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**POLICY PAPER**

# Climate Change Effects on Agriculture and Food Security in Tajikistan

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Climate change is one of the main challenges for Tajikistan's agricultural development and food security both in the medium and longer term. It is considered one of the key obstacles to achieving the country's strategic objectives as defined in the National Development Strategy for 2016–2030, which includes ensuring food security and access to quality nutrition by 2030. Using IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), this article examines the effects of climate change on agriculture and food security in Tajikistan. The model simulation results show that yields of some major crops will decline significantly and project an overall negative effect of climate change on the agriculture sector in the country. Climate change will be one of the main challenges for food security, leading to an increased number of people at risk of hunger, malnourishment, especially among children and other vulnerable groups, and insufficient per capita calorie intake. Lower food availability may lead to higher food prices, which would negatively affect the livelihood of the population.

**Keywords:** Tajikistan; agriculture; climate change; population; equilibrium model; food security

## 1 Introduction

Tajikistan is a small, landlocked and mountainous country in Central Asia with a relatively open economy. Its population has grown at a faster pace than that of any other country in the Eastern European and Central Asian regions due to its high birth rate. With a median age of 24.7 years and about 35 per cent of the population under 15 years old, Tajikistan's population is young (Khakimov 2015).

Since 2000, Tajikistan has experienced rapid economic growth. The average rates of GDP and GDP per capita growth, for the period 2000–2014, were nearly 8 per cent and 5.8 per cent, respectively. The main drivers of recent economic growth were remittances and the agricultural sector. From 2007 to 2014, Tajikistan had the world's highest remittance to GDP ratio with remittances comprising 48 per cent of the country's GDP in 2014 (World Bank 2016).

According to the Federal Migration Services (FMS) of the Russian Federation, the number of Tajik labour migrants in 2014 was approximately 1.2 million, equivalent to 15 per cent of the country's population, 28 per cent of the labour force, and 50 per cent of the economically active population (CBR 2016; TAJSTAT 2015b).

Agriculture plays a crucial role in the economic growth of Tajikistan and in ensuring food security. Food security and access to quality nutrition is defined as one of four strategic priorities of the country within the National Development Strategy (NDS), and is highlighted in the new agricultural policy (Government of Tajikistan 2016; IMF 2010). Since independence, agricultural policy has primarily focused on land reform and achieving agricultural growth through improving private land use and enhancing farm productivity. Nearly 90 per cent of all agricultural products are produced in the private sector. While household plots cover only 20 per cent of the sown area, they contribute about 50 per cent of the aggregate crop production in the country. Households hold about 87 per cent of livestock inventories and produce 94 per cent of livestock output (Khakimov 2015). The sector's contribution to GDP was around 30 per cent from 1985 to 2000 and close to 22 per cent from 2001 to 2015 (World Bank 2016). To support agricultural producers, the government revised its Tax Code and introduced a unified tax system for producers of agricultural products in 2005, which simplified farmers' taxation by either eliminating or unifying several taxes such as land tax, property tax, income tax on agricultural workers, road user tax, agricultural value-added tax, etc. (IMF 2005). The Tax Code was further revised in 2013 to eliminate barriers for agricultural producers (Government of Tajikistan 2012). Nevertheless, agricultural growth faces many challenges, including limited land resources, rapid population growth, climate change, land degradation, and water loss due to irrigation channel and drainage system damage.

The climate in Tajikistan is mostly continental with some subtropical and semi-arid zones covering desert areas. The average temperature in July, the hottest month, ranges from 23°C to 30°C and the average temperature during January ranges from 1°C to 3°C. The average annual precipitation level across the country is 760 mm, but it is unevenly distributed. Glaciers in Tajikistan's mountains cover some of the biggest water reserves in the world. More than 80 per cent of the runoff of the Amu-Darya and 1 per cent of the Syr-Darya rivers forms in Tajikistan. In other words, 64 cubic km of water per year or 55.4 per cent of the water resources of the Aral Sea basin are formed within Tajikistan (Water for Life Conference 2015; UNECE 2012).

Climate change is one of the main challenges for food security in Tajikistan due to the high vulnerability of its natural environment and its low adaptive capacity. Over the last 65 years, average temperatures have increased by 0.7–1.2°C in the valleys, by 0.1–0.7°C in mountainous and highland areas, and by 1.2–1.9°C in cities. Due to climate change, glaciers have lost 20 per cent of their volume and 30 per cent of their area over the past 50–60 years, according to some estimates (Water for Life Conference 2015). Assessing the current trends and impacts of climate change in Central Asian countries, CAREC (2013) finds that the region has suffered more frequent droughts and strong winds, which had a large impact on water availability, crop yields, and pasture productivity from 1940 to 2005.

Food security, health, livelihood assets, food production, and distribution channels are also affected by climate change (FAO 2008; UNECE 2012). Heltberg, Reva, and Zaidi (2012) suggest that climate change can potentially deepen poverty by lowering agricultural yields, raising food prices, and increasing the spread of water-borne diseases as well as the frequency and severity of natural disasters. In their earlier work, Heltberg and Bonch-Osmolovskiy (2011) assessed Tajikistan's vulnerability and capacity to adapt to ongoing and future climatic changes. Their results indicate that the eastern mountainous area of the Districts of Republican Subordination (DRS), the lowlands, the southern Sughd, and

Khatlon hills are most vulnerable to climate change. Projecting impacts, vulnerabilities, and adaptations in Asia, Hijioka et al. (2014) suggest that water scarcity is expected to become a major challenge in many parts of Asia, including Central Asia. Tajikistan's main agricultural valleys are among the most vulnerable to the impact of climate change, where water availability is a major climate-change-related concern (Heltberg and Bonch-Osmolovskiy 2011). Bobojonov and Aw-Hassan (2014) suggest that the impact of climate change on incomes derived from agriculture in Tajikistan is expected to be crop-specific. The authors argue that due to climate change, income from cotton will decline, while wheat revenue will remain constant, assuming that current prices and management practices prevail. Moreover, they claim that climate change will positively affect semi-arid and humid zones, while arid zones will undergo losses.

Fay, Block, and Ebinger (2010) studied the effects of climate change in the Europe and Central Asia (ECA) region and found that Tajikistan is the most sensitive to climate change[1] and has the least adaptive capacity[2] among 28 countries in the region. OSCE (2010) provides a review of the legislative framework and discusses a national programme of action to address issues and challenges related to climate change. The study underlines the potential impacts of climate change on natural resources, key sectors of the economy, the health of the population, the lifestyles of local communities, and the adaptation and coping mechanisms of households. Increased water stress and losses from climate-related disasters may further hinder productivity growth in Tajikistan, a country that already suffers from low agricultural productivity (Heltberg, Reva, and Zaidi 2012).

There have been a number of analytical assessments of the impact of climate change on agriculture and food security in Tajikistan (e.g. Bobojonov and Aw-Hassan 2014; OSCE 2010; CAREC 2013; Heltberg, Reva, and Zaidi 2012; Lerman and Wolfgramm 2011; Makhmadaliev et al. 2008; Bann et al. 2012; FAO 2008; Fay, Block, and Ebinger 2010; Khakimov and Mahmadbekov 2009). However, neither partial nor general equilibrium models have been applied for any analysis. This study aims to fill an existing research gap to some extent. The study supports the stated objective in three ways. First, it assesses the vulnerability/resilience of agriculture to climate change. Second, it presents findings and raises stakeholder awareness on the likely impacts of climate change on Tajikistan's agricultural sector. Finally, it helps to develop policy recommendations for mitigation strategies.

The main research tool used in this study is IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) – a global partial equilibrium model which integrates economic, water, and crop models and simulates national and international agricultural markets, enabling us to conduct integrated analysis of changing environmental, biophysical, and socio-economic trends. The water simulation component of the IMPACT model estimates changes in water supply and demand for irrigation and other water-using activities. The model is designed to examine future global food supply, demand, trade, prices, and food security. IMPACT covers 56 agricultural commodities, 159 countries, 154 water basins, and 320 food production units (for more details, see Rosegrant et al. 2012).

[1] The climate change sensitivity index is based on physical indicators (available renewable water resources per capita and the extent of air pollution), economic indicators (share of employment and value of assets), overall quality of infrastructure, share of population over age 65 (as a most sensitive group of population) and economic indicators capturing the importance of agriculture in the economy (share of employment and value of assets). For more details,, see Fay, Block, and Ebinger (2010).

[2] Adaptive capacity index comprises social (income inequality), economic (GDP per capita), and institutional measures. For more details, see Fay, Block, and Ebinger (2010).

## 2 Climate Change and Recent Trends in Economic Development and Agriculture

### *2.1 Economic Development and Demography*

Tajik economic development suffered a sharp decline during the early post-independence period between 1992 and 1997. From 2000 onward, national GDP and GDP per capita on average increased by 8 per cent and 5.8 per cent, respectively. The National Development Strategy (NDS) for 2016–2030 is the main strategic document outlining Tajikistan's long-term development priorities (Government of Tajikistan 2016). The policy document postulates three scenarios for national economic development, as shown in **Table 1**.

In our study, we assume that the rate of GDP growth will be within the figures mentioned under the industrial scenario of the NDS. Furthermore, we assume that average annual GDP growth will not change from 2030 to 2050, as shown in **Figure 1**.

As mentioned earlier, Tajikistan's population is young, with a high growth rate. The absolute population increased eightfold between intercensal periods from 1913 to 2010, reaching 8 million people (Khakimov 2015). In terms of trends in the urban and rural populations, the share of Tajikistan's total population living in urban areas increased from 9 per cent in 1913 to 37 per cent in the 1970s. Since the late 1970s, the rural population has grown at a faster pace, due to a high concentration of the population living in the countryside. Higher rural population is expected to persist and serve as a source of growth for the total population in the future (Khakimov 2015). UNDESA (2015) proposes three scenarios for population growth

**Table 1:** The National Development Strategy Goals, 2016–2030.

| | The scenarios | | |
|---|---|---|---|
| | **Inertia** | **Industrial** | **Industrial-innovation** |
| GDP average growth rate, annual | 4–5% | 6–7% | 8–9% |
| GDP growth, (2030 against 2015) | 3.5–3.7 times | 4.6–4.8 times | 5.5–5.7 times |
| GDP per capita, PPP (in 2030) | $4,500–5,500 | $5,500–6,000 | $7,000–7,500 |
| Agriculture sector's share of GDP, 2030 | 22.5–23% | 19–19.5% | 17–18% |

Source: The National Development Strategy Document for the period 2016–2030.

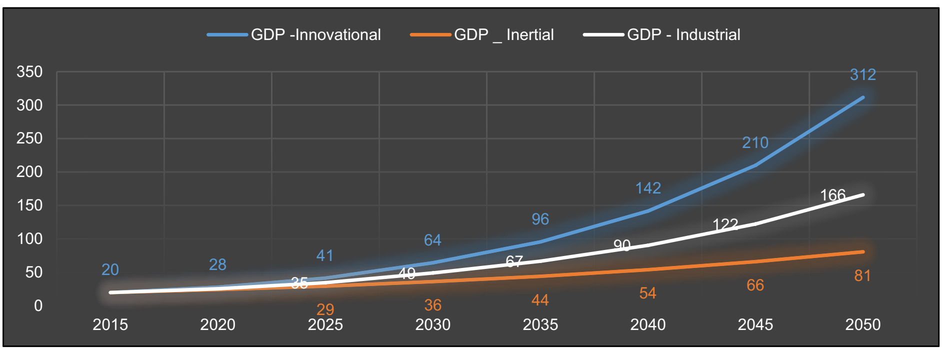


**Figure 1:** GDP growth projection, billion 2005 constant US$.

Source: Own compilation based on the National Development Strategy Document for the period 2016–2030 and IMPACT result.

in Tajikistan: high, medium, and low growth rates. Our study uses the medium scenario, which is more consistent with historical trends in its population growth assumptions, and is also in line with assumptions made in the NDS for 2016–2030 (**Figure 2**).

### *2.2 Agricultural Development*

Agriculture contributed approximately 22 per cent of total GDP, with an average annual sectoral growth rate of 7.3 per cent during the 2010–2014 period (**Figure 3**). Official statistics and Labour Force Survey (LFS) data indicate that 45–65 per cent of the labour force is employed in the agricultural sector[3] and the majority of the rural population depends on agricultural income (TAJSTAT 2009, 2015b; Khakimov 2015).

Crop production accounts for 69 per cent of sectoral value-added. Major agricultural zones are located in Khatlon, Sughd, and the DRS. Many mountainous areas of the country are not suitable for cultivation. Crops are cultivated mainly in valleys (irrigated, including by pump irrigation) and downhill (rain-fed) zones. Irrigated land produces 90 per cent of gross agricultural output (GAO). Most barley, maize, and rice crops are cultivated in Sughd, while cotton and wheat are cultivated in Khatlon (**Table 2** and **Figure 4**). Water use has decreased in recent years compared to 1990 largely because of reduced land being allocated for cotton. More than 80 per cent of the country's total freshwater intake is used for irrigation (World Bank 2007).

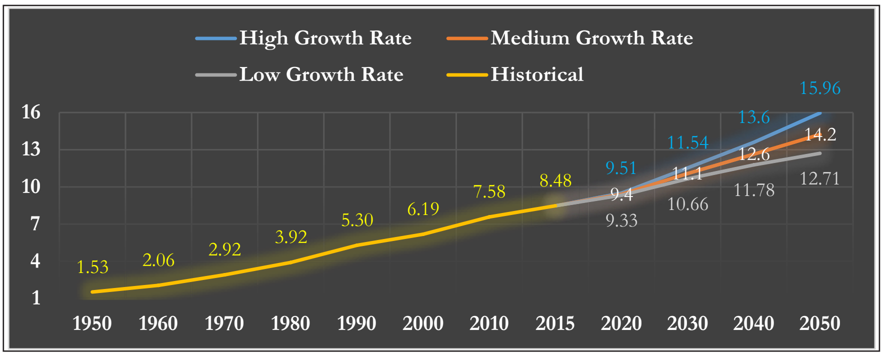


**Figure 2:** Projections of population growth in Tajikistan for 2015–2050, in millions.

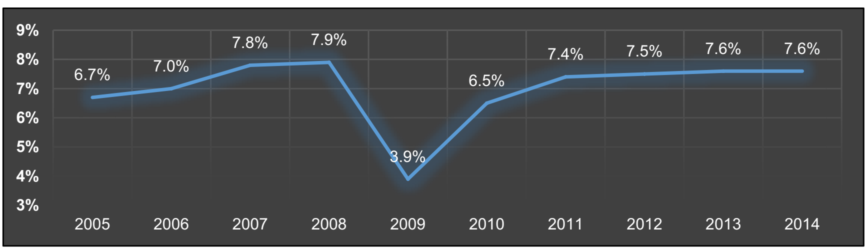


**Figure 3:** Agriculture value-added annual growth rate, %.
Source: TAJSTAT (2010, 2015a).

[3] Respectively in accordance with official current statistics and the 2009 Labour Force Survey (LFS).

**Table 2:** Distribution of cultivated area of main crops by region in 2015 (000 hectares).

| Crops | Regions | | | | |
|---|---|---|---|---|---|
| | Sughd | Khatlon | DRS | MBAR | Total |
| Barley | 56.6 | 12.9 | 6.7 | 1 | 77.2 |
| Cotton | 43 | 113 | 3.6 | 0 | 159.6 |
| Maize | 10 | 5.7 | 3.2 | 0 | 18.9 |
| Potato | 13.9 | 11.5 | 11.9 | 2.5 | 39.8 |
| Rice | 7.8 | 2.5 | 1.5 | 0 | 11.8 |
| Wheat | 49.8 | 174.8 | 66.6 | 4.5 | 295.7 |

Source: TAJSTAT (2015a).

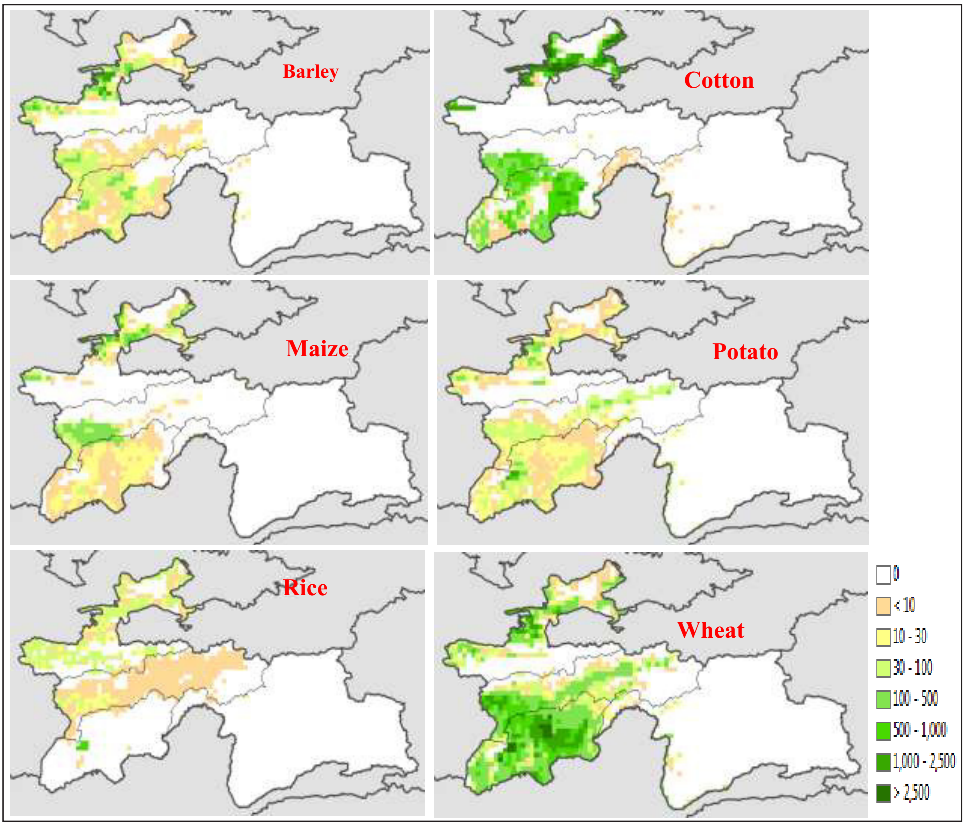


**Figure 4:** Allocated land under main crops in Tajikistan, in hectares.
Source: Own illustration using SPAM model.

**Table 3** and **Figure 5** illustrate average yields of main crops in different regions of Tajikistan between 2012 and 2014. Potato and rice yields in Sughd are higher than the national averages, while wheat and cotton yields are highest in Khatlon. Maize yield is highest in the DRS.

**Table 3:** Yield of main crops by region (average of 2012–2014), in metric tons.

| Crops | Regions | | | | |
|---|---|---|---|---|---|
| | **Sughd** | **Khatlon** | **DRS** | **MBAR** | **Tajikistan** |
| Barley | 1.20 | 2.90 | 1.94 | 1.98 | 1.81 |
| Cotton | 1.91 | 2.18 | 1.97 | 0.00 | 2.10 |
| Maize | 4.83 | 4.29 | 4.96 | 4.41 | 4.66 |
| Potato | 26.26 | 22.61 | 22.10 | 22.89 | 23.72 |
| Rice | 4.28 | 3.61 | 3.86 | 0.00 | 4.08 |
| Wheat | 1.96 | 3.25 | 2.50 | 2.42 | 2.61 |

Source: TAJSTAT (2015a).

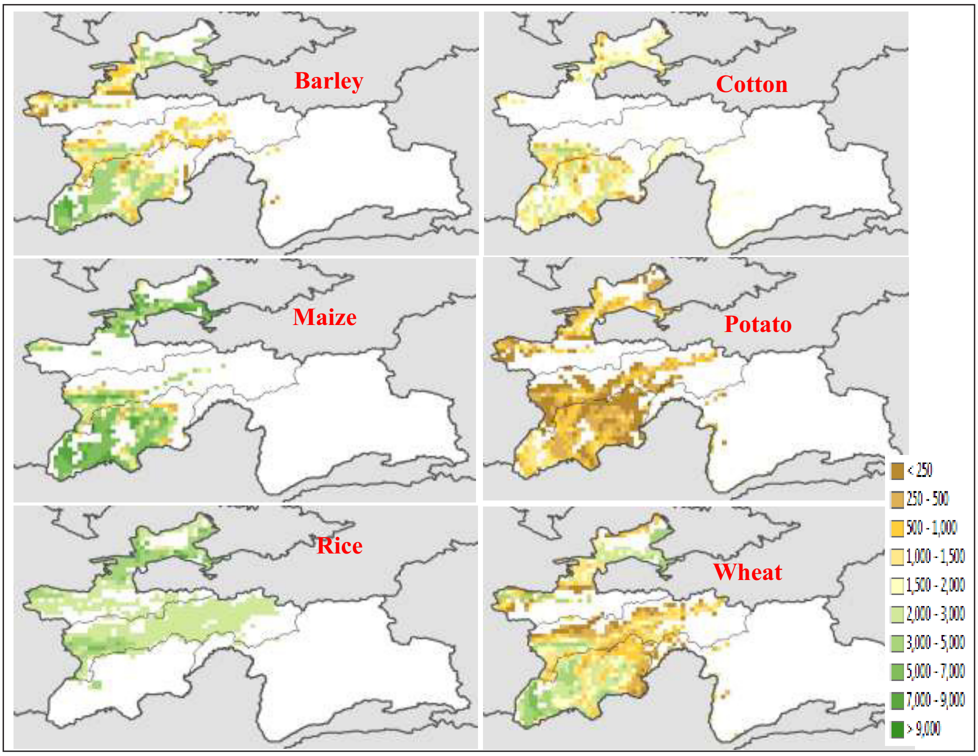


**Figure 5:** Crop yields by geographic location, kg/hectare.
Source: Own illustration using SPAM model.

Tajikistan's agriculture does not receive any direct subsidies from the government, and all prices have been liberalized since 1991. Agricultural markets in Tajikistan are highly distorted and inefficient due to inappropriate government regulations and inadequate competition. Local monopsonies for cotton processing and marketing reduce producer incentives and are a major cause of low producer prices for cotton. Farm input markets are also distorted by the monopsony position of cotton investors. Input prices are high and service is poor as a result.

This situation changed slightly in 2009 after the government allowed producers to sell their harvest to any cotton ginners (Khakimov 2015).

Land reform has been characterized by the reorganization of large state farms into smaller private (*dehkan* or peasant) farms, managed and operated mainly by individuals or family members. **Table 4** shows the change in the number of farms due to institutional reforms and farm restructuring in Tajikistan.

Despite institutional reform and privatization of farm production, *dehkan* farms were responsible for only 31 per cent of gross agricultural output in 2014, while households produced 63 per cent of agricultural products (**Figure 6**). *Dehkan* farms only produced 3 per cent of livestock output, while households held 87 per cent of livestock inventories and produced 93 per cent of the livestock output. The remaining crops and livestock were produced by agricultural enterprises (TAJSTAT 2015a).

### *2.3 Historical Trends of Temperature and Precipitation Changes*

Relying on historical and projected trends in temperature and precipitation, Broka et al. (2016) suggest that Tajik agriculture is particularly vulnerable to climate change, with rising temperatures and falling precipitation projected in both the medium and long term. In the medium term, rising temperatures are expected to increase the rate of glacial melt and the

**Table 4:** Types and number of agricultural farms in Tajikistan.

| Type of farms | Number of farms | | | | |
|---|---|---|---|---|---|
| | 1991 | 1997 | 2003 | 2008 | 2014 |
| Kolkhozes | 206 | 354 | 169 | 1 | – |
| Sovkhozes (state farms) | 362 | 348 | 148 | 7 | – |
| Corporate farms | 19 | 13 | 6 | – | – |
| Private farms (*dehkan* farms) | – | 8,023 | 16,431 | 30,842 | 108,035 |
| Agriculture enterprises | – | – | – | – | 1,107 |
| **Total** | **587** | **8,738** | **16,574** | **30,850** | **109,142** |

Source: Own compilation based on TAJSTAT (2015a, 2015b).

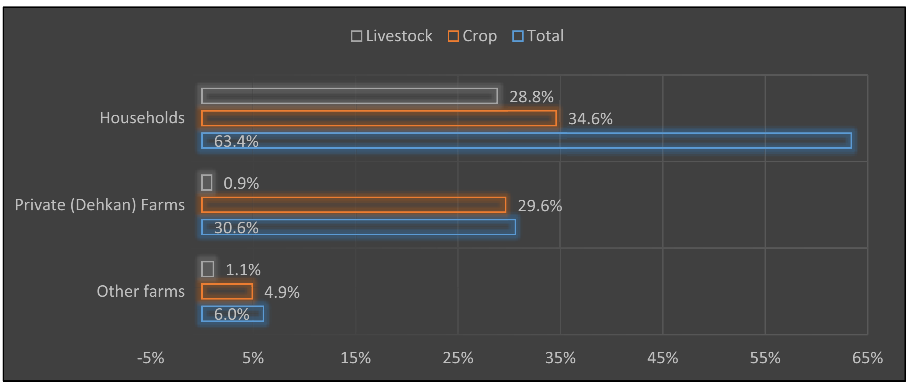


**Figure 6:** Share of different types of farms in gross agricultural output, 2014.
Source: TAJSTAT (2015a).

associated risks of flooding. In the long term, together with falling precipitation, water availability for irrigation will become a major challenge.

According to historical data provided by the Climate Change Knowledge Portal for Development Practitioners and Policy Makers (CCKP), average annual precipitation levels might not be significantly different between the periods of 1961–1990 and 1991–2016. However, changes in precipitation levels have taken a more seasonal pattern, which directly affects agricultural activities. While precipitation levels increased in January–February of the 1991–2016 period more than from 1961–1990, the reverse can be observed during March–May. From August onward precipitation patterns for the two date ranges remain more or less the same (**Figure 7**).

Contrary to precipitation data, the average monthly temperature has increased for all months during the 1991–2016 period compared to 1961–1990. Overall, the average annual temperature increased by about 0.63°C between 1991 and 2016 compared to 1961–1990 (**Figure 8**).

### *2.4 National Climate Change Mitigation and Adaptation Strategy*

The *National Communication of the Republic of Tajikistan under the UN Framework Convention on Climate Change* underlines response measures aimed at mitigating climate-change issues.

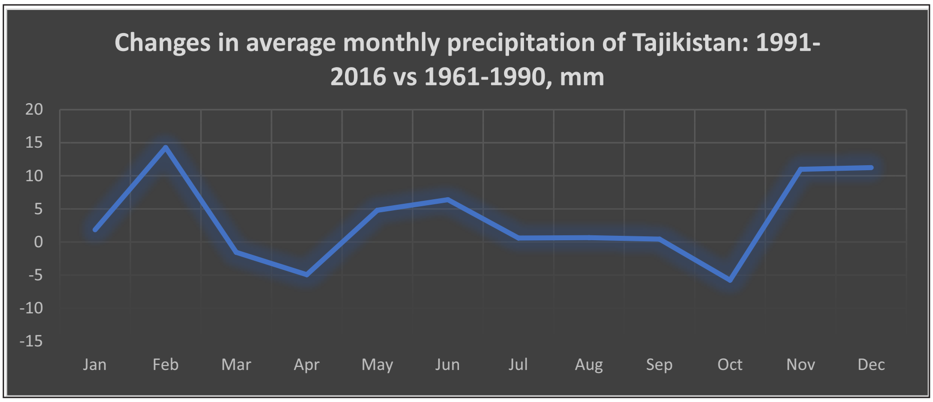


**Figure 7:** Monthly precipitation changes in Tajikistan: 1991–2016 vs 1961–1990, mm. Source: CCKP (n.d.).

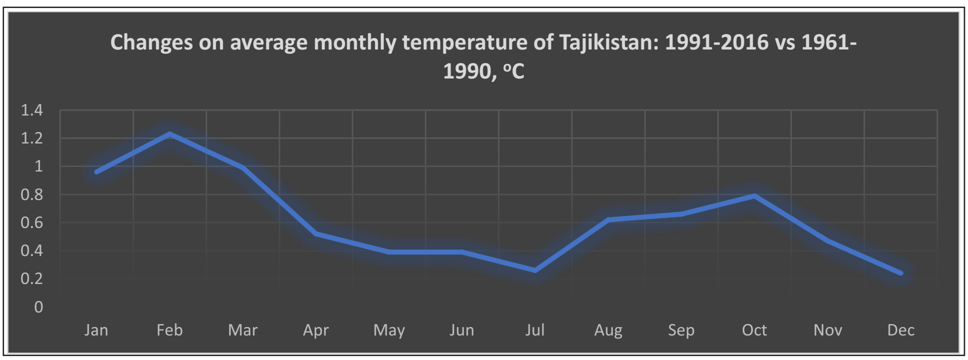


**Figure 8:** Monthly temperature changes in Tajikistan: 1991–2016 vs 1961–1990, °C Source: CCKP (n.d.).

The government of Tajikistan was involved in developing three national communications in 2003, 2008, and 2014. Tajikistan has signed and ratified several important international treaties. The government has also adopted several programmes, strategies, action plans, laws, and enactments related to climate change at the state level to implement its national policy and to meet the requirements of international treaties (Kayumov and Novikov 2014).

The State Committee for Environment Protection under the Government of the Republic of Tajikistan developed the National Strategy for Climate Resilience in cooperation with the Asian Development Bank (ADB). Donor organizations and countries have provided support to develop and implement the National Strategy for Climate Resilience.

## 3 Modelling Alternative Scenarios and Analysis of Results

### *3.1 Overview of Simulated Scenarios*

The simulation analysis involves five scenarios, with one baseline scenario and four climate-change scenarios. The baseline scenario (Sc1)[4] allows for change in supply and demand factors with no climate-change assumption. The four scenarios with different climate models involve the following assumptions:

**MIROC Climate Change Scenario (Sc2):** Model for Interdisciplinary Research on Climate (MIROC), developed at the University of Tokyo Center for Climate System Research using the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment with Representative Concentration Pathway (RCP) 8.5.

**Hadgem Climate Change Scenario (Sc3):** Hadley Centre Global Environment Model (Hadgem), UK Climate Change Scenario, using the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment with Representative Concentration Pathway (RCP) 8.5.

**GFDL Climate Change Scenario (Sc4):** Geophysical Fluid Dynamics Laboratory GFDL, Princeton University, using the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment with Representative Concentration Pathway (RCP) 8.5.

**IPSL Climate Change Scenario (Sc5):** Institute Pierre Simon Laplace (IPSL) Global Climate Modelling Centre (France), using the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment with Representative Concentration Pathway (RCP) 8.5.

In this analysis, the results of the baseline scenario are compared with the average of the four climatic scenarios. Two important exogenous variables – GDP growth and population growth – are taken into consideration and directly affect the global demand for food, which in turn indirectly affects most other economic variables in the model. Assumptions concerning national GDP and population growth were described in the previous section.

### *3.2 Temperature and Precipitation Changes in Regions of Tajikistan by Climate Change Scenarios*

**Figures 9** and **10** show projections for temperature and precipitation changes in 2050 compared to 2000 by geographical location from the four climate-change models used in this analysis. The Hadgem climatic scenario projects an increase in precipitation levels. The other three models project a precipitation decrease in at least some parts of the country. All four scenarios project an increase in temperature. The effects vary in both magnitude and location.

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[4] In scenario 1, the terms business as usual, baseline scenario and no-climate-change scenario are used interchangeably.

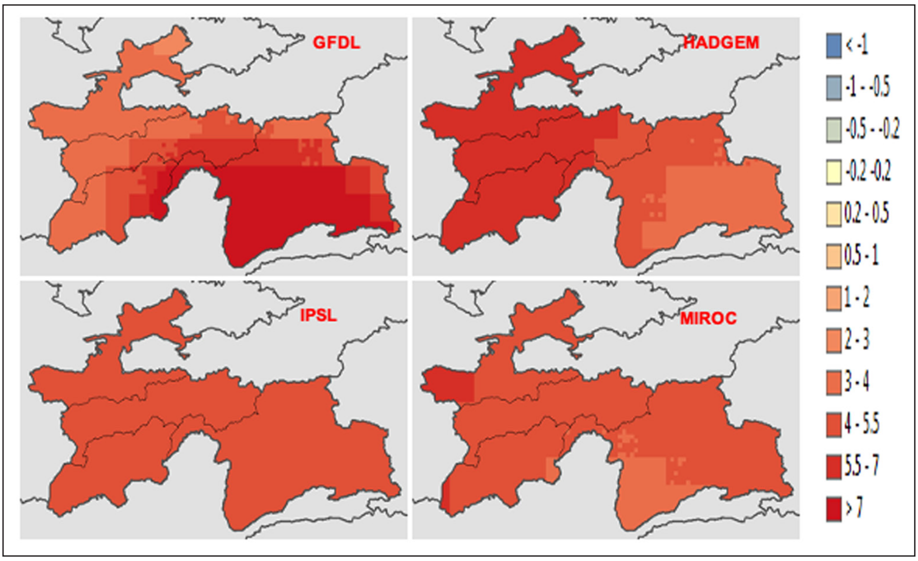


**Figure 9:** Temperature change in regions of Tajikistan, 2050 compare to 2000, °C. Source: Authors based on Müller and Robertson (2014).

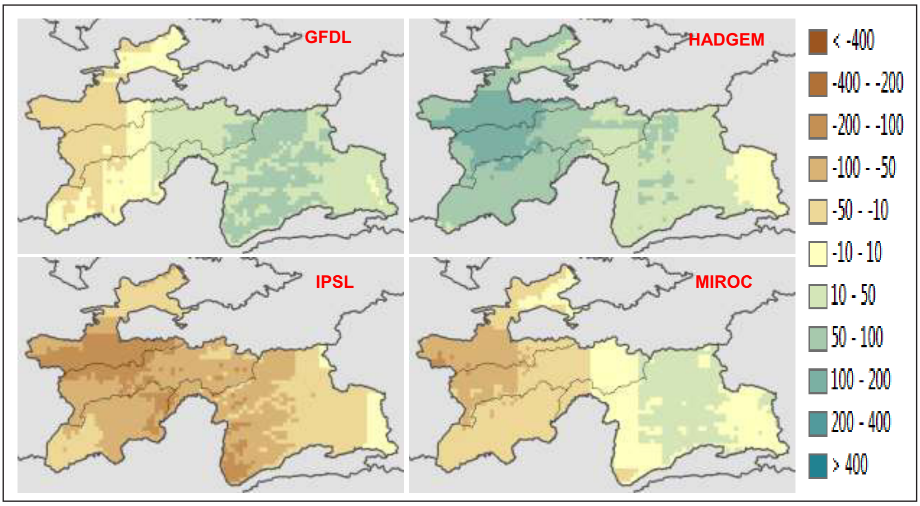


**Figure 10:** Precipitation change in regions of Tajikistan, 2050 compared to 2000, mm. Source: Authors based on Müller and Robertson (2014).

Different climate scenarios project different levels of change in precipitation in 2050 compared to the base year 2000, as shown in **Figure 10**.

### *3.3 Temperature and Precipitation Changes by River Basins*

Variation of precipitation levels over months in a typical year is projected to intensify. Variations are most notable between November and April (**Figure 11**).

All four climatic scenarios predict an increase in temperature in both the Amu-Darya and Syr-Darya river basins (**Figure 12**). It appears that the largest rise in temperature will occur in July, already the warmest month. It also appears that at least for the warmest months of the year, daytime temperature is projected to rise more than night-time temperature.

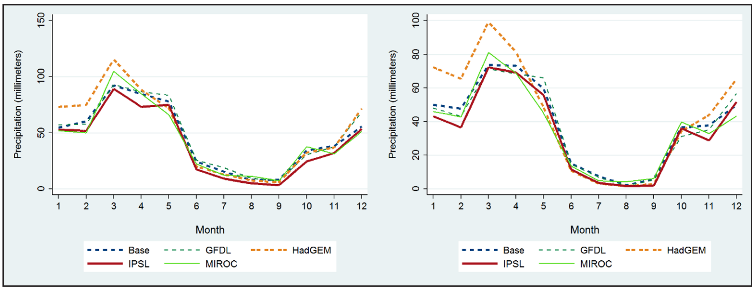


**Figure 11:** Precipitation projection: Amudarya and Syrdarya river basins.
Source: Authors based on Müller and Robertson (2014).

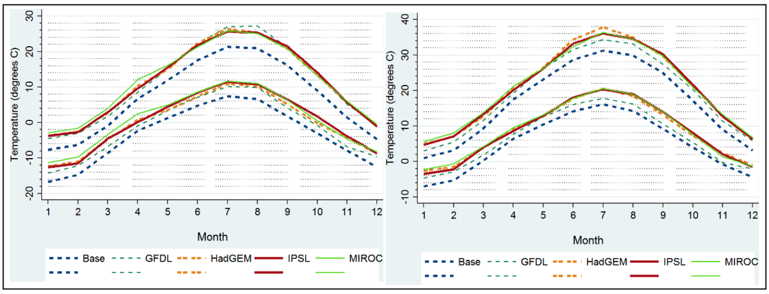


**Figure 12:** Monthly temperature projection: Amudarya and Syrdarya river basins. Source: Authors based on Müller and Robertson (2014).

### *3.4 Changes in Crop Yields*

Climate-change effects on individual crops will depend on their tolerance of heat and water availability. Winter crops in temperate climates often increase productivity in warmer temperatures, in contrast to spring crops which are more likely to experience heat stress in response to warming. Changes in seasonal rainfall patterns and severe weather events may affect planting and harvesting.

In this study, the impact of climate change is considered only for certain categories of crops in Tajikistan. The IMPACT model reveals the direct effects of climate change on crop productivity. The IMPACT model also accounts for changes in productivity throughout the world, along with changes in demand driven by global population and income growth.

Most arable land under major crops is irrigated in Tajikistan. **Figure 13** presents projections on yield changes on irrigated land. The climate change scenario 'CC' represents the average value obtained from the four different climate models.

The findings suggest that by 2050, barley, wheat, and maize yields will suffer a substantial decline due to climate change. On the other hand, the growth in rice yields between 2015 and 2050 shows virtually no difference between the baseline and climate-change scenarios. Overall, rice yields are expected to increase by about 40 per cent.

**Figure 14** shows the results of a similar exercise involving crop categories such as vegetables, fruit, potatoes, and cotton. Under the no-climate-change scenario, vegetable yields are projected to rise steeply until around 2030 and then level off through 2050. Under the climate-change scenario, however, yields are projected to rise more modestly through 2030, then decline through 2050. A similar pattern can be observed in the case of temperate fruits.

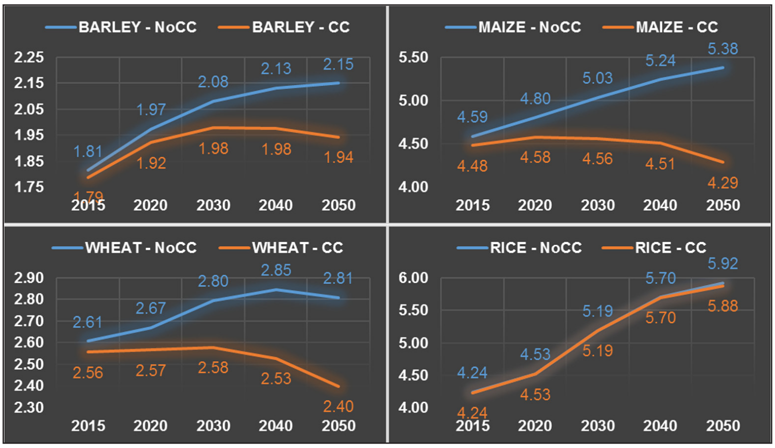


**Figure 13:** Irrigated crop yields in climate-change vs no-climate-change scenarios, metric tons/ha: barley, maize, wheat, and rice.
Source: Authors based on IMPACT model. Note: 'CC' averages the yields from the four different climate models.

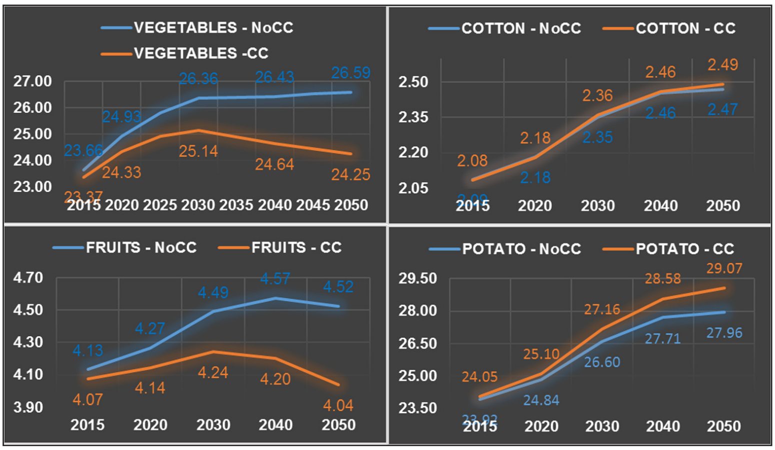


**Figure 14:** Irrigated crop yields in climate-change vs no-climate-change scenarios, metric tons/ha: vegetables, cotton, fruit, and potatoes. Source: Authors based on IMPACT model. Note: 'CC' averages the yields from the four different climate models.

Two points must be considered with respect to how fruit and vegetables are modelled in IMPACT. First, they are aggregates of many different crops, and as such, it is difficult to interpret effects on individual crop types. Second, climate impact on yields is inferred from the crop model results for other crops, and therefore one should exercise caution in making direct comparisons. For potatoes, the climate impact on yield is expected to be small but positive, unlike for any of the other aforementioned crops. Potato yields are projected to increase by about 21 per cent under the climate-change scenarios. Likewise, cotton yields are projected to increase by about 20 per cent over the same timeframe. Projected climate-change-induced yield changes for 2015–2050 are summarized in **Figure 15**.

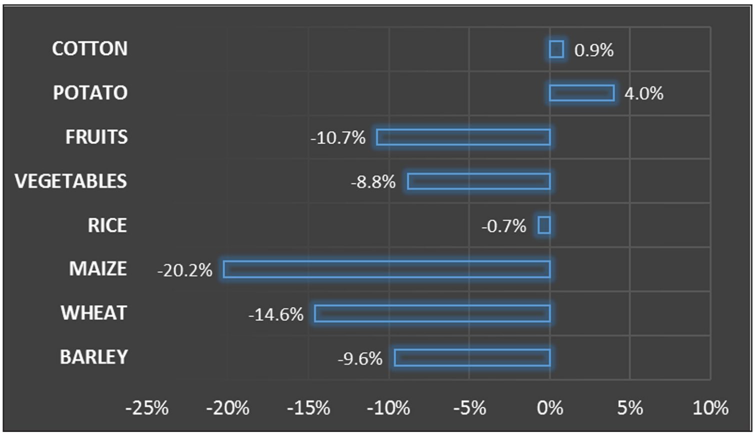


**Figure 15:** Changes in irrigated crop yields under climate-change scenario, 2050/2015 (%). Source: Authors based on IMPACT model.

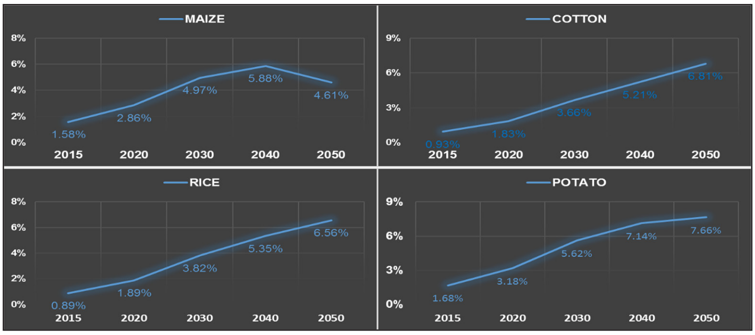


**Figure 16:** Changes in areas allocated to crops in climate-change vs no-climate-change scenarios (%): maize, cotton, rice and potatoes. Source: Own compilation based on IMPACT model results.

### *3.5 Area Changes*

Farmers make choices about expanding or reducing the area allocated for crops in response to signals such as productivity, expected prices, competition from other crops, and land demand. These are all factors that alter the profitability of a particular crop. Climate change ultimately effects area choices through all of these avenues. **Figures 16** and **17** display differences in allocated area between the climate change and baseline scenarios.

Increased yields for cotton and potatoes under projected climate change, noted in **Figure 15**, may lead to a significant expansion of the area allocated to these crops. As a result, land areas allocated to cotton and potatoes are projected to increase by about 7 per cent and 7.7 per cent respectively by 2050 due to climate change. In the case of maize, despite major yield losses due to climate change as shown in **Figure 15**, the area under maize is projected to expand by almost 5 per cent in Tajikistan by 2050. This expansion will be driven by an increase in international maize prices caused by major yield losses projected for the world's leading maize producers. The cultivated area for rice will increase by 6.5 per cent by 2050 in the climate-change scenario compared to the baseline (**Figure 16**).

Simulation scenarios project a negative effect of climate change on areas under barley, wheat, fruit, and vegetables as shown in **Figure 17**. Compared to the no-climate-change

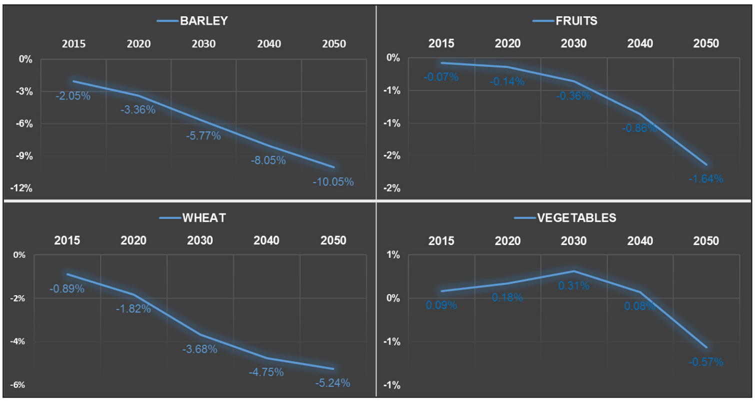


**Figure 17:** Changes in areas allocated to crops in climate-change vs no-climate-change scenarios: barley, wheat, vegetables, and fruit.
Source: Own compilation based on IMPACT model results.

effect scenario, areas under fruit and vegetables are projected to decrease by about 1.64 per cent and 0.5 per cent respectively by 2050 due to climate change.

However, because the growth of the area under the no-climate-change scenario is large, the overall area under fruit and vegetables is projected to grow by 28 per cent and 19 per cent respectively between 2015 and 2050, despite the climate-change effect. This suggests that increased global demand may offset other factors to encourage increased allocation of land for horticulture. On the other hand, barley and wheat land allocation is expected to fall in absolute terms over the same timeframe by 8 per cent for barley and 8.5 per cent for wheat.

### *3.6 Changes in Domestic Supply and Demand*

Continuing population growth in Tajikistan is expected to lead to an increased demand for many agricultural products. The ability of farmers to expand production will be limited by climate change and the other constraints mentioned earlier. The excess demand can be satisfied by importing foods.

**Figures 18** and **19** show projected shifts in domestic supply and demand for selected categories of crops by 2050. Projection estimates suggest that climate change is going to have a negative effect on domestic supplies of barley, wheat, and maize, whereas the supply of rice is projected to be positively affected.

Over the same period, domestic demand for maize, rice, and wheat is projected to be slightly dampened due to climate change. Demand for barley, however, is expected to slightly increase due to climate change.

**Figure 19** shows shifts in domestic supply and demand for cotton, potatoes, vegetables, and fruit. Cotton is primarily grown for export while potatoes are primarily grown for domestic consumption. Still, both see similar growth projections for supply and demand. While domestic supply of both cotton and potatoes is projected to increase due to climate change, demand for these crops is expected to decline under the climate-change scenario.

Projected shifts in domestic demand and supply of fruit and vegetables are consistent with the assumption of supply being more negatively affected by climate change than demand for these products.

In the aggregate, national food demand (as measured in metric tons) rises over time, largely in response to a growing population. But climate change projections show a decrease in the 2050 level of consumption by 2 per cent compared to the baseline (without any changes in

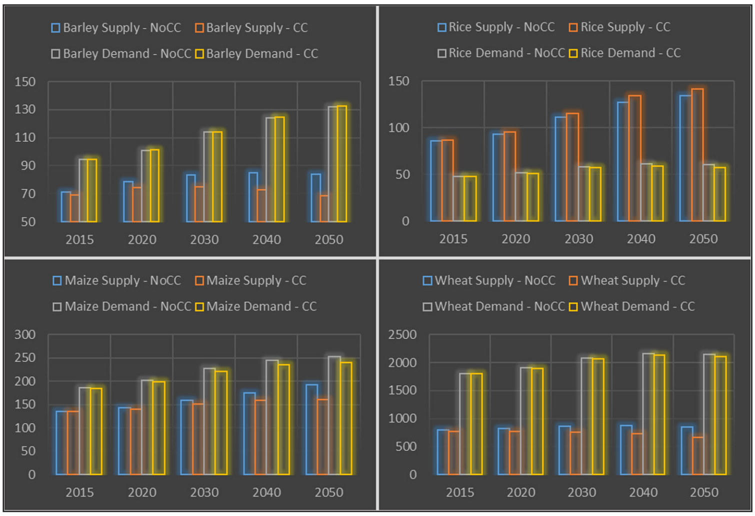


**Figure 18:** Crop supply and demand shift in response to climate change (000 metric tons). Source: Own compilation based on IMPACT model results.


**Figure 19:** Crop supply and demand shift in response to climate change (000 metric tons). Source: Own compilation based on IMPACT model results.

the model regarding population or income). This is primarily a response to higher prices that will be experienced globally as a result of climate change (**Figure 20**). While this is a relatively small difference, the cost burdens will fall more heavily on poorer households, especially on those who do not produce their own food.

### *3.7 Net Trade Changes*

Tajikistan is a net importer of agricultural products. Most staple foods, such as wheat, coarse grains, animal products (including beef and poultry), and processed foods are imported. However, it is a net exporter of some vegetables, fruit, and cotton. Under climate-change

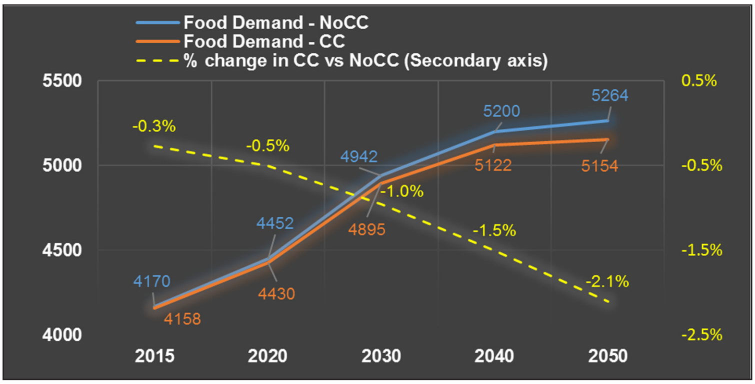


**Figure 20:** Food demand shift in response to climate change (in 000 metric tons, unless otherwise indicated) Source: Own compilation based on IMPACT model results.


**Figure 21:** Net trade changes on commodity level: climate-change vs no-climate-change scenarios, 000 metric tons Source: Own compilation based on IMPACT model results.

scenarios, cotton and rice exports are projected to rise. On the other hand, fruit exports are projected to decline over the same period under the climate-change scenario. Imports of barley, maize, vegetables, and wheat are expected to grow under climate change, all of which would have risen more slowly under the baseline. Interestingly, projections indicate that Tajikistan could become a net potato exporter under the climate-change scenarios, which would not have been the case otherwise (**Figure 21**).

### *3.8 Food Security and Food Availability*

Climate change will affect all four dimensions of food security: availability, accessibility, utilization, and stability of food systems. It will have an impact on human health, livelihood assets, food production and distribution channels, and will affect purchasing power and market flows (FAO 2008). We have seen how climate change is projected to raise food prices across the board. Higher prices serve as an obstacle to food access for the most vulnerable people with lower incomes and a higher share of their income spent on food. Ultimately, this leads to many poor people being unable to purchase enough food of the right quality to satisfy their nutritional requirements. A lower calorie intake can often form a vicious circle with disease and hunger. Climate-induced variability of production can interfere with food security by creating instabilities in food availability, access, and utilization (Krishnamurthy, Lewis, and Choularton 2014).

Our estimations show that by 2050, per capita food availability is going to slightly decline under the climate-change scenario (**Figure 22**).

Similarly, calories per capita availability is projected to fall by about 1.9 per cent by 2050 under the climate-change scenario (**Figure 23**).

Although the overall number of malnourished children is expected to decline significantly, climate change leads to a higher number of malnourished children than there would be without climate change – 4.6 per cent higher in 2050 (**Figure 24**).

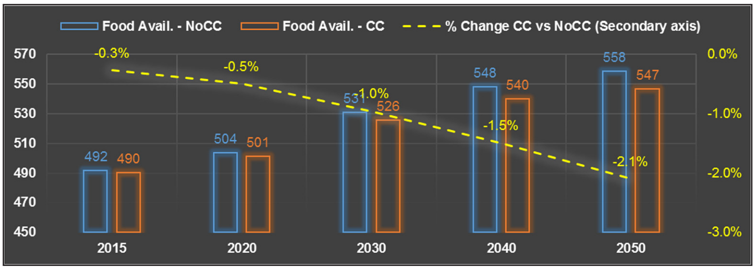


**Figure 22:** Food availability in climate-change vs no-climate-change scenarios, kg per capita per year (unless otherwise indicated).
Source: Own compilation based on IMPACT model results.

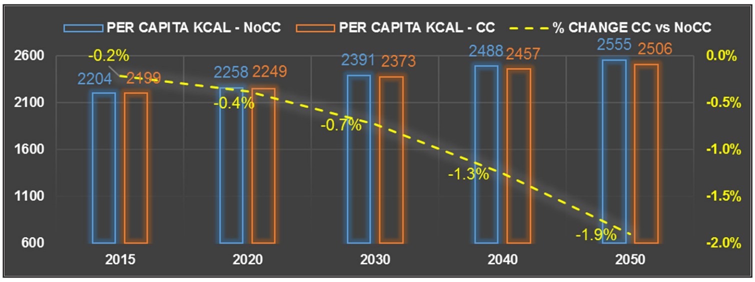


**Figure 23:** Calories per capita in climate-change vs no-climate-change scenarios, KCal.
Source: Own compilation based on IMPACT model results.

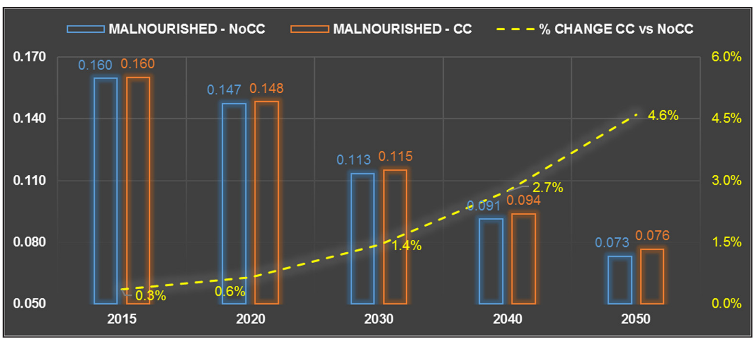


**Figure 24:** Malnourished children: climate-change vs no-climate-change, millions.
Source: Own compilation base on IMPACT model results.

The given rate of GDP growth reduces the number of people at risk of hunger in both scenarios. Allowing for climate change, the number is projected to decline by 34.5 per cent between 2015 and 2050, while it is projected to decline by 40 per cent without the effects of climate change (**Figure 25**). As the graph shows, this is a difference of almost 10 per cent of the number of people at risk.

## 4 Discussion

The findings of the study show that the effect of climate change on Tajikistan's agricultural sector is mostly negative. **Table 5** summarizes the overall impact of climate change on area, production, demand, and producer prices for selected agricultural products. From the table, we note that wheat, barley, maize, fruit, and vegetables seem to be particularly vulnerable to climate change in Tajikistan, having some large negative values in the yield and supply columns. Increases in producer prices could be specifically good for export crops, because they improve the trade balance. Yet while the effect is somewhat mixed for farmers, price increases are bad for consumers who have to use a higher proportion of their income on food.

**Table 5** only tells part of the story – what will probably happen, compared to what could have happened without climate change. **Table 6** (next page) presents a more complete story and displays what the future will look like compared to what the present is. From this table,

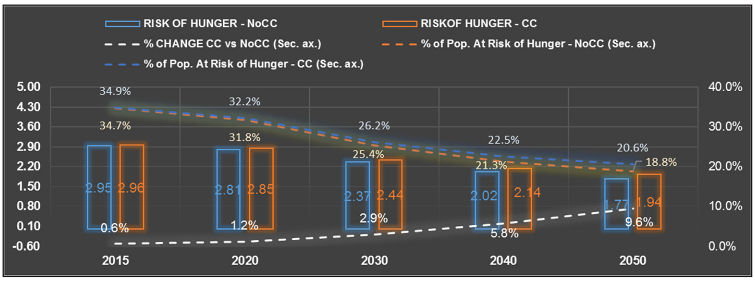


**Figure 25:** People at risk of hunger: climate-change vs no-climate-change, millions.
Source: Own compilation based on IMPACT model results.

**Table 5:** Overall effects of climate change: climate-change vs no-climate-change in 2050 (percentage difference).

| | Yield | Area | Supply | Demand | Producer price |
|---|---|---|---|---|---|
| Maize | –21.8 | 3.9 | –18.6 | –4.7 | 41.0 |
| Cotton | 0.9 | 7 | 7.9 | –1.9 | 17.0 |
| Rice | –1.2 | 6.4 | 5.4 | –4.9 | 20.5 |
| Potatoes | 3.9 | 7.7 | 10.7 | –6.9 | 30.6 |
| Barley | –9.6 | –10 | –18.2 | 0.2 | –3.1 |
| Fruit | –10.7 | –1.6 | –12.2 | –1.3 | 9.7 |
| Wheat | –14.6 | –5.3 | –21.1 | –2.2 | 10.1 |
| Vegetables | –8.8 | –0.6 | –9.2 | –2.7 | 10.7 |

Source: Own compilation based on IMPACT model results.
*Notes*: Statistics computed for combined rain-fed and irrigated crops.

**Table 6:** Change in agriculture between 2015 and 2050 under climate change (percentage difference)

| | Yield | Area | Supply | Producer price |
|---|---|---|---|---|
| Wheat | –7.5 | –9.4 | –16.1 | 27.9 |
| Cotton | 18.6 | 21.0 | 45.2 | 36.9 |
| Fruit | –2.2 | 27.8 | 25.0 | 27.8 |
| Barley | 6.9 | –9.9 | –3.6 | 9.8 |
| Maize | –8.6 | 29.2 | 17.9 | 75.3 |
| Potatoes | 16.1 | 27.3 | 48.4 | 41.3 |
| Vegetables | 2.5 | 19.4 | 22.4 | 47.2 |
| Rice | 38.7 | 19.5 | 66.2 | 42.4 |

Source: Own compilation based on IMPACT model results.
*Notes*: Statistics computed for combined rainfed and irrigated crops.

we can better understand that while both wheat and maize yields are projected to decline in absolute terms between 2015 and 2050, the area under wheat will decline while the maize area will expand, because wheat prices will only rise by 28 per cent while maize prices will rise by 75 per cent.

Cotton yields are expected to improve over time, not so much as a result of climate change, but through continued improvements in technology and management. Given the expected rise in cotton prices, this is also expected to lead to a growth in the area cultivated.

Rice yields are expected to grow as well – more than any of the other major crops in Tajikistan. Nonetheless, its share of all cultivated land is quite small, and by 2050 it will still be small relative to crops such as wheat, cotton, and fruit.

Like wheat, the area under barley is projected to decrease. This appears not to be driven by climate change as much as by meagre projected price increases. If those projections for future prices turn out to be overly pessimistic, the area under barley may not shrink at all, and may even increase.

It is important to note that while IMPACT is useful for predicting future climate impacts, it does not account for all adaptation options. For example, it does not consider spring wheat and winter wheat as separate crops but labels them as just 'wheat'. However, using crop modelling, we observed that climate change is expected to improve winter wheat yield by roughly 5 per cent in Tajikistan, while lowering spring wheat yields by around 15 per cent. This suggests that Tajikistan might not need to reduce wheat cultivation and might not even lose wheat productivity if it is able to discover how to help farmers shift to winter wheat cultivation.

It is worth noting, however, that some findings of this study on the effects of climate change, at the crop level, contradict the findings of previous studies. For instance, Bobojonov and Aw-Hassan (2014) argue that income from cotton in Tajikistan will decline because of yield decline, while revenue from wheat will not change. The findings of our study indicate that cotton yield is higher under the climate-change scenario versus the no-climate-change scenario, which ensures higher producer income, other things being equal. The discrepancy between the findings of these two studies has some potential explanations. First, base year data on yields may differ between the two studies. In our study, the base year for all endogenous variables is the average of three years, 2012–2014. Second, the Bioeconomic Farm

Model (BEFM) was employed in the aforementioned study versus the global partial equilibrium model in this study. Third, in our study, the final year of projection is 2050, while the aforementioned study uses two different future time periods (2010–2040 and 2070–2100). Fourth, our study uses country-level secondary data rather than regional-level survey data. Fifth, regarding calibration of the models, our study uses data at the national level while the aforementioned study uses farm-level data.

At the same time, the findings of our study on food security are in line with results from a tool developed by Met Office Hadley Centre and WFP which estimates indices of food vulnerability to food insecurity for various countries. However, there are some differences in methodology, such as projection periods, climatic scenarios, emissions and adaptations, and the assumed rate of population growth (Met Office Hadley Centre and WFP n.d.).

Some limitations of the approach used in this study should be discussed. The current version of the IMPACT model does not reveal the effects of climate change on livestock. Also, the model being partial, though global, it does not show the effects of climate change in other sectors of the economy. An analysis of climate-change effects on livestock and the implications of the computable general equilibrium model that allow for revealing the effects of climate change in other sectors of the economy should be subject to further studies. Moreover, future analysis should examine the effects of climate change on the agricultural sector by agro-climatic zones.

## 5 Conclusion and Policy Implications

An analysis of main crop yields shows that climate change will have a negative impact on crop yields with three exceptions – cotton, potatoes, and rice, which will have either small positive gains or an almost indiscernible reduction in the case of rice.

Climate change will negatively affect the demand side through changes in global prices, reducing consumption and slowing the reduction of malnutrition and food insecurity. The net trade situation will worsen in both scenarios, due to increased domestic demand through population and income growth, and the negative effects of climate change on the production of most commodities.

Climate change can be considered one of the key obstacles to the achievement of the country's strategic objective defined in NDS 2016–2030, which is to improve the living standards of the population, and one of the four strategic priorities, which is to ensure food security and access to quality nutrition in 2030.

The objectives of this study, tested hypothesis, socio-economic, demographic, agricultural and climate change analysis, as well as the main findings of the study lay the basis for some policy recommendations.

First, the development of climate-change mitigation strategies and capacity building for farmers and rural populations in knowledge related to climate change, including mitigation and adaptation strategies, should be defined as a strategic priority of the country.

Second, in light of the limitations on available resources to invest in climate-change adaptation, cooperation on research and development to minimize the cost of climate-change-related activities would be beneficial for each country in the Central Asia region.

Third, it is necessary to introduce and expand water-saving technologies, in addition to more efficient and expanded irrigation.

Fourth, the introduction of crops and crop varieties tolerant to low moisture or drought should be considered as an option in climate-change adaptation strategies.

Fifth, the introduction of crops and crop varieties tolerant to higher temperatures will minimize the consequences of climate change for the agricultural sector.

Sixth, considering the limited land resources in Tajikistan, the restoration of abandoned land will allow for increased agricultural activity and will increase domestic supply of agricultural products.

Seventh, an expansion of fertilizer use for crops that will be affected negatively should be considered as an option to minimize the effects of climate change on those crops.

Eighth, increased cotton yields, in addition to its gain in the climate-change scenario, will lead to an increase in domestic supply and the development of the textile and sewing industries, which will ensure the competitiveness of the sector in the domestic and global market.

Ninth, expanding winter wheat cultivation should be explored as a means to maintain or even increase wheat production.

Finally, land allocated for potato production should be expanded to allow for the satisfaction of domestic demand, the development of a processing industry, and increased potato exports.

## Competing Interests

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