Land Use Adaptation to Prevent Adverse Effects of Climate Change on the Yield of Irrigated Croplands in the Nukus District, Uzbekistan

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Executive Summary

The environmental conditions in Uzbekistan make it quite challenging for the country to provide food security: it faces a hot arid climate, prevalent weakly developed desert soils, pronounced land degradation and desertification, and a shortage of independent domestic water resources. These issues are exacerbated by climate change, manifested in Uzbekistan by more severe drought. Climate change consequences pose a threat to food security, especially in areas where agriculture plays a dominant role in communities' livelihoods. Located in the northeastern part of Uzbekistan, the Nukus District is a rural area. Irrigated farming is the main component of the agriculture sector, producing crops and accounting for 40 percent of the district's employment.

Historically, the dry, hot climate has compelled farmers to adapt and use most acceptable practices to survive. However, currently, the pace and magnitude of climate change are beyond those to which current agriculture practices can adapt. The aim of our case study is to work out policy options for adapting and enhancing the resilience of farmers in the Nukus District to climate change.

Proposed policies include the widespread adoption of climate-smart agricultural practices that will mitigate the influence of climate change and ensure sustainable agricultural food production. To achieve this goal, farmers must overcome hurdles arising from environmental issues, a lack of investment resources, and the insufficiently harnessed potential of local innovative initiatives and of internationally recognized most effective practices.

The full participation of decision makers on agricultural development at the national and subnational levels will contribute to the achievement of the goal. Local communities (farmers, *dehkans*,[1] and households) that are negatively affected by climate change are direct beneficiaries and key stakeholders in the implementation and expansion of good practices and sustainable farming methods.

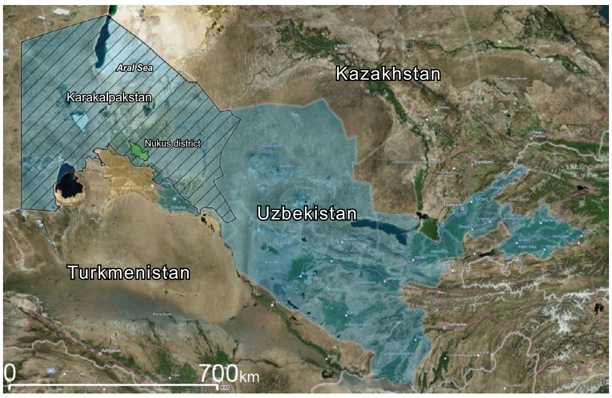
Background

Environmental and Climatic Conditions in the Nukus District

The Nukus District is an administrative unit of the Sovereign Republic of Karakalpakstan, which is part of the Republic of Uzbekistan, located in the Amu Darya delta in the Aral Sea basin (Figure 1). The Nukus District has an area of 943.91 square kilometers; its flat landscape has an elevation of 100–149 meters above sea level. The environmental and climatic conditions of the district are generally similar to those in Karakalpakstan and are invariably difficult for crop farming. Its inland location, deep inside the Eurasian Continent, and its abundant solar radiation define its arid harsh continental climate with hot summers, cold winters, wide seasonal air temperature variation, and extremely low total precipitation rates (Figure 2).

Because of very dry climatic conditions and contrasting seasonal temperatures, the area's soils have low natural fertility and humus content and plants have an insufficient nutrient supply. The flattened terrain impedes natural groundwater outflow and contributes to secondary soil salinization under irrigation. The Nukus District is situated in the lower reaches of the Amu Darya;

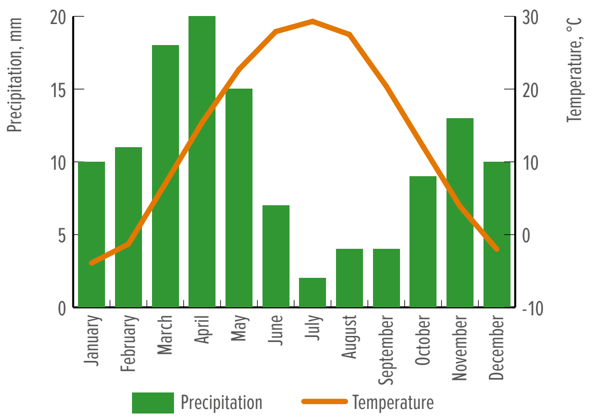
Figure 1: Location of the Nukus District in Karakalpakstan



Source: Author, based on https://www.bing.com/maps.

[1] *Dehkan* farms are family small-scale farms engaged in the production and sale of agricultural products on the basis of the personal labor of family members on the backyard plot granted to the head of the family as a lifelong inheritable possession.

Figure 2: Annual Cycles of Air Temperature and Precipitation, Nukus, 1986–2016 Average



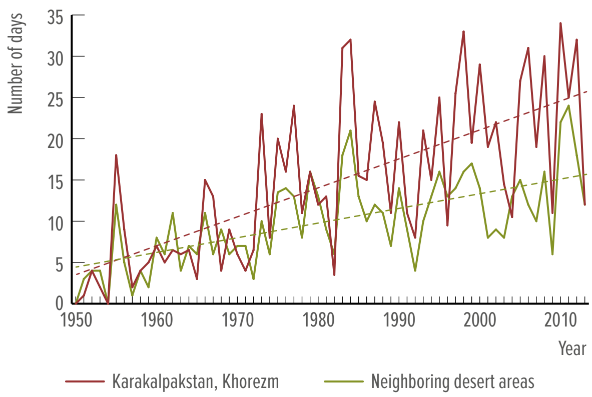
Data source: Uzhydromet.

for this reason, it receives water that is already polluted by water users from upstream areas. In the region, the mineral content of inflowing river water is as high as 1.5–1.8 parts per thousand; the water hardness is twice as high as the maximum permissible concentration. In spite of the harsh environmental and climatic conditions, irrigated crop cultivation dominates the district's economy and, in 2018, was the main source of income and livelihood for 38,941 rural residents whose share in the total population of the district was 80 percent (State Committee of the Republic of Uzbekistan on Statistics 2018).

Climate Change and Its Implications

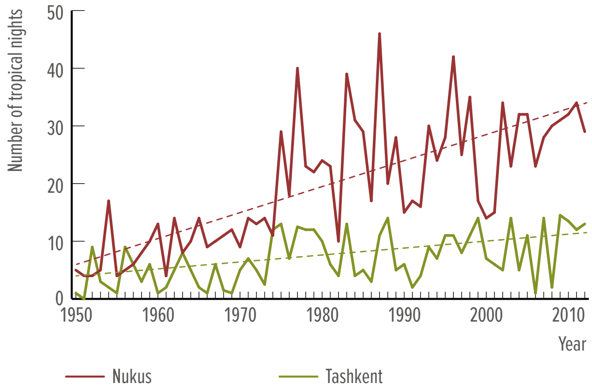
According to the National Communications of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change (UNFCCC), recent decades have witnessed almost a twofold increase in the severity and frequency of droughts typical of the Uzbek climate (UNEP 2016). Climate change impact is particularly painful for the northern areas of Karakalpakstan. In the past, the climatic conditions of this region depended on the water of the Aral Sea. The Aral Sea was a natural regulator, mitigating the cold of Siberian winds and summer heat. Now it is hotter in summer and colder in winter, and the air humidity has dropped (Figures 3–5). In addition to the overall warming,

Figure 3: Variation in the Number of Days with Heat Waves



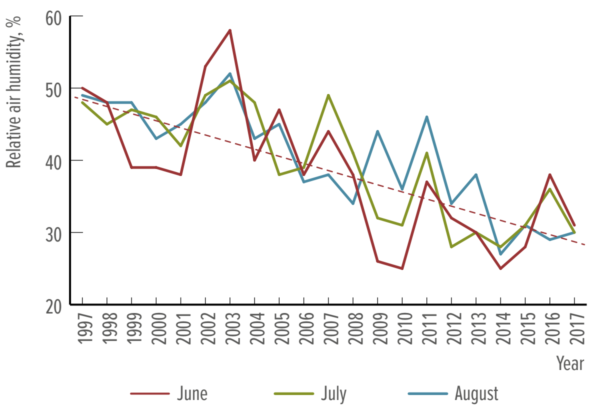
Source: Uzhydromet 2016; UNEP 2016.
Note: A *heat wave* is a period of at least five consecutive days with a significant excess over mean daily temperature.

Figure 4: Changes in the Number of Tropical Nights



Source: Uzhydromet 2016; UNEP 2016.
Note: A *tropical night* is one with an average temperature of 22°C or more.

Figure 5: Changing Air Humidity in Summer, by Year (Nukus)



Source: Uzhydromet 2016; UNEP 2016.

climate change has enhanced the extreme thermic conditions: it has led to an increase in heat waves (five or more consecutive days with a significant excess over the mean daily temperature), the number of nights with an average temperature above 22°C (*tropical nights*), and a decrease in the relative humidity of air in summertime. These changes have led to an increase of evaporation and a corresponding growth in the need for irrigation.

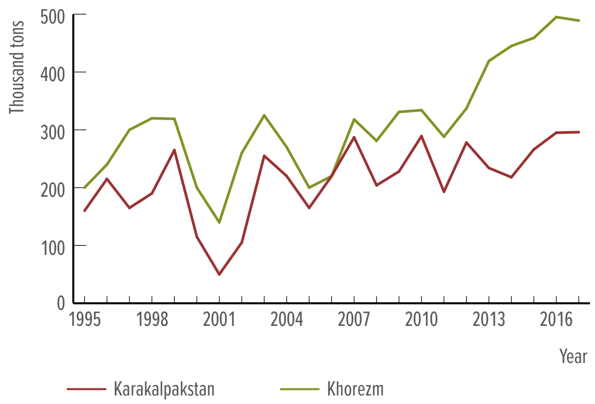
Newly formed on the desiccated Aral Sea bed, the Aralkum Desert has turned into a new "hot spot" and a source of dust and salt transported to adjacent agricultural lands, enhancing their degradation and impairing their crop-producing ability. A recent example: on May 26–27, 2018, a salt storm transported salt "clouds" from the side of the desiccated Aral Sea bed for great distances. Salt was deposited on roads, houses, and vegetation, covering them with white powder like rime ice or frost dew.

Soil salinization in the Nukus District of Karakalpakstan reduces the crop yield. As expert estimates demonstrate, in 2018 the shortfall in production of main crops amounted to 16 percent (8,110 tons), ranging from 3 percent (winter wheat) to 33 percent (potatoes) depending on the salinity tolerance of the crops (Table 1).

During the extreme drought of 2000–01 with its record-breaking low flow of the Amu Darya River, Karakalpakstan received only 30 percent of the water required for land irrigation. As a result, the area received a catastrophic reduction in irrigated areas: a decrease in yield from 14 percent to 17 percent (winter crops) and from to 45 percent to 75 percent (other crops) took place there. Losses of the gross grain harvest amounted 150,000–200,000 tons (Figure 6) (State Statistics Committee 2018).

Increasing the frequency and extremeness of droughts is the biggest threat to Karakalpakstan's food security (Box 1).

Figure 6: Total Yields of Cereal Crops in the Low Reaches of the Amu Darya River



Source: Author's calculations, based on data from the State Statistics Committee 2018.

Table 1: Losses of Gross Output of Agricultural Crops Caused by Soil Salinization in the Nukus District, 2017

	Winter wheat	Rice	Maize	Vegetables	Potatoes	Fruit	Grapes
Area, 1,000 hectares	5.70	0.08	1.80	1.30	0.30	0.22	0.21
Actual harvest, tons/hectare	1.93	1.93	1.89	15.00	12.10	1.14	10.40
Crop losses, tons/hectare	0.06	0.34	0.59	2.44	3.94	0.34	2.83
Shortfall in production							
1,000 tons	0.32	0.03	1.06	3.16	1.18	0.08	0.59
%	3	18	31	16	33	30	27

Source: Authors' calculations, based on data from the State Statistics Committee 2018.
Note: Potential yields are yields that can be produced by a crop depending on soil salinity degree adopted in accordance with Food and Agriculture Organization of the United Nations (FAO) estimates. The potential yield at non-saline soils (100%) in tons/hectare is estimated according to national field experiments.

Box 1. The Drought of 2000–01: Facts

The drought of 2000–01 became a catalyst for desertification and environmental degradation processes. The solute concentration of the water entering Karakalpakstan was 2.1 grams per liter; its hardness was 17 milligrams per liter. Lake systems and wetlands in the northern part of Karakalpakstan, with an area of about 160,000 hectares, almost completely dried up by the end of 2001. As a result of the loss of the wetland habitat of animals and birds, 46 species of fauna were added to the list of the Red Book of Uzbekistan. Fifty-one farms, which rented about 60,000 hectares of lake systems, were on the verge of bankruptcy.

About 200,000 households (1,000,000 people) completely lost their crops. The most affected population (about 600,000 people) needed food, drinking water, and assistance in the supply of agricultural resources. According to estimates by the Ministry of the Economy, agricultural damage in the lower reaches of the Amu Darya (Karakalpakstan and Khorezm) amounted to US$50 million in 2000 and US$80 million in 2001.

Source: Khasankhanova 2013.

Identification of Climate-Smart Farming Practices Used in the Nukus District

It is very important for future development to assess the actual capacity of land users, available technologies, and opportunities; this should be done to reduce the region's vulnerability to adverse climate-related factors. Land use analysis in the northern districts of Karakalpakstan enabled the identification of climate-smart practices that are currently used or were used in the past, and that were demonstrated or are demonstrated now under national/investment projects.

Existing best practices and traditional methods

- ✓ Autumn sowing of wheat in growing cotton fields without primary tillage
- ✓ Agricultural afforestation (establishment of forest shelterbelts to protect agricultural fields)
- ✓ Biological methods of plant pest management
- ✓ Development of greenhouse facilities

Techniques and technologies supported by national and/or investment projects

- ✓ Improved crop rotation in the two-crop system (cotton-wheat) with the introduction of legumes and green manure crops
- ✓ Laser-guided field leveling
- ✓ Zero tillage (no-till) practice
- ✓ Afforestation of degraded parts of arable lands

In this region, the use of best practices ensures a certain level of readiness of the farming sector to climate change.

Interviews for this study with local stakeholders show that the Nukus District offers quite a lot of examples of successful climate-smart practices, but they are not widely replicated. Key obstacles for upscaling climate-smart practices include: (1) low awareness, experience, and knowledge; (2) a shortage of agricultural machinery; (3) the high initial investment costs of introducing technology; (4) a shortage of water resources; (5) the absence of administrative support and adherence to traditional stereotypes (in the case of zero tillage); and (6) the lack of motivation to invest money to get long-term results (in the case of forest shelterbelts).

Policy Issues

National Agricultural Policy

Uzbekistan has been successfully managing to avert threats to its national food security for almost three decades. After it acquired independence in 1991, the country took transformational measures to reform its agriculture sector, which resulted in noticeable achievements. These achievements include grain independence and a domestic supply of staple food that almost fully meets the country's needs.[2] The government provides significant resources for activities to support sustainable land management from internal sources of finance of resources.[3] Large-scale technical activities improved the water supply to 1.7 million hectares and ensured land improvement on 2.5 million hectares (Government of Uzbekistan 2019a). In the recent decade, international donors (the Asian Development Bank, the Inter-American Development Bank, the International Fund for Agricultural Development, and the World Bank) implemented over 20 major projects worth more than US$1.5 billion to support institutional reforms; to reconstruct irrigation and drainage infrastructure; and to establish extension services, develop training programs, and so on.

The new stage of the country's development, including the development of agriculture, started in 2017. The policy document to identify the national policy priorities was the *Action Strategy in the 5 Priority Areas of Development in the Republic of Uzbekistan in 2017–2021* (Government of Uzbekistan 2017a). The strategy envisages comprehensive, systemwide interventions to eventually turn the agriculture sector into an up-to-date, diversified, and sustainable system of production, processing, and marketing.

The newly developed Concept of Efficient Use of Land and Water Resources in Agriculture is aimed at restoring soil fertility; introducing up-to-date irrigation and farming methods; implementing innovative tillage strategies; promoting new agricultural trends based on international experience; developing crop breeding and seed production; maximizing the yields of croplands and agricultural outputs, along with their downstream processing and selling; developing a modern system of logistics and marketing; and accelerating the integration of research and practice.

According to the low-carbon development strategy, by the year 2030 the adaptation capacity of water management and agriculture will increase by about 40 percent in the most vulnerable areas prone to desertification, land degradation, and droughts (CER/UNDP 2015).

Uzbekistan has joined the National Policy to Combat Drought Initiative of the Food and Agriculture Organization of the United Nations (FAO), the World Meteorological Organization (WMO), and the United Nations Convention to Combat Desertification (UNCCD) (WMO/UNCCD/FAO/UNW-DPC 2013). The implementation of this initiative will make it possible to refocus from response measures (in a crisis) to preventive measures that ensure readiness to respond to drought. Under the climate agenda, Uzbekistan ratified the Paris Agreement in 2018 to contribute to the stated common goal.

The Government of Uzbekistan and the global community pay much attention to addressing issues arising from the Aral catastrophe. A special charity fund called Muynak-2019 was set up. Under the Aral Sea Region Development Program, it is planned to implement 67 projects in 2017–21 (Government of Uzbekistan 2017d) to improve the quality of life and water resource management, with a total cost amounting to US$1.2 billion. In 2019, 100 billion Uzbekistani soms will be made available for afforestation of 500,000 hectares on the desiccated Aral Sea bed (Government of Uzbekistan 2017d, 2019b). To provide a programmatic approach to addressing the problems, a UN Multi-Partner Human Security Trust Fund for the Aral Seas Region in Uzbekistan was established under the aegis of the UN.[4]

Adaptation Policy Issues

Issues related to irrigated land fertility: Currently, the irrigated land fertility rate in the Nukus District is below average because of inefficient land use and the low potential of adaptation to unfavorable natural and climatic conditions. Under a long-term development strategy and with the intensification

[2] Currently, the share of grain imports does not exceed 5 percent of total consumption whereas, in the early 1990s, grain imports accounted for over 80 percent of total consumption.

[3] Sustainable land management helps to adopt climate-smart agriculture because it is also aimed at striking a good balance between resource utilization and long-term maintenance of production capacity.

[4] Further information about the trust fund can be found at https://www.uz.undp.org/content/uzbekistan/en/home/library/poverty/un-multi-partner-human-security-trust-fund-for-the-aral-sea-regi.html.

of crop cultivation, there are plans to diversify the range of crops by switching to the cultivation of grains, leguminous crops, vegetables, oil-producing plants, melons and gourds, fruits, and so on; moreover, a reduction in the area planted with cotton is planned. However, to improve the fertility of irrigated lands, maintain soil health, and adapt to climate change, it is necessary to undertake an additional set of activities (including implementing efficient crop rotation, increasing organic matter in the soil, applying new drought-resistant and salt-tolerant crop varieties, and so on).

Issues related to the recording of irrigation water use in agricultural fields: The restructuring of the farming sector has produced numerous water users—both farmers and dehkan farms. To ensure efficient and equitable allocation of water within farms, water user associations have been set up in the country; there are also agencies that monitor and control conditions of irrigated lands. However, proper recording of water use for agricultural fields has not yet been put in place and the irrigation system features have poor water use discipline. Because of the lack of water meters, each norm-based diversion of irrigation water to farmers' fields is measured only "approximately." This leads to high irrigation rates as well as loss of water to leakage and surface discharge to fields located close to the water source; farms located at the farthest distance to the water source are facing a shortage of irrigation water. For this reason, farmers are not motivated to introduce water-saving technologies and save irrigation water.

Issues related to irrigated land improvement: The ongoing process of irrigated land improvement is focused on renovating and restoring drainage systems as well as activities aimed at efficient use of water resources under ongoing regional programs. A special Land Reclamation Fund has been set up under the Ministry of Finance. But this limited focus on drainage-related works only fails to bring about long-term success. According to guidelines and recommendations of the World Bank, drainage infrastructure reconstruction projects should be implemented concurrently with the rehabilitation of irrigated lands within their catchment areas, using innovative approaches and technology to ensure high rates of return from improved land and growth of agricultural productivity (World Bank 2009).

Issues related to the lack of integration between crop production and cattle breeding in the irrigated area: Farm restructuring in the irrigated area had led to a concentration of livestock farming in dehkan farms, which disrupted in the relationship between crop production and livestock production. As a result, the access of the crop cultivation farms to organic fertilizers decreased. Fields of alfalfa, an important crop in a rotation, were replaced with wheat, which has impaired the feeding base for livestock farms.

These and other policy issues exist today, but they are being gradually addressed at the government level. Food policies are being evaluated and adjusted with due regard to population growth, pressure on natural resources, and burdens on agricultural producers.

Stakeholder Groups

In Uzbekistan, the range of land use stakeholders is vast and includes ministries, agencies, institutes, decision makers, farmers, dehkan farms, and households. Each of these stakeholders undertakes different activities and plays a different role in decision making about the promotion and upscaling of climate-smart best practices at different levels. Stakeholders can be grouped by level:

National-level stakeholders include government organizations, ministries and agencies, and research and development institutions as well as nongovernment and nonprofit organizations. The two ministries responsible for agricultural policies and decision making in agricultural production and food security are the Ministry of Agriculture and the Ministry of Water Management of the Republic of Uzbekistan. The Ministry of Innovation Development is responsible for developing research and innovation activity; to do this, it needs financial resources. Responsibilities for environmental management, monitoring, and sector-specific responsibilities related to natural resources rest with several ministries and institutional entities, including the State Committee on Ecology and Environmental Protection; the Ministry of Health; the State Committee of the Republic of Uzbekistan on Land Resources, Geodesy, Cartography and

State Cadastre; the Centre of Hydrometeorological Service/Uzhydromet, and so on.

Subnational (regional/district)-level stakeholders are, primarily, (1) regional and district *khokimiyats* (local authorities) responsible for implementing government decisions and monitoring their implementation at the local level; (2) regional offices of the Ministries of Agriculture and Water Management, including services in charge of monitoring of salinity, water-logging, and irrigated land conditions, control of water consumption, and drainage quantities and quality; (3) basin irrigation systems administrations and irrigation system administrations (ISAs); and (4) research institutes, nongovernmental organizations, and so on.

The focus of the responsibilities of national and subnational organizations and agencies resides with the implementation of rural development and water management strategies as well as the operation of agricultural and water management facilities and sites.

The local level includes the following stakeholder groups: (1) agricultural producers and their associations; (2) councils of farmers and self-governance bodies; and (3) rural communities whose income depends on agricultural production.

Formally, local-level beneficiaries do not belong to public-sector entities and carry out their own businesses in agricultural production or providing inputs for crop growers.

To clarify the position of various stakeholders based on their interests, the amount of power they have, and their attitude toward institutional objectives and implementation methods, the information on stakeholders has been systematized (Table 2).

Table 2. Key Stakeholders and Their Interest in Land Use Adaptation to Climate Change

Number	Stakeholder	Interest
	PRIMARY STAKEHOLDERS	
1	Dehkan farms	Improvement of land yield and improvement of livelihood
2	Farmers	Sustainable harvests and income
3	Women and vulnerable groups	Sustainable family budgets and access to food
4	Local government bodies	Sustainable production and income
5	Water user associations	Meeting demand for water and improvement of irrigation services
6	The owners of small land plots (dachas) and their associations (Tovarischestvo)	Growing organic fruits and vegetables for own consumption
	SECONDARY STAKEHOLDERS	
7	Ministry of Agriculture Ministry of Water Management	Implementing policy on efficient water and land resources use; integration of adaption approaches in development strategies and plans
8	Ministry of Finance	Implementing financing strategy, mobilization of external and internal resources
9	Uzhydromet	Fulfilling the obligations assumed under the UNCCD and the UNFCCC
10	State Committee on Ecology and Environmental Protection	Ensuring the best use of available resources, monitoring and preservation of the environment
11	State Committee of the Republic of Uzbekistan on Land Resources, Geodesy, Cartography and State Cadaster (Goskomzemgeodezkadastr)	Achieving the objectives under the program for improving soil fertility
12	Ministry of Health	Minimizing the negative impact of climate events and extreme meteorological conditions on population health
13	Ministry of Higher and Vocational Education	Improving training programs, among others
14	Sector-specific and operations services under ministries (basin irrigation systems administrations; irrigation systems administrations)	Ensuring better water allocation and use of water resources
15	Academy of sciences, research institutes, design institutions, and research and production companies	Ensuring access to best practice, services in training programs

(table 2 continued)

Number	Stakeholder	Interest
16	Nonstate nonprofit organizations, mass media, and other institutions of civic society	Improving eco-education, promotion of eco-friendly approaches, and public awareness campaigns
17	Agricultural advisory centers, extension services, and so on	Disseminating knowledge, training land users, and bridging the gap between science and production

Note: UNCCD = United Nations Convention to Combat Desertification; UNFCCC = United Nations Framework Convention on Climate Change.

The comparative position of various stakeholders depending on the degree of their influence and importance in implementation of adaptation activities is reflected in the **Importance/Influence Matrix (Box 2)**. *Importance* in this context refers to the activities of a specific group of stakeholders that ensure the implementation of adaptation measures in agriculture and the land use system; *influence* means the existence of authority to make decisions, provide funding, and monitor the implementation of measures.

Group A includes stakeholders with high importance for activities but low influence. These are, mostly, primary stakeholders that require special initiatives and support. Their involvement and participation are important factors for success in adaptation to climatic change.

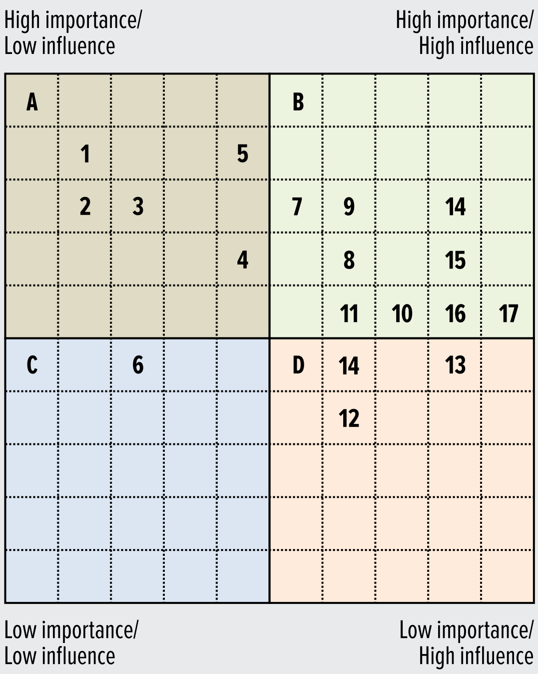
Group B is a group of stakeholders with high importance (responsible institutions such as sector ministries, state commissions, and science and civic society organizations) that may have a substantial impact on success.

Group C (low importance and low influence) in our case is represented by small landowners.

Group D (low importance and high influence) is represented by stakeholders that can influence decision-making and policy implementation, but their interests are not related directly to this activity.

The numbers in the matrix follow the numbers assigned to each stakeholder in Table 2.

Box 2. Importance/Influence Matrix



Policy Options

In order to achieve sustainable production of food, the Nukus District should develop climate-smart agriculture based on the sustainable intensification of crop cultivation. This includes cultivating drought-resistant and salt-tolerant varieties and types of crops and their rotation; implementing soil protection and resource-saving principles of agriculture; and utilizing mechanization techniques to maintain soil health and ensure the efficient management of water resources. It also includes a wider application of innovative approaches, practices, and coordination mechanisms and the involvement of stakeholders, among other actions.

1. **Climate-Smart Land Use Management of Irrigated Salt- and Drought-Affected Lands**

The term *climate-smart land use management* refers to a complex set of interventions, technologies, and approaches designed to mitigate the adverse consequences of climate change on farming, increase the productivity of land resources, and safeguard food security under climate change and variability. The following set of activities is proposed for the Nukus District.

Laser-guided field leveling: In irrigated crop farming, soil and field preparation for the vegetation season is no less important than drainage operations. Laser-guided field leveling is one of the key approaches in the system of measures intended to improve agricultural productivity and ensure water efficiency. The main drawbacks of traditional leveling methods consist of poor precision and uneven the surface of the field. Laser-guided field leveling enables farmers to get rid of these drawbacks and is a recommended up-to-date innovative technique for enhancing irrigated land capacity.

According the Khorezm Rural Advisory Support Service (KRASS), laser-guided field leveling enables farmers to: (1) reduce labor costs by 11–23 percent, (2) reduce the costs of mechanization by 11–14 percent (starting in the second year), (3) reduce the amount of water needed for irrigation by 20–30 percent, and (4) increase cotton and wheat yields by 10 percent (Egamberdiev, Rudenko, and Nurmetov 2012). Laser-guided field leveling capacity is 1–3 hectares per day per leveler. Regarding the frequency of leveling, it is advisable to do it once every five to eight years on dry soil to avoid compacting the soil. The most convenient time is July-August after harvesting winter wheat.

The cost of laser-guided field leveling is about US$350 per hectare. But initial costs are offset by its benefits (Egamberdiev, Rudenko, and Nurmetov 2012).

Deep ripping: To improve soil properties, the soil needs to be periodically ripped up to a depth of 60 centimeters to destroy its compacted layer—the so-called *plough pan*. The effect of deep ripping is manifested in yield increases of 10–30 percent and reduced water consumption of 10 percent. The best time for both deep ripping and laser-land leveling is in summer after the winter wheat harvest. Deep loosening costs pay off as soon as the second year.

Improvement of current crop rotation by combining cotton and winter wheat: In the Nukus District, the farming land fertility score a low 43 (a score of 100 is best), which guarantees wheat yields of about 1.7–1.8 tons per hectare. Low humus content (0.6–0.7 percent) and loss of soil life (soil macro- and micro-fauna) are attributed to low application rates of organic fertilizers and the removal of plant residue from fields. To address the dropping fertility, it is recommended to repeatedly insert legumes and green manures into existing crop rotations and also to use all plant residue left on the fields after harvesting.

Cultivation of double crops and green manures allows a field to be covered with vegetation all year, which reduces nonproductive evaporation from the soil surface and halts re-salinization processes; legume bacteria living in the roots of legume plants absorb free nitrogen from the air to store it in the soil. Plant residues are ploughed back into the soil, where they replenish the stock of organic matter and improve soil structure (Figure 7a, 7b).

Using this technology, land users can harvest two food crops (wheat and legumes) during a single year and earn additional income as well as improve their diet and food security. This technology does not require large additional financial or labor inputs, and the generated income from the double crop harvest not only covers all the costs, but also brings profits (World Bank 2009).

Irrigation best practices: Double crops require additional water resources for irrigation. Lessons learned from projects (World Bank 2009) show that, in Karakalpakstan, with its shallow groundwater table, only one watering of 500–800 cubic meters per hectare is needed for a second crop. Water-efficient irrigation techniques allow irrigation water to be saved with alternating dry and watered furrows and/or using transportable trays.

Minimization of soil treatments: Sowing winter wheat among the growing cotton plants without primary tillage is already used by many farmers

Figures 7a, 7b: Legume Bacteria and Soil Structure after Improved Crop Rotation

Source: World Bank 2009.
Note: Demonstration site in the Beruni district of Karakalpakstan.

because minimized tillage enables the farmer to reduce the number of tractor runs, thus saving fuel and lubricants and depreciating resources; to reduce CO_2 emissions; and to reduce the risk of soil compactness. It also—which is no less important—makes it possible to sow wheat on optimal dates independent of cotton harvesting. This is a promising practice because minor improvements would make it more effective. The Uzbekistan Research Institute of Agriculture Mechanization and Electrification has designed and successfully tested a special-purpose sowing machine to sow wheat among growing cotton.

Balanced plant nutrition (fertilizer system): Mineral fertilization to ensure balanced plant nutrition enables a noticeably broadened scope of moisture uptake by crops when moisture is insufficient (Baliuk, Medvedev, and Nosko 2018). An important role is played by organic fertilizers. The systematic application of manure is good for soil: manure improves its water-physical properties and structure; it also increases the number of beneficial soil microorganisms. In many countries, organic waste composting has become a processing industry using organic wastes to produce fertilizers. Applying composted organic matter demonstrates significant potential for carbon sequestration. For this reason, the farmer should know the agricultural soil properties of his field. Before beginning field operations, it is necessary to test for key soil properties (soil texture, humus and nutrient content, salinity degree, density, water-retaining capacity). The results of such tests will provide a basis for calculating fertilizer application rates that ensure the achievement of yield targets as well as rates and needs for other operations (irrigation schedules, deep ripping needs, and so on).

Forest shelterbelts for irrigated arable lands: In the arid zone, irrigated arable land is a human-made ecosystem; therefore, it cannot regulate itself. One of environmentally grounded management decisions is the establishment of a network of forest shelterbelts to protect fields. Apart from their main purposes (to mitigate dry wind impact and to cool down the air and soil), forest shelterbelts also support the emergence of new ecosystem, improve the human habitat, and diversify the monotonous picture of agricultural lands, creating new agroforest landscapes and improving environmental conditions.

Afforestation of degraded arable lands: In the Nukus District, about 2,500 hectares of long-fallow lands have been withdrawn from agricultural use. These lands have low and unstable yields. A thorough selection of species is important to provide such environmental services as reducing water-logging through transpiration (bio-drainage) and soil salinity control; some species enrich the soil with nitrogen owing to their nitrogen-fixing capacity, and leaf litter enriches it with humus. It was recommended to use the following three species for the afforestation of Karakalpakstan's salinized degraded lands: Russian olive (*Elaeagnus angustifolia*), which is a nitrogen-fixing species; Euphrates poplar (*Populus euphratica*), which is a fast-growing species; and Siberian elm (*Ulmus pumila*), which is a long-lived species (Khamzina, Lamers, and Vlek 2012). Afforestation provides opportunities to join efforts to combat land degradation and to reduce CO_2 concentration in the atmosphere.

Biological methods of plant pest management: These methods are widely used in Karakalpakstan and in Uzbekistan as a whole. In the Nukus District, there are functioning bio-factories and bio-laboratories for *Chrysoperia* spp., *Habrobracon hebetor*, *and Trichogramma* propagation. Under contracts with farmers, specialists from district laboratories examine the farmers' fields and take plant pest management measures. Biological pest control operations are cheaper than chemical treatments; in addition, unlike chemical treatments, they do not pollute the environment.

2. Institutional Activities for Expanding Climate-Smart Management of Irrigated Lands

Analysis and evaluation of Uzbekistan's state adaptation policy and its institutional framework demonstrate that the country has a favorable environment for developing climate-smart land use in agriculture. The country has put in place a solid institutional framework capable of providing comprehensive technical and scientific support to primary land users in their activities aimed at adopting climate-smart practices.

Since scaling up climate-smart practices is a long-term and evolving process, responsible institutions should constantly interact with partners and organizations at various levels, including national funding agencies and programs, local and national governments, the private sector, civil society, community organizations, and the research community. Each of these groups plays different roles in the scaling up of sustainable land management.

The government—along with educational and scientific institutions and the country's public organizations—pays special attention to increasing knowledge, raising public awareness, and improving access to advanced technologies for sustainable water and land management.

The state provides information to land users in the form of recommendations through state institutions, and by organizing campaigns and individual events. With the joint participation and financing of international projects, the khokimiyats—with the support of the Ministry of Agriculture and the Ministry of Agriculture and Water Resources—initiate an increase in the knowledge and awareness of farmers through events such as fairs and "farmer days."

In accordance with the Decrees of the Cabinet of Ministers of the Republic of Uzbekistan, various forms of rural advisory services have been created; these include counseling centers and distribution services at higher educational institutions, departments, and organizations. A significant contribution to raising awareness and scaling up climate-smart practices for a wide range of beneficiaries is made by national and regional programs and projects implemented in the country.

KRASS is currently operational in the Aral Sea region; the joint AF/UNDP/Uzhydromet project on "Developing climate resilience of farming communities in the drought prone parts of Uzbekistan" is under way (AF/UNDP/Uzhydromet 2019). Land users of the Nukus District can find detailed information on modern resource-saving technologies, including laser-guided field leveling, in the Project Information and Advisory Center in Nukus.

3. Climate-Smart Land Use Activities

The discussion of the proposed set of activities aimed at developing climate-smart land use in the Nukus District of Karakalpakstan with the stakeholders identified this as a priority. Climate-smart land use is consistent with the area of state agricultural policy aimed at a technical upgrade of agriculture, implementation of innovation tillage technologies, wider application of modern irrigation methods, and so on (Government of Uzbekistan 2017a, 2017b, 2017c, 2019a). The recommended climate-smart practices were successfully demonstrated in various agroclimatic regions of Uzbekistan, including northern Karakalpakstan, with a positive response from the farmers.

The proposed climate-smart practices are low risk. Project experience has shown that financial contributions for initial implementation and maintenance pay off the next year. Laser land leveling is the most expensive of the practices. However, in a typical farm cultivating wheat or cotton, the costs are already paid back by the third year. The cost of laser equipment pays off within 1 to 3 years, depending on the source of borrowed funds and the farm field area (WOCAT SLM Database, Laser leveling of the fields to increase the efficiency of on-farm use of irrigation water [Uzbekistan]; Egamberdiev, Rudenko, and Nurmetov 2012).

As stakeholders confirmed, a solid knowledge base and successful pilot projects are needed to implement climate-smart practices. These practices are not yet widely used by farmers in Uzbekistan. The following key obstacles for upscaling climate-smart practices are identified:

- ✓ Low awareness, lack of experience, and lack of knowledge
- ✓ Shortage of required equipment and agricultural machinery
- ✓ Shortage of water resources
- ✓ High initial investment costs of technology introduction (in the case of laser-guided field leveling)
- ✓ Long wait for benefits (in the case of afforestation)

To overcome financial barriers, it is possible to recommend that farmers unite and make centralized purchase equipment through associations of farmers and local authorities (such as khokimiyats and the regional department of the Ministry of Agriculture). Furthermore, the country has leases available to obtain equipment needed to ameliorate lands and water-saving irrigation technologies as well as crediting that reduces economic barriers.

Mass training of farmers within the framework of the Global Environmental Fund's Small Grants Program (GEF SGP) and the UNDP/AF/Uzhydromet project currently being implemented in the northern regions of Karakalpakstan makes a significant contribution to increasing farming potential, reducing one of the main obstacles to mainstreaming laser land leveling on a large scale (AF/UNDP/Uzhydromet 2019).

The overview of state adaptation policy, consultations, and discussions with local stakeholders allows us to be optimistic that the implementation of the set of climate-smart practices is a practicable effort that will realistically help improve the resilience of irrigated agriculture in the face of climate change in the Nukus District of Karakalpakstan.

Assignment

Uzbekistan's approved Concept of Efficient Use of Land and Water Resources in Agriculture until 2030 is aimed at taking integrated measures to address many issues related to the low production capacity of soils and the need for adaptation to adverse environmental conditions and adverse impact of climate change. According to the Concept, one of the strategies for improving cropland productivity is the resumption of using the croplands that were withdrawn from agriculture because of their high soil salinization, the deterioration of their drainage and irrigation systems, the lack of water for soil leaching, and so on.

Assignment: Develop a roadmap and activities to restore the fertility of the Nukus District's arable lands that currently have the status of long-fallow lands because of the loss of productivity for various environmental and economic reasons.

Policy Recommendations

The issue of the adaptation of agriculture to climate change in Uzbekistan is being integrated into government plans and development programs in a way that supports the climate-smart agriculture. It is important to ensure cooperation and the concerted action of various administrative levels as well as comprehensive involvement of all stakeholders (including decision makers, the business community, academia, civil society, and the rural community as a whole) in the process of adaptation.

In order to improve the knowledge and skills of land users and the agricultural community, it is necessary to:

- ✓ Strengthen and reinforce the operation of existing local information and advisory centers as a link between science, education, and practice.
- ✓ Reinforce knowledge sharing not only among land users but also among decision makers.
- ✓ Increase the efficiency of agricultural budget expenditures with a focus on the implementation of programs aimed at capacity building; testing and adapting new climate-smart technologies; improving soil fertility, disseminating knowledge; building capacity of human potential; and attracting private investment in agriculture, logistics, protection environment, and so on).

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Abbreviations

ADB	Asian Development Bank
AF	Adaptation Fund
CNH	Case New Holland
FAO	Food and Agriculture Organization of the United Nations
GACSA	Global Alliance for Climate-Smart Agriculture
GEF	Global Environmental Fund
ISAs	irrigation system administrations
KRASS	Khorezm Rural Advisory Support Service
SGP	Small Grant Programs
SLM	Sustainable land management
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

Appendix

Suggested Teaching Methodology Based on the Cornell Case Study Approach

The case studies presented in this publication were developed for use in graduate and undergraduate teaching using a participatory social entrepreneurship teaching methodology developed by Professor Per Pinstrup-Andersen, Cornell University. Initially used for teaching at Cornell University, this type of case studies was subsequently adopted by other universities in the United States, Africa, and Asia. The overall objective of the methodology is to strengthen the analytical capacity of the students within the context of a simulated food policy context. Evaluations by students during the 15 years the methodology has been used have been consistently positive and enthusiastic. To be successful, the methodology requires preparations by both students and instructors prior to each class. The case(s) to be discussed should be made available to the students at least a week prior to the class and it is critically important that all students have read the case study prior to coming to class and be prepared to discuss the pros and cons of various policy options from the point of view of each stakeholder group identified in the case study.

The class should be run as a simulated role-playing meeting of stakeholder group representatives interested in the particular food policy issue to be discussed. One or two students, who should simulate the role as external consultant(s), should give a 10 to 15 minute overview presentation of the case, with emphasis on the policy options identified in the case study and a policy recommendation. Each of the remaining students should be assigned the role of a stakeholder group representative. The assignment may be made a week ahead of the class session or at the beginning of the class session. Then a debate moderated by the instructor follows, in which each stakeholder representative expresses his/her position about the various policy options and the consultants' recommendation.

The moderator should guide the debate by following up on the points made and seek the response of other stakeholder groups. The moderator should call on specific representatives as needed to maintain an exciting, cohesive, and fast-moving debate. Attempts should be made to arrive at a consensus around the consultants' recommendation on one or more policy options. In cases when no consensus can be obtained (likely to be the majority of cases), a brief discussion should be held on the relative power of each stakeholder group and which one is likely to make the final decision about the policy option to be pursued. The length of the debate section of the class depends on the length of the class session. In a 50 minute class session, the debate portion should be limited to 25 minutes, leaving the last 10 to 15 minutes of each class session for the instructor to pull the findings of the debate together and relate them to the broader food policy issue within which the case study belongs. Such a "mini-lecture"—in which the students' experience from the debate and the written version of the case study is placed in a broader food policy context—is critically important.

In order to ensure that all students participate actively, it is recommended that the class size be limited to 20–25 students. Although the methodology was developed for real-time classroom instruction, it could also be used in online distance learning, particularly if real-time video-based interaction among the students could be included. While the above-mentioned mini-lectures would help ensure a cohesive food policy course, experience at Cornell University indicates that the integration of a few lectures based on a textbook would further strengthen the cohesiveness of the course. The textbook used at Cornell is *Food Policy for Developing Countries* by Per Pinstrup-Andersen and Derrill Watson, Cornell University Press, 2012.