Technology Needs Assessment for Adaptation in the Water and Agricultural Sector in Central Asia

Regional Environmental Center for Central Asia (CAREC)

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IGES is an international research institute conducting practical and innovative research for realizing sustainable development in the Asia-Pacific region.

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Acronyms

ADB	Asian Development Bank
APAN	Asia Pacific Adaptation Network
CAREC	Regional Environmental Centre for Central Asia
EC	European Commission
FAO	UN Food and Agriculture Organization
GDP	Gross domestic product
GIS	Geographic Information System
ha	hectare
IC	Initial Communication under UNFCC
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
IWRM	Integrated water resource management
RS	Remote Sensing
SNC	Second National Report under UNFCCC
TJS	Tajik somoni (national currency)
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WUA	Water Users Association

INTRODUCTION

Importance of water and agriculture for Central Asia

Central Asia is comprised of the countries Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan and covers approximately 4 million km2 with a population of over 55 million. The five countries are a part of the Aral-Sea Basin, a closed drainage system fed by two big rivers - the Amudarya and the Syrdarya. Water and agriculture have historically been among the main drivers behind major socio-economic and geo-political transformations that took place in Central Asia over the past century. Characterized by considerably arid climate, the region relies on comparatively few water sources to provide irrigation for agriculture. Nevertheless, it is difficult to overestimate the importance of the latter for Central Asia as the agricultural sector in some countries accounts for up to 30% of GDP and provides employment for half of the region's population.

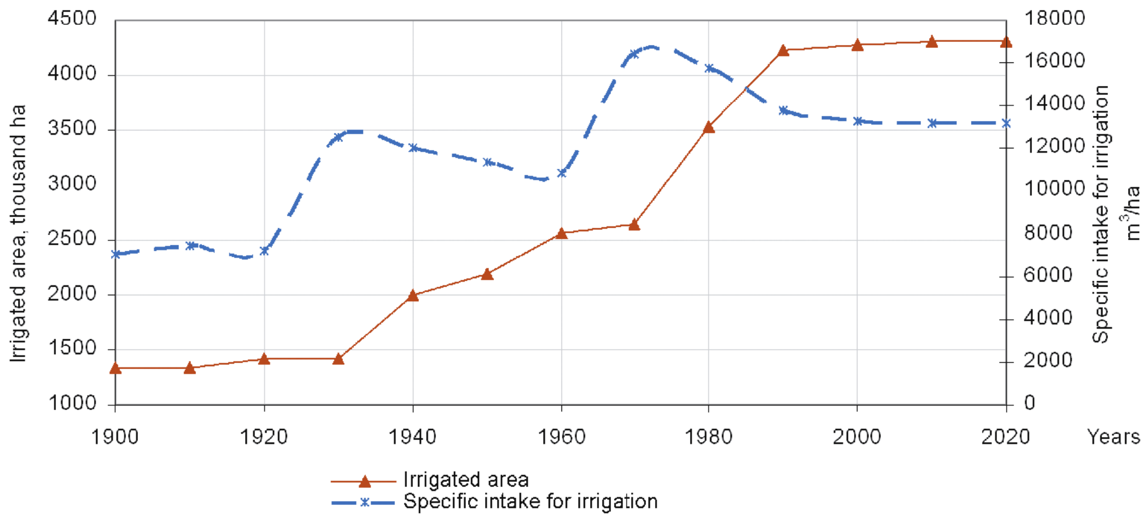
Table 1. Main socio-economic indicators related to agriculture in Central Asia

Country	Total population *(1000s)*	Rural population (% of total population)	Agriculture, value added to GDP *(%)*	Arable land *(1000 ha)*	Irrigated area as % of total arable land	Agricultural water withdrawal *(km3/yr)*
Kazakhstan	15 841	42%	6,40%	23 400	15%	28,63
Kyrgyzstan	5 271	65%	29,20%	1 276	84%	9,45
Tajikistan	6 783	74%	22,40%	742	97%	10,96
Turkmenistan	4 980	51%	12,50%	1 850	94%	24,04
Uzbekistan	27 128	64%	19,80%	4 301	98%	54,37

Source: FAO AQUASTAT database

It is estimated that agriculture consumes as much as 90% of the total renewable surface water in the region. The high level of water consumption by agriculture reflects its heavy dependence on irrigated lands, which have been enormously expanded since the 1950s, mainly for cotton and wheat production. In Uzbekistan for example, whilst the size of the irrigated area had nearly tripled over the past 60 years, water consumption per hectare had also rose by 40% from about 10000m3 in the 1950s to 14000m3 in the 2000s (Figure 1) (UNDP, 2007). One of the reasons for the growth in water withdrawals per hectare is the continuously expanding irrigation system, which resulted in water being transferred over huge distances and eventually led to increasing seepages and water losses (O`Hara 2000). Another reason is that the centrally planned Soviet economy did not consider water as an economic good; for a long time irrigation was focused on the development of water resources for supporting agricultural expansion rather than efficient use of water on fields.

Figure 1. Trends in irrigated area and water intakes in Uzbekistan since 1900



Source: UNDP, 2007

Table 2. Water supply and withdrawals of the Central Asian countries from the main river systems in the region

Country	Total water supply to the main rivers[1] (km3/year)	Total water withdrawal (km3/year)	Supply/withdrawal ratio
Kazakhstan[2]	28	33	85%
Kyrgyzstan	47	11	424%
Tajikistan	65	12	543%
Turkmenistan	3	25	12%
Uzbekistan	9	60	15%

Source: FAO AQUASTAT database and World Bank (2009)

The massive withdrawal of water from the Amudarya and the Syrdarya for expanding irrigated agriculture was achieved at a huge cost to the environment, eventually leading to the diminishing of the water inflow into the Aral Sea from 54 km3 in the 1960s to 5 km3 in the 1990s (Zonn et al..,

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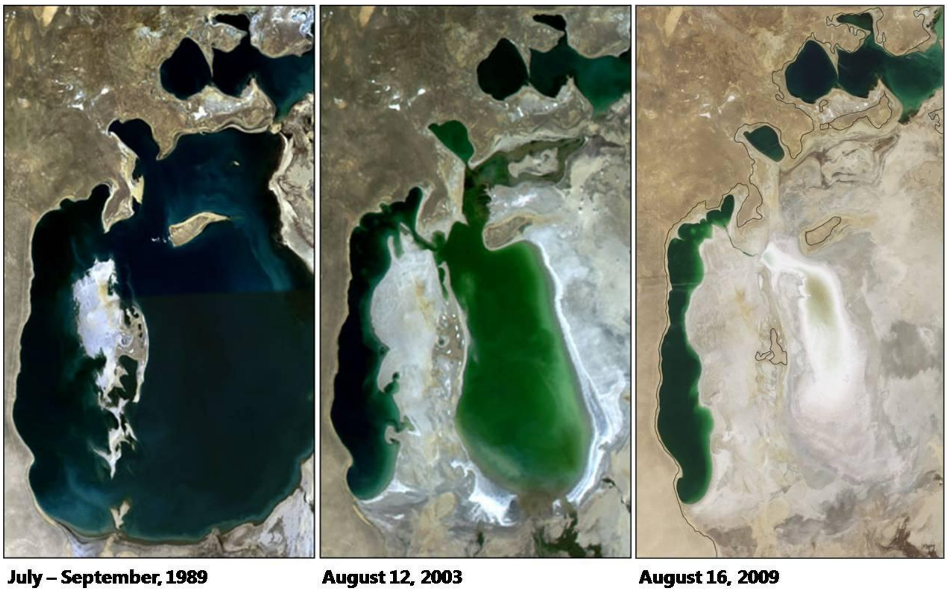
1 Return water is not included
2 Data corresponds only to the southern part of Kazakhstan, which belongs to the Syrdarya river basin

2009). Rapid drying of the sea, which by 2007 had shrunk to 10% of its original size, caused disastrous environmental, health and socioeconomic consequences for the basin`s population.

Depletion of the Aral Sea is the most evident example of the conflict between water for agricultural development and environment. While on a global scale, there is profound disagreement about how much water is needed to ensure food security and economic prosperity and how much is needed to sustain natural ecosystems (IWMI 2009), there is a common consensus among experts and policymakers that the unprecedented agricultural expansion in Central Asia during the 20th century represents a case where the trade-off is unjustifiably skewed towards the former.

Figure 2. Change in the Aral Sea area since 1998 to 2009



source: http://geoserver.isciences.com

Water and agriculture in Central Asia in the context of climate change

According to the available vulnerability assessments of climate change impacts in Central Asia water resources and agriculture will be most heavily affected by climate change in the future. Whilst there is still a certain degree of uncertainty about climate change impacts, it is commonly admitted that climate change is expected to exacerbate further water scarcity in Central Asia. Cruz et al.. (2007) claim that water resources in Central Asia are very vulnerable to the impacts of climate change, which can cause runoff from snowmelt, glaciers and precipitation in the mountain ranges that feed most of the region's rivers. Reportedly, the results of simulations of the possible regional climate development, done by the countries within the national communications under the United Nations Framework Convention on Climate Change (UNFCCC), show persistence in the present run-off to 2030 under moderate scenarios (Table 2). It should be noted, that some studies (SNC Tajikistan 2008) suggest that increased runoffs in the short term would be attributed to intensified glacier melting, and therefore the river flows will be eventually reduced in the long term. Under extreme scenarios, however, the runoffs of the Syrdarya and Amudarya rivers may be reduced by 28% and 40% respectively (IC Uzbekistan 1999).

Table 3. Expected changes in water resources of the Syrdarya and Amudarya rivers under different climatic scenarios (% of the annual flow rate)

River basin	Annual flow rate (km3/year)	Climate scenarios				
		Regional, by the year 2030	GFDL	GISS	UKMO	CCCM
Syrdarya	37.2	+4	+1	-2	-15	-28
Amudarya	78.5	-3	0	-4	-21	-40

Source: IC Uzbekistan, 1999

Even under moderate scenarios, it is expected that annual flow fluctuations and drought frequency will rise (IC Uzbekistan, 1999). Moreover, it is expected that seasonal river flow fluctuations will also transform due to changes in precipitation patterns, which can adversely affect water supply during the vegetation period (Ososkova et al., 2000).

Expected changes in precipitation, the river volumes and hydrological regimes will consequently affect the agricultural production in the region. It is anticipated that glacial degradation and reduced river flows will further exacerbate water shortages already existing throughout many parts of Central Asia. Irrigated agriculture thus is the most prone to climate warming, and farmers located at the end of the irrigation networks will be at the frontier of climate change. In addition, climate change will likely lower productivity of pastures, which serve as important sources of fodder for the livestock sector.

Goal, scope and approach of the study

Due to high climate change vulnerability of the irrigated agriculture, which remains an important livelihood source for significant parts of Central Asia's population, any perspective adaptation actions in the countries should largerly focus on raising resilience of that particular sector.

As an overview of the national communications under UNFCCC shows, all countries in the region acknowledge the possible drastic consequences of climate change and have already elaborated a set of measures in response of these challenges. Nevertheless, on-ground adaptation in the region is still limited to single-stand actions implemented mainly within pilot and demonstration projects. One of the issues in this regard, is that whilst the countries provide a comprehensive list of necessary adaptation measures, there is almost no information given on practical means and ways of their implementation (CAREC, 2010).

Adaptation technologies refer to a wide range of tools that help to achieve actual adjustments in resilience of social institutions to climate change. In this regard adaptation measures are usually differentiated into a set of *hard* and *soft technologies*. Hard adaptation measures refer to the use of specific technologies and actions involving capital goods, whereas soft adaptation measures comprise specific knowledge, skills and practices. Clements et al. (2011) elaborates this classification further by separating also *organizational technologies* that respond to climate change threats through establishing a necessary institutional framework.

- "**Hard technologies** refer to the tangible aspects such as the manufactured objects, the machinery, the equipment and tools required to produce goods or services. For example, a sprinkler irrigation system.
- **Soft technologies** refer to the processes associated with the production and use of the hardware, including know-how (such as manuals and skills), experiences and practices (such as agricultural, management, cooking and behavioral practices). Soft technologies also encompass elements of awareness-raising, including education and training. For example, capacity building in animal health.
- **Organizational technologies** refer to the institutional framework, or organization, involved in the adoption and diffusion process of a new technology. Organizational technologies relate to ownership and institutional arrangements of the community/organization where the technology will be used. An example is the establishment of Water User Boards."

Source: Clements et al, 2011

Using the Clements et al.`s definitions above, this desktop study aims to outline technologies that address adaptation needs in water resource management and the agricultural sectors of the Central Asian countries and highlight the main institutional, technological and economic barriers for their promotion.

It may be an impossible task to compile in a comprehensive way all technologies in the agriculture and water sectors with potentials for climate change adaptation (Lybbert and Sumner 2010), instead this report describes technologies reflected in the proposed national measures. The determination of technology needs is therefore based on the review of the main adaptation measures in the water and agriculture sectors proposed by the Central Asian states in their national communications to UNFCCC. In fact, some of the measures in the national reports already define technologies needed for adapting water resources and agriculture to the most pressing climate change impacts. In the remaining cases, where respective needs are not explicitly defined, the study determines needed adaptation technologies by assessing the scope of a measure and outlining possible technology options for its implementation.

In the next step by tracking relevant pilot projects and study results that took place up to date in Central Asia and beyond, the report outlines main issues and barriers for adoption and upscale of technology on a mass scale.

MAIN CLIMATE CHANGE CHALLENGES FOR THE WATER AND AGRICULTURE SECTORS IN CENTRAL ASIA AT NATIONAL LEVEL

Kazakhstan

Kazakhstan, located in north-central Eurasia, lies between the Caspian Sea in the West and the Altay mountains in the East. The land area is 2.7 million km^2, which makes Kazakhstan the ninth largest country in the world. Its population is estimated at about 16 million people.[3] Around 56% of the population lives in the urban areas.

The country's landscape is diverse, represented by 4 climatic zones: forest-steppe, steppe, semi-desert and desert. The climate is characterized as sharply continental with limited precipitation. The country's major lakes include the Aral Sea, Balkhash, Zaysan and Tengiz. There are about 39,000 rivers and temporary streams within the territory of Kazakhstan, while the major rivers are represented by the Ili, Irtysh, Ishim, Ural, Syrdaria and Charyn rivers. Although the country is

[3] The Agency of Statistics of the Republic of Kazakhstan http://www.stat.kz/Pages/default.aspx

quite rich in water resources, they are distributed unevenly across the territory. Thus, the eastern and south-eastern regions of Kazakhstan are considered as zones with comparatatively higher water availability, whereas the other regions experience water shortages to different degrees. Around 50% of the rivers flowing on the territory of Kazakhstan originate in the neighboring countries.

Kazakhstan possesses huge hydrocarbon, mineral and metal resources. Despite the development of different sectors of the state's economy, the country is considered as export-oriented. The agriculture sector of the economy contributes to 6.4% of the total GDP but still employs around 32% of the country's population. The principle crops are wheat, cultivated in the rainfed northern and central parts, cotton and rice in the southern part of the country.

The impact of climate change on water resources and agriculture

It is estimated that agriculture consumes 78% of the country's total water intake. The Second National Report under UNFCCC (SNC) suggests that climate change will likely have a significantly negative impact on precipitation patterns, especially in the arid regions of the country. These changes would force farmers to intensify irrigation, which would put additional stress on the scarce water resources in the arid zones. The southern Kazakhstan where water-intensive crops (rice and cotton) are cultivated is likely to be the most vulnerable to climate change in the near future. This part of the country has already experienced water scarcity during the last decades. According to the SNC assessment, owing to multiple reasons the water inflow has declined from 58.8 km^3 to 43.7 km^3 per year in the last decade.

Kazakhstan is one of the six largest exporters of grain in the world, specializing mostly on spring wheat and exporting grain to more than 40 countries. Potentially, a decline in yields can negatively affect not only the country's welfare itself, but also its main wheat importers and food security in the region. According to the assesments, slight increases in average temperature will have a positive effect on wheat growth, but further increases may dramatically affect the yield from 2050 to 2085, since the temperature change is expected to exceed the optimum of 2-4^{0}C during the period of formation and loading of grain. However, this simulation does not take into consideration an excess of carbon dioxide in the atmosphere, which is considered as a photosynthesis stimulator.

Suggested climate change adaptation measures

The SNC proposes the following measures for alleviating climate change risks on water resources and arable agriculture:

- Adoption of microirrigation technologies;
- Construction of necessary infrastructure to access groundwater;
- Reconstruction of the irrigation and water supply systems;
- Support to breeding programmes for development of drought-tolerant crop varieties;
- Introduction of advanced farming technologies (soil-protecting and moisture-conservation technologies);
- Crop diversification and rotation.
- Adjustment of water releases from the region`s hydroelectric dams to the needs of the irrigation;

Kyrgyzstan

Kyrgyzstan is lying on the junction of the Tian Shan and the Pamir mountain ridges and the mountain terrain covers over 80% of the total country area. With its large glacier systems of 417.5 km^3, occupying about 4% of the country's territory, Kyrgyzstan is recognized as a water-rich country in the region. The mountainous landscape serves as a prerequisite to the country's network of five thousand rivers. The major ones are Kara Darya and Naryn, which meet on the territory of Uzbekistan and form the Syrdaria River, which feeds the Aral Sea.

Due to significant altitude differences across the country, the climate differs substantially throughout different areas. Thus, 4 climate zones can be identified: a valley-submountain zone with hot summers and temperate winters, a mountain zone with temperate winters and warm summers, a high-mountain zone with cool summers and cold winters and the nival belt zone with extremely cold climate.

Kyrgyzstan's economy is mainly represented by hydroelectricity generation and gold production. The agriculture sector contributes to 30% of the total GDP. Arable land accounts for only 7% of the country's total area, mainly located in the northern part of the country, in the fertile Fergana Valley. The main cultivated crops are wheat, barley, maize, vegetables and cotton.

The impact of climate change on water resources and agriculture

About 45% of all Central Asian glaciers are concentrated in Kyrgyzstan. According to the Second National Communication, the rising of temperatures caused significant degradation of glacier in Kyrgyzstan, which has reduced between the mid 1970's and the end of the last century by 15%. The climate change impact on glacier melting imposes serious challenges for the downstream countries as well, since they are dependent on the glaciers in the upstream countries

As assumed by the SNC, climate change would positively affect pasture vegetation growth. On the other hand, the SNC modeling results suggest reduction of humidified areas and therefore aridification of climate in the coming years. These changes will have negative implications on the productivity of the agricultural lands, especially on the Fergana Valley.

Suggested climate change adaptation measures

As irrigation contributes to 92-96% of the country's total water intake, adaptation to climate change impacts on water resources could be significantly enhanced by a change of water use techniques. In this respect, the SNC suggests to:

- implement more effective and careful management of irrigation systems;
- regulate surface water flow by creation of artificial water reservoirs;
- adopt modern, more efficient systems and modes of water distribution; and
- stimulate water saving by implementation of a paid water system.

For adaptation in the agriculture sector the SNC proposes to:

- develop modern systems for early notification and prevention of natural and temperature anomalies, daily and seasonal weather forecasts;
- promote breeding programmes on diversification of crop and cattle varieties and development of varieties and species, resistant to the expected alterations in the climatic conditions;
- introduce crop rotation systems;
- adopt efficient irrigation techniques; and
- retime crop cultivation according to changes in the temperature regime during the seasons in order to adjust crop cultivation to the new favorable temperatures during the period of sprouting and bushing out

Tajikistan

Tajikistan is another Central Asian country with a predominantly mountainous landscape. Around 93% of the country's territory is occupied by mountains and 6% is covered by glaciers. High concentration of glaciers on its territory makes Tajikistan a water mogul in the region – along with Kyrgyzstan the country supplies around 70% of the rivers to the Aral Sea Basin (Bizikova et al., 2011). The climate can be described as continental, subtropical, semi-arid and extremely arid in some areas.

The population of Tajikistan is over 7 million people, nearly 70% of which live in the rural areas. The economy of the country is predominantly supported by non-ferrous metallurgy, light industry and agriculture. The country has a big hydropower potential, but only 5% of all the possible energy capacity is produced. The agriculture sector of the economy contributes 25% of the total GDP and provides 70% of the country's employment. Main crops are cotton, cereals, vegetables, fruits and melon.

The impact of climate change on the water resources and agriculture

The glaciers of Tajikistan play essential roles in water availability in Central Asia. The warming trend in the last years has a significant impact on the fragile glacier ecosystems, in particular on the high altitude areas of the Pamir, Zeravshan and Pamir-Alai. According to the SNC, the glaciers have been melting at an alarming rate over the last century, and as a result 1/3 of the glacier area has been degraded since 1930. The SNC also reports about decreased water flow in the rivers in the recent years.

The SNC suggests that water requirement for crops will rise by 1 to 10% in different areas of the country by 2030. Climate change induced heavy rain, mud flow on the one hand and high air temperature, dust storm as well as frost and extreme cold temperature on the other hand, negatively impact crop production and lead to significant crop failures:

Table 4. crop yield losses due to extreme weather events in Tajikistan

Crop	Unit	Time period						
		1999	2000	2001	2002	2003	2004	2005
Cereal crops	Area affected, thousand ha	26.6	154.9	3.6	8.4	10.5	2.9	5.0
	Money Loss, thousand TJS	1839.8	51035.3	1524.1	6767.9	3814.4	1724.8	2826.6
Cotton crops, including replanting	Area affected, thousand ha	13.4	11.6	3.2	12.9	16.8	3.2	6.4
	Money Loss, thousand TJS	1526.0	3157.9	971.3	3365.7	3560.9	1117.8	5965.3
Total	Area affected, thousand ha	81.3	268.1	343.3	39.1	50.5	12.0	19.4
	Money Loss, thousand TJS	14294.8	87282.0	198937.4	31810.5	15538.0	7513.8	16370.7

SNC Tajikistan

Suggested climate change adaptation measures

The SNC proposes the following measures for alleviating climate change risks on water resources:

- To introduce water-saving irrigation systems (including microirrigation technologies);
- to increase efficiency of intra-farm network and inter-farm channels;
- to construct dams and diametric dikes in order to regulate river flows; and
- to conduct channel dredging and flow straightening works.

Relevant adaptation measures for mitigation of climate change impacts on the country's agriculture include:

- strengthening material and technological base of the farms in order to reduce crop losses due to adverse weather events;
- planting tree shelterbelts;
- introduction of anti-hail systems;

- reconsider crop planting location based on the assessment of crop resistance to conditions of different climatic zones,e.g. cotton is more tolerant to high air temperature and soil salinity compared to cereals and potato, therefore, it is more cost-effective to cultivate cotton in hotter areas;
- breeding programmes for development of drought-tolerant and pest-resistant crop varieties.

Turkmenistan

Turkmenistan lies in south-western part of Central Asian between the Caspian Sea in the West and the Amudaria River in the East. The country's climate is characterized as sharply continental and extremely dry. About 80% of the country's territory is covered by the Garagum Desert, which lacks any surface water resources whereas the remaining 20% of the territory is mainly occupied by mountains. Turkmenistan's main river systems are Amudaria, Murgab, Tejen and Etrek, which originate on the territories of the neighboring countries. The total water resources are estimated at 25 km3 (an average annual water content).

The population of Turkmenistan is over 6 million people, 54% of which live in the rural areas. Being rich in hydrocarbon, the country has an export-oriented economy. The main export commodities are natural gas, oil, electricity and textile products. With a contribution of as high as 20% of the country`s GDP, agriculture plays a significant role in Turkmenistan's economy. Crop production and animal breeding contribute respectively 40 and 60% to the total economic output in the agricultural sector. Crop and livestock production has been growing rapidly since 1996. By 2030 the total arable land area in the country is expected to increase from the current 1.7 million ha to 2 million ha and the water demand for irrigation is respectively projected to increase from 21 km3 up to 25 km3.

The impact of climate change on the water resources and agriculture

Turkmenistan is situated in the middle to down reaches of the Amudarya, which is the source of 90% of the total water supply in Turkmenistan. According to the SNC, water supplied to Turkmenistan through the Amudarya river can diminish by 10-15% in the future due to climate change and increased water withdrawal in the upstream countries. An assessment of climate change impacts on the other river systems in the country suggests that the annual runoffs of such rivers as Tejen, Mugrab and Etrek will also reduce by 5-8% in the future. On the other hand, the more arid climate will foster water uptake from the rivers which will put additional stress on the water resources.

Since the largest share of the water resources in Turkmenistan is consumed by agriculture, the shrinking water resources and decreased precipitation will directly affect agricultural productivity, and consequently adversely influence the socio-economic situation and food security in the country. Diminished precipitation and higher evaporation rates would stimulate greater water intake from the rivers for crop production, which could lead to a change in hydrological regime of the rivers and water scarcity in the downstream areas, especially during the vegetation period.

Suggested climate change adaptation measures

Regarding proposed adaptation actions, the SNC refer to measures encompassed by the Water Management Development Cooperation of Turkmenistan by 2030. Accordingly, respective adaptation measures are the following:

- Improvement of water management (transition to integrated water resource management – IWRM);
- optimization of agricultural production arrangement for providing the country with the necessary agricultural production, and minimization of water resource use;
- conducting of measures enabling increase of efficiency ratio of the irrigation systems;
- innovation in advanced irrigation techniques (drip, micro-spray) and enhancement of existing ones (traditional);
- conducting of measures for land reclamation improvement;
- construction of additional water reservoirs; and
- reconstruction of the existing and construction of new hydrotechnical facilities allowing reduced water losses and support rational water use.

The SNC provides a roughly-assessed water-saving potential for the suggested measures for 7450 – 7500 million m3 of water (Table 1). Nevertheless, it also admits at the same time that this saving can be realized upon development of a comprehensive plan of action which should be preceded by an assessment of its respective costs.

Table 5. Estimated water-saving potential of some measures envisaged in the Water Management Development Cooperation of Turkmenistan by 2030.

Measure	Water recovery potential, million m^3
Complex reconstruction of 280 thousand ha of the irrigated area	700
Used-irrigated-land improvement for area of 400 thousand ha	750 – 800
Application of advanced irrigation techniques (drip, micro-spray, siphons and tube irrigation, ect.)	1800
Reuse of low-mineralized drainage water	3500
Use of refined domestic sewage water	300
Total	**7450 - 7500**

SNC Turkmenistan

The SNC also proposes the following measures for alleviating climate change risks in agriculture:

- A breeding programme on development of drought-tolerant crop varieties;
- retiming of the field works (tillage, fertilizing, cultivation and harvesting) according to changed the temperature regime during the seasons in order to adjust crop cultivation to the favorable temperature regime during the period of sprouting and bushing out;
- land reclamation activities;
- planting of forage woody-bushed plants for the grassland protection;
- introduction of grassland rotation; and
- optimization of the agricultural crop structure in order to minimize water consumption;

Uzbekistan

Occupying the central geographic location in the region, Uzbekistan borders with all the other Central Asian countries. 78% of the country's territory is occupied by plains and 21.2% by mountains and mountainous valleys. A vast territory is covered by the Kyzylkum Desert, which ranges from the Aral Sea to the Zeravshan River Valley. The country's climate is characterized as continental with hot summers and little precipitation. Summer temperatures reach 45-49^0 C in the central areas of the Kyzylkum Desert.

The agriculture sector contributes to 24% of the total GDP and employs around 28% of the country's population. Domestic agricultural production covers about 80% of the country's food demand. Principle crops are cotton, wheat, corn, rice and vegetables. With an annual output of 3.6 million tonnes, Uzbekistan is recognized as the second largest cotton exporter of the world.

Uzbekistan's water resources are mainly presented by the Syrdaria, Amudaria and Zeravshan rivers and these rivers have been intensively exploited for agriculture. With 26.7 million people Uzbekistan is the most populated country in Central Asia. The country's demography has a positive trend, which is expected to lead to further intensification of agriculture and thus greater stress on water resources.

The impact of climate change on water resources and agriculture

The SNC reports that water runoff in the basin has significantly changed over the last decades due to climate change and anthropogenic factors. As the glaciers of neighboring Kyrgyzstan and Tajikistan play an essential role for water availability in the downstream, melting of glaciers in those countries will have adverse impacts on water availability in Uzbekistan, where agriculture accounts for 90% of the country's total water intake.

Aridification of climate adversely affect agricultural productivity of the arable lands in Uzbekistan. As the Ministry of Agriculture and Water Resources of Uzbekistan reports, over 50% of the country's arable land is considered saline. The greatest degree of salinization was revealed in the lower course of the Amudaria River. Soil erosion also has a growing trend. Currently, about 56% of Uzbekistan's territory is exposed to deflation and about 20% to water erosion. Land degradation is seen as a serious threat for the agricultural productivity of the country.

Suggested climate change adaptation measures

SNC proposes the following measures for mitigating climate change risks on water resources and agriculture:

- Reformation and re-orientation of economic development strategy for more efficient utilization of available water resources;
- extensive introduction of water-saving technologies in the water-consuming industrial branches, agriculture and communal utilities sector;
- improvement of irrigation and drainage systems for reducing water loss

- potential water resource recovery through utilization of unconventional sources (groundwater, water harvesting etc);
- transition to a flexible planning system in determining the optimal volume of agricultural output;
- optimization of the crop structure and expansion of drought-resistant and salinity-tolerant crop cultivation;
- expansion of winter crop cultivation; and
- introduction of crop rotation.

PROPOSED ADAPTATION MEASURES IN THE WATER AND AGRICULTURE SECTORS AND THE ASSOCIATED TECHNOLOGICAL NEEDS

The previous section revealed a comparatively wide range of measures proposed by the Central Asian governments to combat specific climate change challenges in the water and agriculture sectors of the region. Nevertheless, taking into consideration the type and scope of the suggested measures, all proposals can be grouped under specific general categories. Accordingly, the proposed adaptation actions in the water sector can be classified into measures of improving water use efficiency through enhancing monitoring of water resources use, establishing early warning systems or allowing for better regulation of rivers flow. The proposed actions in the agriculture sector consist of measures that increase water use efficiency on the farm level, allow adapting of existing agricultural practices to anticipated climate fluctuations, promoting new land conservation practices, optimizing crop structure and introducing special financial instruments for farmers.Many of the measures proposed by the SNCs encompass certain adaptation technologies, for example drip irrigation or crop rotation (as soft measures)

Other proposed measures rather suggest a set of technologies (or propose a range of possible technology options), for example, monitoring of water resources. Table 6 below, thus compiles the main hard, soft and organizational technologies corresponding to the major adaptation measures proposed by the countries in the water and agriculture sectors.

Table 6. Needed adaptation measures in Central Asia (according to the National Communication reports under the UNFCCC) and their associated technologies

	Proposed measures	Hard technologies	Soft technologies	Organizational technologies
WATER SECTOR	**Development and introduction of the monitoring and early warning systems**	meteo stations, equipment for the snow and glaciers monitoring	enhanced climate and weather forecast models, use of GIS and RS	research and extension services to enhance the capacity and delivery of information to the agricultural sector
		hydroposts, water volume measurement in the irrigation network, water measuring devices at the farm level		
	Improve regulation of annual river discharge	water reservoirs*		subregional and basin-level water sharing coordination
	Increasing water use efficiency in agriculture	microirrigation technologies, laser leveling	new irrigation practices, e.g. alternative furrow irrigation	Introduction of IWRM at the national level
AGRICULTURE		rehabilitation of the water irrigation networks for reduction of water loss	regulation of groundwater use for agricultural purposes	Water Users Assiciation (WUAs), introduction of payment system/scheme for irrigation water delivery
	Optimization of crop structure		research and promotion of drought-resistant crop varieties	crop diversification, switch to less water intensive crops
	Adapting the agricultural practices to the anticipated climate fluctuations		introduction of climate-specific insurance schemes	expansion of the winter crops to take advantage of increased water availability,
	Promotion of the sustainable agricultural practices	zero-tillage	Nutrient management, crop rotation	

Though each technology in the table above is linked to the particular adaptation measure, it should be noted that its implementation may help address the multiple phenomena caused or exacerbated by climate change (Table 7). In addition, the technologies among the major adaptation measures differ with respect to their implementational levels – farm, community, national or even regional. In this respect, most measures and technologies for the water sector usually refer to adaptation on the sectoral (or basin) level, whereas land use-related agricultural technologies are usually comprised of farm level interventions.

Table 7. Adaptation technologies and main climate change imperatives they correspond to

Technologies/Measures	Drought	Need for soil moisture conservation	Need for water use efficiency	Land degradation, soil infertility, erosion	Heat stress	Pest and disease control	Excess rain, flooding, storms	Milder winters, longer growing seasons
Watershed management (IWRM and WUA)	x	x	x	x			x	
Water reservoirs	x	x		x	x		x	
Microirrigation technologies	x		x					
Alternative irrigation techniques	x		x					
Laser levelling	x		x	x				
Crop diversification	x	x	x	x		x		x
Using of water-efficient crops	x		x	x				x
Heat- and drought-resistant varieties	x	x	x		x			x
Crop rotation	x	x				x		
Zero tillage	x	x	x	x				
Nutrient management and use of organic matter	x	x		x				

Based on World Bank 2009

The remaining part of this section gives an overview of the main technologies determined by the adaptation measures in the water and agriculture sectors and discusses main barriers associated with their introduction/promotion in the region.

Technologies for adaptation in the water sector

Development and introduction of monitoring and early warning systems

Due to considerable fluctuations in the annual river runoffs in the region, theagriculture sectoris highly dependent for irrigation, hydrometeorological observations and forecasting of water availability during the vegetation periods, which are crucial for decision-making, both at the national and agricultural levels. As climate change is expected to increase annual variability of river flows, more robust forecasting is needed to raise preparedeness of the agriculture sector for possible damage through droughts and floods. Relevant measures proposed in the National Communication reports of the Central Asian countries to the UNFCCC consist of technological modernization of hydrometeorological stations and foresee improvements in weather and climate forecast models.

Given that a significant share of the Amudarya and Syrdarya runoffs originate in upstream catchments, any form of an early warning system for water resources in the region will largely depend on hydrometeorological and glacier observations in Tajikistan and Kyrgyzstan. It is necessary to note that all the countries in Central Asia operated an extensive and comparatively well-equipped network of meteorological stations during the Soviet times. After the collapse of the Soviet Union and due to subsequent economic hardship, most countries could not continue running their meteorological facilities, and as a consequence, many stations were closed (see Table 8). A significant decrease in the number of observation stations, along with the poor equipments of the remaining stations in the countries, resulted in insufficient data and overall worsening of the quality of hydrometerological services. In addition to the diminished abilities of hydrological forecasting, the capacity of the hydrometereological agencies in some of the countries also decreased with respect to estimating comparatively long-term processes, such as glacial melt (JPM 2009).

Table 8. Number of meteorological and hydrological stations in Kyrgyzstan, Tajikistan and Turkmenistan before and after the independence.

	Kyrgyzstan		Tajikistan		Turkmenistan	
	Actual number, 2008	reduction since 1985, (%)	Actual number, 2008	reduction since 1985 (%)	Actual number, 2008	reduction since 1985 (%)
Metereological stations	32	62	57	22	48	52
Hydrological stations and posts	76	48	81	41	32	45
Agrometeorogical stations	31	55	37	46	48	15

Source: Tsirkunov V (2009)

The main reasons behind the deterioration in the respective meteorological services is insufficient state financing for climate and hydrological observations and a lack of adapted weather and climate forecast models (Bigozhin, 2009). Most of the hydrometeorological agencies haven't seen visible modernization in observation, data collection and forecasting techniques since the independence of the Central Asian states. In the context of insufficient funding, technologies with comparatively low operation cost such as ***automated hydrological stations***, etc., have the potential to improve the situation. ***Geographic information systems*** (GIS) and ***remote sensing*** (RS) offer another technological options contributing to the rehabilitation of the observation and forecasting services in the region at a comparatively low-cost level.

Several studies point out the need for more enhanced measurement of the use of water resources in Central Asia, to allow for more efficient management of water resources, at national, basin and community levels. In this regard, observation and monitoring of hydrological parameters on the remote mountain watershed areas of Kyrgyzstan and Tajikistan are of particular concern. To a larger extent, the reasons behind deterioration of hydrological monitoring are the same as those for meteorological observations – lack of state funding and lack of capacity of the hydrometerological agenciess staff. On the main watersheds and rivers, monitoring of water had been implemented with a help from water measurement facilities, so called **hydroposts**, butince the independence, almost half of the

"..Sector information provided by different bodies is rarely comparable, data are weak and unreliable, and databases are incomplete and inconsistent. Gaining a clear picture of the situation in the water sector at any time is virtually impossible, because the monitoring system is in decline and data is collected by various agencies independently without any coordination between them. Sector monitoring systems need to take account of actual levels of access to and quality of water, and link services with funds.."

A Human Rights-Based Approach (HRBA) to Improve Water Governance in Europe & CIS, Phase 2. Tajikistan water sector assessment.

hydroposts were shut down in the upstreams of Tajikistan and Kyrgyzstan which resulted in reduced capacities for hydrological assessments.

Another big obstacle in improving the system of water resources monitoring is the lack of regional cooperation in information exchange and harmonization of measurement methods, pointed out by a number of studies and projects implemented in the region. Apparently, there is some evidence that in some of the countries, information exchange is not appropriately facilitated even on the national level, due to the lack of coordination between the various state bodies.

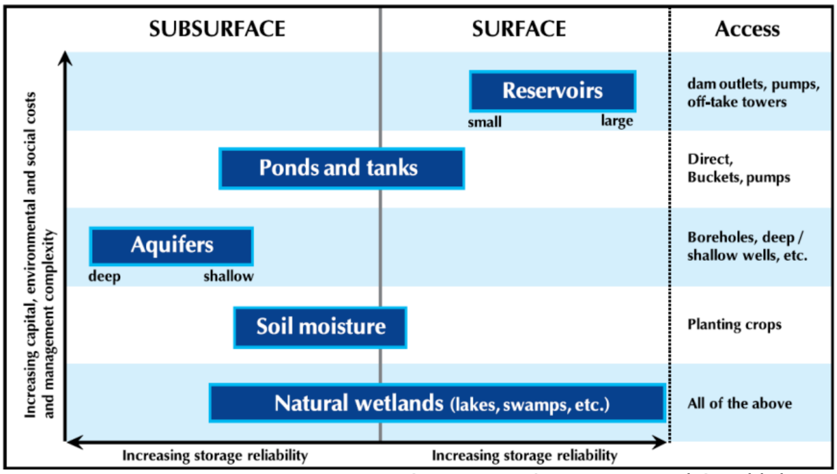
In 2000 the Swiss Agency for Development and Cooperation (SDC) initiated an eight-year project «Swiss support to the National Hydro Meteorological Services (NHMS) in the Aral Sea basin» that aimed to assist the NHMS of the region in providing reliable hydro-meteorological data, flow and flood forecasts to key end-users. The overall goal of the project was to assist the countries in making improved water management decisions at the national and regional levels. A number of key hydrological and meteorological stations responsible for providing the end-users with observation data and flow forecasts have been rehabilitated and provided with automated hydro-meteorological and communication equipments. Several internationally-funded projects (GISCA, CAWA, etc.) also promoted the use of GIS and RS in Central Asia for a better-informed decision making in water resources management. In addition to addressing the respective technological gaps in the use of GIS and RE, the projects also focused on capacity building in using these technologies.

Improve regulation of annual river discharge

As it was noted before, the agriculture sectors in the region are subjected to high fluctuations in river runoffs, and it is expected that climate change will likely bring even higher annual variability in the river flows. Faced with this issue, Tajikistan and Kyrgyzstan have proposed measures for higher control over river discharge, specifically referring to the development of ***water reservoirs*** in the region. Water reservoirs allow for storing of large volumes of water, which can be used for multiple purposes. It should be noted that several large dams were built during the Soviet times in Tajikistan and Kyrgyzstan to support agricultural expansion and maintain water supply stability in southern Kazakhstan, Uzbekistan and Turkmenistan. Since the dams were equipped with hydropower generation facilities, operation of these water reservoirs also allowed forpower generation during the vegetation periods.

However, water reservoirs are usually associated with high investment, social and environmental costs which, in many cases, diminish the viability of this technological option. Even if the potential benefits of a dam project (be it for regulation and/or hydropower generation) exceed the possible externalities, the construction of a new dam in the region faces difficulties given the transboundary nature of the rivers and unresolved disputes over water resources management between the upstream and downstream countries (Vinokurov, 2007).

Figure 3. Water storage potentials and associated investment, environmental and social burdens of various options for water



Source: McCartney M. and Smakhtin V., 2010

Increasing water use efficiency through better governance of water management at national and community level

Introduction of IWRM: The Integrated Water Resource Management (IWRM) approach acknowledges that management of water resources is not merely a technical engineering task but that it also should address social, economic, political and environmental processes and needs. It does not only include the proper maintenance of water sources and distributional entities but also assesses the ever-changing needs of all of the related stakeholders, including the environment. In this regard, a well-established IWRM is capable of coping with climate change challenges, by incorporating robust and flexible solutions (Slootweg 2009). Management does not end here as the efficient utilization and maximum productivity of water resources should be enforced. In order to fulfill this process the governance system of water management needs political commitment with suitable institutional arrangements and a legislative framework, (financial) incentives, public participation and with respect to it adequate capacity development (Dukhovny et al., 2008).

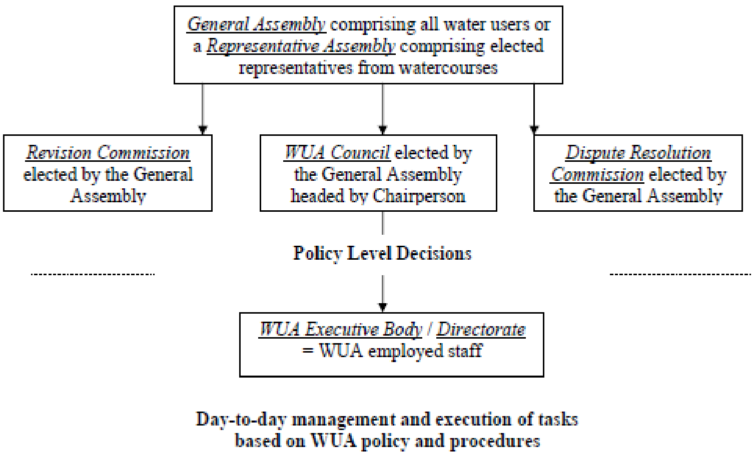
Dukhovny et al.. (2008) states the following destabilizing factors within the water management situation in the Central Asian region:

- Disputes among the countries regarding water and energy resources and the lack of mechanisms to tackle this issue; the lack of conflict resolution mechanisms and procedures to recover losses due to breaches of the existing agreements on water sharing;

- insufficient information interchange among the riparian countries, primarily an exchange of hydro-meteorological data to ensure a more accurate forecast of water availability and to improve transboundary water management; and
- The lack of policies and programmes for regional economic integration, and insufficient cooperation to improve the irrigated farming productivity on the basis of a model that enables optimizing the rural labor in the region.

Water Users Associations (WUAs): Water Users Associations are an integral part of the Integrated Water Management described above as an instrument of public participation. WUAs are non-profit organizations, founded and managed by a collection of agricultural water users having access to one and the same "hydrological sub-system". The association collectively provides capital, labor and knowledge in order to maintain their irrigation and drainage system. (Contractual) agreements mark the membership to the association and its specificities. Similarly the WUA establishes contractual agreements about the time and volume of water supply with the irrigation provider and the payment of the respective delivery. As a result, the canals are maintained, the contractual agreement between the water users should lead to a steadier water supply and a more equitable distribution of water among farmers. By collectively presenting themselves to the irrigation provider water users have a higher bargaining power, allowing them to adapt the time and volume of water supply to their agricultural needs (IWMI, 2003).

Figure 4. Typical Organizational Structure of a WUA



Source: IWMI (2003)

Along with being an organizational tool for more sustainable use of water resources, the WUAs (and its participatory approach) establish an important framework enabling the promotion of technologies for water use efficiency among farmers. However, a "Water Productivity Improvement at Plot Level" (WPI-PL) project[4] identified the following constraints for the use of the full potential of WUAs in Central Asia for raising water productivity at the agricultural level:

- Undeveloped legal framework and financial mechanism for interaction between the WUAs and farms;
- low technical skills of the WUAs specialists coupled with the understaffing of the WUAs; and
- low level of farmers' knowledge.

Technologies for adaptation in agriculture

Increasing water use efficiency on the farm level

Many studies (Khorst, 2002; World Bank, 2003; Dukhovniy et al., 2008) point out at the inefficient use of water in agriculture as the most challenging issue for the economic development, food security and environment in Central Asia. From a climate change perspective, raising irrigation efficiency would be instrumental in addressing water scarcity and food security and raising crop production because a larger area could be irrigated with the same volume of water. In terms of environmental sustainability, improved irrigation efficiency may release more water for the environmental flow, thus alleviating, to some extent, the Aral Sea crisis. In addition, Wolters and Bos (1989) list other benefits of enhancing irrigation efficiency:

- Decreased vulnerability of agriculture to water shortages and fluctuations;
- reduced investment costs for drainage to control waterlogging and salinity; and
- reduced competition in agriculture with other water users.

Granit et al. (2010) also state that more than 50% of the water diverted within the Aral Sea Basin is lost, although not all the amount is wasted as a certain percentage is return-flow. The reuse of the return-flow in agriculture is hardly feasible though, due to the high mineralization from salinised soils. Furthermore, the remaining water and other resources are far from being efficiently utilized. An Iidependent analysis suggests that Uzbekistan's cotton industry could as much as double its productivity, inferring that similar improvements were possible in the other

[4] WPI-PL is a Swiss Development Cooperation Agency`s project that was implemented in the Ferghana valley (shared by Uzbekistan, Kyrgyzstan and Tajikistan)

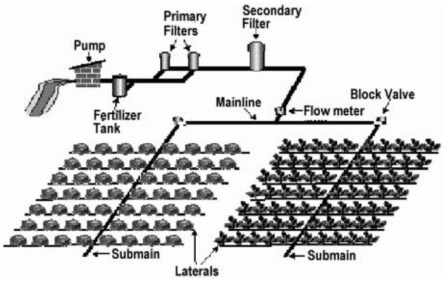
agriculture sectors. Water use efficiency in Central Asia is not encouraged through the current incentive system of quotas and set payments, nor is water use widely measured.

As water availability in the region “is expected to decrease in the long term due to melting of the glaciers that feed the region’s main water courses” (ibid.), structural changes in (transboundary) water management, supply systems and water use efficiency in agriculture are priorities for adapting to climate change. The following section will present and discuss possible solutions for enhancing water use efficiency in agriculture and assess their feasibility within the Central-Asian socio-economic context.

Micro-irrigation technologies refer to the slow application of water directly to roots of plants or onto a soil zone. It involves a network of valves, pumps and tubes whereas the application devices can range from on- and in-line drippers, sprayers and sprinklers. Its application can result in higher yields and generally offers higher water use efficiency than for instant surface irrigation. On the downside it is an expensive technology (Reinders, 2006).

The widespread utilization of the micro-irrigation technologies within Central Asia is questionable, though. They “do not suit the major rice growing areas […] nor do they suit growing staple grains”. Furthermore it has to be noted that these technologies “can be targeted at selected environments where water costs are high” and that they merely reduce water *waste* while the actual amount of necessary water for growing crops stays the same (UNCTAD, 2011). In the light of water-intensive agricultural production, i.e., of rice and cotton, in Central Asian states and water costs that do not reflect water scarcity, the feasibility of the micro-irrigation techniques has to be carefully examined.

Figure 5. Components of a micro-irrigation system



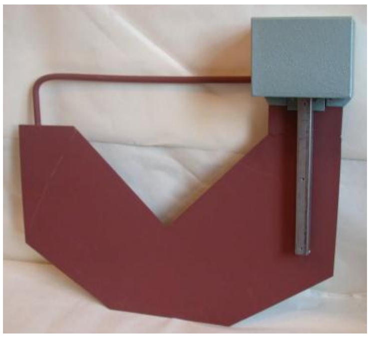
Source: Reinders (2006)

Furrow irrigation enhancements: There are a number of possibilities to enhance water productivity of irrigation through alterations in the furrow regime. They are of different complexity and necessary monetary and timely investments but generally they are simple and cheap to achieve. For instance, ***skip furrow (alternate furrow)*** requires farmers to only release water into every second furrow, leaving the other one dry. This technique prevents excess irrigation automatically and requires no capital or time investment (ICARDA, 2007). The research conducted by Bekchanov et al. (2010) showed an increase in water productivity of around 50%

with the introduction of the alternate furrow irrigation in cotton production, whereas the additional costs of implementation are equal to the simultaneously reduced costs.

Shortening the furrows is a similar technique. If water infiltrates too fast and thus does not reach the end of the furrow, yields can be increased by shortening them. These short furrows require greater care "as the flow must be changed frequently from one furrow to the next", but irrigation is more efficient by lowering percolation losses of irrigation (Walker, 1986). According to Bekchanov (2010) this method enhances water productivity by ca. 13%. Although the respective pilot testings have resulted in moderate increase in yields, the method still had a positive financial rate of return.

Figure 6. Furrow water flow measurement device



Source: Hamjamberdiev, "Irrigation problems in Central Asia" (www.anped.org/media.php?id=105)

Double-sided furrow application (Double flow) refers to the irrigation of one furrow not only from one but from both ends. As a result, a higher uniformity of water application over the entire length of the furrow is achieved. This technique led to a water productivity increase between 22 and almost 40% and a positive financial return of the implementation (Bekchanov, 2010).

The ***surge flow technique*** confers to the application of water in successively longer lasting intervals in order for the soil to drain standing water. The idea behind this form of irrigation is the reduction of water infiltration at the top end of the furrow decreasing runoff of water and subsequently increasing water advancement within the furrow (Mitchell and Stevenson, 1994).

Although the enhancement of water productivity is similar to that of the alternate dry furrow, the irrigation surge flow requires considerable investment (equipments for water dissemination, tubes, valves, etc.), when compared to the above furrow irrigation techniques. The net income change is lower than that of the alternate dry furrow.

Figure 7. Tractor with mounted levelling implement

Source:http://www.ushaengineerings.co.in/laser-leveler.htm

Laser leveling: A laser beam generator is utilized to generate a plane of laser light that is used as leveling reference. The laser beam is received by a light sensor which directs the hydraulic system of the leveling implement attached to a tractor. This approach to land leveling is 10 to 50 times more accurate than visual judgment or manual hydraulic control, and requires less skill than conventional leveling (Walker, 1989). Laser leveling is an important precursor technology for other sustainable agricultural practices (discussed below) as it enhances their effectiveness. The greatly enhanced levelness of agricultural soils leads to a uniformed distribution of water and plant nutrients, enhancing crop as well as water productivity. Operational efficiency is also enhanced, saving operational time and thus fuel consumption and emissions. As the drought stress is assumed to increase with the ongoing climate change, the enhanced water use efficiency is to be seen as the most important with respect to climate change adaptation.

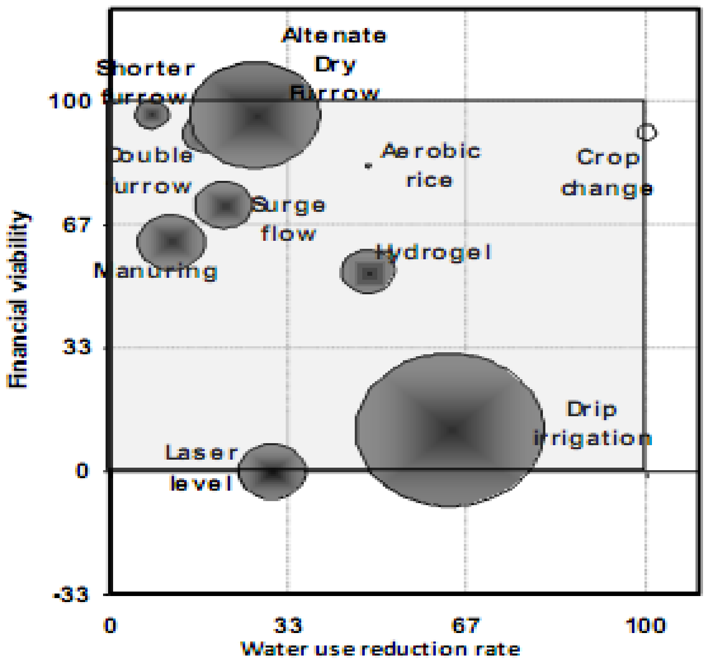
Pilot testing implemented within the IWRM in Ferghana and ZEF projects showed that the use of laser leveling had resulted in increased crop yields, improved water use and productivity. Nevertheless, there are different views on the financial viability of laser leveling for farmers. Some evidence suggest that the additional benefits, which include an increase in crop yields and savings in labor, cultivation and irrigation costs, outweigh the costs associated with the purchase and operation of the equipment (Abdullaev et al, 2007). Some other findings (Bekchanov et al, 2010) argue that inadequate water pricing hampers economic attractiveness of the technology, but suggest that it could have a potential for dissemination upon the establishment of an intermediate agent that would provide laser leveling services to farmers.

Summary on technologies for farm-level water use efficiency

As indicated in the references above, the most comprehensive assessment of technologies allowing for water productivity at the farm level in Central Asia up to date has been conducted within the study pursued by Bekchanov et al. Though those technologies were assessed with consideration of agro-climatic conditions, agricultural practices and socio-economic peculiarities, which dominate the downstream of the Amudarya river, their findings have good potentials for the extrapolation in other parts of Central Asia, located in comparable agrozones and characterized by similar socio-economic contexts. In addition, it should be noted that the study relied on data obtained through research carried out in different parts of Central Asia, by the Central Asia Irrigation Research Institute (SANIIRI), International Water Management Institute (IWMI), and the Scientific Information Center of the Interstate Commission for Water Coordination of Central Asia (SIC-ICWC).

There is a high variation in needed initial costs among the technologies, with some methods requiring virtually no investment on one end (such as *double furrows, for example)*, and highly intensive capital on the other (e.g. micro-irrigation techniques or laser leveling). Though all of the above mentioned technologies achieve higher water productivity and increased yields, their actual performance correlates with their investment costs - more water-efficient technologies call for higher investment costs. (see Figure 8)

Figure 8. Water use reduction rate, economic efficiency, and financial viability of water



Source: Bekchanov et al. 2010

One of the barriers preventing wide dissemination of costly but efficient water-saving technologies and practices in the region is obviously the lack of an incentive system that would push both upstream and downstream farmers of irrigation networks to adopt these technologies. It is also noted that in the absence of a regionally-differentiated incentive system, only less capital-intensive measures (such as the double flow, short and alternate dry furrow techniques) would have the potentials for promotion. Limited access to financial resources is another grave problem in Central Asian agriculture. This is an institutional barrier that poses a constraint for every modernization attempt in the agriculture sector, not related to changing management practices through mere capacity building measures.

As long as this institutional barrier is not removed, attention will have to be turned to disseminating the abovementioned relatively inexpensive efficiency-enhancing techniques. At the same time, this would raise awareness of the necessity and benefits of water saving in the light of future climate change – laying the ground for acceptance and implementation of the more expensive methods once the financial sector is realigned.

Crop structure optimization

Along with altering important factors for irrigated agriculture such as annual temperature trend, water supply and evaporation rate, climate change also raises pest and pathogen stress. Rising temperatures may influence pest population growth, migration and overwintering cycles and they are expected to faster adapt to changes in climate than plants.. The direction of climate change impacts upon the spreading of plant diseases is not entirely clear. Nontheless, asdiversified agriculture represents a greater variety of natural systems and diversity of animal species that pose natural enemies to certain pests., itslows or interrupts disease transmission and also limits production losses through diseases as the risk is spreadDiversifying agriculture also provides a larger resilience of crops to changes in temperature and precipitation (Lin 2011).

Switching to less water-intensive crops: In the course of diversifying cropping systems, the introduction of less water-intensive crops should be considered in the first order to address the impacts of climate change on water supply. This especially holds for Central Asia, as agriculture in many parts heavily relies on water-intensive crops. Apparently, a massive agro-economic dependency on water-intensive crops poses a challenge for the introduction of less water intensive crops as this would require major structural, economic and social changes. In this respect the EastWest Institute (2011) suggests the pooling of stakeholders' resources to "jointly research alternative cultivation methods, investigating new, less water-intensive crop choices and perhaps crop genetics." The participation of multiple stakeholders in addressing the question of switching crops will ensure feasibility as well as help indentify a socio-economically acceptable way for structural changes in Central Asia's agriculture.

Bucknall et al. (2003) notes that there are adaptation measures already being attempted by the farmers, such as the switching to other crops. However, they face challenges in the process since the government restrictions in some Central Asian states limit the possibilities of crop variants to grow, or even when to grow and harvest them and which inputs to apply.[5] Furthermore they state that access to information on new techniques for the farmers is limited and that the collective decisions are more influenced by the local power structures rather than by the farmers.

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5 This, by the way would also influence the practice of conservational agriculture and nutrient management discussed below.

***Promotion of drought-resistant varieties*:** Central Asia has high vulnerability to droughts, which will have higher frequency and severity due to climate change. The Consultative Group on International Agricultural Research (CGIAR) calls for promotion of alternative crop variations that are more resilient to droughts. Relevant national research institutions have been testing specific drought-resistant varieties, suitable for the region`s distinctive agro-climatic conditions. Unfortunately, gained success has not been transferred to agriculture on a smaller or larger scale. Several international research institutions are also affiliated with the research of drought-tolerant crop species - International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), the International Institute of Tropic Agriculture (IITA), the International Center for Research and Dry Areas (ICARDA) or the International Maize and Wheat Improvement Center (CIMMYT).

Conservational agricultural practices

***Crop Rotation*:** Instead of the monocrop agricultural production, crop rotation relies on the "alternation of subsistence, cash and green manure/cover crops [...] with different characteristics, cultivated on the same field during successive years, and following a previously established sequence." Through the rotation of crops, farmers get a better control over weeds, pests and insects and the soil more uniformly extracts nutrients – or even regains nutrients under inclusion of legumes in the rotation cycle. Crop rotation also means constant vegetative soil cover, either with live crops or dead plant residues and has to be combined with minimal tilling in order to produce the biggest benefits (Florentín et al., 2011).

With respect to climate change adaptation, the implementation of crop rotation maintains/increases soil organic matter content, improves soil structure and helps achieve a more abundant and lasting soil cover – all factors which help increase water/nutrient retention capacities of the soil to combat degradation of soils through desertification, a prevalent danger for Central Asia.

However, there is a need to overcome a political obstacle to crop rotation: the state's orders that enforce cultivation of specific crops such as cotton or wheat, - be it for the reasons of economy or food security, causing inflexibility of the farmers. Also, a research on Kazakhstan suggests that there is a certain inertia of the farmers to stick to the production of specific crops. There exists the more viable economic alternatives and also the necessary operational changes for new crops hinder the feasibility for large scale farms (Suleimenov et al. 2005). This calls for increased research and discussions concerning feasible crop combinations for rotation – ideally with farmers to parallely promote the benefits of crop rotation.

Figure 9. Zero-tillage seedling system

Source: Desbiolles (2008).

Zero-Tillage (ZT): The basic principle behind zero-tillage is the absence of soil disturbance through tillage in agricultural production. "No-tillage is defined as a system of planting (seeding) crops into untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done". Zero-tillage is just one element of *conservation agriculture*, it is furthermore important to keep soil permanently covered with plant residues and to apply crop rotation as well as growing cover crops (Derpsch et al. 2010).

In order to achieve minimal soil disturbance, seeds are sown into undisturbed soil with the help of *disc openers.* (*Desbiolles 2008).* Adopting conservation agriculture including zero-till can reverse the loss of organic matter in soil and, through improving soil porosity and coverage with residues, enhance water retention in times of drought. ZT has been actively promoted in Kazakhstan in the last decade; it is especially common in northern Kazakhstan (Ibid.). This presents an opportunity for making use of the existing knowledge and experience already gained in Central Asia over the years to scale up the use of ZT techniques.

Fileccia (2009) states that there is an increasing interest in the adoption of ZT in northern Kazakhstan, due to the positive financial rate of return. He also notes several hindrances, though: "the organizational capacity and the type of mechanical equipment available with 'small' and 'medium'- sized farms." At the same time commonly available equipment also has limited applicability with respect to the maximum area cultivatable with ZT. Furthermore there is a "transition period" in which yields are temporarily lower compared to conventional tillage, leading to certain reluctance in adopting the new technique – making information dissemination and demonstration of the long-term benefits necessary.

Nutrient Management: In the context of sustainable or conservation agriculture methods, such as zero-tillage described above, an adequate management of nutrients plays an important role. As conservation agriculture focuses more on soil and its capacities, rather than specific crops integrated nutrient management similarly aims at ensuring soil health. Four general aspects have to be followed i) enhancing biological processes in soil ii) enhancing biomass production and biological nitrogen fixation iii) adequate access to all necessary nutrients iv) keeping soil acidity within ranges to ensure effective biological and chemical processes. By following these general rules the soil will be able to absorb and retain nutrients – be they applied as industrial fertilizer or in the form of *green manure* at the right time and in the right quantity – as well as water (Kassam and Friedrich 2009).

Bekchanov et al. (2010) in their study also assessed the impact of *manuring*, i.e. applying livestock manure as a fertilizer. For potato, cotton and wheat production the application of manure was in each case associated with an increase in water productivity of at least 30%. It also leads to higher yields and enhances soil productivity and economic efficiency. Apparently, despite the overall benefits of manuring for land reclamation, the FAO (2009) states that the application rate of organic fertilizer in form of manure in the region is substantially lower than the recommended rate. They see a hurdle to more extensive application, though: “manure application is restricted due to an insufficient supply by the underdeveloped livestock sector”.

CONCLUSION

Climate change imposes serious challenges for Central Asia, and the water and agriculture sectors will be the most affected sectors, given already existing water scarcity issues throughout the different parts of the region that are highly dependent on irrigated agriculture. The governments of Central Asia recognize these threats and have identified necessary measures for alleviating the expected climate change impacts in these sectors. This report highlighted major technologies corresponding with the proposed measures, and tried to assess their merits as well as outline main associated barriers by reviewing relevant studies and pilot projects in Central Asia and other regions (Table 9).

Table 9. Discussed adaptation technologies in the water and agricultural sectors and some major barriers for their adoption

Technologies	Institutional/policy deficiencies	Requires enhanced coordination/ between the stakeholders	Special skills/expirience	High capital costs	High operation inputs	Limited geographical applicability	Underdeveloped market for the technology
Watershed management (IWRM and WUAs)	x	x					
Water reservoirs (big)		x		x		x	
Micro-irrigation technologies				x		x	x
Alternative irrigation practices					x		
Laser levelling			x	x			
Crop diversification	x		x			x	x
Use water-efficient crops	x		x			x	
Heat- and drought-resistant varieties							x
Crop rotation			x				
Zero tillage				x			x
Nutrient management and use of organic matter			x		x		

There is no doubt that adapting to climate change in the region requires adoption of certain hardware technologies that enable more efficient use of water in agriculture. Nevertheless, the findings of this report suggest that the so-called soft *technologies* are of equal importance and that, in some cases, they might even emerge as a prerequisite for the viability of technical measures. For example, installation of intra-farm flow measurement devices might become a questionable measure if there is a weak coordination mechanism used by the farmers that share a common hydrological sub-system. In fact, many proposed adaptation measures in Central Asian countries can be realized only through an integrated application of hard and soft technologies. This especially refers to adaptation in the water sector, where proposed measures require, as a rule, both technical modernization of hydrological facilities and the introduction of new techniques and practices for data processing.

Whilst the technologies differ in the level of application (farm level, national and even transboundary), it is suggested that an adaptation action should envisage a comprehensive approach, inclusive of all inter-related technologies. As it was revealed, introducing technologies at the local level may be dependent on the promotion of organizational measures at the national or even transboundary levels. Establishment of the WUAs on the sub-canal level, for example, might turn more effective upon enhanced IWRM framework on the canal irrigarion network.

Apart from that, promoting some technologies at the local level may require adjusting policies on the national level first. As an example, farmers in the upstream of the irrigation network may have little incentives to adopt water saving technologies unless there are enforcing or stimuli mechanisms in place. Similarly, limited flexibility of farmers in some of the countries to choose what crops to grow, represents another institutional issue that prevents crop diversification and switching to drought resistant crops. In this regard it could be supposed that fostering adaptation in the region will require revision of existing policies and institutional frameworks in the water and agriculture sectors.

With respect to needed capital investment, there is some evidence that the more efficient technology is, the higher the capital costs are. Some technologies, particularly soft and organizational measures on the farm level, require zero capital investment but may impose higher labor or other inputs during the course of operation. When it comes to monitoring of water resources and establishment of information delivery systems, the issue is rather more about supporting operation and maintainance of the respective facilities and equipment. This calls for a careful consideration of appropriate financial schemes that allow sustaining operation of adaptation technologies, particularly in the water resources sector.

Insufficient technical skills also present a barrier for smooth adoption and upscaling of adaptation technologies in the region, which refers to technologies used both on the national and farm levels. It should be mentioned that numerious projects up to date concentrate on capacity building activities for practitioners and public officials. Nevertheless, it is argued that project efforts conducted at the local level by organisations “on land management, water storage and testing new species that better suited the new climatic conditions”, resulted in generated knowledge that was not implemented (Bizikova et al. 2011). Therefore, it is necessary to strengthen capacity building activities especially in dissemination of soft and organizational technologies and ensure sustainability of the respective efforts.

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