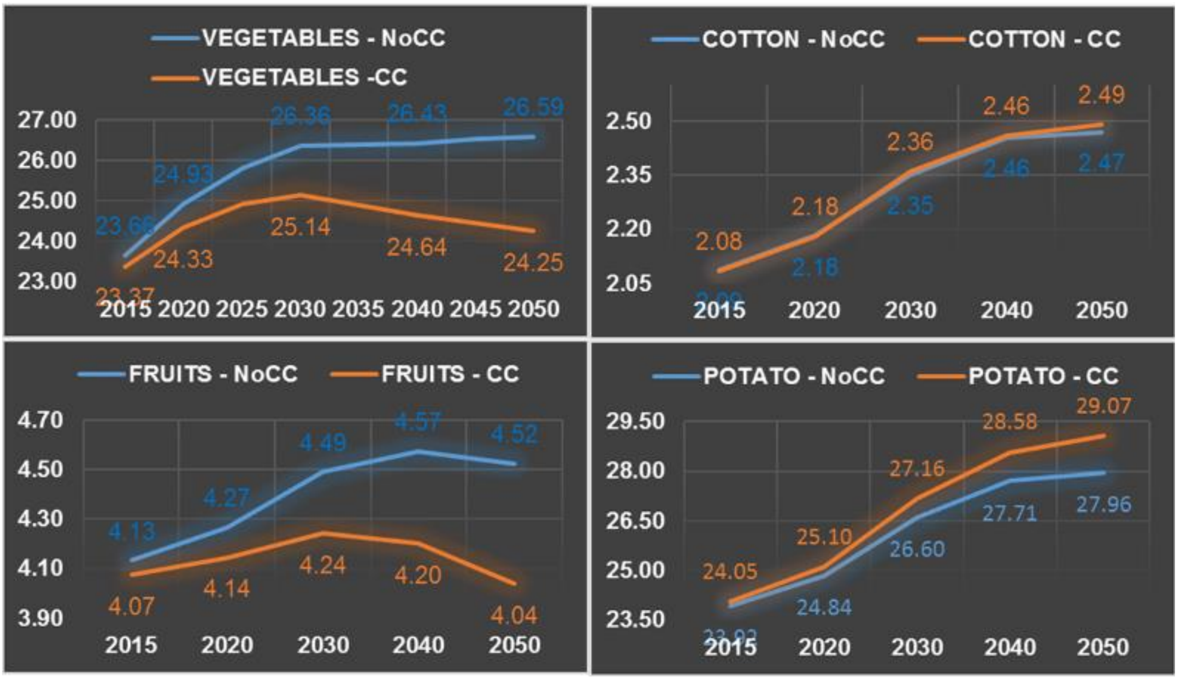


Source: (Khakimov et al., 2020).

In Tajikistan, irrigation is necessary for a large amount of arable land that is used for key crops. Figure 10 shows projected yield changes on irrigated land. The average values from four different climate models are represented by the letter 'CC,' which stands for the climate change scenario. These forecasts highlight the significance of comprehending and becoming ready for changes in agricultural productivity under changing climatic circumstances by providing insights into the possible effects of climate change on crop yields. It will be essential to put adaptive measures and sustainable water management techniques into place to lessen the possible effects of shifting climatic scenarios on Tajikistan's irrigated crop output (Khakimov et al., 2020).

According to the research findings, there is a substantial expectation that the yields of barley, wheat, and maize in Tajikistan would fall significantly by 2050 due to climate change. On the other hand, estimates of rice yields from 2015 to 2050 indicate little difference between the baseline and climate-change scenarios, with an estimated 40 percent predicted rise overall. These findings highlight the ways in which crop-specific adaptation methods are required to meet the particular difficulties that various crops in Tajikistan's changing climate confront. They also highlight the crop-specific effects of climate change on agricultural production (Khakimov et al., 2020).

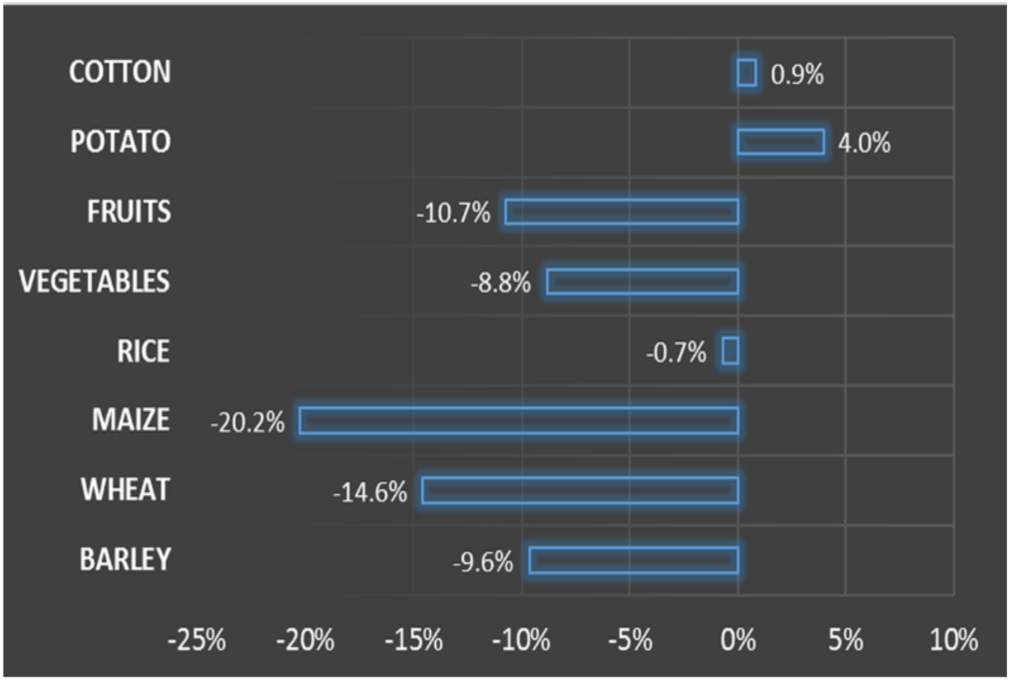
Figure 11: Potatoes, cotton, vegetables, and fruit, the irrigated crop yields in metric tons/ha under climate change versus non-climate change scenarios.



Source: (Khakimov et al., 2020).

Analyses of a variety of crop categories, including vegetables, fruits, potatoes, and cotton, show some intriguing tendencies, as shown in Figure 11. Vegetable yields are predicted to rise sharply until around 2030 in the absence of climate change, at which point they are predicted to reach a low point through 2050. On the other hand, the climate-change scenario indicates that yields would climb more moderately until 2030 and then drop until 2050. The situation of temperate fruits exhibits a similar trend, highlighting the complex effects of climate change on many crop categories and the need of comprehending these dynamics for efficient agricultural planning (Khakimov et al., 2020).

Figure 12: Changes in Irrigated Crop Yields in the Context of Climate Change, 2050–2015 (%)



Source: (Khakimov et al., 2020).

The figure 12 emphasizes that most agricultural crops in Tajikistan are projected to suffer from climate change, with negative effects on yields predicted for barley, wheat, and maize. It does, however, provide exceptions, indicating that rice, cotton, and potatoes could have better results. These findings highlight the need for comprehensive plans and adaptive measures to meet the unique difficulties posed by climate change on a variety of agricultural products, with substantial ramifications for the nation's food and nutrition security (Khakimov et al., 2020).

Table 2: An overview of the primary risks and effects of climate change on agriculture

Climate Change Risks	Impact on agriculture
Increases in temperature	▪ Reduction in agriculture and pasture productivity ▪ Invasive species and pests ▪ Crop losses due to insects, diseases, weeds ▪ Heat stress and heat-related mortality for livestock ▪ Higher evapotranspiration rates ▪ Increased GSL
More frequent extreme temperatures	▪ More frequent and intense heat waves causing rapid crop damage, soil erosion ▪ Loss of rural livelihoods and income ▪ Increased local and national food prices
Changes in precipitation including extreme precipitation events	▪ Decrease in yield and production of crops, perennial fruit trees, and livestock ▪ Rapid crop damage, soil erosion ▪ Loss of rural livelihoods and income ▪ Possible displacement due to extreme events ▪ Increased local and national food prices
Droughts	▪ Rapid crop damage, soil erosion ▪ Increase in salinization levels ▪ Increased need for irrigation ▪ Reduction in yield of rain-fed or irrigated crops ▪ Loss of rural livelihoods and income ▪ Possible displacement from land ▪ Increased local and national food prices
Disappearance of glaciers and reduction in water flows	▪ Short run: a higher amount of meltwater in spring causing floods and mudflows ▪ Long run: decrease in water availability and storage ▪ Increased river flow anomalies ▪ Decreased yield and production of crops, perennial fruit trees, and livestock ▪ Loss of rural livelihoods and income ▪ Increased local and national food prices
Early or late frost	▪ Decrease in yield of crops, perennial fruit trees, and livestock ▪ Loss of rural livelihoods and income ▪ Increased local and national food prices
Dust storms	▪ Decrease in yield and production of crops, perennial fruit trees, and livestock ▪ Wind and soil erosion ▪ Loss of rural livelihoods and income ▪ Increased local and national food prices

Source: (USAID,2021)

3.4 Food security in Tajikistan

Over the past 20 years, Tajikistan has experienced a notable increase in both the frequency and intensity of extreme weather occurrences. The increased frequency and intensity of extreme weather events, together with the unpredictable nature of precipitation, directly endanger economically vulnerable areas of the country. Food security is one of the industry’s most at risk as these weather-related uncertainties might interfere with agricultural practices, lowering animal and crop harvests. The heightened occurrence of severe occurrences, such floods or droughts, may cause financial losses, affecting many people' means of subsistence and aggravating issues with food stability and availability. In order to promote sustainable development in Tajikistan and strengthen resilience in important sectors, it is imperative that these climate-related vulnerabilities be addressed. Food insecurity has been an ongoing problem in several parts of Tajikistan, most notably in the province of Gorno-Badakhshan Autonomous Oblast (GBAO), where rates have regularly above 20 percent of the population over the study period. Furthermore, comparable persistent levels of food insecurity were experienced by several districts in the Khatlon province and the Region of Republican Subordination (DRS). This emphasizes the geographical differences and the necessity of focused solutions to deal with particular problems in various contexts. The recurrence of food insecurity in these areas emphasizes how critical it is to put policies in place to increase food stability, accessibility, and availability in order to improve the general well-being of the impacted communities. The significant frequency and persistence of food insecurity across several provinces suggests that several aspects of food security have been impacted for a long time. The chronicity of these problems is anticipated to intensify as a result of climatic variability and change, even though these challenges are probably driven by reasons other than climate. Furthermore, attempts to guarantee stable and secure food supplies for impacted communities may be made more difficult by the increasing seasonal changes brought about by the increased frequency of extreme weather events brought on by climate change. In order to effectively address these issues, comprehensive solutions that take into account both the current vulnerabilities and the changing effects of climate change on Tajikistan's food security are needed (WFP, 2017).

In addition to threatening the availability of food, the predicted effects of climate change on agricultural productivity have a substantial influence on livelihoods and the economy. The anticipated fluctuations and decline in household earnings may intensify pre-existing vulnerabilities. Furthermore, the nutrition status of already vulnerable groups, such as children and pregnant and lactating mothers, may worsen if coping techniques become more common in the face of these difficulties. It is imperative that impacted communities make quick adjustments and concentrated efforts to strengthen their resilience in order to lessen the possible harm to food security and the welfare of Tajikistan's most vulnerable citizens (WFP, 2017).

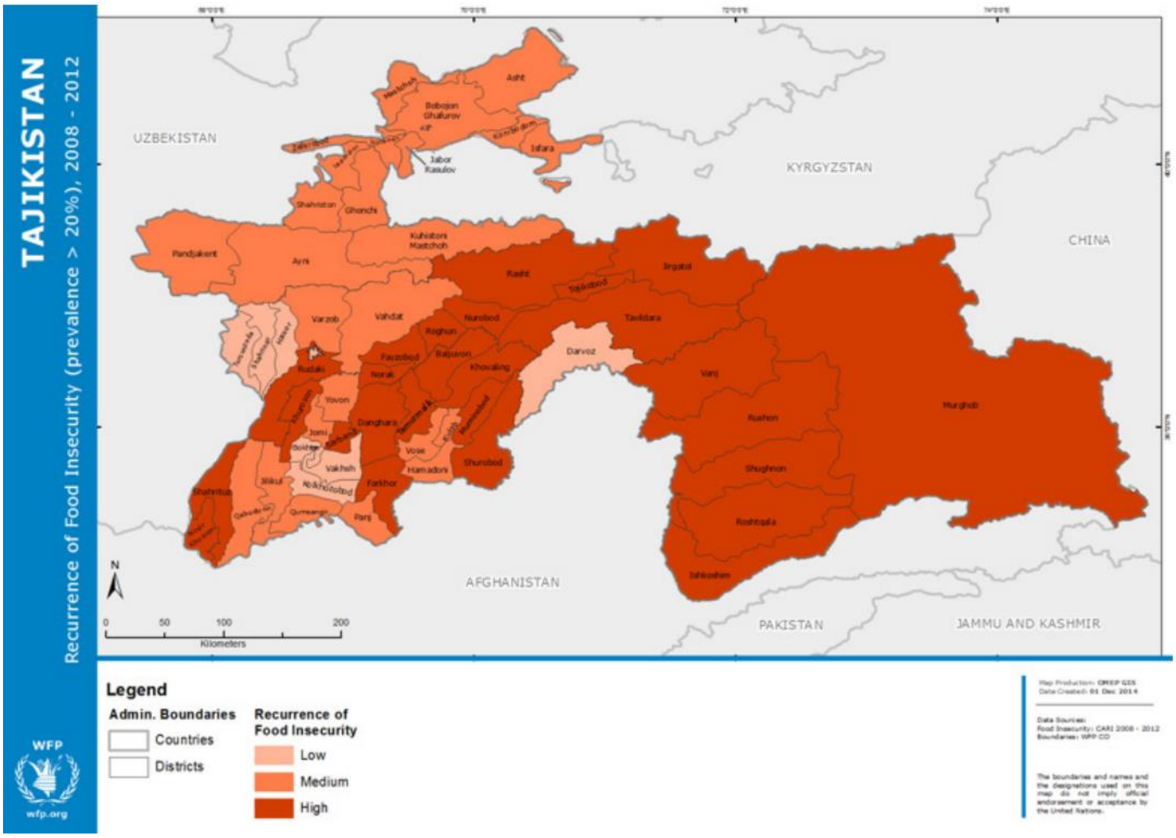
In fact, Tajikistan may be able to provide a consistent, stable, and varied food supply if it prioritizes development focused on agriculture. This strategy can increase wages and job possibilities in addition to addressing concerns about food security, especially in rural regions. Through the promotion of resilient and sustainable agriculture methods, Tajikistan can strengthen its ability to deal with the effects of climate change and protect its people. Two thirds of Tajikistan's total agricultural output is produced by irrigation, which is a major component of the country's agricultural productivity. Rain-fed agriculture is necessary for 55% of cereal crops, which constitute a significant portion of agricultural activity. This is an essential point to remember. Regretfully, the dependence on rain-fed crops frequently results in significant losses in agricultural productivity, with around one-third of these losses being ascribed to climate-related incidents. Drought and a lack of water provide a significant obstacle to agricultural production, affecting yields and adding to the industry's overall losses. It is expected that the effects of climate change, such as rising temperatures and faster rates of evaporation, would make agricultural production require more water. Crop yields may decrease by 5 to 30 percent by the year 2050, according to projections. The predicted rise in temperature brought on by climate change also raises the possibility of ecosystems changing, which would encourage the spread of diseases and pests. This further compounds the difficulties Tajikistan's agricultural environment faces by endangering food production in a number of agricultural areas. Tajikistan's Khatlon province has several obstacles to food security, chief among them being the degradation of irrigation systems. The livelihoods of rural populations who depend on a steady supply of water for crop cultivation have been negatively impacted by the severely reduced agricultural yield caused by the damaged status of irrigation systems. The province has yearly environmental shocks including hailstorms, floods, and pest and disease outbreaks in addition to infrastructural problems; these events all lead to crop failures and decreased productivity. Together, these elements highlight the complex dynamics affecting food security in Khatlon and highlight the need for allencompassing policies to reduce the effects of environmental variables on agricultural operations and solve infrastructural deficiencies (WFP, 2017).

Due to a number of variables, including a restricted variety of exports, a strong reliance on remittances, and a substantial dependency on food imports to meet consumption demands, Tajikistan's food system is vulnerable. Remittances were 48% of GDP in 2014. This significant economic contribution has fluctuated over time due to governmental changes and economic crises in important recipient nations like Russia, which is a major destination for Tajik migrant workers. Due to the country's increased reliance on foreign markets, both the economy and a significant segment of the population are vulnerable to economic shocks, especially those resulting from changes in food prices. This highlights the necessity of adopting diversified economic approaches and strengthening resilience measures (WFP, 2017).

Tajikistan is particularly vulnerable to food insecurity due to a variety of factors, including poverty rates, institutional capacity, susceptibility to meteorological variables, and elevation. Different parts of Tajikistan are more or less vulnerable than others; the most vulnerable area is the 'Districts of Republican Subordination' (DRS) oblast, especially its eastern mountainous regions. Surprisingly, despite their difficult circumstances, certain sparsely inhabited high-altitude mountain zones are among the least vulnerable. On the other hand, one of the four most susceptible places is the South Khatlon valley, which is characterized by a higher population density. This emphasizes how intricately population distribution, economic activity, and regional risk interact, making it difficult for adaption planners to implement sophisticated methods that address various vulnerabilities across the nation. Some areas of Tajikistan are more vulnerable to climate change than others, such as the southern Sughd highlands, the eastern Region of Republican Subordination (RRS) Mountains, and the lowlands and hills of Khatlon. These regions' elevated susceptibility is a result of their strong reliance on agriculture. Low levels of education and money lead to a weak adaptive ability, which increases their susceptibility. Despite their mild exposure, they are susceptible because of their high sensitivity and little potential for adaptation. On the other hand, when taken as a whole, metropolitan regions show the least amount of susceptibility. This is explained by their relatively lower sensitivity, greater potential for adaptation, and decreased average exposure; this emphasizes the need for a variety of measures to address the variable degrees of susceptibility in various situations and areas (WFP, 2017)

Different livelihood zones in Tajikistan show unique seasonal patterns of food security that are strongly associated with the harvest and lean seasons. These patterns are apparent, with variations in the total levels of food insecurity throughout the zones and different degrees of recurrence that go over the 20 percent mark. These dynamics highlight how critical it is to comprehend and address the unique difficulties and vulnerabilities encountered by various livelihood zones in order to provide more focused and successful interventions aimed at improving food security in Tajikistan (WFP, 2017).

Figure 13: Recurrence rates of instances in which over 20% of the population experienced food insecurity



Source: World Food Organization, 2017

The country of Tajikistan is expected to have rapid population expansion, which would increase demand for a wide range of agricultural products. However, in addition to the previously mentioned difficulties, climate change places limitations on farmers' ability to increase productivity. Consequently, the increasing need may have to be satisfied by importing food products, which illustrates the intricate relationship between population trends, agricultural capacities, and foreign dependencies in meeting Tajikistan's changing food demands (Khakimov et al., 2020).

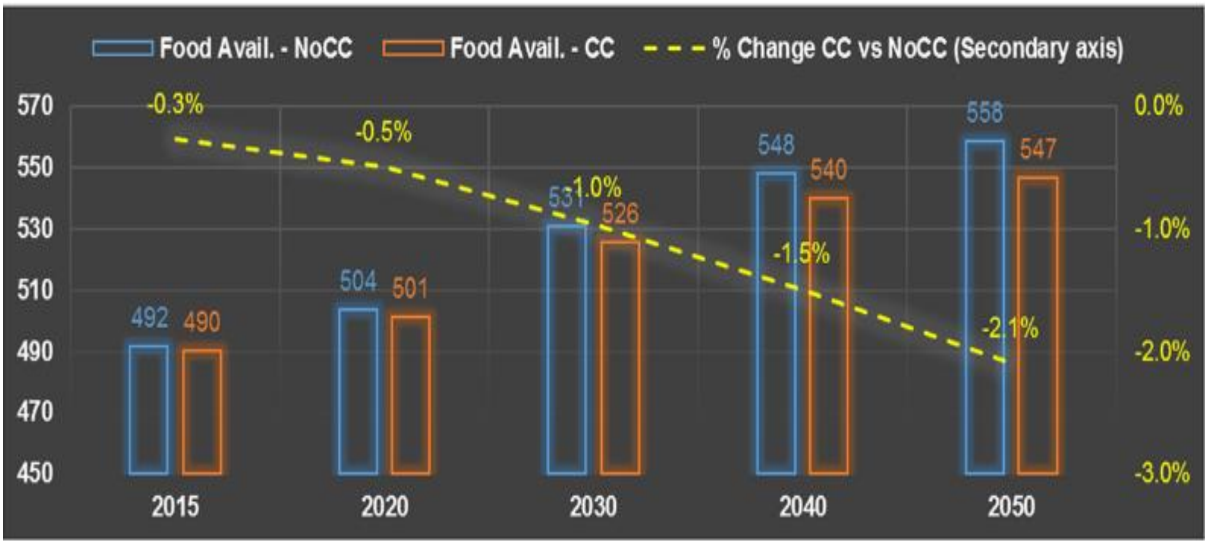
By 2050, the forecasts shown in Figures 14 show expected changes in the domestic supply and demand for particular crop categories. These projections suggest that domestic supplies of barley, wheat, and maize are expected to be negatively impacted by climate change. On the other hand, climate change is predicted to have a favorable impact on the rice supply, indicating possible changes to Tajikistan's domestic crop production environment in the upcoming decades (Khakimov et al., 2020).

Figure 14: Climate change affects crop supply and demand (000 metric tons).

Source: (Khakimov et al., 2020).

Tajikistan considers itself to be a net importer and is mostly dependent on its imports of agricultural products. The country's high reliance on imported processed goods, wheat, coarse grains, and other animal products like chicken and beef highlights its susceptibility to changes in the global supply chain and external market conditions. Due to its reliance on imports, this food system is vulnerable to supply chain interruptions and changes in the price of food internationally. Because of this, Tajikistan struggles to provide food security and keep the prices of staple foods steady, which highlights the need of developing plans to increase local agricultural output and lessen reliance on outside resources (Khakimov et al., 2020).

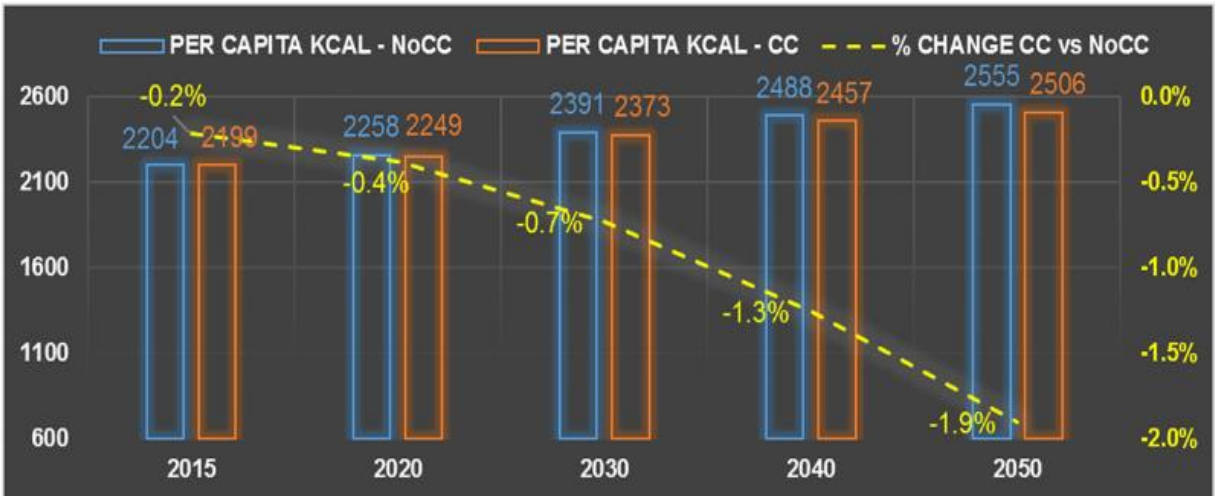
Figure 15: Food availability in scenarios with and without climate change, kg per capita annually



Source: (Khakimov et al., 2020).

According to the estimates, under the climate-change scenario, per capita food availability is predicted to slightly decrease by 2050 (Figure 15). According to Figure 16, the same climate-change scenario also projects a 1.9 percent decline in calories per capita availability by 2050. These results underline the necessity for comprehensive policies and initiatives to improve food security in the face of changing climatic circumstances and show the possible difficulties in providing enough food supplies for the people of Tajikistan (Khakimov et al., 2020).

Figure 16: Calories per capita in scenarios with and without climate change, expressed in KCal.



Source: (Khakimov et al., 2020).

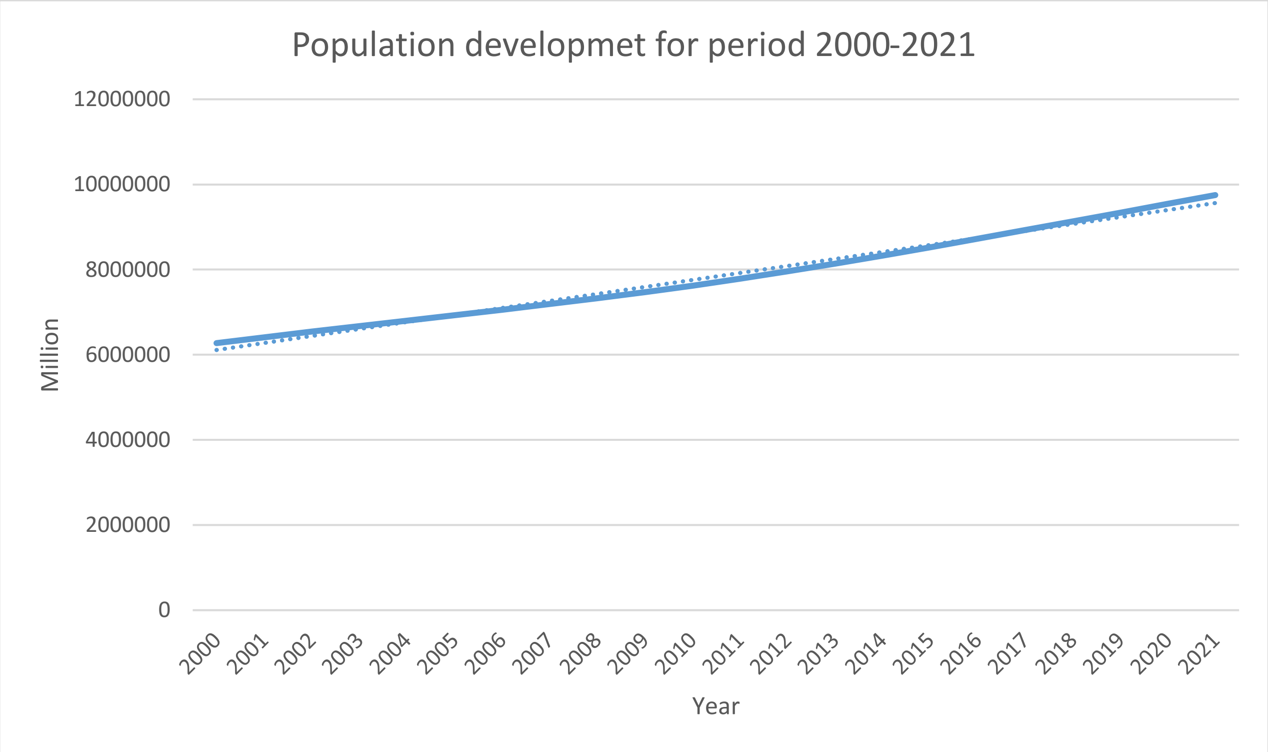
4. Practical Part

In the application portion (part 4), the author uses statistical software to analyse regression analysis to examine the relationships between variables and Excel for descriptive statistics to provide information about the features and patterns of the dataset.

4.1 Descriptive and Trend analysis

A trend analysis for population dynamics is shown in Figure 17, providing a thorough visual analysis of changes in the population over a certain period of time. This graph is a useful resource for comprehending long-term demographic patterns, which helps with strategic planning and informed decision-making across a range of industries.

Figure 17: Trend analysis for population:



Source: Own work, FAOSTAT 2023

The graph above displays the population dynamics of Tajikistan from 2000 to 2021. It reveals a trendline equation that may be easily identified:

$$\mathbf{y = 164400x + 6\ 000000 + 06}$$

$$\mathbf{R^2 = 0.9902.}$$

The relationship between the year (x) and the total population of Tajikistan (y) is represented mathematically by this equation. Examining the equation, the slope, represented by 164400, highlights a yearly population growth of 164,400 on average. Conversely, the y-intercept, denoted by 6E+06, indicates that there were approximately 6 million people living in the country in 2000, the year the millennium began (x = 0). These conclusions drawn from the equation show how Tajikistan's demographic evolution during the previous 20 years has been steadily evolving.

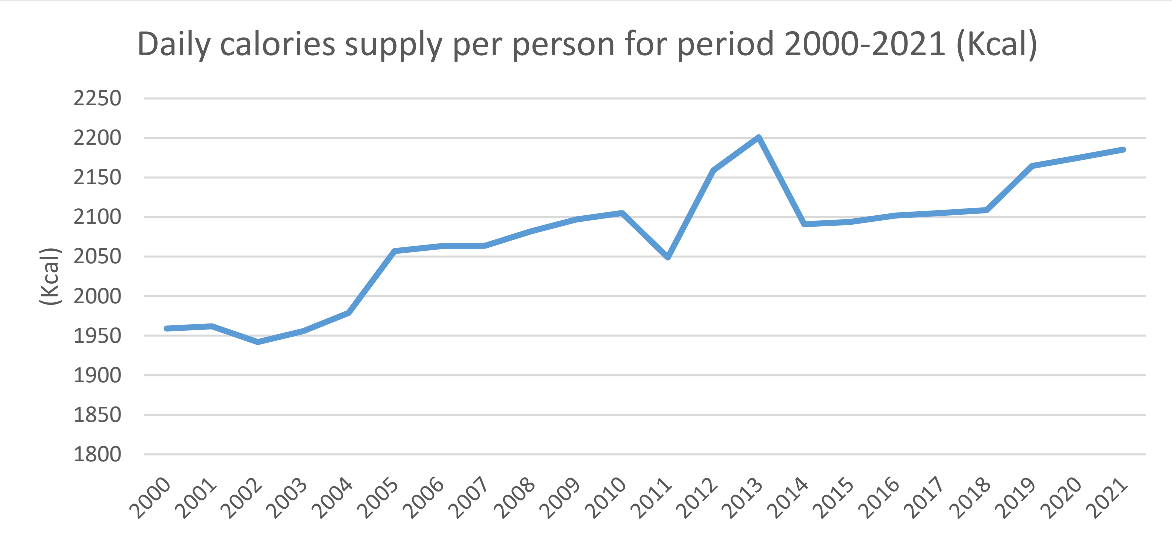
R-squared = 0.9902, which is close to 1.0 (perfect fit). This implies that the fitted trendline is an excellent fit for Tajikistan's population trend. The year explains approximately 99.02% of the change in the overall population in this situation.

The population of Tajikistan has been growing gradually over time, according to the equation's positive slope (164400). Tajikistan’s rapid population expansion may have a number of effects on the country's economy, including a rise in the need for resources, services, and infrastructure.

Tajikistan's consistent population expansion, as shown by the equation's positive slope, points to a rise in the country's overall need for food and basic resources. Both the demand for food and the food supply systems may be impacted by an increasing population. For food security, it is essential to meet this demand sustainably. The agriculture sector is essential to guaranteeing food security since there are more people to feed. To address the dietary demands of the expanding population, sustainable farming techniques are crucial.

Given the country's expanding population and the effects of climate change on its water supplies and agricultural output, resilience issues may arise. Strong adaptation techniques are required because of the interaction between population increase and climate change. This can entail boosting food security through resource-effective resource management and resilient agriculture techniques. In order to preserve or increase food security despite environmental changes, policymakers must take into account the population's participation in plans for reducing and adapting to climate change.

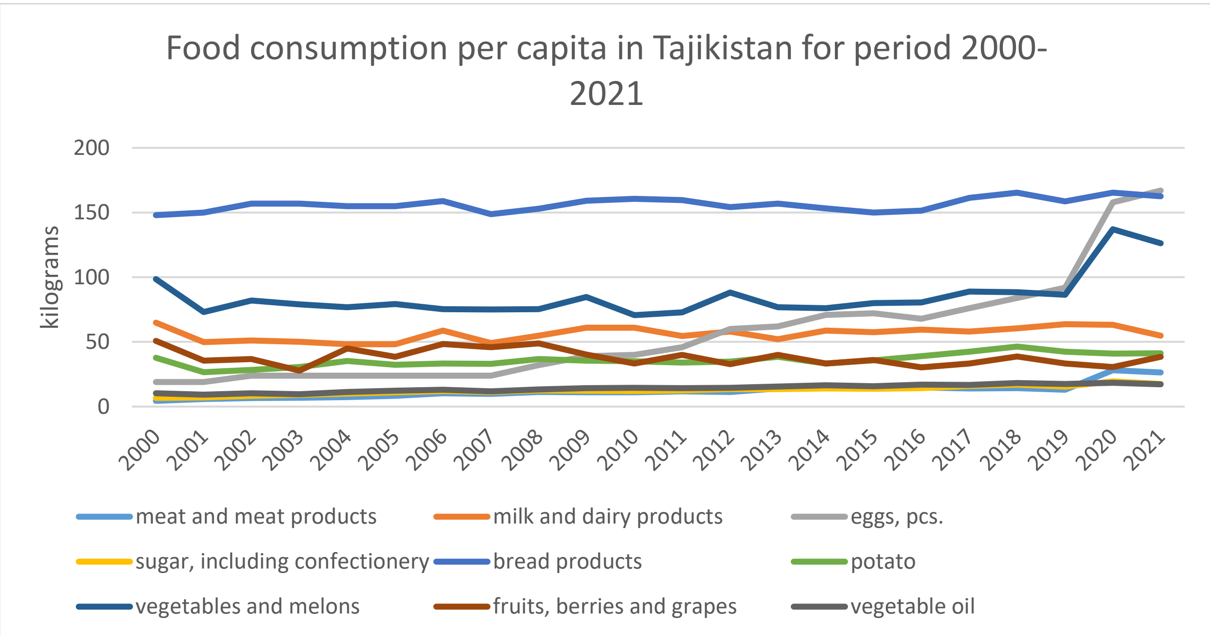
Figure 18: Daily calories supply per person in Tajikistan for period 2000-2021:



Source: Own work, world in data 2023

The daily calorie supply in Tajikistan from 2000 to 2021 is depicted in the accompanying graph, which is an essential part of our analytically practical study. In the Republic of Tajikistan, it is noteworthy that daily calorie supply per person has consistently increased over the past 20 years, reaching a peak in 2013 at 2200 kilocalories (Kcal) per day per person and a low point in 2002 at 1942 Kcal per day per person. 2077 Kcal per day per person is the 21-year average. This astounding development is directly related to Tajikistan's consistently rising yearly economic growth of about 6-7%.

Figure 19: Food consumption in Tajikistan for period 2000–2021, kg per capita



Source: Own work, (ASUPRT 2023)

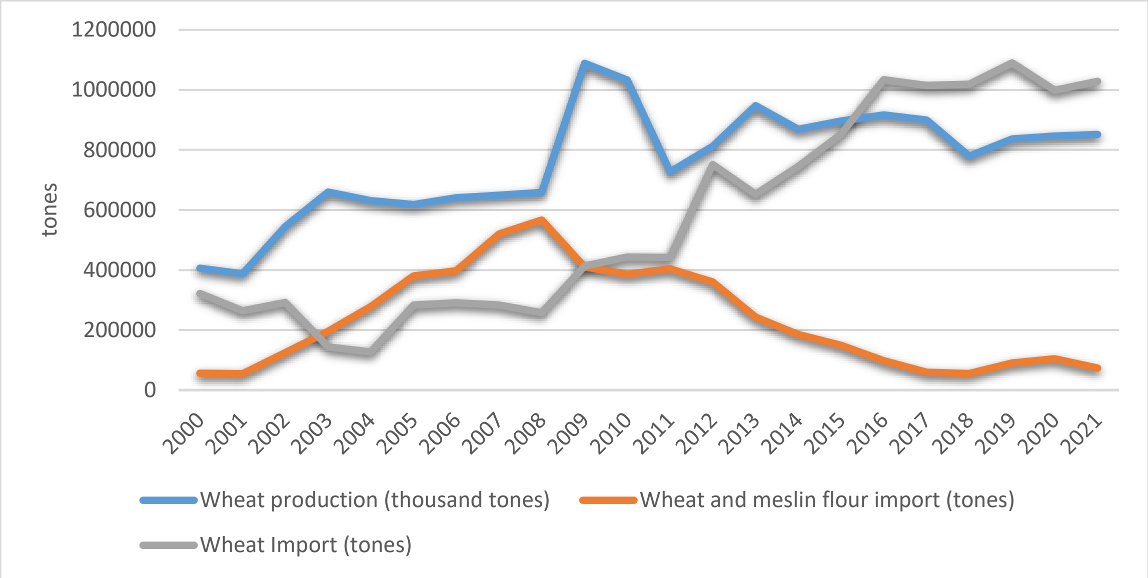
Based on data from the Tajik Statistical Office's household sample survey, the graph above provides an overview of the per-capita food consumption trends in Tajikistan for the years 2000 through 2021. This informative chart illustrates important changes in the nation's food consumption as well as a historical perspective. Looking more closely at the data, we can see that several foods stand out as being essential to Tajikistan's diet throughout the time period in question. Bread items, milk, and other dairy products are among these basic necessities, along with potatoes, a variety of vegetables, and melons.

Bread continues to be a prominent food item and is sometimes referred to be the ultimate staple. The population's sustenance is dependent on it, as evidenced by the consistently increasing consumption. The highest consumption is in 2018 and 2020 which is 165,5 kg per capita.

Tajikistan's nutrition has changed significantly and consistently throughout the previous two decades, from 2000 to 2021. The second most popular food group at this time was vegetables and melons, which is astonishing. This long-lasting pattern of food intake reached a notable high in 2020, when people in Tajikistan consumed an average of 137.1 kg of vegetables and melons per capita. This long-term food preference demonstrates the ongoing value of vegetables and melons in the everyday lives of Tajikistan's citizens, offering insightful information about the development of dietary practices and nutritional preferences within the country over this time.

Throughout the years 2000 to 2021, milk and dairy products were regularly among the most popular foods in Tajikistan. Notably, the year 2018 saw the highest average consumption, at the point 60.8 kg per capita. This accomplishment shows how important and popular dairy-based nutrition continues to be in Tajikistan's diet.

Figure 20:Analysis of Wheat and Flour Imports and Production in Tajikistan: 2000–2021



Source; Own work, FAO 2023

We can see historical information on wheat production, wheat imports, and wheat and meslin flour imports from 2000 to 2021 in the graph above. In Tajikistan, wheat output has gradually increased over the past few years compared to 2001, when it was at its lowest point at 387,314 tons. With 1,088,591 tons produced, 2009 was the year with the greatest output level. Tajikistan produced 759,123 tons of wheat year on average. Although there have been variations since 2009, there is a general downward tendency.

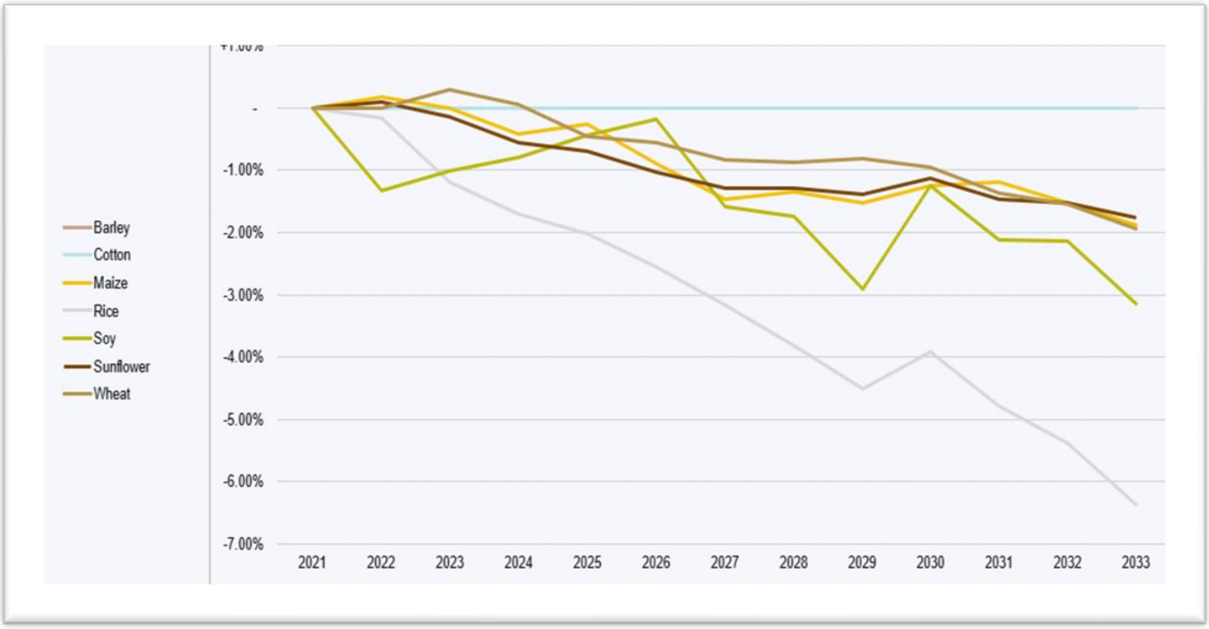
We can observe a consistent rise in imports of wheat and meslin flour up to 2008, when they peaked at 566,661 tonnes. After 2008, imports generally fell, with the exception of 2019 and 2020, when they slightly increased, perhaps as a result of the COVID-19 issue, which had an influence on all countries. Over the past 22 years, an average of 236,085 tons of wheat and meslin flour were imported yearly.

As it is shown in the the graph, there has been a clear trend of significant rises every three to four years since 2004 when we look at wheat imports into Tajikistan during the previous two decades. With 127,200 tons imported this year, it was the lowest point on the graph. Tajikistan imported 1,090,208 tons of wheat in 2019, which was a record high. Tajikistan imports around 579,498 tons of wheat annually on average.

The data study of Tajikistan's wheat output, imports of wheat, and imports of wheat and meslin flour from 2000 to 2021 indicates significant patterns and difficulties for the nation's food security. Tajikistan's wheat output has been rising steadily throughout the years, with some variations following the high in 2009. This shows how crucial it is to increase local wheat production and yields in order to secure food security. The erratic pattern of wheat imports also highlights the significance of developing reliable supply networks and being ready for eventual interruptions, which are made worse by difficulties in the dynamics of global trade and climate. Dependence on imports, especially during times of world crisis, may compromise food security.

Prioritizing actions to increase domestic wheat output will ensure Tajikistan's self-sufficiency. In order to lessen the consequences of climate change, this entails assisting farmers through improved agricultural techniques, technology adoption, and robust crop types. To mitigate the negative consequences of climate change, invest in agricultural techniques and technology that are climate resilient. This includes enhanced land management techniques, crop diversity, and water-efficient agricultural techniques. Enhance food management and storage practices to reduce waste and guarantee food availability in emergency situations. This entails making investments in more advanced distribution and storage infrastructure.

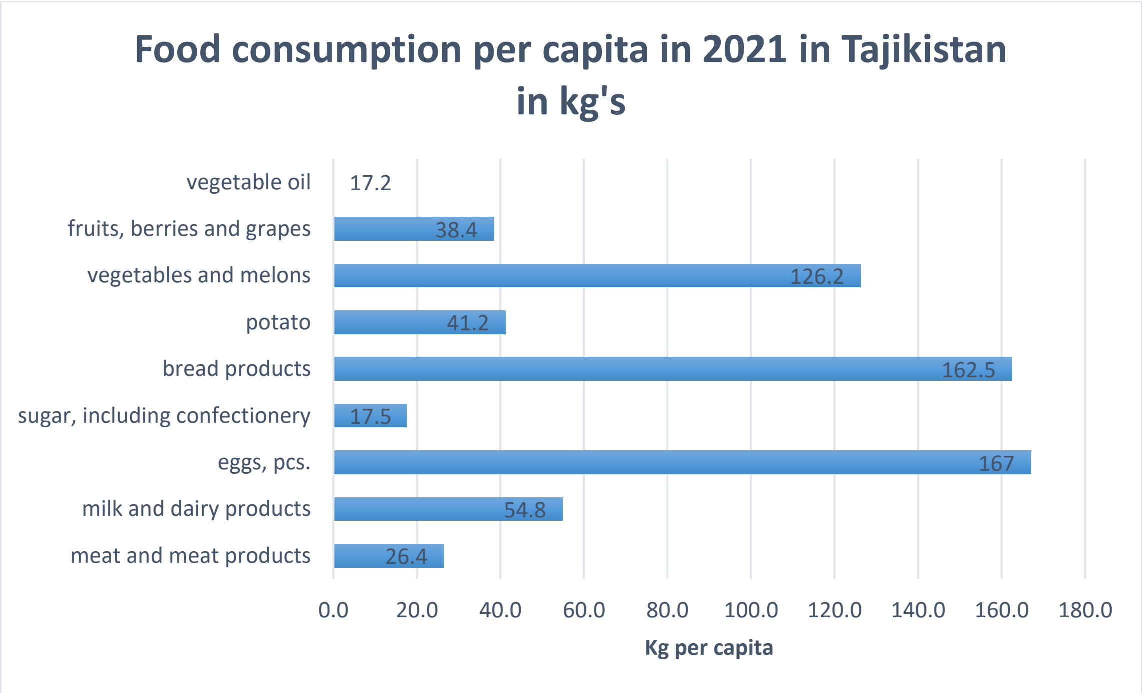
Figure 21:Crop yield predictions for period 2021-2033



Source: International Fund for Agricultural Development, (Ifad.org 2023)

The agricultural crop yield in Tajikistan for the next ten years has been predicted using the Climate Adaptation in Rural Development Assessment Tool. The explanations provided in the picture above provide light on the substantial effects that these projections will have on food security and agricultural productivity. The findings show a worrying pattern that might lead to a possible decline in Tajikistan's yield of a number of crucial crops during the following ten years. Barley, cotton, maize, rice, soy, sunflower, and wheat are some of these crops. These crops are important sources of food and calories for the local people, therefore a drop in them might have significant effects on the country's food security. This prognostic analysis emphasizes how crucial agricultural yield is, particularly in light of the challenges posed by climate change. In order to protect food security, it is necessary to adopt agricultural techniques that are climate resilient and to make investments in agricultural growth. This is highlighted by the downward trend in crop yields. The diet of many Tajik households is based on these products, especially wheat, therefore solving this problem is not just a matter of economics but also of food availability and nutrition. In order to ensure a resilient and food-secure future for Tajikistan, these findings highlight the urgent need for deliberate steps to support agriculture output and advance efforts at climate adaptation.

Figure 22: Food consumption per capita in 2021 in Tajikistan



Source: Own work, (ASUPRT 2023)

The graph presented above provides a clear picture of the per capita food consumption in Tajikistan for the year 2021 and provides insightful data about the local population's dietary choices. Understanding the complex relationship between agricultural productivity and food security depends on this data. At first look, it is clear that bread goods are in charge because they make up a sizeable 25% of the graph which 162.5 kg per capita. This highlights the crucial significance that bread plays in the daily caloric intake of Tajikistan's citizens, making it the foundation of their diet and a key source of critical nutrients. Despite being measured in pieces, eggs come in second on the list of food items consumed per person in Tajikistan, making up 26% of the graph which is 167 pieces per capita.

As we delve further into the data, it becomes apparent that vegetables and melons claim a noteworthy 19% of the chart, positioning them as the second-largest food category in per capita consumption. This highlights the significance of horticultural and melon production in Tajikistan's agriculture, not just for dietary variety but also for the essential vitamins and minerals they provide. Milk and dairy products account for 8% of the graph, highlighting their importance as important sources of calcium and protein in Tajik diet. Their presence emphasizes the crucial position that livestock and dairy farms play in the framework for overall food security. Potatoes, another nutritional mainstay, account for 6% of the chart, while meat and animal products make up a more modest 4%. This diagram essentially illustrates the complex connection between agricultural productivity and food security in Tajikistan. It is proof of the value of basic meals like bread, eggs, vegetables, and dairy products, all of which are supported by the agriculture industry. Policymakers and other stakeholders must understand these consumption patterns because they offer a road map for enhancing food security by concentrating on the production and availability of these essential nutritional components.

Table 3:Data Table

Year	Daily caloric supply per capita (Kcal)	Population total	Income per capita (current US$)	Wheat production (thousand tones)	Wheat and meslin flour import (tones)
2000	1959	6272998	137	406196	56236
2001	1962	6408810	169	387314	54548
2002	1942	6541755	187	544565	124911
2003	1956	6672492	233	660222	196486
2004	1979	6801204	305	631328	278181
2005	2057	6929145	334	618467	380658
2006	2063	7057417	401	640339	397836
2007	2064	7188391	517	649300	520600
2008	2082	7324627	705	659096	566661
2009	2097	7468596	667	1088591	410100
2010	2105	7621779	740	1033144	385833
2011	2049	7784819	838	726880	403700
2012	2159	7956382	959	812588	360342
2013	2201	8136610	1038	947350	242942
2014	2091	8326348	1094	868368	185011
2015	2094	8524063	970	896362	148967
2016	2102	8725318	801	917081.4	97617
2017	2105	8925525	844	899653	59113
2018	2109	9128132	851	778986.3	55131
2019	2165	9337003	889	836884	90870
2020	2175	9543207	852	846000	104802
2021	2185	9750064	917	852000	73321

Source: (FAO, world bank and world data) Own work ,2023

A detailed time series dataset for the years 2000 to 2021 is provided in the table above. This dataset is an essential building block for our research of the variables affecting food security in Tajikistan, especially considering climate change projected. developments. The table's preponderance of information population, Income per capita, What production, wheat and meslin flour import all of which play important roles in Tajikistan's food security, is worth noting. The collection also contains statistics on daily per capita calorie supply, the important factor in our analysis. This dataset will be crucial in revealing the complex processes that affect food security in Tajikistan as we continue with our investigation. We seek to provide useful insights on approaches for a resilient and food-secure future by analysing the relationship between these factors and their implications for the country's food security.

4.2 Regression model

The prior chapter's economic model is used in the regression model. The final regression model estimation shows clearly how the dependent variable (daily calorie supply per capita) and the independent variables (population overall, imports of wheat and meslin flour, per capita income, and wheat production) are related.

The regression model looks like this:

- In this model, the aim to understand how the total population, per capita income, imports of wheat and meslin flour, and wheat production affect the daily calorie supply per person.

$$yt = \beta 0 + \beta 1x_1 + \beta 2x_2 + \beta 3x_4 + \beta 4x_4 + \varepsilon$$

Where :

y = Daily calorie supply per capita in Tajikistan

$\beta 0$ = Y – Intercept (the value of Y when all X are zero)

x1 = Population total

x2 = Wheat and Meslin Flour Import

x3 = Income per capita

x4 = Wheat prodiuction

ε = Residual value

By analyzing these regression model, the end result is to understand the relationship between these factors and how each influences the daily calorie supply per person in Tajikistan.

4.2.1 Model 1 with all independent variables

Table 4: Model 1 with all independent variables

Model: MODEL1
Dependent Variable: Daily caloric supply percapita (Daily caloric supply percapita (Kcal)

Number of Observations Read	23
Number of Observations Used	22
Number of Observations with Missing Values	1

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	106789	26697	23.15	<.0001
Error	17	19606	1153.28989		
Corrected Total	21	126394			

Root MSE	33.96012	R-Square	0.8449
Dependent Mean	2077.31316	Adj R-Sq	0.8084
Coeff Var	1.63481		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	1607.09702	107.84045	14.90	<.0001
Population total	Population total	1	0.00004720	0.00001630	2.90	0.0101
Wheat and meslin flour import (t	Wheat and meslin flour import (tones)	1	0.00012479	0.00005946	2.10	0.0511
Income per capita (current US$)	Income per capita (current US$)	1	0.06685	0.05682	1.18	0.2556
Wheat production (thousand tones	Wheat production (thousand tones)	1	0.00003550	0.00006683	0.53	0.6022

Source: Own calculations, SAS Studio 2023.

Several independent variables, including "Total Population," "Wheat and Meslin Flour Import," "Income per capita," and "Wheat production," were added to our first model with the intention of determining their impact on the daily calorie supply per capita in Tajikistan. The analysis's results showed that "Wheat and meslin flour import" "Income per capita" and "Wheat production" had no statistically significant effect on per capita daily calorie supply since their related p-values were higher than the significant level of 0.05. In stark contrast, "Total Population" showed a statistically significant positive coefficient, indicating that it is a considerably impacting on the number of calories consumed daily per person in Tajikistan.

The author has decided to leave out "Wheat production" in order to improve the model and better comprehend the factors that affect the daily calorie supply per capita. This tactical change tries to expose the more important factors affecting the daily caloric supply per person. By doing this, author want to clarify the relationship between "Total Population," "Wheat and Meslin Flour Import," and "Income Per Capita," as well as how these variables affect food security in Tajikistan.

4.2.2 Model 2 without wheat production variable

Table 5:Model 2 without first insignificant variable

Model: MODEL1
Dependent Variable: Daily caloric supply percapita (Daily caloric supply percapita (Kcal)

Number of Observations Read	23
Number of Observations Used	22
Number of Observations with Missing Values	1

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	106463	35488	32.05	<.0001
Error	18	19931	1107.29765		
Corrected Total	21	126394			

Root MSE	33.27608	R-Square	0.8423
Dependent Mean	2077.31316	Adj R-Sq	0.8160
Coeff Var	1.60188		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	1613.87099	104.92689	15.38	<.0001
Population total	Population total	1	0.00004849	0.00001579	3.07	0.0066
Wheat and meslin flour import (t	Wheat and meslin flour import (tones)	1	0.00013141	0.00005697	2.31	0.0332
Income per capita (current US$)	Income per capita (current US$)	1	0.07976	0.05033	1.58	0.1304

Source: Own calculations, SAS Studio 2023.

In the table above, three independent variables—total population, imports of wheat and meslin flour, and per-capita income—are combined to show the results of a new regression model. Notably, the research shows that the P-value for Per Capita Income remained above the 0.05 level of significance. This suggests that income per capita in Tajikistan retains its status as an insignificant factor when compared to the dependent variable, which in this case is daily caloric supply per capita.

An improved model will be built in order to explore the complexities of this relationship in more detail and to improve the accuracy of our findings. The income per capita will not be included in this updated model as an independent variable. This painstaking modification aims to improve our comprehension of the dynamic interactions between the total population, wheat and meslin flour import, and the crucial component of food security, daily calorie supply per capita.

4.2.3 Final model

Table 6:Final model

Model: MODEL1
Dependent Variable: Daily caloric supply percapita (Daily caloric supply percapita (Kcal)

Number of Observations Read	23
Number of Observations Used	22
Number of Observations with Missing Values	1

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	103682	51841	43.37	<.0001
Error	19	22712	1195.37946		
Corrected Total	21	126394			

Root MSE	34.57426	R-Square	0.8203
Dependent Mean	2077.31316	Adj R-Sq	0.8014
Coeff Var	1.66437		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	1480.59029	65.18814	22.71	<.0001
Population total	Population total	1	0.00007067	0.00000759	9.31	<.0001
Wheat and meslin flour import (t	Wheat and meslin flour import (tones)	1	0.00018138	0.00004930	3.68	0.0016

Source: Own analysis, SAS Studio 2023.

Author have narrowed attention to include two important independent variables in the final model: "Total Population" and "Wheat and Meslin Flour Import," while focusing the study on the crucial dependent variable, "Daily Caloric Supply per Capita." The outcomes, as tastefully displayed in the table above, shed light on the dynamics at work.

It is crucial to first emphasize the statistical importance of both "Total Population" and "Wheat and Meslin Flour Import." These two factors have become important factors of Tajikistan's daily calorie supply per capita. Their linked p-values, which strongly confirm their relevance in our research, underline their statistical importance.

Daily Calorie Supply per Capita (Y) = 1480.59 + 0.00000759 * Total Population + 0.00018 * Wheat and Meslin Flour Import.

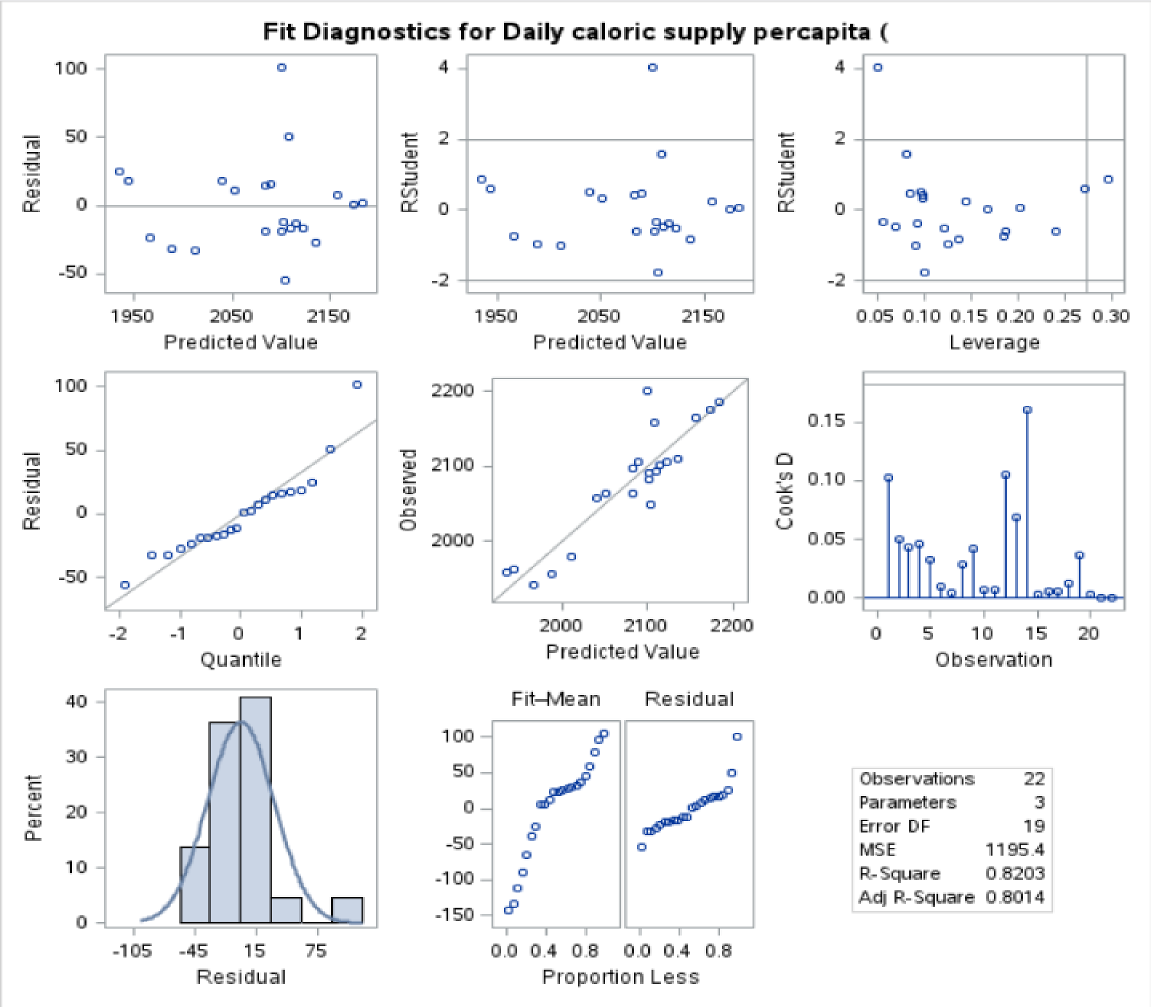
The coefficients provide useful information upon deeper inspection. "Total Population" has a coefficient of 0.00000759, showing that there is a little but significant increase in the daily calorie supply per capita for each additional unit of population. This increase in food availability is especially important in a population that is expanding, especially in light of climate change and its effects on food security.

A coefficient of 0.00018 is assigned to "Wheat and Meslin Flour Import" on a similar note. This means that there is a noticeable increase in the daily calorie supply per capita for every additional unit of imported wheat and meslin flour. This coefficient highlights the significant influence of imports on food security, which cannot be overstated.

Additionally, the intercept coefficient, which serves as an example for our investigation, is 1480.59. When the values for "Total Population" and "Wheat and Meslin Flour Import" are both set to 0, it represents the daily calorie supply per capita.
An important indicator of the efficacy of our model is the adjusted R-square value, which is notably 0.8014. Due to the combined effects of "Total Population" and "Wheat and Meslin Flour Import," which together have a high adjusted R-square value, 80.14% of the fluctuation in daily caloric supply per capita may be explained. This strong explanatory capability highlights how robust our model is at understanding the intricate interaction of factors affecting food security in Tajikistan.

In conclusion, the findings we have provided provide important insights into the complex dynamics of food security in the face of climate change, especially within the Tajik agricultural sector. In order to ensure food supply in the face of changing climatic situations, "Total Population" and "Wheat and Meslin Flour Import" have become important variables. This has cast light on the crucial role that population dynamics and import methods play. This thorough knowledge serves as the foundation of our study and offers a strong base for stakeholders and policymakers attempting to negotiate the challenging landscape of food security in a rapidly changing global environment.

Table 7:Diagnostic of the model



Source: Own work, SAS studio 2023.

According to the observed plot we can see most of the points fall alongside the diagonal line which indicates that data fits model well. Quantile plot shows that residuals are normally distributed as the point located along the diagonal line the residuals histogram supports this as well. In the residual predicted plot, we can see that most of the residuals are scattered randomly around zero indicating there is no issues such as heteroscedasticity or non-linearity. Since residuals seem to be evenly distributed around the line, which also suggests that residuals are independent, the data also looks to be homoscedastic. As the observations surpass the +2 interval, one observation for these data exhibits positive big residuals, according to the second graph, which shows studentized residuals. And also Leverage Plot indicates that this one data point has an impact on the overall model fit.

5. Results and Discussion

The research results are analyzed and given in section 5, "Results and Discussion," which facilitates a detailed discussion of the significance of the study's findings and offers insights into its findings.

Tajikistan, one of the countries in Central Asia most affected by climate change, faces numerous risks from the region, such as desertification, water scarcity, and glacier melting. Degradation of the soil, a rise in the frequency of extreme weather events, and a reduction in water availability are putting the region's agricultural sector, which is a critical source of income for many, in danger. Additionally, the effects of climate change in Central Asia combine with other socioeconomic issues like poverty, unstable political systems, and restricted access to resources and technology, making adaptation attempts much more difficult.

With an average annual population growth of 164,400, the trend analysis for Tajikistan's population dynamics reveals a consistent rise in the country's population throughout time. The fitted trendline fits Tajikistan's population trend quite well, as evidenced by the R-squared value of 0.9902. The nation's economy may be impacted by this quick population growth in a number of ways, including an increase in the demand for infrastructure, services, and resources.

Over the previous 20 years, Tajikistan's daily calorie supply per person has steadily increased due to food consumption, peaking in 2013 at 2200 kilocalories (Kcal) per person. The staple foods of the Tajik cuisine include bread, milk, and other dairy products, as well as potatoes, a range of vegetables, and melons. Bread is still a popular dietary item, and its consumption is steadily rising.

The statistical analysis of Tajikistan's wheat production, wheat imports, and wheat and meslin flour imports between 2000 and 2021 reveals important trends and challenges for the country's food security. Putting more emphasis on initiatives to boost domestic wheat production will guarantee Tajikistan's independence. The Climate Adaptation in Rural Development Assessment Tool has been used to project Tajikistan's agricultural crop yield for the next ten years. The results indicate a concerning trend that could potentially result in a decrease in Tajikistan's yield of several important crops over the next ten years.

The dependent variable (daily calorie supply per capita) and the independent variables (total population, imports of wheat and meslin flour) have a strong correlation, according to the regression model estimation. The combined impacts of "Total Population" and "Wheat and Meslin Flour Impor" may explain 80.14% of the variation in the daily caloric supply per capita, according to the modified R-square value of 0.8014.

5.1 Comparison with other author findings

The analysis conducted out in the first phase of the diploma thesis's practical part indicates that Tajikistan's population grew steadily and consistently between 2000 and 2021. A 164,000 yearly average rise in population is indicated by the trend analysis. Concerns over Tajikistan's rising food consumption need are raised by this country's significant and ongoing population expansion. The results are in line with other studies, such the one done by Khakimov et al. (2020), which also emphasizes the important effect that population expansion has on the demand for food. Effective methods and policies are desperately needed to guarantee food security and satisfy the escalating demands of a growing population as it continues to increase. Even though Tajikistan is experiencing significant population increase, it might be less than that of several other developing nations in the area, such Afghanistan and Uzbekistan, where reports of higher population growth rates due to various socioeconomic variables have been made (UNFPA, 2020).

The descriptive graph shows that throughout the previous 21 years, the daily calorie supply per capita has consistently increased. Data from 2000 to 2021 show a tendency toward increase, with the average daily supply of calories per person reaching 2077 Kcal. This increase in daily caloric consumption is indicative of improved food availability and nutrition for Tajikistan's populace, which is a good thing and related to economic growth in Tajikistan in last two decade according to Hydromet (2022).

According to the data analysis conducted between 2000 and 2021, bread products have been the most important food item consumed in Tajikistan. 2020 saw the greatest bread consumption, with 165.5 kilograms of bread consumed per person. Melons and vegetables came in second place, bread was the third most important item, and dairy products came in third. These results highlight how important agriculture is to Tajikistan and how important bread, vegetables, and dairy products are to the country's food security. The trends in food consumption show how crucial it is to maintain agricultural output in order to fulfil the requirements of people in terms of food security.

The International Fund for Agricultural Development's Climate Adaptation in Rural Development Assessment Tool reveals a worrying pattern that points to a possible drop in Tajikistan's essential crop yields over the course of the next 10 years. It is expected that crops including barley, cotton, maize, rice, soy, sunflower, and wheat—which are essential in providing the local people with food and energy—will encounter difficulties. There might be significant effects on Tajikistan's food security if these crops' yields decline. This is consistent with findings by Smutka et al. (2022), which highlight the higher probability of heatwaves and droughts having a detrimental effect on the nation's net production as a whole and agricultural output. Protecting the country's food supply and climate change resilience depends on addressing these issues. Similar issues have been reported in other developing nations, including those in South Asia and Sub-Saharan Africa, where changes in temperature and precipitation patterns brought on by climate change have been connected to variations in agricultural yields and the results of food security (IPCC, 2019).

To find out what factors affect Tajikistan's daily calorie supply per capita, a regression analysis was performed. The import of wheat and meslin flour, per capita income, population as a whole, and wheat output were the independent factors taken into account. There were three regression models used. All independent variables were included in the first model, one insignificant variable was eliminated in the second model, and all insignificant variables were omitted in the final model. The final model showed that Tajikistan's daily calorie supply per capita is positively impacted by both the country's total population and the statistically significant imports of wheat and meslin flour. This suggests that a rise in the daily caloric supply per capita is correlated with population growth and the importation of wheat and meslin flour. This emphasizes how important population trends and food imports are to Tajikistan's food security. This result is consistent with research by Khakimov et al. (2020), which highlights the significance of certain food commodities in the context of changing climate conditions and predicts an increase in imports of these goods under climate change.

The influence of climate change on Tajikistan's agriculture and food security is a significant issue that needs immediate action. Tajikistan is among the most climate change vulnerable nations in Central Asia because of its strong reliance on agriculture, limited ability to adapt, and susceptibility to natural disasters. The country's GDP could decline by 5.8% as a result of climate change by 2050, mostly as a result of losses in the agriculture sector, according to the World Bank (2019). Increased temperatures, less precipitation, less water availability, degraded soil, pest infestation, and crop failure are some of the predicted effects of climate change. Millions of people's livelihoods and access to food may be threatened by these effects, particularly the impoverished in rural areas who depend on subsistence farming.

Certain suggestions for enhancing Tajikistan's food security and climate change resistance might be offered in light of the study's findings. Among these are:

- Investing more in irrigation infrastructure, managing water resources, and conserving soil can increase agricultural output and lower the likelihood of crop failure caused by heat waves and droughts.
- Increasing the diversity of crops grown, including more climate-resilient types of staples like maize, wheat, and barley, and encouraging the production of fruits and vegetables, which are richer in nutrients and use less water than cereals.
- Enhancing domestic food processing and storage capabilities in order to lower post-harvest losses, enhance agricultural goods' value, and improve year-round food supply and accessibility.
- Increasing regional and global trade cooperation and integration to take use of the comparative advantages of nearby nations in terms of agricultural output and markets, as well as to make it easier to import necessities like wheat and meslin flour.
- Enhancing social protection and safety net programs for the most vulnerable groups in society, such as women, children, and rural households, where there is a greater risk of food insecurity and malnutrition because of poverty, limited access to health and education resources, and lack of income opportunities.

6. Conclusion

This paper's primary goal was to evaluate the effects of climate change, both present and future, on Tajikistan's agricultural and food security. It did this by reviewing the literature and doing a practical section that entailed gathering and analysing data using a variety of methods and tools. The paper also attempted to offer some policy suggestions for improving the food system's and the agriculture industry's resilience and adaptability to the difficulties brought on by climate change.

The Food and Agriculture Organization, the World Bank, World Data and the International Fund for Agricultural Development are just a few of the secondary data sources that were used in the thesis's descriptive and regression analyses to examine how climate change is affecting Tajikistan's agricultural industry and food security. To estimate the parameters and assess the fitness of the multiple regression equation that is formed, the study makes use of a multiple regression model, the Ordinary Least Squares (OLS) technique, a t-test, and multiple coefficients of determination. Regression diagnostics are also used to find important data and assess the assumptions' validity. This comprehensive approach offers a complete examination of the intricate factors influencing Tajikistan's food security.

Tajikistan is among the most climate change susceptible nations in Central Asia, according to the literature assessment, because of its heavy reliance on agriculture, its hilly topography, and its vulnerability to a variety of natural disasters. The review also demonstrated how the country's agro-climatic conditions, water availability, crop yields, livestock productivity, and pest and disease dynamics have already been impacted by climate change and how these effects are expected to worsen going forward, particularly under the high emissions scenario. Furthermore, the review showed that climate change has a significant impact on nutrition and food security because it can decrease food availability, accessibility, utilization, and stability while raising the risk of malnutrition and food insecurity for millions of people, particularly the impoverished and marginalized groups.

The paper concluded that climate change poses a serious threat to Tajikistan's agriculture and food security and that it is urgently necessary to develop and implement effective adaptation and mitigation policies and programs. These conclusions were based on the results of the literature review and the practical section.

To conclude, the results of the thorough investigation carried out for this thesis illuminate important facets of Tajikistan's agriculture industry and the consequences for food security. Climate change presents a number of complex difficulties to the nation's largely irrigation-dependent agricultural sector, affecting crop yields, water availability, and overall productivity. The challenge of guaranteeing food security is increased by socioeconomic considerations combined with the vulnerability of some places. The study emphasizes how the daily calorie supply per capita is shaped by population increase and food imports, particularly wheat and meslin flour. According to the regression analysis, these variables are crucial in shaping Tajikistan's situation with regard to food security. Concerns over the stability of food production in the future are also raised by the anticipated effects of climate change on agricultural yields. Overcoming these obstacles requires a comprehensive approach that takes technology innovations, legislative initiatives, and adaptive tactics into account. Improving food security may be aided by the possibility of using underused arable land, leveraging modern technology, and addressing the vulnerabilities of certain locations. To realize this promise, though, significant financial and technological expenditures are required. Given Tajikistan's complex challenges with climate change, population dynamics, and agricultural practices, the country has to plan ahead and take proactive steps to ensure that its food supply is robust and sustainable.

Despite the statistical insignificance of the results regarding income per capita and wheat output, these findings must be taken into consideration when discussing Tajikistan's food security. As a staple crop, wheat is essential to the nation's food consumption patterns. The importance of wheat production for maintaining a steady and varied food supply is confirmed by the larger agricultural landscape and socioeconomic dynamics, even though the statistical study may not have shown a clear association. A household's ability to make purchases and have access to a variety of food products is significantly influenced by income per capita, even if it was not shown to be statistically significant in the regression model. By facilitating healthier dietary choices and reducing vulnerability to economic shocks, higher income levels typically result in increased food security. Even in cases where our analysis did not find these characteristics to be very significant, it is crucial to keep in mind that they can still have a significant influence on Tajikistan's food security. This indicates that the nation's agriculture faces a wide range of issues and difficulties that we must consider.

7. References

1. Agency of Statistics under the President of the Republic of Tajikistan (ASUPRT). (2021). Retrieved from https://www.stat.tj/en

2. Asian Development Bank (ADB). (2017). Addressing Climate Change and Migration in the Asia and Pacific Region. Manila: Asian Development Bank.

3. Belay, A., Mirzabaev, A., Recha, J. W., Oludhe, C., Osano, P., Berhane, Z., … & Solomon, D. (2023). Does climate-smart agriculture improve household income and food security? evidence from southern Ethiopia. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-023-03307-9.

4. CISPM (n.d.), Tajikistan. (n.d.). INFORMATION MATERIAL. Dushanbe: The State Committee on Investment and State Property Management of the Republic of Tajikistan.

5. Hydromet (2022), Tajikistan, A. f. (2022). FOURTH NATIONAL COMMUNICATION OF THE REPUBLIC OF TAJIKISTAN UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE. Dushanbe: Agency for Hydrometeorology of the Committee for Environment Protection under the Government of the Republic of Tajikistan.

6. Hydromet of Tajikistan, A. f. (2018). THE FIRST BIENNIAL REPORT OF THE REPUBLIC OF TAJIKISTAN ON INVENTORY OF GREENHOUSE GASES UNDER THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE. Dushanbe: Tajikistan, Agency for Hydrometeorology under the Committee on Environmental Protection under the Government of the Republic of Tajikistan.

7. Intergovernmental Panel on Climate Change. (2019). Special Report on Climate Change and Land. Retrieved from https://www.ipcc.ch/srccl/

8. James, G. - Witten, D.- Hastie, T.- Tibshirani, R. (2013). An introduction to statistical learning with application in R. New York, USA: Springer. ISBN 987-1-4614-7137-7.

9. Khakimov, P., Aliev, J., Thomas, T. S., Ilyasov, J., Dunston, S. (2020). 'Climate Change Effects on Agriculture and Food Security in Tajikistan', Silk Road Journal, Volume 2, Page numbers 89-112. Available at: https://silkroadjournal.online/article/id/653/ (Accessed: 19 November 2023).

10. Kummu, M., Guillaume, J. H. A., Moel, H. d., Eisner, S., Flörke, M., Porkka, M., … & Ward, P. J. (2016). The world's road to water scarcity: shortage and stress in the 20th century and pathways towards sustainability. Scientific Reports, 6(1). https://doi.org/10.1038/srep38495.

11. Lerman, Z., & Sedik, D. (2009). Agricultural development and household incomes in Central Asia: a survey of Tajikistan, 2003-2008. Eurasian Geography and Economics, 50(3), 301-326. https://doi.org/10.2747/1539-7216.50.3.301.

12. NISBET, R. - ELDER, J. - MINER, G. (2009). Handbook of statistical analysis and data mining applications. Amsterdam, Netherlands: ISBN 978-0-12-374765-5.

13. Our World in Data. (2023). Daily per capita caloric supply in Tajikistan. [Online] Available at: https://ourworldindata.org/grapher/daily-per-capita-caloric-supply?tab=chart&time=2000.latest&country=~TJK [Accessed 24 December 2023].

14. Smutka, L., Čechura, L., Krepl, V., Čábelková, I., Procházka, P., Malec, K., Akhmedov, S., Kotyza, P., Mach, J., Davlatzoda, S., Kasimov, F., Hakimov, F., Zabirov, M., Kulhánek, A., Messana, D., Činčera, P., Němec, L., Homidov, A., Gaforzoda, B., Saidzoda, M., Kamolov, J., J., (2022). Assessment of the Costs and Benefits of Climate Change Adaptation in Agriculture, Forestry, and Water Management Sectors of Tajikistan; Deliverable 1. Report on existing and forecast future changes in climate in six target districts and observable impacts of agriculture, forestry, water resources. Faculty of Economics and Management, Czech University of Life Sciences Prague & Dekonta under the UNDP project 115-2021-RF.

15. United Nations Environment Programme (UNEP). (2021). Frontiers 2020/21: Emerging Issues of Environmental Concern. Nairobi, Kenya: United Nations Environment Programme.
16. United Nations Development Programme (UNDP). (2020). Central Asia: Climate Change Risk Assessment and Adaptation Strategy. New York: UNDP.

17. USAID (2021) "Climate Risk Assessment for the South-West Khatlon Region:. Available at: https://example.com/climate-risk-assessment.pdf (Accessed: 19 November 2023).

18. United Nations Population Fund. (2020). State of World Population 2020. Retrieved from https://www.unfpa.org/publications/state-world-population-2020 (Accessed: 24 November 2023).

19. World Bank (2022). Tajikistan - Climate Data Historical. [Online] Available at: https://climateknowledgeportal.worldbank.org/country/tajikistan/climate-data-historical (Accessed: [12 December 2023])

20. World Bank. (2023). Tajikistan Economic Update: Focusing on Boosting Private Sector Dynamism in Tajikistan. [Online]. Available at: https://documents1.worldbank.org/curated/en/099062723061541337/pdf/P1796530c969b005c0b9f80aaf2ece82ff0.pdf (Accessed: 12 November 2023).

21. World Bank and Asian development Bank (2021), Climate Risk Country Profile: Tajikistan. 1818 H Street NW, Washington, DC 20433: The World Bank Group and the Asian Development Bank.

22. World Food Programme. (2017). CLIMATE RISKS AND FOOD SECURITY IN TAJIKISTAN. Retrieved from https://docs.wfp.org/api/documents/WFP-0000015482/download/#:~:text=Tajikistan%20is%20classified%20as%20the,increasingly%2C%20droughts%20and%20water%20scarcity.

23. World Bank and Asian development Bank (2021), Climate Risk Country Profile: Tajikistan. 1818 H Street NW, Washington, DC

24. World Bank. (2019). Toward Climate Adaptation and Resilience in Agriculture: A World Bank Program in Central Asia. Retrieved from https://openknowledge.worldbank.org/handle/10986/32919

8. List of pictures, tables, figures, and abbreviations

List of Figures:

FIGURE 1 : MAP OF TAJIKISTAN 14
FIGURE 2: KÖPPEN – GEIGER MAP OF TAJIKISTAN 19
FIGURE 3: OBSERVED AVERAGE ANNUAL MEAN – TEMPERATURE OF TAJIKISTAN FOR 1901–2020 20
FIGURE 4: MONTHLY CLIMATOLOGY OF MIN TEMPERATURE AND MEAN TEMPERATURE, MAX TEMPERATURE AND PRECIPITATION 1991-2020 FOR TAJIKISTAN 20
FIGURE 5: PROJECTED MEAN TEMPERATURES, TAJIKISTAN. REFERENCE PERIOD 1995-2014, MULTI-MODEL ENSEMBLE 22
FIGURE 6: PROJECTED MEAN-TEMPERATURE ANOMALY, TAJIKISTAN REFERENCE PERIOD 1995-2014, MULTI-MODEL ENSEMBLE. 23
FIGURE 7: PROJECTED DAYS WITH HEAT INDEX >35 °C, TAJIKISTAN, REFERENCE PERIOD 1995-2014, MULTI-MODEL ENSEMBLE 24
FIGURE 8: THE PROJECTED PRECIPITATION ANOMALY 2020-2040, TAJIKISTAN, REFERENCE PERIOD 1995-2014, MULTI-MODEL ENSEMBLE 25
FIGURE 9: ALLOCATED LAND UNDER MAIN CROPS IN TAJIKISTAN, IN HECTARES. 33
FIGURE 10: CROP YIELDS FROM IRRIGATION IN METRIC TONS/HA FOR BARLEY, MAIZE, WHEAT, AND RICE UNDER CLIMATE CHANGE AND NON-CLIMATE CHANGE SCENARIOS. 38
FIGURE 11: POTATOES, COTTON, VEGETABLES, AND FRUIT, THE IRRIGATED CROP YIELDS IN METRIC TONS/HA UNDER CLIMATE CHANGE VERSUS NON-CLIMATE CHANGE SCENARIOS. 39
FIGURE 12: CHANGES IN IRRIGATED CROP YIELDS IN THE CONTEXT OF CLIMATE CHANGE, 2050–2015 (%) 40
FIGURE 13: RECURRENCE RATES OF INSTANCES IN WHICH OVER 20% OF THE POPULATION EXPERIENCED FOOD INSECURITY 45
FIGURE 14: CLIMATE CHANGE AFFECTS CROP SUPPLY AND DEMAND (000 METRIC TONS). 46
FIGURE 15: FOOD AVAILABILITY IN SCENARIOS WITH AND WITHOUT CLIMATE CHANGE, KG PER CAPITA ANNUALLY 47
FIGURE 16: CALORIES PER CAPITA IN SCENARIOS WITH AND WITHOUT CLIMATE CHANGE, EXPRESSED IN KCAL. 47
FIGURE 17: TREND ANALYSIS FOR POPULATION: 48
FIGURE 18: DAILY CALORIES SUPPLY PER PERSON IN TAJIKISTAN FOR PERIOD 2000-2021: 50
FIGURE 19: FOOD CONSUMPTION IN TAJIKISTAN FOR PERIOD 2000 -2021, KG PER CAPITA 50
FIGURE 20:ANALYSIS OF WHEAT AND FLOUR IMPORTS AND PRODUCTION IN TAJIKISTAN: 2000–2021 52
FIGURE 21:CROP YIELD PREDICTIONS FOR PERIOD 2021-2033 53
FIGURE 22: FOOD CONSUMPTION PER CAPITA IN 2021 IN TAJIKISTAN 54

List of tables:

TABLE 1: DYNAMICS OF THE MAIN MACROECONOMIC INDICATORS OF THE REPUBLIC OF TAJIKISTAN FOR 2010-2019 27
TABLE 2: AN OVERVIEW OF THE PRIMARY RISKS AND EFFECTS OF CLIMATE CHANGE ON AGRICULTURE 41
TABLE 3:DATA TABLE 56

TABLE 4: MODEL 1 WITH ALL INDEPENDENT VARIABLES 58
TABLE 5:MODEL 2 WITHOUT FIRST INSIGNIFICANT VARIABLE 59
TABLE 6:FINAL MODEL 60
TABLE 7:DIAGNOSTIC OF THE MODEL 62

List of Formulas:

FORMULA 1: MULTIPLE REGRESSION MODEL 11
FORMULA 2: ESTIMATING REGRESSION COEFFICIENTS 11
FORMULA 3: OLS 11
FORMULA 4: MULTIPLE COEFFICIENT OF DETERMINATION 12