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Climate Change Impacts on Agriculture and Adaptation Options for Uzbekistan

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ABSTRACT

Climate change is likely to reshape agriculture in an irrigated, water-scarce transition economy like Uzbekistan. We use IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model and evaluate the direct effects of climate change on Uzbekistan's agriculture through 2050. We assume changes in GDP, population, and technological progress to be exogenous. We find that climate change and the corresponding temperature increase will have significant adverse effects on the long-term yields of cotton and wheat through changes in water availability, precipitation patterns, crop yields, and the use of land, water, and other natural resources, but harvested area responses may differ. All climate change scenarios are similar in predicting an increase in harvested area for temperate fruits and vegetables, but their yield gains remain conditional on market prices, policy reform, water use and institutional constraints. For policymakers, this makes climate change adaptation actions an opportunity for incentives and structural reforms as well as for technology to adapt to changing environmental conditions and to ensure food security.

INTRODUCTION

At the time of independence in 1991, Uzbekistan was a predominantly agrarian country with a heavy reliance on cotton production. In the years since then, the country has undergone major changes in its industrial and agricultural sectors. Aiming to achieve industrialization, the government has invested heavily in mining and manufacturing. In agriculture, the Government of Uzbekistan has pursued self-sufficiency in wheat and significantly increased the area under wheat at the expense of other crops.

Agriculture has gradually declined in importance compared to manufacturing and service sectors, but it still employs 25% of the labor force and provides livelihoods to the majority of the population residing in rural areas (World Bank 2025). The new government of Uzbekistan adopted a five-year development plan – "Action Development Strategy of Uzbekistan" for 2017-2021, followed by the Development Strategy of New Uzbekistan for 2022-2026. In 2023, the new "Uzbekistan – 2030" strategy was approved[1]. According to the new strategy, the conservation of water resources and environmental protection are among the key priorities. The Strategy emphasizes the impact of climate change and the drying of the Aral Sea on agricultural development and people's livelihoods. Recognizing the importance of climate change, Uzbekistan joined the Paris Climate Agreement in 2017.

Uzbekistan's agricultural sector is vulnerable to climate change due to its geographical location and arid climate. In some parts of the country, summer temperatures may reach 44°C to 45°C and winter temperatures may go down 25°C to 30°C. In the last 20 years, the average temperature increased by more than 1°C (Uzhydromet & UNDP Uzbekistan 2015). Ninety percent of agricultural land in Uzbekistan is irrigated, making the sector highly dependent on water availability, especially in peak summer months. Water has become scarcer during the summer months when it is most needed due to changes in precipitation patterns in the region – more rain and snow are falling in spring and early summer months and less in winter months. This also means that Central Asia is experiencing more rainfall and less snow than in the second half of the 20th century. Climate change and the resulting melting of glaciers and loss of ice cover over time have had consequences for water use and agriculture in the region (Luterbacher et al. 2008). All climate change studies for Uzbekistan predict that the mean temperature will continue to increase in the next 40-50 years (ENVSEC 2015; Spektorman 2015; Sutton et al. 2013; Uzhydromet & UNDP 2015; World Bank 2010). However, temperature variability will differ across seasons and regions of Uzbekistan. It is expected that summer will become warmer (Uzhydromet & UNDP Uzbekistan 2015), and the number of hot days across the country is forecast to increase (Spektorman & Plocen 2015). Although there is a broad consensus on trends in mean temperature, assessment of the precipitation levels differs depending on the assumptions of the models, geographical zones, and seasons. Precipitation is likely to increase during spring and autumn and decrease during summer (Gupta et al. 2009; Sutton et al. 2013; World Bank 2010). Increase in rainfall level is projected for the desert, steppe and piedmont zones, while a decrease is expected in the Highlands zone (Sutton et al. 2013). Accelerated melting of mountain glaciers will likely compensate for lower snowfall and irregular precipitation patterns.

Most studies project that climate change will adversely affect Uzbekistan's agricultural sector. Impacts on wheat, alfalfa and pasture are the smallest, while impacts on cotton, vegetables, and fruits are substantial (Gupta et al. 2009; Sutton et al. 2013; Uzhydromet & UNDP Uzbekistan 2015; World Bank 2010). Higher temperatures are expected to increase the mortality rate of livestock, especially cattle and chickens, due to wide-spread diseases (Sutton et al. 2013; World Bank 2014). Thomas et al. (2021) showed that Central Asia, compared with other regions, is projected to experience greater climate shocks, primarily due to temperature changes.

In this study, we contribute to the literature in three ways. First, we apply the IPCC's Fifth Assessment Report AR5-based IMPACT simulations to a heavily irrigated, water-constrained transition economy in which climate impacts are filtered through institutional legacies of state-led crop allocation and the trade-

[1] https://strategy.uz/index.php?static=strategy_actions&lang=en

off between food security and export earnings. Second, we show that climate change adaptation responses may differ. Under simulated climate change scenarios, yields for cotton and wheat fall in the long run, but the harvested cotton area can still grow when global price incentives dominate, whereas wheat loses both yield and area. Third, we highlight that effective policy response to climate change is not only biophysical adaptation but also the result of trade-offs among export earnings, producer incentives, employment opportunities, domestic food availability, water scarcity and rural livelihoods. In that sense, Uzbekistan provides an analytically useful country case for understanding rapidly changing environmental and economic conditions where institutions, incentives and reforms remain in transition.

We begin the paper with a geographic and socio-economic overview. This is followed by a discussion of the agricultural development and current and future climate trends in Uzbekistan. Then, we present the methodology and assumptions used for the simulations and examine the results. We conclude the report by emphasizing the main implications of climate change on agriculture and proposing potential actions for policymakers.

UZBEKISTAN: DEMOGRAPHY, SOCIO-ECONOMIC STATUS, AGRICULTURE AND CLIMATE

Uzbekistan is a landlocked country located primarily in the lowlands of Central Asia. The country shares borders with Kazakhstan (to the north-east), Kyrgyzstan and Tajikistan (to the south-east and east), Turkmenistan (to the west), and Afghanistan (to the south). The total area is 448,900 km^2. The major portion of the territory is occupied by desert plains, while the north-eastern and eastern landscapes are characterized by mountains and foothills of the Tian Shan and Hissar. Plains are situated in the south-west and north-west and consist of the Ustyurt plateau, the Amu Darya delta and the Kyzylkum desert. Eastern Hissar range is the highest point in Uzbekistan– 4643 m. Most of the country lies between the two largest rivers in Central Asia – Syr Darya in the north-east and Amu Darya in the south-west. Both rivers spring from the Tian Shan and Pamir mountains in the neighboring Kyrgyzstan and Tajikistan and flow into the Aral Sea. The Aral Sea is located in the north-east of the country on the border with Kazakhstan. The Amu Darya and Syr Darya are two major rivers that supply the agricultural sector with water. Due to the use of river water for irrigation, water entering the Aral Sea has diminished considerably.

Demography

Uzbekistan is the most populous Central Asian country – its population reached 38 million at the middle of 2025. The government aims to reduce the national poverty rate to 6% by the end of 2025 from 8.9% in 2024. Most of this progress has come from rural areas. [2]

The population density is approximately 85 people/km², compared to 14 people/km² in Central Asia. However, population distribution varies within the country. Figure 1 demonstrates that the most densely inhabited territory is in the Fergana Valley (Andijan and Ferghana regions) – 500 people/km^2. Population growth rates are highest in the Kashkadarya (46.7 thousand people per year), Samarkand (45.8 thousand people per year), and Andijan (37.2 thousand people per year) regions (Uzhydromet & UNDP Uzbekistan 2015). Northwest of the country, Karakalpakstan and Navoiy regions have the lowest population density of 7-9 people /km2 (State Statistics Committee 2024). The population primarily resides in fertile oases and tends to avoid deserts with saline soils and water scarcity.

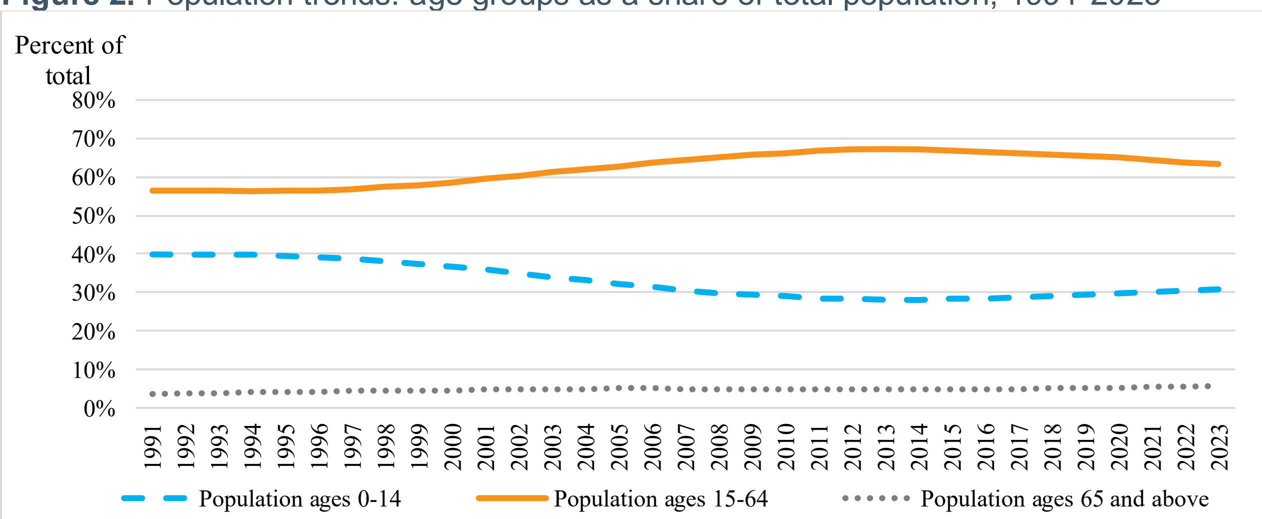
[2] https://www.gazeta.uz/en/2025/08/25/poverty/#:~:text=Uzbekistan%20has%20made%20remarkable%20strides,points%20to%20just%200.7%20points.

Figure 1. Population density in Uzbekistan

Source: National Statistics Committee of the Republic of Uzbekistan (2024). Authors' visualization.

Figure 2 shows the distribution of population by age groups. Uzbekistan has experienced a significant decline in population growth rate from about 4% in the 1980s to 2% in the 2020s. As a result, the share of children in the total population (ages 0-14) has gradually declined from 41% in the 1990s to 30% in the 2020s. As the share of the elderly (65 and above) has remained virtually unchanged, the share of the working-age population (15-64 years old) has increased from 56% in 1991 to 63% in 2023.

Figure 2. Population trends: age groups as a share of total population, 1991-2023



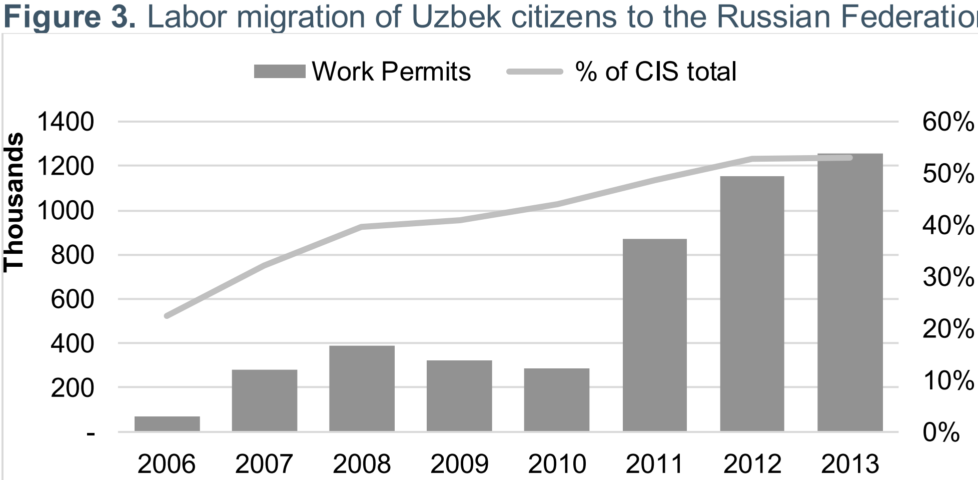
Source: World Development Indicators (World Bank 2025).

In the last decade, the population of Uzbekistan has become more mobile internationally. According to Ajwad et al. (2014), about 7% of the population lives outside of Uzbekistan. This mobility indicator exceeds the average global indicator (3.2%) by more than 2 times. The majority of Uzbek citizens residing abroad have migrated in search of jobs and better livelihoods. According to Ahunov et al. (2015), who use data from the 2013 World Bank/GIZ survey on jobs, skills, and migration and present a profile of Uzbek migrants, the average age of migrants is lower than that of the population. Migration is biased towards men, where 86% of migrants are male and the rest are female. Respondents of the survey primarily cite the difficult monetary situation (push factor) and employment opportunities abroad (pull factor) as the main reasons for migration.

Since the early 1990s, agriculture has shed jobs at high rates – agricultural employment has declined from 45% in 1993 to around 25% of total employment in the 2020s. At the same time, the share of industries in employment has remained virtually unchanged. Service sectors have significantly expanded and absorbed most of the labor shed in agriculture. However, the economy's absorption capacity has remained relatively low, and migration to Russia, Kazakhstan, Turkiye, South Korea and other European countries has become a lifeline for hundreds of thousands of households.

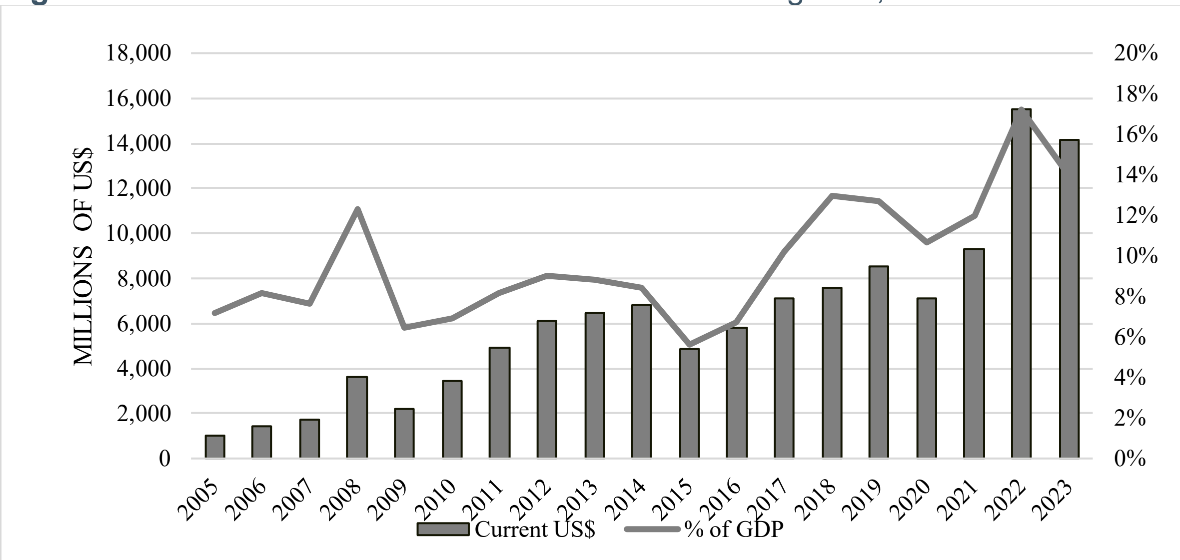
Figure 3 shows the number of Uzbek citizens who have received work permits in the Russian Federation. The number of work permits obtained by Uzbek citizens in the Russian Federation began to grow dramatically in the mid-2000s, rising from <70,000 in 2006 to nearly 1,254,000 in 2013. For the period through 2023, as shown in Figure 4, remittances have increased from 1 billion USD to about 15 billion USD (World Bank 2025). Remittances are mainly spent on consumption, ensuring food security and reducing poverty rates in rural areas.

Figure 3. Labor migration of Uzbek citizens to the Russian Federation, 2006-2013



Source: ROSSTAT (2014).

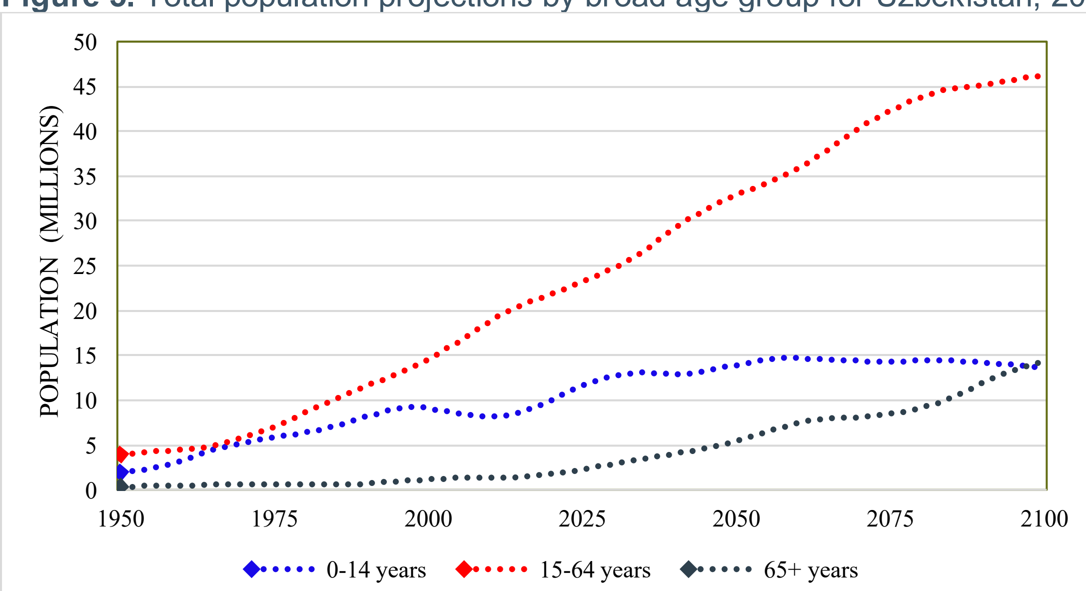
Figure 4. Personal remittances received from Uzbek migrants, 2005-2023



Source: World Bank (2025).

The United Nations (2015) projects that Uzbekistan's population will continue to grow until 2050. Population growth until 2050 will be primarily due to an increase in the number of people in the 15-64 old category. The share of children is forecasted to decrease while the share of the elderly population over 65 years old is expected to increase (Figure 5). The demographics in Uzbekistan will be favorable as the dependency ratio (the ratio of non-working age population to working age population) will continue to fall until 2050. This provides a unique opportunity to reap benefits in the form of higher economic growth.

Figure 5. Total population projections by broad age group for Uzbekistan, 2010-2100

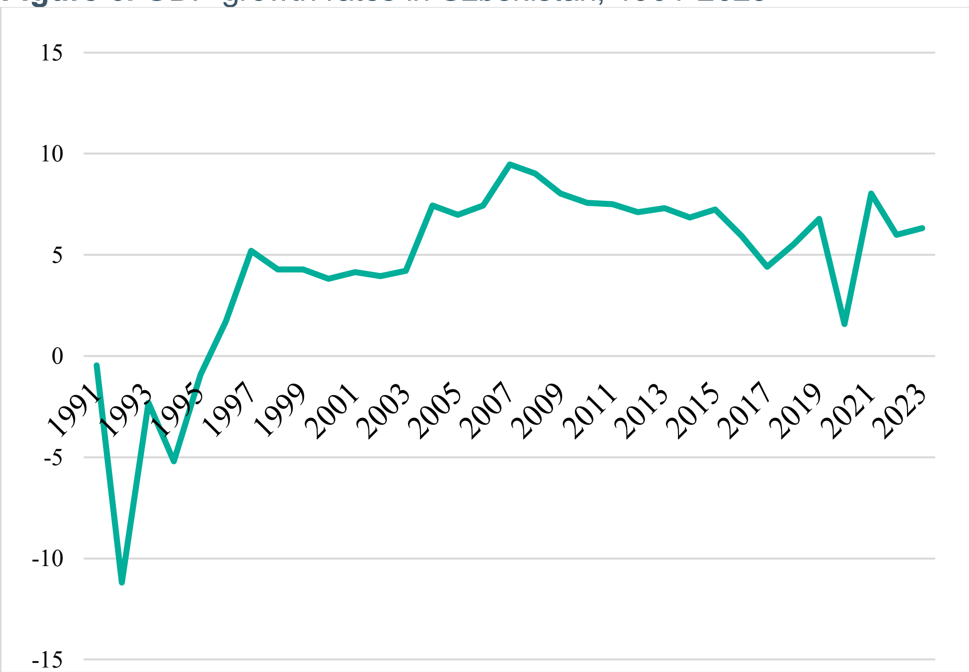


Source: United Nations, World Population Prospects (2024 revision), accessed February 2025.

Socio-economic status

After the collapse of the Soviet Union and the centralized economic system, Uzbekistan's output plummeted. After falling in the first half of the 1990s, output resumed growing in 1996 (Figure 6). Over the next two decades, economic growth in Uzbekistan has been one of the highest in the post-Soviet region.

Figure 6. GDP growth rates in Uzbekistan, 1991-2023



Source: World Development Indicators (World Bank 2025).

In 1990, Uzbekistan's agriculture was the largest contributor to GDP (33%), primarily specializing in the production of cotton (Table 1). After the collapse of the Soviet Union, the Government of Uzbekistan has adopted a new agricultural policy aimed at achieving self-sufficiency in wheat production and food security. At the same time, industrialization policy has been pursued through massive investments in the industrial sector and import substitution policies. As a result, by 2023, the share of agriculture in GDP decreased to a mere 19%, while the share of industry in GDP increased from 17.6% in 1990 to 26% in 2023. Despite obvious successes in decreasing dependence on agriculture, agriculture still directly employs about 27% of its workforce, and indirectly supports the livelihoods of half of its population living in rural areas (Ajwad et al. 2014).

Table 1. GDP structure, 1990-2023 (% of GDP)

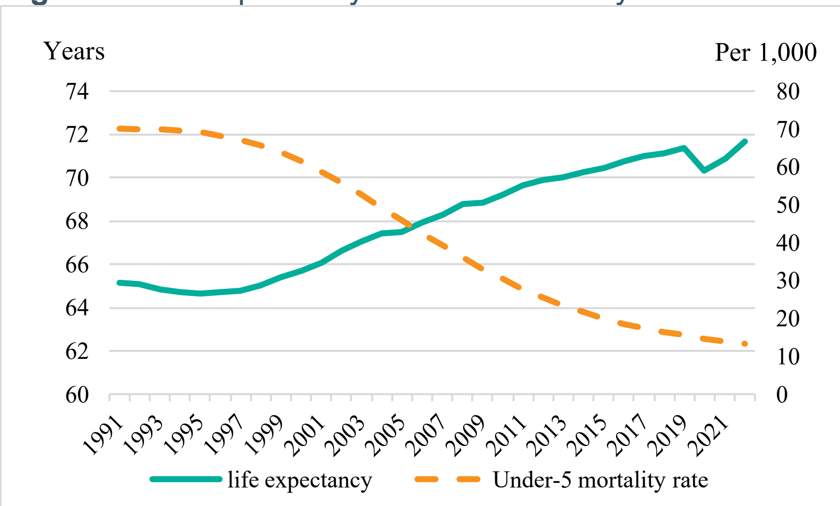
Year	1990	2000	2010	2015	2020	2023
Industry	17.6	14.2	24.1	24	25.6	26.2
Agriculture	33.4	30.1	17.6	17	23.4	19.4
Construction	5.8	6	6.1	8	8.5	7.2
Transportation	5.2	7.7	11.7	43	39.7	43.4
Trade	4.5	10.8	8.8			
Other	22.2	18.7	24.0			
Net taxes	11.3	12.5	7.7	9	6.7	6.2

Source: State Committee for Statistics Yearbook, various years and World Bank (2015).

Over the last 25 years since independence, GDP per capita (purchasing power parity adjusted, current international) increased from US$2,644 in 2000 to US$11,878 in 2024 (World Bank 2025). The prevalence of undernourishment declined from 19% in 2001 to 3% in 2023 (World Bank 2025). In 2015, Uzbekistan was included by the FAO among countries that fulfilled the food security UN MDG goals.

Positive changes have been observed in the life expectancy and child mortality indicators. Figure 7 shows that the under-5 mortality rate has decreased from 71 in 1991 to 13 per thousand in 2022. Life expectancy at birth has increased slightly from 65 in 1995 to 72 in 2022.

Figure 7. Life expectancy and child mortality rate for Uzbekistan, 1991-2022



Source: World Development Indicators (World Bank 2025), World Health Organization (2024).

Agriculture

In Uzbekistan, 46% of the total area is categorized as agricultural land suitable for crop and livestock production (State Statistics Committee 2024). Harvested land constitutes about 20% of this area. Since 2010, total harvested area has had a downward trend mainly due to soil salinization and erosion. Lack of replacement investment in irrigation systems has led to the abandonment of large plots of land in remote areas.

In recent years, there were over 80 thousand large commercial farms, specializing in growing cotton and wheat, and millions of small dekhan farms[3]. These dekhan farms produce the majority of all crops, including more than 65% of all the country's horticultural crops (Asfaw 2020).

All agricultural land in Uzbekistan is owned by the state. Local khokimiyats (district governments) control cropping patterns at large commercial farms, while dekhan farms are allowed to grow whatever the farmers wish. Additionally, unlike on larger farms, where leases must be renewed, leases for dehkan farms are lifetime holdings and can be transferred by inheritance. On paper, household plots cannot be sold, but in reality they are routinely bought and sold, with transactions disguised as the sale and purchase of property on land, not land itself.

[3] In Uzbekistan, all rural households that have household plots are considered dekhan farmers. It is difficult to verify exact number of such households, but their number is estimated to be around 4,8 million households.

Table 2 shows the share of crop farming and livestock production in total agricultural production. In recent years, crop farming has accounted for about 50% of agricultural production, while livestock has accounted for the other half. This ratio has remained stable over the past 4 - 5 years.

Table 2. Agriculture production, 2010-2023

	2010	**2015**	**2020**	**2023**
Total value added	100%	100%	100%	100%
Share of crop farming	58.72%	55.65%	49.49%	50.09%
Share of livestock	41.28%	44.35%	50.51%	49.91%
Growth rates, %				
Crop farming	5.9	5.5	3.2	4.3
Livestock	6.9	6.9	2.1	3.7

Source: State Statistics Committee statistical bulletins, various issues.

In the last two decades, agriculture has undergone significant changes in harvested area, production, and yields (Table 3). In terms of harvested area, the acreage grown with cotton and wheat has reduced, while fruits, vegetables, melon, and potato have gained acreage. Not only have the latter crops expanded in cropping area, but their yields have also increased by 10% to 30% over the decade. On the contrary, cotton yields have risen modestly, while wheat yields have barely inched up.

Table 3. Changes in harvested area, production, and yield for leading agricultural commodities, 2011-2020.

	Rank by Area Harvested	**Thousand Hectares Harvested. Mean for 2011-2020**	**% Change 2011 to 2020. Hectares Harvested**	**Thousand Tons Produced. Mean for 2011-2020 (000 mt)**	**% Change 2011 to 2020. Thousand Tons Produced**	**Yield (mt/ha). 2011-2020**	**% Change 2011 to 2020 Yield**
Wheat	1	1406	–4.9%	6355.02	–7%	4.55	–2%
Cotton	2	1200.3	–19.2%	2956.89	26%	2.51	10%
Fruits	3	406.2	6.5%	4314.02	35%	10.53	27%
Vegetables	4	203.3	21.8%	10090.6	34%	48.68	10%
Potatoes	5	83.8	22.8%	2793.67	54%	28.28	4%
Barley	6	98.4	37%	142.69	16%	1.69	2%
Melons	7	54	22%	1911.20	50%	34.9	23%
Rice	8	61.9	34.3%	337.76	12%	5.52	–17%
Maize	9	40.1	54%	417.48	63%	10.43	6%

Source: State Statistics Committee, various issues and FAOSTAT (2015).

Table 4 shows the average number of livestock in Uzbekistan between 2005 and 2020, with a dramatic increase in cattle, sheep, and chicken numbers. From 2005 to 2020, all types of livestock registered double-digit increases, while the number of chickens has grown at triple-digit rates. The increase in livestock has affected the availability of meat and dairy products positively, better satisfying the needs of the growing population. More than 95% of livestock production is concentrated in dekhan farms, making it difficult to further increase productivity due to the lack of economies of scale. Due to the dramatic decline in fodder crop production, the vast majority of livestock is grazed on pastures, leading to overgrazing and pasture erosion across the country.

Table 4. Livestock (million animals), 2005-2020

	2005	2013	2020	% Change
Cattle	6.25	9.63	12.17	+95%
Sheep	10.60	16.22	18.09	+71%
Chicken	19.05	42.68	52.01	+173%

Source: State Statistics Committee (2021).

Table 5 demonstrates the share of agricultural products in total export. The share of cotton in total exports has declined between 2000 and 2023 by almost 70%, while the share of food products almost doubled and the contribution of fruits and vegetables increased more than four times. As a group, fruits and vegetables have become the major export commodity and, by 2023, the export value of fruits and vegetables equaled that of cotton.

Table 5. Exports value of agricultural products in Uzbekistan, 2000–2023

	2000	2005	2013	2014	2023
Exports value ($ million)					
Total exports	3,264.7	13,044.5	15,080.8	14,663.0	17,739.4
Cotton	897.1	1,474.0	1,162.9	1,036.6	1,380
Food products	176.4	1,265.3	1,479.0	1,559.8	1,287.7
Fruit and vegetables	68.7	1,155.2	1,346.0	1,498.5	1,338
Share in total exports (%)					
Cotton	27.5	11.3	7.7	7.0	7.8
Food products	5.4	9.7	9.8	10.6	7.3
Fruit and vegetables	2.1	8.9	8.9	10.2	7.5

Source: Ministry of Investment, Industry and Trade (https://gov.uz/en/miit); State Statistics Committee (2023).

In the last 10 years Uzbekistan has undergone several waves of agricultural reforms. Under the Agricultural Strategy 2020-2030, Uzbekistan has been moving from administratively controlled cotton-and-wheat production toward a more market-oriented model. Major reforms included the abolition of the state cotton order in 2020, abolition of the wheat quota in 2022, liberalisation of cotton and wheat farmgate prices toward market prices and relaxation of export restrictions for horticulture (World Bank 2020; World Bank 2022). Cotton-textile clusters and contract farming were introduced. These reforms have helped accelerate incentives for producers and for rebuilding agricultural knowledge and innovation systems (AKIS). The government has also initiated stronger incentives for effective water use and irrigation.

Climate change

The agricultural sector in Uzbekistan is highly dependent on irrigation, with 90% of all crops being produced on irrigated lands. Increasing annual temperatures result in greater evaporation and rising irrigation demand. It is expected that climate change impacts will be exacerbated by the decreasing efficiency of the irrigation systems and changes in the precipitation regime. Ultimately, this will have a negative impact on yields, reversing technology gains in the last decades. Uzhydromet and UNDP Uzbekistan (2015) predicts that the negative impact of climate change on individual crop yields will vary from 9% or more in the case of a low impact scenario to 36% or more in the case of a high impact scenario (Table 6).

Table 6. Assessment of reduction in crop yields by 2050 (in %), by different climate change scenarios

	Climate Change Scenarios		
	Low	**Considerable**	**Extreme**
Fruits	12	18	51
Cotton	11	15	37
Potato	11	17	47
Vegetables	12	16	42
Wheat	9	12	36

Source: Uzhydromet and UNDP Uzbekistan (2015).

Earlier projections of the Hydrometeorological Office of Uzbekistan (Uzhydromet 2008) are in line with the above-mentioned forecasts. Even without accounting for the impact of climate change through water balance, the Uzhydromet model predicts about a 10% loss in yields for alfalfa, rice and vegetables and more moderate yield reductions for winter wheat.

The key water resources of Uzbekistan are the river flows of the Syrdarya and Amudarya rivers. Other water resources are reservoirs and groundwater. Table 7 shows the water supply in 2025 and the forecasted water availability by 2050.

Table 7. Current and forecasted water supply in Uzbekistan

River Basins	Forecasted Water (90% Flow Probability)	Surface Water (Share of Uzbekistan at 90% Flow Probability)	Groundwater	Collector-Drain Water	Available Resources
2025					
Syrdarya	25.7	19.9	1.6	2.6	24.1
Amudarya	60.42	32.5	0.3	2.3	35.1
Total		52.4	1.9	4.9	59.2
Total consumption					52.7
Forecasted for 2050					
Syrdarya	24.4	15.9	1.8–2.0	2.8	22.0
Amudarya	51.36	26.0	0.3–0.5	2.5	30.0
Total		41.9	2.1–2.5	5.3	52.0
Total consumption					62–63
Water deficit					11–13

Source: Asian Development Bank (2022).

Increasing temperatures and reduced precipitation are affecting water availability in summer months. UNDP (2023) predicts that the forecasted water supply by 2040 will be lower, ranging from 8% in a no-climate-change-impact scenario to 33.5% in the high impact scenario (Table 8). A considerable reduction in the water supply results from reduced groundwater withdrawals and reduced flows in the Syrdarya and Amu Darya rivers. A deteriorating water supply will further exacerbate the climate impact on the agricultural sector.

Table 8. Assessment of irrigation water shortage by 2040, by climate change impact scenario

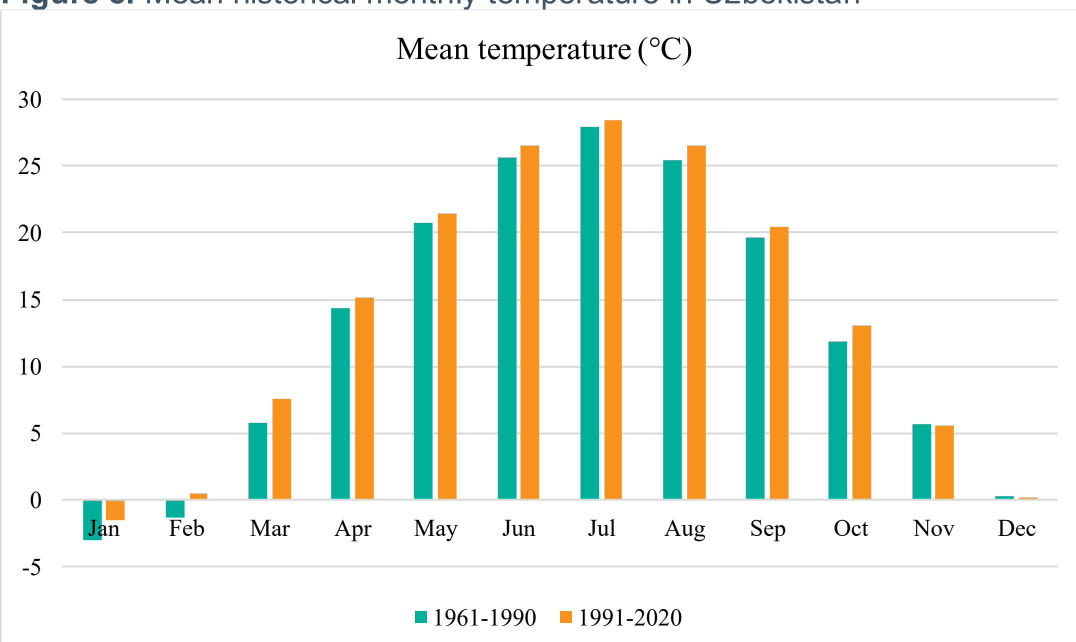
Basin	No Impact of Climate Change		Moderate Impact		High Impact	
	000 m^3	%	000 m^3	%	000 m^3	%
The east of Syr Darya	615927	11.6	940601	17.5	3627991	51.6
The west of Syr Darya	122023	1.9	325942	4.7	2817031	34.4
Amudarya	2174069	8.7	4087848	17.8	8405243	28.9
Total	2912019	8	6074391	15.4	140850265	33.5

Source: UNDP (2023).

Climate change

A steady warming of temperature in Uzbekistan has been observed at least since 1990. Figure 8 shows that in comparison with the 1960-1990 period, during the 1990-2020 period, mean monthly temperature has increased in all months, except December. UNEP (2025) reports that the mean annual temperature in Uzbekistan has increased nearly three times above the global average compared to the previous 60 years due to climate change[4].

Figure 8. Mean historical monthly temperature in Uzbekistan

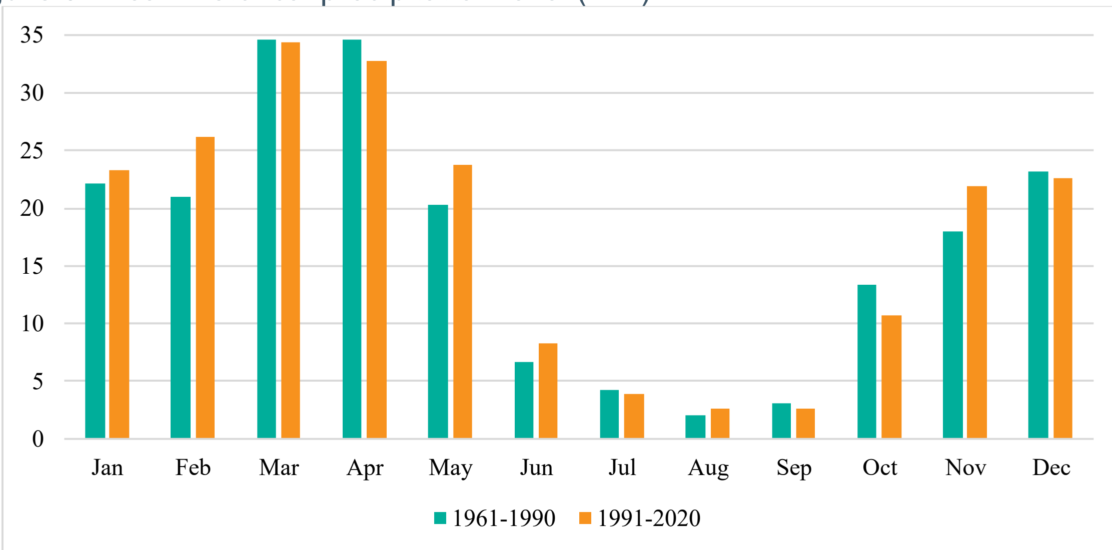


Source: Climatic Research Unit of the University of East Anglia cited by World Bank Group, Climate Change Knowledge Portal

In addition, the standard deviation of mean temperature has changed its pattern: in cold months, standard deviation decreased, while in warm months it increased. The change means that seasonal shift, that is, the shift from autumn to winter and from winter to spring, is happening more rapidly. Figure 9 shows lower precipitation in March, April, September, and October, which used to be rainy months, and higher rainfall in all other months. During the driest three months (July – September), precipitation levels fall; during the wettest (February – April), they rise.

[4] https://www.unep.org/news-and-stories/press-release/climate-change-drives-rising-temperatures-and-severe-drought#:~:text=Temperatures%20have%20risen%20by%20nearly,be%20fed%20with%20less%20water.

Figure 9. Mean historical precipitation level (mm)



Source: Climatic Research Unit of University of East Anglia cited by World Bank Group, Climate Change Knowledge Portal.

Mountain glaciers in Central Asia are an important source of freshwater, providing 10%- 20% of river flows in the Amudarya and Syrdarya basins. In Central Asia, the average rate of area deglaciation is estimated at about 0.6% to 0.8% per year, and about 1% per year in volume (UNDP 2011). The total area of glaciers is estimated to have decreased by a factor of 3 since 1900 (World Bank 2010; World Bank 2014). Rising temperatures are expected to accelerate glacier melting, jeopardizing their long-term use as a source of fresh water.

Freshwater is a scarce resource in Uzbekistan, but it is also extensively misused through inefficient and wasteful irrigation practices. Water is frequently over-allocated to cotton and wheat, and under-allocated to environmental flows into the Aral Sea. Because soil in Uzbekistan is excessively saline, water is frequently used to leach salts and minerals through methods such as waterlogging. It suffices to say that more than 51 percent of the irrigated land is salinized to some degree, with 4% strongly saline, 17% moderately saline, and 30% slightly saline (UzHydromet 2008). Due to changes in the temperature and precipitation regimes, crop yields may decrease as crops become more susceptible to new pests and diseases.

Temperature variations are not uniform across Uzbekistan. In major cities (Tashkent and Ferghana), temperature growth is considerably higher due to the urbanization effect[5]. For example, the increase in annual mean temperatures in Tashkent is two to three times higher than in other regions (Uzhydromet 2015; Uzhydromet &UNDP Uzbekistan 2015).

Uzhydromet indicates that, based on various climate scenarios, the Ferghana valley is recognized as one of the most climate-vulnerable regions in Uzbekistan. Precipitation tends to grow the most in the Ferghana valley and the Tian Shan ridges. As for river flows, temperature variations will be highest along the Amudarya river, while precipitation levels will be highest along the Syrdarya river (Spektorman 2015).

According to Uzhydromet (2015), the largest temperature variations are expected in spring and summer months (the standard deviation of temperature from its mean is expected to steadily

[5] https://www.gazeta.uz/en/2026/01/08/weather/

increase). This will increase the number of extremely hot days in summer and exacerbate the instability of spring weather. Nighttime temperatures are expected to grow more than daytime temperatures. However, daytime temperatures may soar to levels that are risky for people's health, food, and energy supplies. Besides longer periods of hot weather, the number of extremely cold days may also increase.

Regarding precipitation levels, rainfall in northern Uzbekistan is projected to increase in winter and decrease in all other seasons. In the south, winter precipitation is expected to remain unchanged, while in all other seasons it will decrease. Such changes may result in increased frequency of floods and torrents.

METHODOLOGY

Our simulations of climate change impact on agriculture are done in the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model, which was developed by the International Food Policy Research Institute (IFPRI) researchers at the beginning of the 1990s (Robinson et al. 2015). Over time, IMPACT's core multimarket economic model has been improved, and additional modules have been added to simulate global production, trade, demand, and prices for agricultural commodities. Additional modules include climate models (Earth System Models (ESMs), water models (hydrology, water basin management, and water stress models), crop simulation models (Decision Support System for Agrotechnology Transfer [DSSAT]), and welfare analysis.

IMPACT is better suited for simulations of development scenarios. In this respect, IMPACT is not a forecasting model. It is a partial equilibrium model in that it covers only agricultural commodities and therefore cannot be used to simulate variables such as GDP and factors of production. Different versions of IMPACT have been used in several important research publications to examine the linkage between the production of key food commodities and food demand and security at the national, regional and global levels (Ignaciuk & Mason-D'Croz 2014; Nelson et al. 2010; Rosegrant et al. 1999; Rosegrant et al. 2005; Scott et al. 2000).

General circulation models (GCMs, sometimes referred to as climate models) are developed by climate scientists to determine how a climate might change in response to greenhouse gas (GHG) accumulation in the upper atmosphere. The IMPACT simulation model run in this study uses the following climate models from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5):

- GFDL-ESM2M, which was produced by the National Oceanographic and Atmosphere Administration General Fluid Dynamics Laboratory (GFDL) (Dunne et al. 2012);
- HadGEM2-ES, the Hadley Centre Global Environmental Model (HadGEM), from the Met Office Hadley Centre (Collins et al. 2011; Martin et al. 2011);
- IPSL-CM5A-LR, generated by Institut Pierre-Simon Laplace (IPSL) (Dufresne et al. 2013); and
- MIROC-ESM-CHEM, (MIROC), from the Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (University of Tokyo), and National Institute for Environmental Studies (Sakamoto et al. 2012).

In the IPCC's AR5, each GCM was produced with four different representative concentration pathways (RCPs), which indicate the pattern of emissions and accumulation of greenhouse gases (GHGs). RCPs (RCP2.6, RCP4.5, RCP6.0, RCP8.5) show the different climate scenarios corresponding to the amount of accumulated GHGs, with the ones with higher numbers associated with higher emissions. In our study, the GCMs are based on RCP8.5.

Most papers that have studied climate change and its impact on agriculture in Central Asia and Uzbekistan agree that the impact will be largely negative. Some previous studies suggest that the average temperature in Uzbekistan is expected to increase by 2°C -3°C over the next 50 years (ENVSEC 2015; Sutton et al. 2013;). The GCMs used in this chapter project an even greater increase in temperature by 2050 (Thomas 2017), with the mean daily maximum temperature of the warmest month rising between 2.7°C and 4.9°C on average across Uzbekistan. Precipitation levels are forecasted to increase during fall and winter, but are expected to decrease during summer. Coupled with higher evaporation rates, this will lead to wetter off-season months and drier summer months, putting additional strain on irrigation infrastructure.

IMPACT takes as inputs GDP and population growth based on the SSPs (shared socioeconomic pathways) developed for the IPCC to analyse the impact of climate change on the global economy and people in general. In this report, we use SSP2 ("middle of the road") scenario. SSP2 assumes that both GDP and population will take neither too low nor too high values. Mostly national income and population growth rates will be governed by a trend of recent periods. Per-capita income levels grow at a medium pace on the global average, and income levels between developing and industrialised economies will converge slowly. Population growth will be putting increased pressure on resources, and improvements in air pollution and access to energy will be modest. Vulnerability to climate and other global changes will decrease marginally over time.

In addition to economic and climate models, we have also made several assumptions about land and water availability in Uzbekistan. Since 1992, arable land area in Uzbekistan has decreased by about 75,000 ha, or by 1.7%. Most of the decline happened in the 1990s, and since then the arable land area has remained remarkably stable. In our projections through 2050, we assume that the overall arable land area will remain fixed for the period until 2050. This assumption does not seem overly restrictive, since in circumstances of lower investment in the irrigation system and an acute water shortage, it is difficult to expand the arable land area.

In terms of basin efficiency, we assume that it will continue to decline until 2020 as it did between 2005 and 2014. We assume that greater investments in irrigation facilities and wider use of new technologies will arrest the decline and slowly improve the basin's efficiency after 2020. In addition to the basin efficiency, we also assume that the water storage capacity in Uzbekistan would increase by 1% annually between 2015 and 2030, and by a more modest 0.5% annually thereafter. The Government of Uzbekistan has been investing heavily in building additional water reservoirs as an adaptation strategy for climate change and expected water shortages during vegetation periods.

Critics of the simulation models like IMPACT often claim that simulation models do not take into account policy interventions capable of restricting markets. One implication of this is that in a country like Uzbekistan, with its extensive government regulations and price interventions in agriculture, simulation results need to be interpreted with caution. However, when government decisions and interventions are prompted by economic efficiency motives, the outcome of the government interventions might be similar to the outcome of market decisions reflecting underlying supply and demand forces. Thus, as long as producers pursue profit maximization and consumers seek utility maximization, IMPACT results will be quite meaningful for detecting over-all trends and modeling long-term outcomes given basic pricing and production decisions.

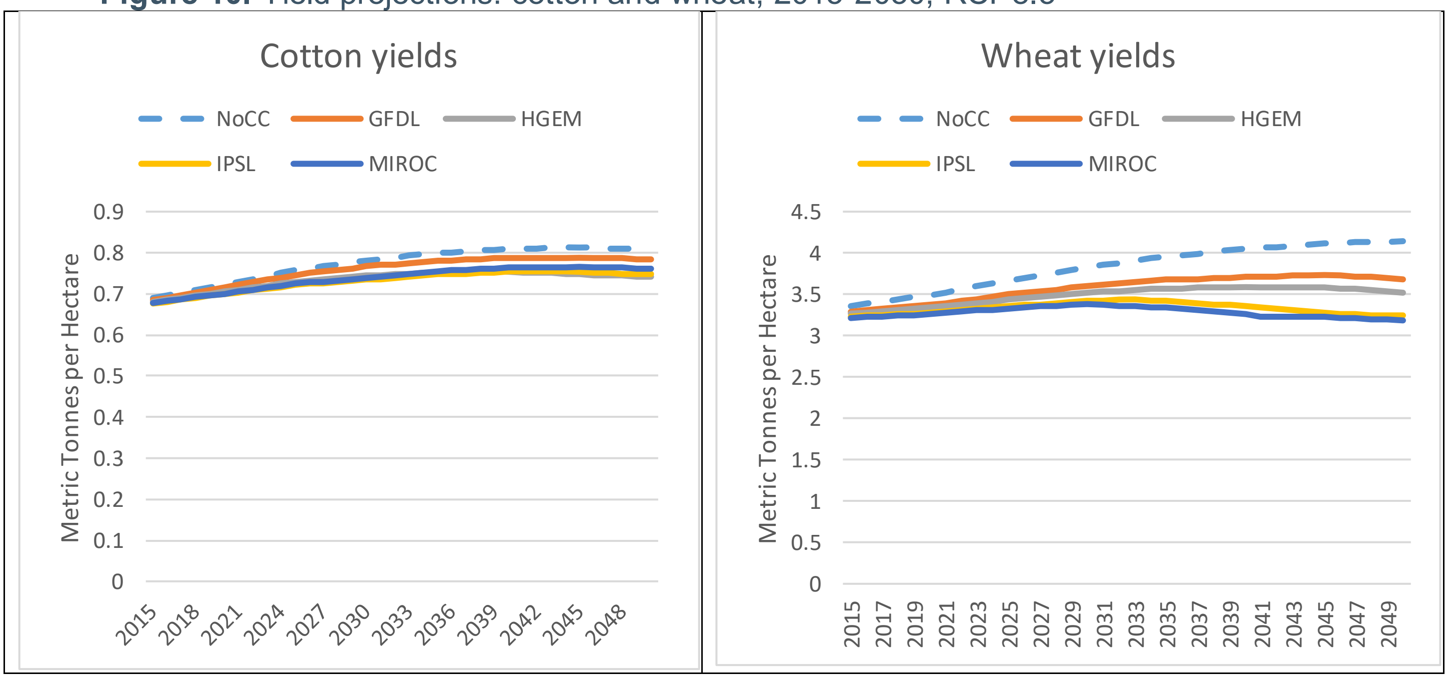
CLIMATE-AGRICULTURE SIMULATION RESULTS

Cotton and Wheat Yield and Land allocation

Demand for cotton and wheat in the long run is determined by world economic growth and population changes, factors which result in increased consumption, trade, and prices of cotton. After all-time high price levels seen in 2009-2011, agricultural commodities have entered a correction phase, and prices for many commodities, including cotton, have significantly fluctuated. Demand for cotton and wheat has remained more or less stable over the last several years.

Figure 10 below shows projections for cotton (lint) and wheat yield in Uzbekistan for the above-mentioned scenarios. What is remarkable is that both the no-climate-change scenario and climate change scenarios predict a slow increase and subsequent decline in both cotton and wheat yields over time. All climate change scenarios show lower yields compared to the no-climate-change scenario throughout the period. Variation among different climate change scenarios is smaller in cotton yield, but sizable in wheat yields.

Figure 10. Yield projections: cotton and wheat, 2015-2050, RCP8.5



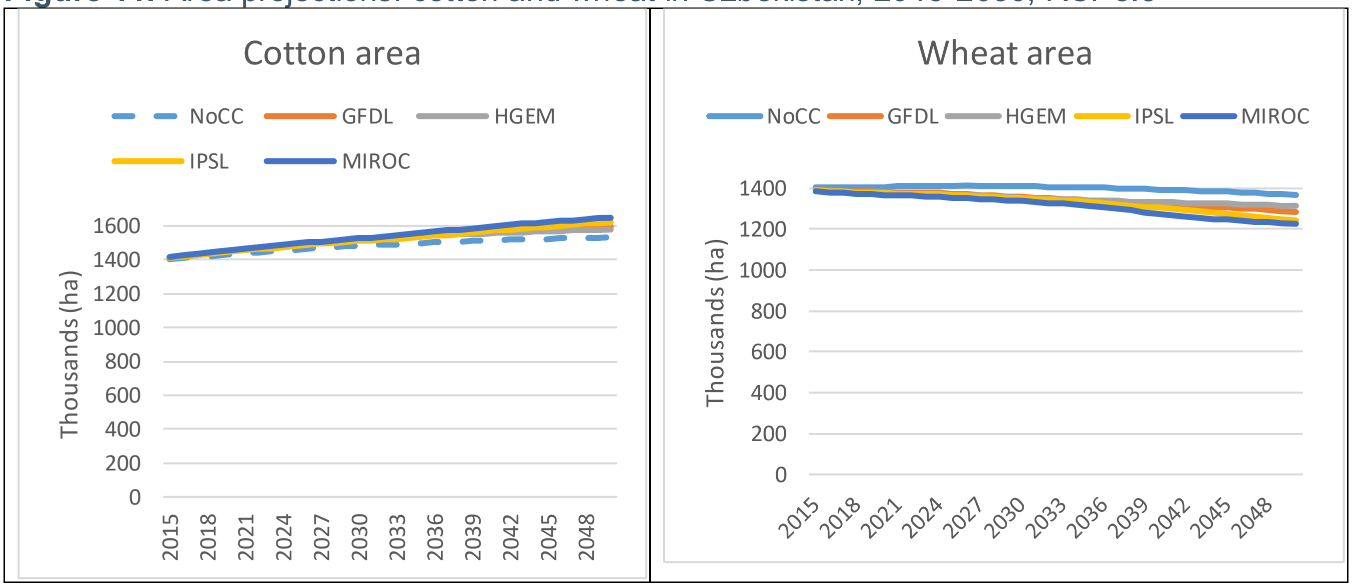
Source: Authors' simulations.

Note: Global Climate Models: NoCC- No Climate Change; GFDL- Geophysical Fluid Dynamics Laboratory; HGEM- High-Resolution Global Environmental Model; IPSL- Institut Pierre-Simon Laplace, MIROC- Model for Interdisciplinary Research on Climate

Despite a significant reduction in cotton yields due to climate change, as compared to what would happen without climate change, we also note that climate change and no-climate-change scenarios are alike in predicting slight increases in harvested area for cotton (Figure 11), with a greater increase in area under climate change. The rise is driven largely by the increase in international prices for cotton. Global demand for cotton is projected to increase, putting significant upward pressure on prices.

In the case of wheat, however, all scenarios predict that harvested area will steadily decrease. Climate-change scenarios predict a greater decline in harvested area than without climate change. Coupled with the decline in yields, the results show that it is economically efficient to reduce the area under wheat cultivation and reallocate the land to other crops better suited to climate change.

Figure 11. Area projections: cotton and wheat in Uzbekistan, 2015-2050, RCP8.5



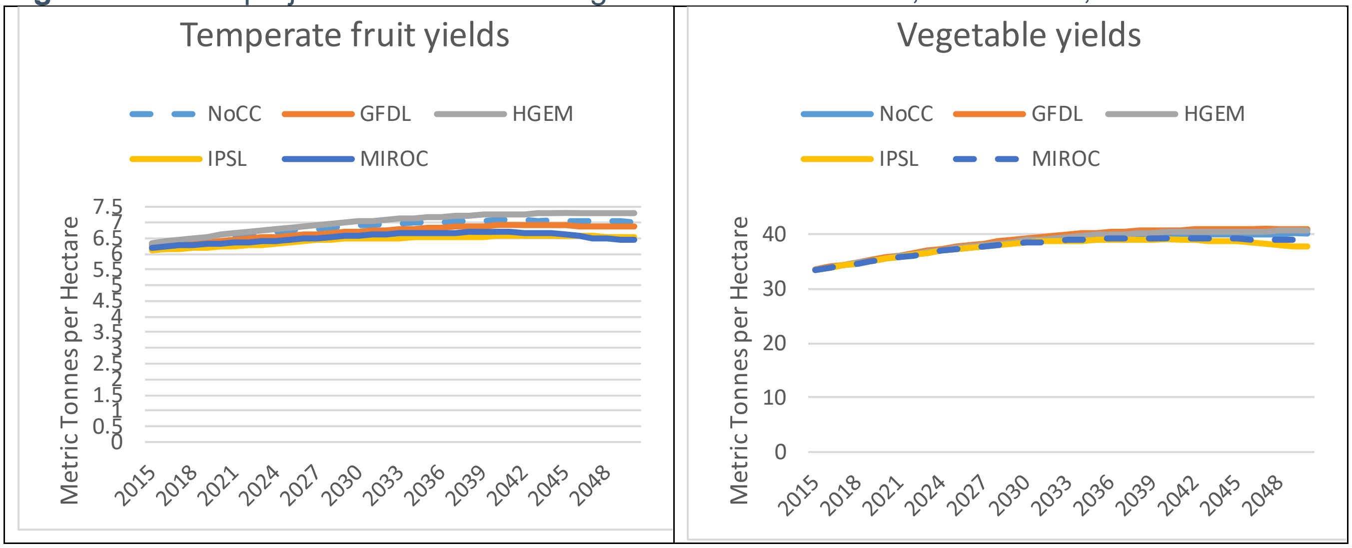
Source: Authors' simulations.

Note: Global Climate Models: NoCC- No Climate Change; GFDL- Geophysical Fluid Dynamics Laboratory; HGEM- High-Resolution Global Environmental Model; IPSL- Institut Pierre-Simon Laplace, MIROC- Model for Interdisciplinary Research on Climate

Fruits and Vegetables Yield and Land Allocation

Demand for fruits and vegetables has been on the rise worldwide due to population growth and rising incomes. As a result, IMPACT predicts that the world prices of fruits and vegetables will increase. Production of fruits and vegetables is expected to keep up with the increase in population. Due to innovations in processing and transportation, trade in fruits and vegetables (both unprocessed and processed) has grown faster than their production, making previously non-tradable varieties tradable. Figure 12 below shows projections for fruit and vegetable yields in Uzbekistan for the above-mentioned scenarios. All scenarios are unanimous in their predictions that fruit and vegetable yields will increase, at least through 2035. But there is a projected slowing and perhaps even decline in yields by 2050 for both groups. There is small variation among different climate change scenarios, with HadGEM being the most optimistic in the long run for fruits and very close to the GFDL GCM for vegetables. MIROC is the most pessimistic for fruit yields and IPSL the most pessimistic for vegetable yields.

Figure 12. Yield projections: fruits and vegetables in Uzbekistan, 2015-2050, RCP8.5

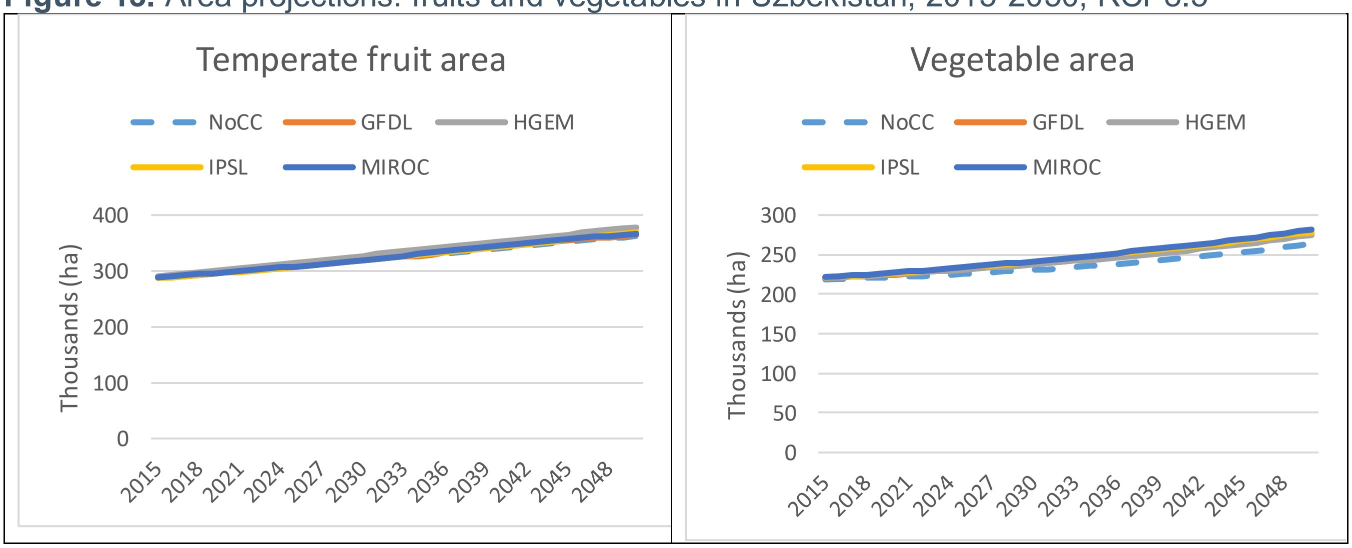


Source: Authors' simulations.

Note: Global Climate Models: NoCC- No Climate Change; GFDL- Geophysical Fluid Dynamics Laboratory; HGEM- High-Resolution Global Environmental Model; IPSL- Institut Pierre-Simon Laplace, MIROC- Model for Interdisciplinary Research on Climate

Climate change and no-climate-change scenarios are alike in predicting steady increases in the harvested area for fruits and vegetables (Figure 13). This result is due to higher global prices driven by growing demand for fruits and vegetables.

Figure 13. Area projections: fruits and vegetables in Uzbekistan, 2015-2050, RCP8.5



Source: Authors' simulations.

Note: Global Climate Models: NoCC- No Climate Change; GFDL- Geophysical Fluid Dynamics Laboratory; HGEM- High-Resolution Global Environmental Model; IPSL- Institut Pierre-Simon Laplace, MIROC- Model for Interdisciplinary Research on Climate

SUMMARY AND POLICY RECOMMENDATIONS

The climate change simulation scenarios matter because they imply different welfare effects across crops and across policy objectives. For example, in a water-scarce setting, more land for cotton may help maintain export earnings and textile value chains, yet it may also put greater pressure on irrigation systems if water availability and use are poorly monitored. At the same time, lower cotton yields could be offset by price increases or productivity gains.

For wheat, climate change simulation results show falling yields and declining harvested area. Wheat has long been tied to food security and self-sufficiency policies in Uzbekistan. This suggests a higher risk of domestic supply shortfalls unless offset through higher productivity in yield growth, strategic storage, and trade-based instruments rather than through area mandates.

The projected results for horticulture are very promising news for both employment and higher value added. The World Bank report (2020) shows that the horticulture sector in Uzbekistan is more productive, uses less water than cotton, and has the strongest job-creation potential if accompanied by modernization and productivity growth. However, these long-run gains are not automatic; they depend on supply chains, logistics, finance, export facilitation, farmer extension services, public investment priorities, storage facilities, as well as water scarcity and broader climate damages. Without any climate action and adaptation, the overall economy of Uzbekistan could be about 10% smaller by 2050 in a no-climate-damage pathway (World Bank 2023).

Uzbekistan's rapidly increasing population needs an ever-growing supply of food, and more than ¼ of households' livelihoods directly depend on agriculture. The high degree of reliance of Uzbek agriculture on water resources for irrigation makes the sector vulnerable to climate change. The wheat self-sufficiency policy the Uzbek Government has pursued since the early 1990s has resulted in a dominance of cotton and wheat and marginalization of other crops. The Government has recognized the need for greater diversification and has begun increasing the area under fruits and vegetables, primarily at the expense of the cotton area (Buriev et al. 2017). At the same time, the government of Uzbekistan has recently implemented significant reforms in its agricultural sector to address climate change, particularly water scarcity and extreme temperatures. For instance, the government has prioritized initiatives such as liberalizing cotton production and reducing the amount of land devoted to cotton. This has boosted the production of fruits, vegetables, and livestock. Efficient irrigation systems and sustainable farming practices were introduced, such as drip irrigation, to improve water management. However, climate change adaptation constraints persist, particularly in the widespread adoption of climate-resilient farming practices and technologies due to limited access to finance, outdated infrastructure, and a lack of technical expertise (training) among farmers.

Climate change and corresponding temperature increases will have significant adverse effects on the production and consumption of agricultural produce. All estimates and forecasts suggest that in the next 40-50 years temperature may increase at least by 2-6°C. The acceleration of warming in the region will have an adverse effect on the availability of water, precipitation patterns, crop yields, and the use of land, water, and other natural resources.

IMPACT predicts that climate change will negatively affect the yields of cotton and wheat in the long term, but due to the greater price increase for cotton, harvested areas for cotton and wheat will behave differently. All climate change scenarios are similar in predicting an increase in harvested area for temperate fruits, but yields are significantly lower compared to the no-climate-change scenario. The impact of climate change on vegetable yields is mixed, but as a result of increases in prices under climate change, it will have a net positive effect on harvested area.

What can and should policymakers do to address future pressure points? Climate change challenges are best addressed by dissecting them for different circumstances and different time horizons. Policies should differentiate between lowlands and highlands, deserts/steppes and piedmonts/highlands, rural and urban, and short-term and long-term. However, some general mitigation and adaptation policies and priorities can still be developed to better address the challenges associated with climate change. In particular, the government, farmers, and private sector should consider the following measures as priorities:

1. **Improve the climate adaptation capacity[6] of the state, farmers, and extension agents and expand climate-smart transition support**. The challenges climate change poses, and the risks it brings, cannot be effectively dealt with without mainstreaming climate change into government policies and long-term plans. These policies and plans should be primarily about enhancing the adaptation capacity of institutions, farmers, and individuals under climate stress. Adaptation capacity begins with good research on climate change scenarios and their impact on agriculture, development of plans and adjustment costs to needed investments in infrastructure, localized advisory services, and on-farm monitoring, Agricultural Knowledge and Innovation Systems (AKIS) and ends with implementation of those plans. In parallel, curricula at agricultural universities and colleges should be revised to reflect current climate trends, local conditions, challenges, technologies, and market demands. The government should use social protection so that smallholders and poorer rural households can participate in the climate-smart transition and can experiment with cropping patterns, continuously adapt to local conditions, and test different seeds and technologies.

2. **Accelerate diversification toward horticulture and other higher-value crop varieties and livestock breeds that are climate-resilient and less water-intensive**. Simulation results show that horticulture offers stronger employment and value-added potential than the traditional cotton-wheat scenario. Water requirements for cultivating crops and breeding animals will increase, not only making water scarcer but also making its supply less predictable. Introduction of climate-resilient new varieties and breeds must be high on the agenda of policymakers to better adapt to the changing climatic conditions. The introduction of new varieties can be an effective way to adapt to climate change only if it is localized and contextualized. Strengthen smallholder farmers' access to quality seed and planting material of main crops originating in Central Asia. These would include apple, apricot, pomegranate, grape, carrot, and onion. Agricultural research and extension services are key in identifying the new varieties and breeds with the characteristics farmers want. Furthermore, the diversity of crop varieties and livestock breeds is a key adaptation tool in the face of adverse environmental conditions, including biodiversity loss, vulnerability to pests and diseases, and yield decline.

3. **Improve efficiency of water use and management and make water saving visible in producer incentives**. In addition to greater demand for water due to the higher temperature and greater seasonal variation, general water runoff is expected to gradually decline in the main rivers of the region – Amudarya and Syrdarya. Coupled with the increase in the output per unit of water, this will require mass introduction of water-saving technologies, basin-level efficiency as well as on-farm capacity to use water optimally. World

[6] Adaptation (or adaptive) capacity is the capacity of a system to adapt if the environment where the system exists is changing. The adaptation capacity confers resilience to perturbation, giving ecological and human social systems the ability to reconfigure themselves with minimum loss of function.

Bank's preliminary analysis shows that the construction of water storage capacity in plain landscapes is not cost-effective (World Bank 2015:124). Mass introduction of water-saving technologies at the farm level is not possible without introducing a tax (fee) for water first. The existing quasi-fee in Uzbekistan (water-user associations' "membership" fee) depends on land size, not the amount of water consumed. Therefore, it provides little incentive to farmers to save water or invest in water-saving technologies such as smart monitoring and metering, sprinkler and drip irrigation, and precision agriculture. The most cost-efficient water saving occurs at the farm level. And the single most important measure the Government of Uzbekistan can implement in a few years is to mandate farmers to use laser leveling of the irrigated land. Despite numerous pilots showing that laser leveling can, on average, save 30%-40% of freshwater, it is not widely used by farmers. Cotton clusters could be reoriented toward water-saving incentives.

In sum, Uzbekistan offers a broader lesson for irrigated transition economies: climate change does not automatically reduce yields, but it also interacts with water scarcity, price incentives, and ongoing agricultural reforms. Hence, trade-offs between food security and adaptation options may intensify because they depend not only on agronomy but also on institutional constraints, market prices, and public policies.

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