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MODERNIZING IRRIGATION IN CENTRAL ASIA
CONCEPT AND APPROACHES

FAO INVESTMENT CENTRE

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MODERNIZING IRRIGATION IN CENTRAL ASIA
CONCEPT AND APPROACHES

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CONTENTS

Tables, boxes and figures

Tables

Tables in annexes

Boxes

Figures

Figure in annexes

Foreword

Irrigated agriculture has been, and remains, a major sector in Central Asian economies. The challenge ahead is to make sure the irrigation sector in the region can evolve in line with changing socio-economic and climatic conditions and respond to the need for reliable irrigation water delivery for more productive and resilient agriculture, prosperous farming and sustainable access to affordable and nutritious food.

Modernizing Central Asia's irrigation is key to realizing these goals. It applies technical, institutional and managerial upgrading of irrigation schemes to improve the efficient use of water and land resources and water delivery service to farmers.

This process would ensure that all parts of the irrigated agriculture value chain are working together. Along with improved farm agronomic practices, it will contribute to increasing crop yields and crop production. With more reliable irrigation water supply and greater income, farmers will be prepared to invest in new technologies and contribute financially to sustaining irrigation and drainage systems.

This publication draws on the experiences and insights gained during a stocktaking study carried out by an FAO team as part of the World Bank's regional assistance programme on irrigation modernization in Central Asia. It suggests a framework for developing modernization solutions in the I&D sector in the region that allows for more nuanced approaches and interventions, taking into account specific situations and levels of the schemes and sector performance.

We hope this publication will be useful to policy-makers, managers and technical experts in designing irrigation modernization programmes and interventions in the region.

We are grateful to all those who contributed to this knowledge product, providing their valuable technical expertise, insights and advice.

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The stocktaking study was conducted by an FAO team led by Rimma Dankova, Senior Adviser, FAO Investment Centre, and included Maher Salman, Senior Land and Water Officer, FAO, Alan K. Clark, Principal Irrigation Engineer, Northwest Hydraulic Consultants, and Eva Pek, Land and Water officer, FAO. Martin Burton, Irrigation and Institutional Development Consultant, assisted the team with an analysis of the study findings and preparation of this publication.

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Abbreviations and acronyms

AADP	Agriculture Area Development Project
ADB	Asian Development Bank
AFI	alternate furrow irrigation
AMP	asset management plan
ALRI	Agency for Land Reclamation and Irrigation
ASA	Advisory Services and Analytics
BAC	Big Almaty Canal
BOT	build-operate-transfer
CAEDWP	Central Asia Energy-Water and Development Program
CAPEX	capital expenditures
DA	digital agriculture
DBO	design build operate
DBOM	design-build-operate-maintain
DT	digital technology
EE	executive engineer
EPIMICA	Exposure and Practical In-Roads to Modernizing Irrigation in Central Asia
ET	evapotranspiration (Crop water use)
EUWI	European Union Water Initiative
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GIS	Geographic Information System
GPS	global positioning system
GWSP	Global Water Security and Sanitation Partnership
ICT	information and communication technology
I&D	irrigation and drainage
IFC	International Finance Corporation
IMT	irrigation management transfer
IWMI	International Water Management Institute
ISF	irrigation service fee
IWRM	integrated water resources management
JSC	Joint Stock Companies
LLL	laser land levelled
MAR	managed aquifer recharge
MAWR	Ministry of Agriculture and Water Resources
METRIC	Mapping Evapotranspiration at high Resolution with Internalized Calibration
MEWR	Ministry of Energy and Water Resources, Tajikistan
MIS	management information system
MoF	Ministry of Finance
MoWR	Ministry of Water Resources

MOM	management, operation and maintenance
MPA	Multiphase Programmatic Approach
NIMP	National Irrigation Modernization Plan
NWRMP I	National Water Resources Management Project I
O&M	operations & maintenance
OPEX	operating expenditures
PIM	participatory irrigation management
PPP	public-private partnership
RAP	rapid appraisal procedure
ROM	rehabilitate-operate-maintain
SCADA	supervisory control and data acquisition
SMS	short message service
TIIAME	Tashkent Institute of Irrigation and Agricultural Mechanization Engineers
TLL	traditional land levelled
TPS	True Potato Seed
T&V	training-and-visit
TVET	technical and vocational education and training
UNISDR	United Nations International Strategy for Disaster Reduction
WCA	water consumer association
WMO	Water Management Organization
WRP&M	water resources planning and management
WSR	water sector reform
WUA	water users' association

Definitions

Irrigation efficiency	The ratio of effective water use (that is, the water used by the crop) to the water actually applied to the crop.
Irrigation productivity	The ratio of crop output (measured in monetary or physical terms, or both) to water either diverted or consumed.
Water productivity	The ratio of economic output (measured in monetary terms) to water either diverted or consumed for the purpose of producing the outputs.
Effective irrigation	The ratio of effective water use (that is, the water used by the crop) to the water actually applied to the crop minus the volume of water returned or recycled.
Efficiency losses	The water diverted but not used for evapotranspiration (ET).
Off-farm	Term used in Central Asia for the main system, comprising primary and secondary canals.
On-farm	Term used in Central Asia for the command area formerly managed by state and communal farms, now managed by water users' associations and farmers. It comprises the tertiary, quaternary and field channels, and in some cases secondary canals.

Executive summary

Agriculture is important to Central Asian economies, contributing substantially to national export earnings in certain countries. Approximately 80 percent of the limited arable land area is irrigated. The region's largely dilapidated irrigation and drainage (I&D) infrastructure has significantly reduced the area actually irrigated. Most irrigation schemes, though still functional, operate far below their potential due to years of inadequate funding, poor farm economics and management and policy constraints.

Available water resources are not evenly distributed among the five countries, with those downstream (Turkmenistan and Uzbekistan) heavily dependent on regional transboundary agreements to supplement their own internally renewable water resources. Climate change is expected to exacerbate water availability in the region, reducing the volumes of water from glaciers, increasing evapotranspiration (ET) and rainfall fluctuations, and resulting in more severe droughts and floods.

In Central Asia the off-farm (main) irrigation systems are managed by government agencies, while the on-farm systems are operated by either the local government agency, local government or water users' associations (WUAs). The main change has occurred at the farm level where the former state and collective farms have mostly been sub-divided and the land handed over to individual smallholder farmers. In some countries, WUAs have been formed to act as an intermediary management institution between the government agency and the farmers.

The sub-division of the state and communal farms and turnover to individual farmers have negatively impacted the income received by the government agencies to cover the management, operation and maintenance (MOM) costs of the off-farm systems. This has impaired the level of service they are able to provide, which has in turn reduced the farmers' ability and willingness to pay irrigation and drainage service fees. Resolving this issue poses a major challenge in all countries in the region.

Population growth and increasing water scarcity will put even more pressure on the agriculture sector to improve water use efficiency and productivity and to modernize the currently dilapidated I&D infrastructure and MOM of these systems. Pumped irrigation, in particular, will benefit from measures to reduce energy costs and conveyance, as well as distribution and application losses, and increase returns per unit of water pumped. Measures to improve crop selection, seeds, agronomic practices, storage and marketing will lead to increased farmer incomes, while improved levels of service will make farmers more able and willing to contribute to MOM costs. Increased farmer income will also drive farmers to invest in new technologies, including gated pipe (hose), sprinkler and drip systems.

Changing farmer demands for water delivery services are driving agricultural liberalization and policy reforms related to irrigated agriculture. Land ownership is being reformed, top-down control of cropping patterns reduced or removed, markets expanded and entrepreneurial activities encouraged.

This publication, geared to policy-makers, managers and technical experts, draws on the experiences and insights from a yearlong stocktaking study carried out by an FAO team as part of the World Bank's regional assistance programme "Exposure and Practical In-Roads to Modernizing Irrigation in Central Asia". This study identifies key actions to improve the performance of I&D systems in the region through sector modernization.

Modernization is the technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, if required, to improve resource utilization (labour, water, economic resources, environmental resources) and water delivery services to farms.

In addition to improvements in physical infrastructure, changes will be required in the way I&D systems are managed, operated and maintained, allied with the necessary policies, legal frameworks and institutional structures. The design of modernization interventions should be scheme- and context-specific and tailored to the given national and local situations.

The ultimate goal of scheme modernization in Central Asia is to provide farmers with a sustainable, efficient and demand-responsive water delivery service, while also considering agricultural, social and institutional measures that will build on and add value to the enhanced water delivery service. The objectives for modernizing irrigation in Central Asia include the following:

- increase the productivity of the irrigation sector to match growing demands, from both the wider society in terms of food production and exports and farming communities for improved livelihoods;
- ensure greater irrigation efficiency and crop productivity of water in the context of growing water scarcity;
- deliver cost-effective and reliable irrigation services matching the changing demands of farmers;
- more closely match irrigation water supply to demands to reduce water wastage, thereby reducing pumping costs and areas suffering from waterlogging and salinization; and
- contribute to the national development objectives of climate resilient economic growth, food security and poverty reduction (the priority order may vary by country).

Successful modernization of the I&D sector in Central Asia therefore needs to cover a wide range of domains, including engineering, agricultural, institutional, political, economic and financial. In this report such an approach has been conceptualized in five Action Areas (Box 1.1).

The underlying principle for implementing the framework is to apply a management-centric approach to the modernization of existing I&D schemes based on continuous performance assessment and benchmarking. The benchmarking should be done against an established baseline and identified measures to close the performance gap. Irrigation modernization therefore does not begin and end with a discrete modernization project but is part of an ongoing management process focussed on maintaining and enhancing scheme performance over time.

Box 1.1
Action areas for irrigation and drainage sector modernization

ACTION AREA 1	ACTION AREA 2	ACTION AREA 3	ACTION AREA 4	ACTION AREA 5
Policy and legislation to frame the modernization process	**Institutional reform to structure management of the process**	**System modernization for improved service delivery**	**Strengthening agriculture services and practices for enhanced production**	**Building knowledge and information systems for growth**
NATIONAL LEVEL	NATIONAL AND SCHEME LEVEL	NATIONAL AND SCHEME LEVEL	NATIONAL AND SCHEME LEVEL	NATIONAL, BASIN AND SCHEME LEVEL
Policy formulation and legislation to frame and enable change at lower levels	Policy formulation and legislation to frame and enable change at lower levels	Operationalizing changes made in Action Areas 1&2, focusing on performance-based management and service delivery to water users to improve efficiency and productivity	Policy formulation and legislation to frame and enable change at lower levels	Modern data collection, processing and analysis tools for improving the performance of I&D schemes (i.e. MIS and DSS systems, mobile apps on optimum irrigation scheduling, pest control and market prices)

Source: Authors' own elaboration.

Below are some core elements of the Action Areas:

Action Area 1 – Policy development and legislation

In most of Central Asia, water resources and irrigation are currently managed by the same organization. Best practices suggest that given the increase in the importance of other water uses (domestic water supply, hydropower, industry, environment), water resources planning and management should be separate from irrigation management. This requires a change in policies and legislation. In Kazakhstan, for example, reforms include the reorganization of several water-related state enterprises into joint stock companies and the establishment of other agencies for the analysis and supervision of water-related activities.

Other policy reforms taking place in the region include those related to land ownership, property rights, river basin management, relaxation of state control over cropping patterns, support for agricultural innovation (including horticultural development), loosening of restrictions on imports and exports, agricultural diversification and measures to encourage greater private sector engagement in irrigated agricultural, including through public-private partnerships (PPPs).

Action Area 2 – Institutional reform

Once separate agencies have been formed for managing water resources and irrigation, they should be supported in their modernization efforts. For water resources planning and management, that includes: (i) preparing river basin plans; (ii) modernizing water codes; (iii) creating inventories of all uses and users; (iv) developing and implementing water licensing procedures; and (v) monitoring and regulating abstractions from and discharges to rivers and groundwater. For the irrigation and drainage agency, modernization should focus on service delivery, performance and asset management.

Additional modernization reform would focus on measures to increase the engagement and participation of water users in the I&D systems' MOM. The creation of WUAs may be one way to achieve this; however, modern technologies can also improve the linkages between individual water users and the service provider.

The performance-centred approach will also require establishing a programme for scheme performance benchmarking, performance assessment and performance-based management. The management changes should also support the promotion and implementation of service delivery contracts as well as development and adoption of asset management planning.

Action Area 3 – System modernization

Preparation of a National Irrigation Modernization Plan (NIMP) is an important step in establishing the vision, strategy and actions required to modernize the I&D sector. Included within the NIMP will be options for cost-effective modernization of different types of I&D schemes (gravity-fed, pumped; highlands, lowlands; single cropping, multiple cropping; drainage).

Measures to improve water application efficiency are urgently needed in some locations, particularly to reduce over-irrigation leading to waterlogging and salinization. Surface irrigation methods can be improved by relatively low-cost methods such as precision laser or global positioning system (GPS) land grading, use of buried pipe systems to convey water to low-pressure hydrants, use of gated pipe and pulse irrigation and use of soil moisture sensors. Training farmers on improved water application methods, including the use of simple soil moisture monitoring (by auger or moisture sensor) before and after irrigation, would also improve irrigation efficiencies. Alternatively, in-field systems can be converted to sprinkler or drip; however, this will require additional capital expenditures for storage ponds, pumps, filtration equipment, buried pipes and irrigation equipment, as well as additional running costs for pumping to pressurize the network.

The stocktaking study investigated the potential for pressurized pipe systems for three schemes in Kazakhstan and found that these systems offered certain advantages over traditional open channel surface irrigation systems. Advantages include: (i) lower maintenance costs and longer service life; (ii) higher efficiencies with lower conveyance and operational losses; (iii) greatly improved water delivery service, with farmers able to draw water on demand (within design limits); and (iv) accurate volumetric water measurement and water charging.

Action Area 4 – Strengthening of agricultural services and practices

Modernizing farmers' agricultural practices requires research on farmers' current practices followed by education and training to improve their knowledge and skills. The situation in Central Asia is unique in that following independence in 1990, state and agricultural farms were turned over to individual smallholders. At the time of the handover, a large proportion of these new farmers did not have much agricultural training or experience; this knowledge was held by a relatively limited number of trained specialists on the state and communal farms. Furthermore, the farming system was focused on large-scale farming, not smallholder plots.

Precision agriculture could be introduced to reduce costs and increase the efficacy of in-field agricultural processes. This might include remote sensing, GPS guidance systems, use of soil moisture sensors, automated weather stations and the use of drones for monitoring crop and soil condition. Weather forecasting will become increasingly important. In addition, renewable energy can be used to keep the costs of pumped irrigation low while also minimizing the carbon footprint.

Action Area 5 – Building knowledge and information systems

Modern information and communication technologies (ICT) are potentially powerful tools for modernizing the irrigated agriculture sector. Various technologies are available, including remote sensing applications, management information systems (MIS), geographical information systems (GIS) and smart phone apps. Online education and training programmes can be a cost-effective way to upgrade the knowledge of farmers and I&D agency staff. Increasingly, private sector organizations are using ICTs to provide online advice, training and information services to farmers.

Finally, tailoring modernization interventions to suit particular types of schemes is key to their success. It might be suitable to introduce high-tech operating systems in some schemes, but not in others. The key is to recognize the needs and categorize schemes according to their assessed condition, suitability for modernization and potential for sustaining the modernization process. Schemes that might not qualify for modernization should not be neglected, as they could benefit from more focus on the specific issues arising from deferred maintenance (such as the repair/replacement of pumps, or repairs to the main canal system).


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Chapter 1
Introduction

This publication draws on the experience and insights gained during the implementation of a stocktaking study carried out between May 2018 and May 2019 by an FAO team under the World Bank's Exposure and Practical In-Roads to Modernizing Irrigation in Central Asia (EPIMICA) Program. The study culminated in the preparation of the "Modernizing Central Asia Irrigation: Stocktaking and Strategic Discussion Paper", which reported on the current status of the I&D sector in the region together with proposals for modernization.

This report is divided into eight chapters. Following the introduction in the opening Chapter 1, Chapter 2 provides an overview of irrigation and drainage in Central Asia, looking at the current status and issues faced. Chapter 3 examines the forces acting on the sector (the "drivers for change") whilst Chapter 4 builds on this analysis to lay down the challenges and opportunities for the future. Chapter 5 sets up a framework for modernization based on the concept of performance-based management, followed by Chapter 6 where details are provided on the steps that can be taken to modernize I&D schemes in Central Asia. Chapter 7 then outlines an approach for tailoring modernization interventions to suit different types of schemes and circumstances. The conclusions are then presented in Chapter 8.

The main concept of the report draws on experiences of strategic planning and management, with the underlying philosophy that improvement and lasting changes can be made only if driven by informed and capable management. While rehabilitating or modernizing infrastructure and strengthening institutions might be central components of a modernization process, it is the vision, drive, and leadership of those managing the process that make it work. This report is addressed to policy makers, managers and technical experts who wish to see a better, more sustainable future for the irrigation and drainage sector in Central Asia.


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Chapter 2
Irrigation in Central Asia

CLIMATE AND NATURAL RESOURCES

The climate in Central Asia is continental with generally low precipitation, low relative humidity, high solar radiation, and cold winters and hot summers. The annual precipitation in the lowlands is low, ranging from less than 100 mm to 200 mm, occurring mainly in winter and spring with no significant summer rainfall. Most of the precipitation occurs in the mountainous regions, reaching up to 800 mm per year. In contrast, the annual ET in the lowlands and desert areas is within the range of 1400–1600 mm. In these locations, irrigation is essential for agriculture.

Due to the topography and climate, arable land in the region is scarce with less than 10 percent of the total land area in Central Asia being classified as arable (Table 2.1). Due to the arid climate and limited surface runoff, approximately 80 percent of the available agricultural land is irrigated.

The main water resources are the Amu Darya and the Syr Darya, discharging annually some 63 km^3 and 34 km^3 respectively. The seasonal pattern of both rivers is well suited to agriculture, as the snow melt leads to a peak in the river flows during the summer period. Irrigation consumes approximately 90 percent of all abstracted water, placing pressure on availability of water for other uses, particularly hydropower. In this context, water rather than land is the constraining resource.

The important hydrological feature of the region is the transboundary nature of its main river basin systems requiring a cooperative management of the shared water resources among the Central Asia republics (Figure 2.1). The downstream countries (Uzbekistan, Turkmenistan and Kazakhstan) are highly dependent on upstream countries for essential irrigation water originating in upstream Kyrgyz Republic and Tajikistan. The dependency ratio of the annual renewable water resources in Uzbekistan, Turkmenistan and Kazakhstan are 80, 97 and 40 percent respectively (Table 2.2).

A combination of limited water resources and high levels of water withdrawals for agriculture puts considerable stress on water supply in the region. Water stress can be measured by total freshwater withdrawal (water use), as a percentage of total renewable water resources. According to the European Environment Agency, if the total freshwater withdrawal in a country exceeds the water availability by 20 percent or more, this country is facing a water stress situation. Most European countries are well below this threshold with some exceptions in southern Europe. Four of the five Central Asian countries are above this threshold and are therefore classified as water-stressed, in particular Uzbekistan and Turkmenistan (Table 2.2).

Map No. 3763 Rev. 8 UNITED NATIONS
January 2020

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Geospatial Information Section

Figure 2.1
River systems in Central Asia

Source: UN Geospatial. 2020. Map No. 3763 Rev. 8 Central Asia. In: *United Nations*. New York, USA, UN. Cited 5 January 2022. www.un.org/geospatial/content/central-asia

The balance of the internally and externally renewable water resources is shown in Table 2.3. While the region currently has relatively high annual per capita renewable water resources of around 3 800 cubic metres per capita per year (m^3/c per annum), this situation is expected to change in the future with urban and rural water demands anticipated to more than double by 2050 (COWI, 2019). The water use efficiency in the region is currently low. As can be seen in Table 2.3 renewable water resources are unevenly distributed within the region, implying that different countries can have less or more incentive to enact changes to improve water use efficiency. This apparent imbalance is tempered by existing international transboundary agreements in the region between countries in the upper and lower catchments. Without these agreements, Turkmenistan and Uzbekistan would fall into the category of absolute water scarcity with internally renewable water resources being 257 and 531 m^3/c/y respectively.[1]

1 According to the Falkenmark Water Stress Index regions with less than 500 m^3/c/y are classified as absolute water scarce. Water stress in a region starts when water resoures availability falls below 1700 m^3/c/y and a region is considered water scarce if the availability falls below 1000 m^3/c per annum.

Table 2.1
Cultivable areas in the Aral Sea Basin

Country	Area in the basin ('000 ha)	Area suitable for cultivation ('000 ha)	Arable land ('000 ha)	Proportion of arable land (%)
Kazakhstan	34 400	23 872	1659	5%
Kyrgyzstan	12 490	1257	595	5%
Tajikistan	14 310	1571	770	5%
Turkmenistan	48 810	7013	1805	4%
Uzbekistan	44 884	25 445	5208	12%
Aral Sea Basin	154 934	59 162	10 037	6%

Source: World Bank. 2015. Central Asia Water Management Study. Data relates to 2011.

Table 2.2
Average annual renewable water resources in 2012

Country	Annual renewable water resources (ARWR)			Annual water withdrawal	
	Internal (IRWR), km³	Total actual, taking into consideration agreements (TARWR), km³	Dependency ratio %	Agriculture (% of total)	Total (km³)
Kazakhstan	64.4	107.5	40	67	21.143
Kyrgyzstan	48.9	23.6	1	93	8.007
Tajikistan	63.5	21.9	17	91	11.496
Turkmenistan	1.4	24.8	97	94	27.958
Uzbekistan	16.3	48.9	80	90	56.000

Source: FAO, 2012a, AQUASTAT.

Table 2.3
National water endowments

Country	Total Internal Renewable Freshwater (billion m³)	External Renewable Freshwater* (billion m³)	Internal Renewable Freshwater (m³/c/y)	Total Renewable Freshwater Resources (m³/c/y)
Kazakhstan	64.35	72.04	3722	6150
Kyrgyz Republic	48.93	0.56	8385	3976
Tajikistan	63.46	34.2	7588	2583
Turkmenistan	1.41	80.2	257	4609
Uzbekistan	16.34	102.2	531	1635
Average	38.90	57.8	4097	3791

Source: Team calculations based on data from FAO, 2012a, AQUASTAT.
* Surface water resources entering the country.

Table 2.4
Socio-economic characteristics of agriculture in Central Asia

Country	Population (million persons)			GDP (2017)[a]		Share of agriculture employment (2017)[b] %	Agrarian index 2016–2017[c]	Agrarian index 2007–2008[d]
	Total (2017)[a]	Rural (2016)[b] %	Total (USD billion)	Value added by agriculture (%)	GDP per capita (USD)			
Kazakhstan	18.04	46.8	159.41	4	8836	18	22.9	27.7
Kyrgyzstan	6.20	64.1	7.56	12	1219	27	34.4	41.9
Tajikistan	8.92	73.1	7.15	20	802	52	48.4	54.0
Turkmenistan	5.76	49.6	42.36	9	7354	8	22.2	41.8
Uzbekistan	32.39	63.5	48.72	17	1504	22	34.2	38.3

Sources: (a) World Bank Country Profiles, 2017; (b) World Bank Development Indicators, 2016; (c) FAO, 2012b, AQUASTAT; (d) Lerman & Childress, 2013.

Table 2.5
Yields of wheat and cotton, 2015–18

Crop	Year	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
		Average yield (tonnes/ha)				
Seed cotton	2015	2.76	3.09	1.69	1.41	2.59
	2016	2.62	3.14	1.75	1.09	2.34
	2017	2.44	3.18	2.22	1.28	2.38
	2018	2.59	3.24	1.62	1.16	2.07
	Av. 2015–18	2.60	3.16	1.82	1.24	2.34
Wheat	2015	1.19	2.37	3.03	1.21	4.82
	2016	1.21	2.45	3.08	1.17	4.80
	2017	1.24	2.41	3.15	1.11	4.32
	2018	1.23	2.43	3.05	1.07	4.13
	Av. 2015–18	1.22	2.41	3.08	1.14	4.52

Source: FAO. 2020. FAOSTAT. Crops and livestock products. In: FAO. Rome. Cited June 2020. www.fao.org/faostat/en/#data/QCL

AGRICULTURE

Agriculture in Central Asia, where the land is mostly irrigated due to the low summer rainfall and high temperatures, is a major sector in Central Asian economies. Single cropping from March to October is the dominant cropping pattern in the region, with water application mostly by furrow and basins (for rice). There used to be substantial areas under sprinkler irrigation but these have been significantly reduced due to the deterioration of the pumping stations and high pumping costs.

Of the currently estimated population of 75 million in the region, between 46–73 percent live in rural areas (Table 2.4) and are dependent on agriculture for their livelihoods. Agriculture contributes 4–20 percent of the gross domestic product (GDP)[2] and 8–52 percent of total employment. According to the Agrarian

2 In Turkmenistan, Uzbekistan, and Kazakhstan, the extractive industries (such as oil, gas, gold) have overtaken the agricultural sector in terms of contribution to the national economies.

Index,[3] Tajikistan, Kyrgyzstan and Uzbekistan are the three countries most dependent on agriculture in the region.

Due to relatively small landholding size (2–3 ha) and relatively low agricultural production, poverty in rural areas is high, with many of the families engaged in agriculture suffering from food insecurity. For instance, in Tajikistan 73 percent of the population live in rural areas where farming is the primary source of income for only 20–24 percent of rural households. Some 30 percent of rural households are reliant on remittances and daily wage labour as their primary source of income, making them vulnerable to food insecurity.

In some countries, agriculture makes a substantial contribution to national export earnings, with cotton and wheat being the main export crops, mainly to Russia, the EU and China. Kazakhstan is a major exporter of grain and flour, while cotton is an important crop for Tajikistan, Turkmenistan and Uzbekistan. Vegetables and fruit exports, mainly to Russia and China, are also important however to a lesser extent.

Crop yields and production levels are low in the region in comparison with other countries. Based on 2005 data, yields in Central Asia were only 36 percent of their potential (FAO, 2011). Table 2.5 presents more recent data, which shows that yields for the main crops of wheat and cotton remain low by international standards.[4] Improvement in cultivation practices is an area where there are significant opportunities for improving efficiency and productivity.

An additional important factor is the lack of extension and advisory services available to smallholder farmers. In contrast to many parts of the world, in Central Asia there is no experience with extending agricultural advice to small landholders. The pre-independence agricultural research and advisory services, which were established for state and communally run farms have not been adapted to the post-independence situation. Smallholder farms have been created out of the state and communally run farms where little or no training has been provided for the new smallholder farmers. Consequently, agricultural and irrigation practices have generally been relatively rudimentary, with an adverse impact on crop yields and production levels.

This lack of extension advice, coupled with the lack of finance and marketing opportunities, has restricted the uptake of new and innovative farming practices and technologies. Currently the use of advanced irrigation technologies and new approaches to irrigated farming is limited across the region. In areas where sound and reliable knowledge and advice are provided the results can be impressive. Results from the Asian Development Bank (ADB) Agriculture Area Development Project (AADP) in Kyrgyzstan (ADB, 2011) demonstrated that in the areas where farmers were trained through advisory services, yields of seven crops across all participating farms exceeded the average level by an average of 62 percent.

IRRIGATION AND DRAINAGE SYSTEMS

The area equipped for irrigation in each country and the irrigation methods used are shown in Table 2.6. Surface irrigation is the predominant method of irrigation, with small areas of sprinkler and drip/localized irrigation. The low occurrence of

3 The Agrarian Index is the arithmetic average of the share of rural population, the share of agricultural employment and the share of agriculture in GDP, and provides a ranking of countries in relation to their reliance on agriculture. The higher the Agrarian Index the higher the dependency on agriculture.

4 Under irrigation a good yield is 6–9 tonne/ha for wheat and 4–5 tonne/ha for cotton (www.fao.org/land-water/databases-and-software/crop-information/en/ accessed 6 June 2020).

Table 2.6
Irrigation methods

Country	Full control irrigation area*	Surface irrigation		Sprinkler irrigation		Localized irrigation**	
	ha	ha	% of total	ha	% of total	ha	% of total
Kazakhstan	1 199 600	1 158 800	96.60	30 000	2.50	10 800	0.90
Kyrgyz Republic	1 021 400	1 021 000	99.96	400	0.04	-	-
Tajikistan	742 051	742 051	100.00	-	-	-	-
Turkmenistan	1 990 800	1 990 800	100.00	-	-	-	-
Uzbekistan	4 198 000	4 193 577	99.89	-	-	77 400	0.11
Central Asia	9 151 851	9 106 228	99.50	30 400	0.33	15 223	0.17

Note: *This area does not include 866 300 ha of spate irrigation in Kazakhstan.
**Low pressurized irrigation, mainly drip irrigation.

Source: FAO, 2012a, b, c, AQUASTAT.

Table 2.7
Drainage in irrigation areas

Country	Full control irrigation area*	Area equipped for irrigation with drainage facilities	
	ha	ha	% of total
Kazakhstan	1 199 600	343 000	29
Kyrgyz Republic	1 021 400	144 910	14
Tajikistan	742 051	345 200	47
Turkmenistan	1 990 800	1 011 897	51
Uzbekistan	4 198 000	2 840 000	66
Central Asia	9 151 851	4 685 007	51

Note: *This area does not include 866 300 ha of spate irrigation in Kazakhstan.

Source: FAO, 2012a, b, c, AQUASTAT.

sprinkler and drip irrigation represents a significant opportunity for the expansion of these technologies.[5]

The irrigation area equipped with drainage is shown in Table 2.7, with significant areas under drainage in some countries highlighting the existing drainage issues. These systems are gravity or pumped systems, and as with the irrigation network, significant areas have fallen into disrepair with a consequently negative impact on crop production.

There are a number of issues facing the I&D sector in Central Asia, which are summarized in Box 2.1. These issues result in less than optimum agricultural production, high water losses, low water use efficiency, top-tail disparities in irrigation supplies and therefore in income, and a generally unsatisfactory level of irrigation service to farmers. Although some progress has been made towards reforming the sector, the results have been mixed and progress has not yet shown significant improvements in the I&D scheme performance.

5 It should be noted however that as both technologies operate under pressure, they require pumps that incur energy costs. Pumped irrigation systems are generally more expensive to operate than gravity-fed systems.

Box 2.1
Key issues in the irrigation and drainage sector in Central Asia

The key issues include; (i) systems are badly dilapidated and in a poor state of repair (ii) on-farm systems have not adapted from the former state and collective farming system to smallholder irrigation; (iii) in-field irrigation is inefficient and could be significantly improved; (iv) management of the I&D systems has not evolved; (v) the main system operational procedures are often rudimentary; (v) WUAs/water consumer associations (WCAs) have a central role to play in on-farm water management but require additional support to be fully effective; (vii) maintenance is inadequate; (viii) funding for MOM is limited and inadequate.

Source: Authors' own elaboration.

The deteriorated condition of the physical infrastructure is a core factor causing the under-performance of irrigation schemes. Following independence and a move towards privatization of land and liberalization of farming practices, the irrigation area has declined due to lack of investment in maintenance and pumping. Furthermore, this decline is in part due to loss of the capacity for planning and managing operations. In Kazakhstan for example, the irrigation area decreased from 3.56 million ha in 1993 to 2.15 million ha in 2000, while the area actually irrigated in 2010 was just 1.27 million ha. At the same time, sprinkler irrigation declined from 0.55 million ha to just 0.03 million ha (World Bank, 2013). The schemes are still functional but operating below their potential due to the poor condition of irrigation and drainage infrastructures, equipment, funding, farming practices, poor farm economics, and management and policy constraints. Also, many schemes (pumped, in particular) have proved to be uneconomical in the situation of market-oriented transition.

The drainage system is in a similar state of disrepair. For example, in Uzbekistan 55 percent of the irrigated area is affected by salinity and/or high-water tables, particularly in the downstream arid desert parts of the country where cotton dominates cropping. Most irrigation systems have been constructed with open channel surface drainage systems at the on-farm level. These drains then feed into inter-farm collector drains. Roughly 70–75 percent of the irrigated areas have surface drainage only, whereas 15 percent of the irrigated area has horizontal sub-surface drainage systems, and the remaining 10 percent has vertical drains with depths varying from 40 m to 80 m (Burton M., 2014). Weed infestation of the surface drainage system is a major issue, imposing an additional cost on the already stretched maintenance budgets for its removal.

IRRIGATION AND DRAINAGE INSTITUTIONS

In Central Asia, the off-farm systems[6] are managed by government agencies whilst the on-farm systems[7] are operated by either the government agency, local

6 Off-farm systems include the headworks, pump stations, and main canals (primary and secondaries) and drains which are managed, operated and maintained by the government irrigation agency. In some cases the WUA or Federations of WUAs may manage primary and secondary canals.

7 On-farm systems include the tertiary and quaternary canal and drainage network which are managed, operated and maintained by the WUA and/or farmers.

government or water user association. Rayvodkhozs (local level state irrigation management agencies) are responsible for irrigation service delivery to farmers in Kazakhstan, Kyrgyzstan and Uzbekistan. In Tajikistan, there is a newly established semi-autonomous Agency for Land Reclamation and Irrigation (ALRI), which is expected in time to become a fully financially self-sufficient institution.

To some degree the irrigation institutions have held up well since independence despite reduced funding, reduction in staffing and technical capability. The organizational structures have mainly remained intact and their role remains much the same as in the pre-independence period.

The major change in the post-independence period took place at the on-farm level due to the transition from state and communal farms to individual smallholder farms. These changes required the newly created individual farmers to take responsibility for on-farm and field level irrigation operations through the establishment of WUAs. Considerable progress has been made with programmes on the establishment and strengthening of WUAs in Kyrgyzstan and Tajikistan (about 470 and 160 WUAs have been organized to date in these countries respectively), with a considerable support from donors and international financing institutions. In Uzbekistan, there has been less progress with regard to participatory irrigation management (PIM) and irrigation management transfer (IMT). WCAs remain weak with a limited mandate to distribute bulk water supply from the service provider. In Kazakhstan, starting in 2003/04, about 200 WUAs were formed with donor support, however they have recently been disbanded. The emerging model in Kazakhstan assumes direct contract arrangements between farmers and Rayvodkhozs for the service provision. While direct individual contract arrangements between farmers and the Rayvodkhozs seem to work efficiently in the case of large farms, it is not yet clear how well the service delivery can be organized for smallholder farmers in the absence of WUAs. The role of the proposed agricultural farmer cooperatives in irrigation water management is still being clarified.

COST RECOVERY AND FINANCIAL SUSTAINABILITY

As previously mentioned, the lack of sufficient funds from the governments and users to ensure sustainable MOM of irrigation and drainage systems has contributed to the decline in performance of schemes over the last 25 years. This lack of funding constitutes a major threat to the sustainability of I&D investments and the performance of I&D schemes in the future.

Given that government funding for irrigation is likely to be constrained in the foreseeable future, funding for MOM will increasingly need to come from the water users. This is however, a chicken and egg situation where farmers cannot afford to pay more for irrigation water if their crop yields and crop production are low as a result of unreliable, untimely and inadequate supplies of irrigation water, or if their fields are not adequately drained. Currently, payments received from WUAs and other irrigation water users for the service delivery cover only about 30 percent of the MOM costs in all five countries. The burden of the MOM costs on the state budgets is considerable. For example, in 2017 in Kazakhstan the irrigation service provider Kazvodkhoz (national level) and Raivodkhoz (Oblast/scheme) level, received a total state budget allocation of KZT 11 billion (USD 29.1 million), of which 86 percent was used for funding of MOM and only 14 percent for capital investments. In Uzbekistan, the costs for MOM of the schemes comprises about 10 percent of the annual state budget, and 60 percent of the Ministry of Agriculture and Water Resources (MAWR) budget. A large part of the expenditure is for energy costs for pumping schemes. Improving pumping efficiencies and reducing losses from the pump stations to the crop root zone could result in significant savings in pumping costs,and increases in crop yields due to improved water supplies in Uzbekistan and Tajikistan.

Some studies have been carried out in the region to assess the ability and willingness of farmers to pay for the irrigation service. In Kyrgyzstan, the tariff study undertaken under the World Bank National Water Resources Management Project I (NWRMP I) demonstrated that farmers would be able to pay higher irrigation service tariffs, if the service satisfied their requirements.[8] However, the existing government policies have capped irrigation service fees (ISF) at minimal levels for decades thus restricting opportunities for higher MOM cost recovery from water users. In 2018 in Kazakhstan the government proposed a gradual increase of the water tariff for gravity irrigation supply in order to meet around 50 percent of the MOM requirements. With the continuing underfunding of MOM costs, it will be difficult to avoid further deterioration of irrigation and drainage infrastructures. The continual underfunding also puts proposals for system improvements and modernization at risk. In addition to the amount the farmers is able and willing to pay, there are issues related to poor practices by the service providers, including lack of transparency in billing and MOM expenditure.

ENVIRONMENTAL ISSUES

Soil salinization is a major economic and environmental concern in the region. When the water table rises up and reaches 2 m or less below the soil, surface salts are drawn up into the crop's root zones and can have an adverse impact on crop yields. Over time, the salts can accumulate as the water evaporates, and if they are not leached, this can lead to high levels of soil salinity.

High salt levels make soils unsuitable for growing most crops. In Central Asia this problem is exacerbated by water seeping in from irrigation canals, the use of excessive quantities of water, and poor drainage. Turkmenistan and Uzbekistan are the two countries most affected by this problem, as over half of their irrigated land has become saline. In Uzbekistan's Karakalpakstan region, where the Amu Darya River finally dries up, about 95 percent of the land is now saline. An additional consequence is that surplus water from irrigation flows back into rivers, carrying salt from the irrigated land together with chemical fertilizers and pesticides. As a result, river water becomes more saline and more polluted further downstream. In Turkmenistan, in order to mitigate salinisation, only half of the drainage water is allowed to feed into rivers while the remaining half is diverted to natural depressions such as the Sarygamysh Lake.

Controlling ground water tables requires functioning drainage systems, for which rehabilitation has high investment costs. Management interventions include: (i) reducing over-irrigation through the adoption of improved irrigation and agricultural practices, such as the adoption of irrigation scheduling based on the measurement of soil moisture content; (ii) laser land levelling to improve application efficiencies and reduce losses below the root zone; and (iii) improvements in conveyance, control and measurement infrastructure of on-farm distribution systems. Construction of lined on-farm tertiary and quaternary canals can result not only in reduced seepage losses, but also substantially improved and more efficient operations by enabling a more rapid movement of irrigation water around the tertiary command.

8 For more information, see NWRMPI. 2018. Economic justification of improved MOM and IFS financing report

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Chapter 3
Future prospects: drivers for change

As in many parts of the world, the key issues facing Central Asia are related to population growth, pressure on water resources, climate change, and demand from farming communities for improved livelihoods.

With the population in Central Asia expected to rise from the current 75 million to 95 million by 2050, it is estimated that the per capita water availability will be reduced (all things being equal) by more than 33 percent compared to today's levels. During this period the urban and rural water demand is expected to more than double (COWI, 2019). It has been predicted that if the current water management policies continue, there could be a significant slowdown in economic performance (World Bank, 2016).

There are increasing and varied demands on the available water resources, therefore leading to growing water scarcity in the region. Given that the water resources are highly utilized (Table 2.2) the countries of Central Asia are vulnerable to variations in the seasonal river flow and even relatively small shortfalls can have a strong impact on agricultural activities. Climate change is expected to aggravate the water availability situation, with increased ET and rainfall fluctuations, as well as the heightened severity of droughts and floods. Under the projected climate change for the region irrigated agriculture is likely to be the most affected in the water-using sectors, given the prioritized allocation of available supplies towards energy and drinking water needs (Box 3.1).

It is estimated that one-quarter of the volume of water stored in glaciers was lost in the second half of the 20th century, and another quarter will have disappeared by 2025 (Eurasian Development Bank, 2008). In the long term, this means that less water will be available for the region's fast-growing population. While the region currently has relatively high annual per capita renewable water resources of about 3 800 cubic metres per capita per year (m^3/c per annum), this situation is expected to change in the future. According to the data available (CAEWDP, 2016), if population growth continues at its current rate of 1.5 percent per year, the amount of water available per person in the region will fall below 1700 m^3 by 2050, below 1000 m^3 by 2080 and below 500 m^3 by 2120.

A strong driver for strengthening regional cooperation exists through the interconnected water resources network. As discussed in Chapter 2, renewable water resources are unevenly distributed across the region with downstream countries reliant on flows originating in the mountain ranges in neighbouring countries. The imbalance is tempered by international transboundary agreements.

Adding to this complexity climate change will contribute to the ongoing problems of desertification, land degradation and drought in the region. In Kazakhstan, 66 percent of the land area is affected by the land degradation processes while in Turkmenistan and Uzbekistan it is as high as 80 percent. Between 40–80 percent of irrigated lands in the region are salt-affected and/or waterlogged with the most affected countries being Turkmenistan (68 percent), Uzbekistan (51 percent), and Kazakhstan (20 percent) (FAO, 2012c). Unless this situation is addressed, it is likely to deteriorate further.

A core driver for change and reform in the I&D sector is the current state of the sector, as described in Chapter 2. I&D infrastructure is dilapidated, government I&D agencies are under-resourced and under-staffed, service delivery to farmers is poor, irrigation supplies do not match irrigation demands leading both to the low crop yields but also wastage of water contributing to waterlogging and salinization. There are significant benefits to improving the efficiency of pumped irrigation and drainage. Governments need to reduce the financial drain on the government exchequer supporting poorly performing I&D schemes, and seek to increase the contribution that farmers make to MOM costs. This will be possible only if changes are introduced to management, operation and maintenance of I&D systems so that the delivery of reliable, timely, adequate and low-cost irrigation water supplies to farmers is ensured. This process will contribute, along with improved farm agronomic practices, to measurably increasing crop yields and crop production, which can then be marketed and sold at remunerative prices. In sum, all parts of the irrigated agriculture value chain need to be working together. With more reliable irrigation water supply and greater income, farmers will be prepared to invest in new technologies, and furthermore will be able and willing to increase their contribution to sustaining the I&D systems.

Following the disintegration of collective and state farms, farm restructuring and liberalization of farming practices based on the principles of market economy are driving change. The gradual policy changes include the provision of individual property rights, the ability to freely transact such property rights, and the absence of administrative interference in crop choice. For example, the Government of Uzbekistan recently made the decision to gradually move away from state interventions and production quotas in order to promote a market-driven and privately managed cotton value chain, recognizing that its crop yields remain below their potential. In Tajikistan, more than 150 000 private farms have emerged to replace the former collective farms over an area of approximately 550 000 hectares. The positive trend in the country includes a steady agricultural sector in the period from 2010–2016 and a more profitable and sustainable balance between cotton and other crops, in addition to increasing investments in the production and processing of high value fruit and vegetable crops.

The evolving agricultural policies towards further agricultural liberalization in the region provide a more conducive environment for faster and more sustainable agriculture sector growth. Agricultural liberalization has the potential to unleash farmers' entrepreneurial capacity and to stimulate innovation and investment in agriculture. In the context of irrigated agriculture this may exhibit itself in the changing of cropping patterns to more high-value crops, the use of high-quality dressed seeds and an increased uptake of modern irrigation practices, such as the use of sprinkler and drip irrigation. Importantly, it also increases incentives for improving on-farm water management, putting an individual farm enterprise at the centre of irrigation service provisions and creating greater water user incentives to manage water collectively through WUAs or community groups.[9]

A further consideration driving change is the cost of inaction. Central Asia's economies are already facing significant losses from water scarcity

9 These are informal groups of farmers with adjacent farm plots who agree to work collectively. The group may agree to "pool" their land and thus plant larger plots of a particular crop, thus improving efficiency in farming operations (land preparation, planting, irrigation water application, harvesting). It may also improve manpower efficiency, with a reduced number of farmers required to manage the plot, thereby freeing other members to carry out alternative economic activities.

Box 3.1
Projected impacts of climate change on water resources availability in Central Asia

According to the 2014 World Bank report "Turn Down the Heat: Confronting the New Climate Normal", Central Asia is likely to experience more intense warming than the global average.

Average annual temperatures have risen by 0.5 degrees Celsius in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan over the past 30 years. The region's glaciers, which account today for 10 percent of the annual stream flow in the Amu Darya and Syr Darya basins, have already shrunk by one-third in volume since the beginning of the 20th century. As a result, the melting glaciers and snow are changing ecosystem zones. These are especially sensitive in mountains, which make up more than 90 percent of Tajikistan and Kyrgyzstan.

Rainfall fluctuation resulting from climate change is furthermore driving increased floods and droughts. Kazakhstan experienced 300 floods between 1994 and 2013. In the year 2000, drought affected three million people in Tajikistan.

The rise in temperatures is reducing agricultural production and farmers have to go uphill to find land that has a better water supply. Melting glaciers mean water supply is expected to decline by an additional 12 percent across the region by 2050 affecting summer water availability for irrigation. In Kyrgyzstan and Tajikistan, the rapid melting of glaciers creates an incentive for capturing the additional water for hydropower use that may further divert water away from farming.

Source: World Bank, 2014.

compounded by the inefficient water use in agriculture. The growing water scarcity and deteriorating water quality lead to a reduction in agricultural productivity in the region. Insufficient water supply during the growing periods resulting from climate variability impose significant economic and social risks to the countries. According to the UNISDR's "Risk assessment for Central Asia and Caucasus" (2009), a drought in 2000 in Uzbekistan affected 600 000 people and caused an economic loss of USD 50 million. In Turkmenistan, it is predicted that under current trends, 20 percent of production could be lost by 2030 due to the reduced availability of irrigation water (FAO, 2016). In Tajikistan, while in aggregated terms there is an abundance of water resources, limited opportunities to regulate water flows lead to water shortages experienced in about 20 percent of the irrigated land.

Poor irrigation water management, coupled with increasing water scarcity, also contributes significantly to the existing environmental problems in the region causing significant economic and social damage. During the past decades, the water quality in the Amu Darya has deteriorated considerably as a result of the discharge of drainage and industrial water from the riparian countries. About 4 km^3 of drainage water with salinity levels of 6.5–8.5 g/liter is discharged annually into the Amu Darya from Uzbekistan. A 2003 regional study estimated the agricultural losses due to poor management of irrigation systems and resulting water logging and salinization to reach USD 378 million/year in Turkmenistan (Royal Haskoning, 2002). The disposal of saline water is also a major problem in Kazakhstan as only 343 000 ha equipped for irrigation have a drainage system in place (FAO, 2016). Overall, approximately 680 000 ha of land equipped for irrigation have been lost to crop production.


OPEN BEFORE PUMPING

Chapter 4
Irrigation modernization: challenges and opportunities

During the implementation of the stocktaking study key issues were identified in relation to the performance of the I&D sector and I&D schemes in Central Asia. A detailed analysis was carried out using the rapid appraisal procedure (RAP) on three schemes (two in Tajikistan and one in Uzbekistan). The process and results from the assessments are presented in Annex I.

From these detailed studies and other studies in Tajikistan, Uzbekistan, and Kazakhstan (Annexes II to IV, respectively) the challenges have been identified for the I&D sector and I&D schemes in Central Asia.

i. **Challenging environment.** Some of the schemes are in challenging physical environments, with cold winters, limited growing season, mountainous topography, high levels of sediment in rivers, seasonal flooding due to snow melt.

ii. **Systems are badly dilapidated and in a poor state of repair.** In general, the I&D systems are in a poor state of repair (some of them badly so), resulting in an inability to control and measure irrigation supplies in order to provide irrigation water in a reliable, timely and adequate manner. Water is lost through ungated outlets, unutilized flows at night into drains, and damaged embankments.

iii. **The management of the I&D systems has not evolved.** The management systems have not evolved over the last 20–25 years except in cases where there has been support from internationally funded projects. There is little continuous professional development (CPD) of staff through formal training. The use of computers and procedures for data collection and processing of data is generally behind others countries.

iv. **The main system operational procedures are rudimentary.** As a consequence of the system design the operational procedures for the main and secondary canals are relatively rudimentary. There is limited cross regulation to control water levels at offtakes, and limited or rudimentary control and measurement to on-farm systems. These procedures were likely sufficient for the previous situation with state and collective farms but are less suited to the more varied cropping mix and irrigation demand pattern generated by smallholder farming.

v. **Sedimentation is a major issue in some systems.** The lack of sediment exclusion or sediment trapping infrastructure results in high levels of sediment entering the canal system leading to a need for costly desilting. Lack of adequate cross drainage results in sediment-laden surface runoff from upslope of contour canals blocking the canals.

vi. **Maintenance is inadequate.** The condition of the physical infrastructure attests to the inadequate levels of maintenance of the I&D systems over the last 20–25 years. There is a significant level of deferred maintenance. Canal sections have deteriorated, lining is damaged and cracked, gates are damaged or missing. As a result of the deteriorated condition, the maintenance needs and costs are greater due to the fact that the system was not adequately maintained over this period. Because of the limited availability of funds this backlog of maintenance restricts the ability to provide additional finance for modernization.

vii. **Funding for management, operation and maintenance is limited and inadequate.** Lack of funding lies at the centre of the poor state of the I&D systems. The money collected from the ISF is inadequate, partly due to a low setting of the ISF and partly due to low collection rates. Due to poor levels of service, farmers are often unwilling and unable to pay the ISF. Funding is top-down from the Ministry of Finance rather than being bottom-up and based on asset management plans or needs based budgeting. Staffing and operation costs (for vehicles and their running costs) are covered but the shortfall deters the funding of maintenance. In some situations, such as in Tajikistan¸ the cost of operating pump stations requires a major share of the available funds, leaving insufficient money for maintenance.

viii. **On-farm systems have not adapted from the former state and collective farms to smallholder irrigation.** Little support has been provided by government to convert the former state and collective farms, which cultivated crops in large land plots into smallholder farms with numerous small plots. On-farm infrastructure is rudimentary, with limited control and no measurement. Canals are generally unlined with no distribution boxes or formal outlets to farmers' plots. Water losses at this level are estimated to be high.

ix. **In-field irrigation application needs improvement.** Furrow irrigation is the predominant irrigation method. In one or two of the systems the field slopes are excessive for furrow irrigation and consideration should be given to adaptations to cope with these slopes, such as using border strip irrigation or by aligning the furrows across the slope. There is currently little or no research or extension advice to farmers on measures to improve field application efficiency, which would likely yield significant benefits in terms of water savings and more uniform irrigation leading to higher crop yields.

x. **Lack of agricultural extension advisory services.** As a result of the genesis of farming by individual farmers, they are relatively poorly trained in agriculture, agronomy and irrigation. There is little or no agricultural extension available to farmers and therefore, knowledge of efficient irrigation practice is limited.

xi. **WUAs have a central role to play in on-farm water management but require additional support to be fully effective.** WUAs have been formed and generally employ staff to manage, operate and maintain the on-farm systems. Mirabs (field staff) are employed to organize the daily distribution of irrigation water. This practice facilitates good water management and reduces the potential for disputes between water users. Consideration should be given to providing training to these field staff to enable them to act as advisors to the water users.

The opportunities for addressing these issues are summarized in Table 4.1, where possible measures for improvement are identified together with their potential impact. Possible constraints to implementation are also discussed.

Table 4.1
Opportunities and actions for addressing issues facing the irrigation sector in Central Asia

Opportunity	Domain	Measures involved	Possible impact	Possible constraints
Developing enabling agricultural policies	Political	Liberalize government policies on cropping and crop prices. Support for commercialization of agriculture	High	Reluctance by politicians to rely on market forces; lack of commercial systems
Revised irrigation/water sector policies	Political	Develop national irrigation modernization vision and strategies, including changes in "norms"- based policies on determining crop water requirements to ET-based approaches; introduce water accounting systems	Moderate	Reluctance of policy makers to introduce changes; lack of vision and knowledge
Increase crop yields	Agronomy	Improved seed varieties; improved agronomic practices; improved harvesting and storage; established extension services	High	Weak seed production; weak farmer knowledge and skills; credit availability
Switch to higher value crops	Agronomy; Social and cultural	Encourage farmers to plant higher value crops; provision of seeds; reliable markets; government policy on pricing; lack of awareness & understanding of new crops; reliance on subsistence cropping; established extension services to farmers	High	Lack of seeds; lack of market; lack of storage and transport facilities for more perishable crops; rigid pricing
Increase efficiency of water use in agriculture	Irrigation engineering; Agriculture	Reduce conveyance, distribution, application & management losses in irrigation systems; better match irrigation supply to demand; improve level of service provision to water users; relate the level of service-to-service fee charged	Moderate	Poor condition of I&D infrastructure; weak management capability; lack of knowledge & skills for on-farm water management by farmers; lack of incentives for improved performance
Generating greater participation of water users	Social and cultural	Engage water users in MOM of I&D systems; increase agency transparency & accountability; legally binding service delivery agreements between agency and water users; formation & support of WUAs as legal entities	High	Political interference; fear of loss of power by I&D agency; fear of loss of patronage & control by politicians; dependency culture of water users

Source: Authors' own elaboration.

Table 4.2
SWOT analysis for Central Asia countries to progress with irrigation modernization

Strengths	Weaknesses	Opportunities	Threats (Risks)
◆ National agricultural policies are moving towards liberalization and commercializatio although at a different pace in each country. ◆ Larger farm sizes in Kazakhstan and Uzbekistan allowing potentially for faster uptake of modernization approaches. ◆ No crop patterns regulation in Kyrgyzstan and Tajikistan, famers are free to decide on crop patterns. ◆ In Kyrgyzstan, extensive land and irrigation reforms, community based natural resource management (NRM), liberalization of input and output market and trade. ◆ In Tajikistan, increasing government support to family farming. ◆ Growing political acceptance/realization of the need to modernize the irrigation sector. ◆ In Tajikistan, ongoing water sector reforms. ◆ In Uzbekistan, an agriculture modernization programme is underway.	◆ Lack of extension services that will hamper the uptake of advanced technologies and practices by farmers. ◆ Declining technical capacity in the sector and aging staff. ◆ Weak/underfunded state irrigation management institutions with limited capacities to lead the process. ◆ Limited knowledge of advanced irrigation practices and approaches. ◆ Political reluctance to commit to the modernization agenda. ◆ Low credit availability to farmers to pursue irrigation improvements. ◆ Political reluctance to revise policies in support of the modernization process. ◆ Large proportion of smallholder farmers in Kyrgyzstan and Tajikistan (slower uptake of innovations/less competitiveness). ◆ State crop orders on cotton and wheat production in Uzbekistan and wheat in Kazakhstan (gradually diminishing). ◆ In Kazakhstan, policies to subsidize large unprofitable farms. ◆ Lack of funding for MOM of irrigation systems.	◆ Current poor state of outdated irrigation infrastructure and MOM procedures provides an opportunity for significantly improved performance through modernizatio programmes. ◆ Improved I&D performance can address the challenge of growing water scarcity through more efficient water use. ◆ Current low levels of agricultural productivity and agricultural water productivity provide significant opportunity for improvement. ◆ Presence of development partners willing to support governments with the modernization agenda in the region. ◆ Greater engagement of the private sector in improving agricultural practices can raise agricultural production and farmer income. ◆ Opportunity to increase agricultural exports (availability of external markets for agricultural products from Central Asia).	◆ Inadequate funding of modernization programmes. ◆ Lack of regional cooperation on the irrigation modernization agenda. ◆ Sustainability of donor-supported modernization initiatives is not ensured by governments/irrigation authorities in the longer-term.

Source: Authors' own elaboration.

Although challenges do exist, there are also considerable opportunities for the Central Asia countries to engage with the irrigation modernization agenda (Table 4.2). The SWOT analysis details a number of challenges that the Central Asian countries may face while progressing with the modernization agenda. However, there are also several external factors (opportunities) and internal factors (strengths) that create the positive momentum for engaging with irrigation modernization in the region. Table 4.1 outlines possible performance gaps, their impact and possible constraints to closing the performance gap for I&D schemes in Central Asia.

Solutions to addressing the identified weaknesses and threats may be constrained by factors that can limit the implementation of the modernization agenda in the region. Successful modernization is not straightforward and failure to achieve targeted performance objectives, in some instances, require further investigation of the underlying causes. In the I&D sector the main constraints can be summarized as:

- **at policy level:** effective modernization, policy and strategies need to be in place to provide the modernization process with a vision at the national level and a roadmap to follow. These also include broader policy frameworks and a legal framework for (basin) management of water resources as well as the necessary revisions of existing 'norms' for determining crop water requirements. Further development of water policies and regulations are necessary to create incentives for farmers and irrigation authorities to pursue water saving and conservation irrigation practices. Above all, this should include the removal of state caps where they exist, on the level of irrigation service fees to allow for a better cost recovery level in the sector;
- **on the institutional side:** strong public sector agencies are required for development and management of irrigation schemes providing services to farmers. Effective farmer participation on smallholder schemes requires the organization of farmers into water user associations and development of their capacity through training and extension advice. The current public sector institutions are struggling to manage the existing irrigation systems and will require strengthening and/ or stronger private sector collaboration (possibly under Design Build-Operate contracts) to manage various aspects of modern irrigation;
- **general lack of awareness of opportunities for modernization:** in some cases proposals and initiatives for change and modernization are being introduced into a country's irrigation sector by external actors working with donors or development agencies. Change is best effected when it is initiated and implemented within national governments and sector organizations, rather than imposed upon them externally Developing 'buy in' from politicians and agency personnel has to be one of the single most important components of any modernization programme. As part of the highly successful World Bank supported WUA formation and support programme in Kyrgyzstan, key actors were taken on study tours to the United States and Europe to see for themselves the role and impact of farmer-managed irrigation systems This personnel then became the champions of the process;
- **lack of knowledge by professionals:** of possible choices for technical as well as other modernization measures can be a significant constraint to modernization. The respective advantages and disadvantages of a modernization initiative and the ability to fit site specific contexts might not be adequately understood by policy makers and/or irrigation agency personnel;
- **competing demands for finance from other sectors:** irrigation has to compete with other sectors (roads, health, education) for government funds. Government is constrained by the funds available and has to make strategic choices on where to invest. Well prioritized irrigation modernization strategies are necessary to ensure that the higher costs of modernization interventions will bring higher benefits and investment returns. Modernization programmes should be well embedded in the national socio-development context, contributing to its most important priorities and agendas.

Chapter 5
A framework for modernization

This chapter looks at establishing a framework for modernization of the I&D sector and I&D schemes in Central Asia. It first provides a definition of modernization and then describes the approach to modernization as a performance-based management process. The components that make up a modernization programme or project are identified and categorized into five action areas. Finally, some initial steps in the process are also laid out.

DEFINITION OF MODERNIZATION

The concept of modernization has evolved over the last two decades and no longer focusses only on the introduction of updated infrastructural hardware and techniques. According to the definition by FAO:

> As opposed to mere rehabilitation, the concept of modernization applies technical, institutional, and managerial upgrading of irrigation schemes in order to improve resource utilization (water, land, environment, labour) and water delivery service to farmers.[10]

These characteristics of modernization are resumed in a more recent definition provided by the ADB in Box 5.1.

In addition to improvements in the physical infrastructure, changes will be required for the institutional and legal systems in relation to water rights, delivery services, accountability mechanisms and incentives (Renault, 1998). Modernization can be seen as a way of analysing the irrigation sector and scheme performance in a holistic manner, in order to identify forward looking transformational responses and change.

10 Quote taken from FAO regional consultation on modernization, Bangkok, 1996.

Box 5.1
Definition of modernization

Modernization is:

"The process of upgrading infrastructure, operations and management of irrigation systems to sustain the water delivery service requirements of farmers and optimize production and water productivity."

This is further clarified as:

- process: means that the modernization of systems is a continuous exercise. This must account for future changes in the irrigation system and service requirements of the farmers. Ideally the process will align with existing government development and budgetary timeframes and systems;
- upgrading: means improving what is existing – not replacing or rehabilitating;
- It means applying design best practices to infrastructure to optimize operation requirements and maximize system performance and efficiencies.
- infrastructure: means all physical assets related to the irrigation system including headworks, conveyance systems, drainage systems, monitoring systems, communication systems, farm and access road networks, and operation buildings;
- operations and management: means all human resources and management processes responsible for managing, operating and maintaining the irrigation system including ground and surface water management, and the associated physical infrastructure;
- irrigation system: encapsulates all physical and non-physical components that contribute to convert water and nutrients into food and fiber. This includes the infrastructure, water resources, agency staff, farmers, services providers, supply and market chains;
- sustain: means that the irrigation system will continue to operate with its optimal performance. This includes managing the water resources to account for reallocations to other users, preventing adverse depletion, and enhancing resilience to climate variability and adverse impacts anticipated from climate change. It also means ensuring that all costs relating to management, operation, maintenance, and asset depreciation of the system are affordable and are fully covered through either government, user (farmer), or private sector financing;
- water delivery service requirements of the farmers: means ensuring reliable, adequate and flexible supply of water as agreed with farmers allowing them to maximize water and agricultural productivity. This requires farmers to be involved in the planning, design and operation of the irrigation system, and in routine water management decisions;
- to maximize production and water productivity: means farmers must endeavor and be supported through technology transfer and extension services, to optimize the productivity of their land with the available water.

Source: ADB, 2015.

Box 5.2
Objectives of irrigation modernization in Central Asia

- Increase the productivity of the irrigation sector to match growing demands, both from the wider society in terms of food production and exports but also farming communities for improved livelihoods.
- Ensure greater irrigation efficiency and productivity of water in the context of growing water scarcity.
- Deliver cost-effective and reliable irrigation services matching the changing demands of farmers.
- More closely match irrigation water supply to demands to reduce wastage of water, thereby reducing pumping costs and areas suffering from waterlogging and salinization.
- Contribute to the national development objectives of climate resilient economic growth, food security, and poverty reduction (the priority order may vary by country).

Source: Authors' own elaboration.

OBJECTIVES OF MODERNIZATION

The ultimate objective of scheme modernization is to provide farmers with a sustainable, efficient, and demand-responsive water delivery service, while also considering agricultural, social, and institutional requirements when designing irrigation modernization interventions (Box 5.2). In designing modernization interventions, integrated rather than single solution approaches are needed that incorporate physical improvements to the delivery system, together with economic, institutional, and agronomic improvements. Importantly, modernization of the government-farmer relationship from a culture of top-down, supply-orientated management to bottom-up, demand-driven, service-orientated culture will be required. In addition, it will be necessary to support farmers in the development of entrepreneurial capabilities and independence. Modernization of policies towards greater farmer liberalization from too much government control would also be an important element of this sector. In all cases the design of modernization interventions should be scheme and context specific and tailored to the given national and local situations.

This modernized service delivery will better match the changing demands of farmers and ensure higher irrigation efficiency and productivity in response to the growing water scarcity. Better service delivery will also contribute to the national development objectives of economic growth, food security, poverty reduction and climate resilience (Box 5.3).

IDENTIFYING COMPONENTS OF A MODERNIZATION PROGRAMME

As discussed in the previous chapters, there are a variety of issues in the I&D sector covering a wide range of domains – engineering, agricultural institutional, political, economic and financial. Modernization of the sector requires a holistic approach encompassing all these domains (Figure 5.1).

The concepts and activities described in Figure 5.1 and the issues raised in previous sections can be grouped into five action areas (Table 5.1). Action Areas 1–4 can be considered as the four core areas, while Action Area 5 – 'Building Knowledge and Information Systems for Growth' – can be seen as involving cross-cutting activities supporting the other four action areas.

Box 5.3
Efficiency objectives and typical interventions

In Central Asia, irrigation is the largest water user, yet at a time of increasing water scarcity there is low water use efficiency and productivity in this sector. To achieve the objectives of increasing irrigation efficiency and productivity, possible relevant modernization interventions include:

- increasing water use efficiency: (i) infrastructure investments in gates and control structures, lining of canals, construction of interceptor canals and reservoirs; (ii) modern information and control systems; and (iii) management improvements such as rotational delivery schedules;
- improving water productivity: (i) improved irrigation technology and on-farm water management; (ii) crop intensification and diversification and improvements in crop husbandry; (iii) moving towards higher value crops/increased value addition at farm level; and (iv) improved market access and value chain linkages. This should be accompanied by improvements in farming practices and along the value chain.

All the above modernization packages should include interventions targeted at achieving improved system performance, service-oriented management and financial self-sufficiency. This can include: (i) investing in institutional change in irrigation management agencies; (ii) promoting water user participation in modernization implementation, cost sharing and system management; (iii) capacity building at all levels for all stakeholders; and (iv) exploring the engagement of the private sector in different aspects of the schemes development and management.

Source: FAO, 2017a.

IRRIGATION MODERNIZATION

Modernization means systemic changes

- Modernization is to provide farmers with a sustainable, efficient and demand-responsive water delivery service. Actual modernization interventions need to be tailored to each irrigation schemes with different climatic and physical settings, and cropping and farming practices.
- When designing irrigation modernization interventions, agricultural, social and institutional requirements need to be taken into account.

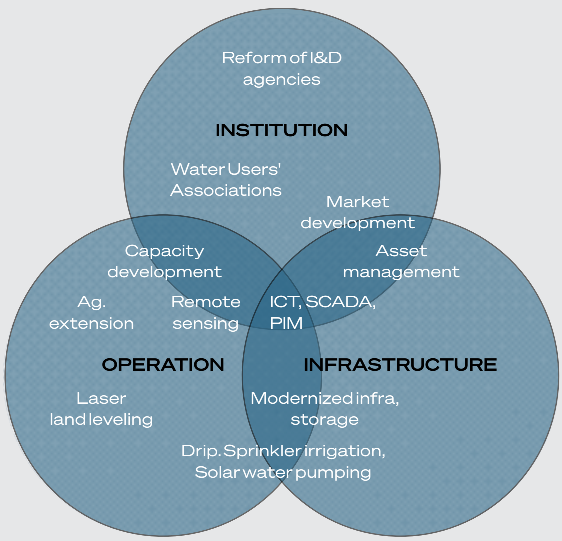

Figure 5.1
Domains of irrigation modernization

Source: World Bank, 2019a.

Table 5.1
Action Areas for irrigation and drainage sector modernization

ACTION AREA 1 Policy development and legislation to frame the modernization process	ACTION AREA 2 Institutional reform to structure management of the process	ACTION AREA 3 System modernization for improved service delivery	ACTION AREA 4 Strengthening agriculture services and practices for enhanced production	ACTION AREA 5 Building knowledge and information systems for growth
National level	National and scheme level	National and schemelLevel	National and scheme level	National, basin and scheme level
Action will be required at the highest level through policy formulation and legislation to frame and enable change at lower levels	Institutional reform will be required to change the way that organizations do business, particularly in relation to service delivery to water users. This reform will require significant inputs to raise awareness and understanding, as we as building knowledge and skills	Changes made in Action Areas 1&2 will be put into operation in Action Area 3. The focus will be on performance-based management and service delivery to water users to improve efficiency and productivity	The purpose of irrigation is to make agriculture more secure and improve crop production. Water is one, albeit important, input. Measures need to be taken to improve the utilization of all inputs (seed, water, fertilizer, labour) to increase agricultural production. Improving farmers' knowledge and skills will be a key part of the process	Management and decision-making rely on reliable, timely and accurate data. Modern computer-based data collection, processing and analysis tools offer significant opportunities for improving the performance of I&D schemes, ranging from MIS and DSS systems for system MOM to mobile phone apps informing farmers irrigation scheduling, pest identification and (best) market prices

MODERNIZATION PROCESS

The final part of the modernization framework is to identify the key steps for identifying and implementing changes. The following steps are some of the key parts of the process:

i. preparation of a plan and strategy for modernization. To have a coherent and effective approach to modernization it will be necessary for each country to identify its particular objectives for the sector and prepare a short-, medium- and long-term plan to achieve them. Broad objectives for the modernization plan will presumably be to increase agricultural production, improve water use efficiency and productivity and increase farmer income. Preparation of the modernization plan will presumably identify areas where additional study is required, for example on approaches for assessing the cost-benefit of different modernization approaches (e.g. conversion of schemes to sprinkler or drip irrigation versus modernization of surface irrigation methods), classification of schemes in terms of suitability for modernization, and cost-effectiveness of measures for reducing costs on pumped irrigation schemes;

ii. establishing a programme of benchmarking, performance assessment and performance-based management. The purpose of modernization is to improve performance. In order to establish a comprehensive modernization programme it will be necessary to implement a benchmarking programme to assess the performance of I&D schemes, and identify gaps in the performance and measures through modernization to close these gaps. To accomplish this, a standardized performance assessment approach, possibly based on FAO's MASSCOTE approach, needs to be developed. The introduction of performance-based management will require the development of appropriate performance indicators and mechanisms to hold scheme managers accountable for water delivery and where appropriate, scheme output. Measures to improve scheme output will likely require managers to work with WUAs and farmers, and agricultural agencies. Annex VI outlines details of a performance-based management process;

iii. promotion and implementation of service delivery contracts. Service delivery contracts can play an important role in improving the level of service provided to water users and the collection of irrigation service fees, both factors that contribute to improvement in scheme performance;

iv. formation and support of Water Users Associations. In the right circumstances, formation and support of WUAs can have a marked and beneficial impact on the performance of I&D schemes. WUAs can share the MOM load with the government I&D agency and can act as a valuable link between the government agency and water users. Formation and support of WUAs is not a short-term initiative, and will require funding and support over several years, as in Kyrgyzstan. However, if successful it will prove to be cost-effective and beneficial;

v. development and adoption of asset management planning. Asset management planning can be used to identify the costs and benefits of modernization of I&D schemes. The results can be used to rank I&D schemes by different metrics of cost, benefits, cost-effectiveness, sustainability, and running costs for inclusion in the modernization programme. As part of the AMP, engineering studies can be carried out to determine the actual cost of maintaining and repairing I&D infrastructure, thereby determining the level of funding required for sustaining the infrastructure over time. This information can be used to demonstrate to government, and in particular to the Ministry of Finance, the realistic levels of MOM expenditure required to sustain I&D schemes. The studies can also quantify the financial and economic cost of not providing adequate funds for MOM;

vi. promote adaptive research and development of smart irrigation technologies. Support needs to be provided to universities and research institutes to develop, test and where merited promote modern technologies for wider uptake. Some technologies will be country-specific but most of them will be applicable in the region. Regional collaboration between universities and research institutes needs to be refined and strengthened;

vii. identify mechanisms for providing agricultural extension and advisory services. The deficit in agricultural extension and advisory services in the region is a matter of considerable concern as it is fundamental to enabling farmers to improve their irrigation and agronomic practices to improve agricultural production;

viii. identifying and strengthening relevant information systems. There are significant opportunities for reducing costs and improving data and information collection, processing and analysis using modern applications. Remote sensing, GIS, computer-based MIS, short message service (SMS), Apps, as well as other applications have dramatically altered the way in which data are collected and used. Organizations can be supported to develop the capability of the use and application of these techniques, together with providing the hardware and software to apply them country-wide;

ix. modernization of education and training in the I&D sector. To ensure sustainability a basic feature of the modernization process is that it is initiated and driven by national professionals. This will mean that the younger generation of professionals need to be aware of modern processes and practices. Support is required for funding, and technical assistance to subsidize the modernization of I&D education and training in universities, research and training institutes. These organizations can be twinned effectively with similar organizations in other countries to provide knowledge exchange and development of education and training materials;

x. strengthening of computer modelling. Universities, research institutes and I&D agencies would benefit from developing their capability in the use of computer models. Some of the areas where this is important are: (i) water resource management (e.g. the Mike11 and HEC models); (ii) flood management; (iii) crop consumptive use (e.g. the CalPoly METRIC model); (iv) surface irrigation modelling (e.g. BASCAD, WinSRFR); (v) and irrigation scheduling (e.g. CROPWAT). Support is required to identify the modelling needs and the purchase and training in the use of appropriate models;

xi. maintaining and strengthening regional collaboration. Regional cooperation in relation to water resources planning and management is essential to all countries in the region. To this end, the existing structures for regional collaboration need to be maintained and strengthened. Technical and financial support are required to support collaborative engagement and cooperation between all countries in the region. As many of the issues identified in this report are generic to all countries in Central Asia, joint study tours, training and collaborative research and development can be used to strengthen ties between countries.



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Chapter 6
Implementing irrigation modernization in Central Asia: key actions and activities

This chapter outlines a range of actions that can be taken to modernize the I&D sector and I&D schemes in Central Asia. Table 6.1 summarizes the possible components of a modernization programme for the I&D sector, which contribute to the overall objectives of a modernization programme. These components relate to issues to be addressed and their associated activities for resolution, as discussed in the following sections.

Action Area 1

POLICY AND LEGISLATION

Modernization of the I&D sector and the way I&D schemes are managed, operated, and maintained will presumably require changes in policy and legislation. An example of this is the WUA and WCA formation and establishment, which requires tailor-made legislation. Efforts to form single function water users' associations using existing legislation such as this, for forming cooperative associations have not proved to be successful.

A further area where legislation may be required is in revision of the Water Code. There are several examples in the region of revision of the Water Code. In the Kyrgyz Republic, Tajikistan and Kazakhstan changes were made to the structure of the Department of Water Resources to provide some separation between management of water resources and management of I&D systems. Separation of the I&D agency from water resources management is recommended to promote more objective and holistic water resources planning and management. This separation requires changes in policy, legislation, and institutional structures.

This is not always an easy process but it will be required in the case where the upcoming challenges with water resource planning, management and allocation are to be addressed. In the Kyrgyz Republic separation of the two processes was proposed under the Water Management Improvement Project (WMIP). Although full separation was not achieved the approach was followed through under the follow-on project where a clearer boundary was drawn between the two. Under the Water Sector Reform (WSR) Programme in Tajikistan the

Ministry of Land Reclamation and Water Resources has been abolished and the Ministry of Energy and Water Resources (MEWR) created with a separate Agency for Land Reclamation and Irrigation (ALRI) established for managing I&D schemes. In Kazakhstan, reforms include the reorganization of a number of water-related state enterprises into joint stock companies and the establishment of other agencies for analysis and supervision of water-related activities. Further examples of policy changes in the region are shown in Box 6.1.

Table 6.1
Possible components of a modernization programme – issues and activities

OVERALL OBJECTIVES

- Increase the productivity of the irrigation sector to match growing demands, both from the wider society in terms of food production and exports but also farming communities for improved livelihoods.
- Ensure greater irrigation efficiency and productivity of water in the context of growing water scarcity.
- Deliver cost-effective and reliable irrigation services matching the changing demands of farmers.

ACTION AREA 1 Policy development and legislation to frame the modernization process	ACTION AREA 2 Institutional reform to structure management of the process	ACTION AREA 3 System modernization for improved service delivery	ACTION AREA 4 Strengthening agriculture services and practices for enhanced production	ACTION AREA 5 Building knowledge and information systems for growth
ISSUES	ISSUES	ISSUES	ISSUES	ISSUES
Water resources planning and management needs to be modernized and strengthened Land tenure needs to be updated (in some countries) Restrictions on cropping need to be lifted and market forces allowed to frame farmer decision-making Framework for PPP needs to be formulated	Water resources planning and management needs to be reformed and restructured The I&D agencies should be performance-based, service delivery focused organizations Water users need to have more say in scheme MOM	I&D systems need to be more responsive to users' needs I&D systems need to move towards on-demand irrigation Water use efficiency needs to be greatly improved, thereby contributing to an increase in the productivity of water Where feasible pumped irrigation schemes need to be converted to gravity fed	The range and quality of seeds needs to be improved Advice and information on crop selection and management needs to be strengthened Farmers' crop husbandry and irrigation practices need to be strengthened The number of storage facilities needs to be enhanced Improve crop marketing to incentivize farmers and add value	Real-time information systems are at the core of water resources planning and management Real-time information systems facilitate performance-based service delivery for farmers Knowledge and information systems form the foundation for increased knowledge, awareness and understanding by farmers Information systems are central to modern marketing of agricultural produce

Table 6.1
Possible components of a modernization programme – issues and activities (continued)

OVERALL OBJECTIVES

- Increase the productivity of the irrigation sector to match growing demands, both from the wider society in terms of food production and exports but also farming communities for improved livelihoods.
- Ensure greater irrigation efficiency and productivity of water in the context of growing water scarcity.
- Deliver cost-effective and reliable irrigation services matching the changing demands of farmers.

ACTION AREA 1 Policy development and legislation to frame the modernization process	ACTION AREA 2 Institutional reform to structure management of the process	ACTION AREA 3 System modernization for improved service delivery	ACTION AREA 4 Strengthening agriculture services and practices for enhanced production	ACTION AREA 5 Building knowledge and information systems for growth
KEY ACTIVITIES	KEY ACTIVITIES	KEY ACTIVITIES	KEY ACTIVITIES	KEY ACTIVITIES
Enact legislation for separating WRP&M from I&D Enact new Water Code Enact legislation for greater engagement of beneficiaries in I&D scheme MOM	Separate WRM from I&D. Establish separate agencies Prepare and maintain river basin plans. Implement updated Water Code Refurbish river monitoring networks Formulate and agree I&D service delivery agreements with water users Implement greater engagement by water users in I&D scheme MOM	Prepare national plan for modernization of I&D sector and individual schemes Identify priority schemes for modernization Identify schemes where phased cost-effective improvement is possible Formulate and implement asset management planning Formulate and implement benchmarking and performance-based management Where feasible, convert pump-fed schemes to gravity-fed Identify and close unviable I&D schemes and provide alternative sources of livelihood	Engage universities and research institutes in programmes for improving on-farm management practices Provide credit arrangements for modernization of water application Engage public-private partnerships in developing markets Develop market information and marketing apps for farmers Engage public-private partnerships in developing markets	Establish remote sensing unit for WRP&M, I&D and land use planning and management Develop MIS systems for planning and management in WR and I&D sectors Develop on-line education and training programmes for WRP&M and I&D practitioners and farmers Support modernization of education and teaching on WRP&M, I&D and agriculture in universities Engage private crop input providers in knowledge and information provision for farmers Continued and strengthened dialogue and regional level collaboration

Source: Authors' own elaboration.

Box 6.1
Trends in agricultural policies in Central Asia

Kazakhstan. The 2003 Land Code allows private ownership with full property rights, creating a legal basis for individualized farming and market-driven reforms. However, farmland use efficiency has remained low, and the movement of land from less to more efficient farmers has been slow. Different parts of the country require different kinds of irrigation support. In the north, large commercial farms produce grains and oilseeds using rain-fed technologies, while the livestock sector is being gradually developed and pastures require irrigation. Large farms receive the most farm support. In the south, many farmers have small landholdings, produce mainly horticulture products and depend on irrigation and drainage services. Farm support measures largely bypass them but recently more attention has been given to the needs of small farms, including programmes for raising their productivity, improving access to irrigation, and integrating them into agrifood value chains. The public funding of agricultural services has increased over time, gradually replacing direct farm subsidies.

Kyrgyz Republic. The Kyrgyz Republic was an early reformer in Central Asia and its development has benefited from private-sector-led growth, land reform, irrigation reform, development of rural financial markets, and privatization and liberalization of input and output markets and trade, and community-based approach to natural resources management. This resulted in rapid growth between 1996 and 2002. Since that time, growth has fluctuated and at times stagnated. Agriculture continues to face major production and marketing constraints, that is, insufficient access to reliable irrigation and low usage of quality seed amplified by a lack of professional agricultural advisory services. As a result, agricultural sector growth has been erratic since 2005. In order to become fully effective, fundamental reforms require the completion of a number of policy changes. This includes, for example, the elimination of distortions in the land market and better public expenditures on core programmes for driving agricultural innovation and knowledge systems (i.e. education, research, and advisory services). Another important area for public action is the provision of support to farmers for their integration into value chains, sanitary and phytosanitary measures, and market infrastructure.

Tajikistan. Since 2013, the Government of Tajikistan has intensified the implementation of reforms to liberalize agricultural farming, with new linkages between farm restructuring and irrigation investment and also increasing technical support for new family farms. Cropping patterns, no longer regulated as they once were by central government, have demonstrated a sharp rise in wheat production, with a reduction for all other crops including a reduced production of maize and potato. The agricultural sector reforms are accompanied by the ongoing water sector reforms focusing on the introduction of river basin management, better division of institutional functions (i.e. policy, regulatory, and operational) and the increased role of water users in water and irrigation management. In general, the execution of reforms is now underway and making slow but increasing progress. The lack of high-quality agricultural public programmes similar to that in Kyrgyz Republic lessens agricultural transformation.

Uzbekistan. The Government of Uzbekistan has launched many agricultural reforms since 2017, along with the overall economic liberalization. Significant progress has been made with liberalizing horticulture and livestock subsectors by removing major restrictions for their export and import. In 2020, the government abolished the state production and procurement of cotton, and in 2021 the state production and procurement targets will be phased out for wheat. All of these reforms have encouraged agricultural diversification, including the shift of cropland to production of horticulture products and the increase in horticulture exports. The Strategy for Agricultural Development 2020–2030 adopted in October 2019 provides an impetus for further reforms, including strengthening of farmland tenure security, increasing efficiency of agricultural markets, and enhancing the quality of agricultural public services. A vast majority of productive cropland is being irrigated, but irrigation services remain tailored to production of cotton and wheat, leaving many horticulture farmers without reliable irrigation water supply.

Source: Contribution of S. Zorya, World Bank staff, Tashkent.

Land tenure arrangements in some countries will require changes in policy and legislation if land tenure issues do not hinder the modernization process. Farmers with legal rights to their landholdings represents a key factor for incentivizing farmers. Associated with this is a need to change policies and legislation related to government control of cropping patterns. Furthermore, progress towards a more productive, market-driven farming economy cannot take place without reform in these key areas.

Policies and legislation may be required to enable public-private participation in the I&D sector. This is a fundamentally different model to previous public sector models and will require careful drafting to avoid some of the pitfalls experienced with PPP in some countries.[11] To date, three countries in the region (Kazakhstan, Uzbekistan, and Tajikistan) have enacted legislation to support PPP.

There are opportunities for private sector investments in the irrigation sector but due consideration needs to be given to a range of issues including: (i) the returns that a private investor can expect; (ii) the level of service delivery fees to be charged; (iii) farm profitability; (iv) the ability and willingness of farmers to pay the service fees; (v) the level of sharing of the costs between the private sector entity and government (e.g. who pays the costs of rehabilitation/ modernization, government or the private sector entity). Evidence shows that PPPs in irrigation are likely to succeed in a policy environment supporting high value and commercial agriculture, and where farming is profitable. Strong government commitments and considerable subsidy as well as government insurance of downside risks are important factors of success. A recent study for Tajikistan (World Bank, 2012) concluded that significant reforms[12] are required to increase the attractiveness of irrigation for private investment. In the absence of these reforms, it is unlikely that significant private resources can be mobilized for irrigation MOM or development.

Action Area 2

INSTITUTIONAL REFORM

As noted in the section on Action Area 1, Ian important starting point for modernizing the I&D sector is to separate I&D management from water resources planning and management. As the Central Asian economies develop they move away from an agricultural base to a broader economy based on industry, business, and services. Since 1990 the agricultural share of the GDP has decreased in all Central Asian countries from between 30–40 percent down to between 5 and 20 percent. In addition, in all countries except Turkmenistan where agricultural employment has risen to around 50 percent since independence, the share of agriculture in the labour force has also declined. Although agriculture will remain the largest consumer of the available water resources, it will have to increasingly

11 In the United Kingdom, for example, the repayments required for some PPP initiated capital projects are placing a heavy burden on local governments' annual budget, resulting in the need to cut other local services.

12 The proposed reforms included the revision of the Water Code in order to implement river basin integrated water resource management and to streamline the more than 50 laws governing water uses and protection. Other reforms included the extension of economic instruments for water service provision, the transfer of the management of on farm irrigation infrastructures to water users associations, the development of a formal system of electricity subsidy for irrigation purposes, a mechanism for recovering depreciation charges on irrigation infrastructure and amendments of the current legislation in order to streamline the use of PPPs in irrigation.

relinquish its share due to pressure from other more productive economic sectors, continuously requiring greater amounts of water for their activities. To facilitate this re-formation of the water sector, it will be necessary to form separate agencies for water resources planning and management (WRP&M) and irrigation and drainage.

Once separate WRP&M agencies have been established, they should be engaged in a number of key tasks, all within an integrated water resources management framework including rehabilitation of river flow monitoring systems and meteorological stations; preparation of river basin plans; implementation of a modernized Water Code; preparing inventories of water uses and users; issuing of water licences; and regulation and monitoring of abstractions.

The re-purposed I&D agencies should be reformed to focus on service delivery, performance and asset management. Service delivery agreements (Figure 6.1) can be prepared for all water users, which will include a licensing element. These agreements will state the terms and conditions for service provision, together with the obligations of both parties (the service provider and water user). Central to the agreement are the fees to be paid for service delivery. The service delivery agreements represent some of the first steps towards creating increased trust between the I&D agency and the water users; together with other measures they will hopefully enhance transparency and accountability, increase water users' ability and willingness to pay their service fees.

Asset management planning should form the basis for determining the funds required to properly maintain and sustain I&D systems (Burton, M.A., Kingdom W.D. and Welch J.W., 1996). Funds should be allocated from the ministries of finance to the I&D agencies based on the preparation of 20-year country-wide asset management plans (AMPs) for all viable schemes, with updated plans being prepared each 5 years. Allied to the AMPs will be engineering studies to establish the relationship between investment in maintenance and repair and economic and financial returns to this investment, as well as to establish the levels of ISF required to sustain the systems.

A further key step in the modernization process will be measured to increase the participation of water users in the management, operation, and maintenance of the I&D systems. The formation of water users' associations are one way to achieve this.[13] The process of increased participation will mean that farmers and their representatives are not only engaged in day-to-day activities with the I&D agency, but also in the preparation of AMPs and modernization plans for their systems. More engaged and informed water users tend to better maintain their I&D systems. They are also more likely to pay the irrigation (and/or drainage) service fee if they can see how the fee is determined.

Action Area 3

SYSTEM MODERNIZATION FOR IMPROVED SERVICE DELIVERY

Preparation of a NIMP for the modernization of their I&D systems. Although there is a common shared I&D history and experience in the region, there are noticeable differences in how each country wishes to develop its I&D sector. Some countries, such as Tajikistan and Uzbekistan, strongly rely on pumped irrigation, while other countries such as the Kyrgyz Republic predominantly have gravity-fed systems. Similarly, within each country there are differences in the types of I&D scheme due to climate, topography, and markets. The National Irrigation Sector Modernization Plan can group schemes into different categories and apply appropriate measures for, and degrees of, modernization. One key aspect of such

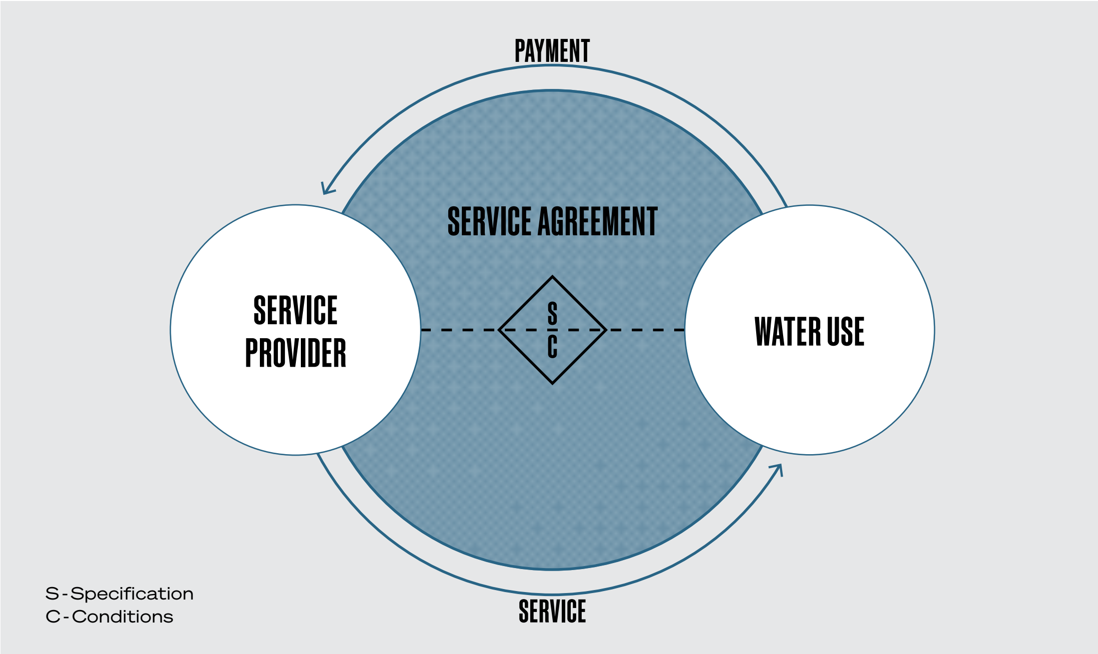


Figure 6.1
Core elements of service delivery

Source: Huppert & Urban, 1998.

a plan might be to identify unviable pumped I&D schemes and identify measures for closing these schemes and providing alternatives sources of income for those affected. The introduction of rural industry into the area might be a viable alternative. Schemes that cannot be closed due to social or political imperatives will require that the level of government subsidy be determined and mechanisms be devised for delivery of these subsidies.

The key to the modernization plan will be to identify the most cost-effective measures for each scheme (Box 6.2). This might be assessed individually for each scheme or assessed for types or groups of schemes. For example, providing sediment exclusion works could be a cost-effective solution for improving the performance of hill schemes, whereas in flat or flood plain land the focus could be on providing buried pipe systems as a way of reducing waterlogging and salinization losses caused by seepage from open channels. The modernization could be implemented in one step, or in a phased manner depending on circumstances.

It will be important to modernize the management and operation practices to optimize the benefits obtained from physical modernization of I&D systems. Management of the systems should be performance-based, with the setting of achievable targets, monitoring and evaluation of results and, where appropriate, rewarding staff for performance levels achieved. Such measures have proved to be highly cost-effective and have achieved significant improvements in performance.

Box 6.3 demonstrates the considerable improvement in irrigated areas that can be achieved with existing irrigation commands through performance-based

Box 6.2
Future possible modernization initiatives in Central Asia

A number of modernization initiatives are considered possible, including: (i) enhanced data collection and decision support systems for irrigation control and flow monitoring; (ii) greater use of buried uPVC/HDP pipes for water distribution; (iii) increased (balancing) storage in canal systems, particularly where canals supply pressure pipes; (iv) conjunctive use of canal and pumped groundwater; and (v) adoption of efficient field irrigation systems.

This investment is justified on the basis of: (i) energy and water use efficiency gains; (ii) reduced maintenance cost for buried pipe systems; (iii) the lowering costs of technological "smart" systems; (iv) efficiency and crop productivity gains that are possible from data informed operations meeting crop and farmer service demands; and (v) smart volumetric metering for irrigation service charging.

However, there are several bottlenecks to modernization including: the suitability/availability of national guidelines for modernization,[14] ability of (national) consultants to identify alternatives and design modern irrigation systems, conservative nature and ability of service providers/ institutions to manage modern hardware.

Source: Authors' own elaboration.

management innovation coupled with a modern management information system (MIS).

In all Central Asian countries, the cost of pumping is a central issue. Modernization in these circumstances can include a range of measures ranging from converting pumped schemes to gravity supply, to replacing and modernizing the pumps and/or improving the efficiency with which farmers use pumped water. Box 6.4 provides an example of the significant savings that can be made if the current inefficiency of pumped irrigation can be reduced.

Where waterlogging and salinization are an issue, modernization measures will focus on both reducing the cause (over-irrigation) and alleviating the problem (provision of drainage). Measures to reduce conveyance and application losses might include the installation of buried pipe networks, whilst measures to improve the application efficiency might include laser land levelling and planning, conversion of surface irrigation to sprinkler or drip, and/or education and training of farmers in efficient water application methods. A study in Australia (IWMI, 2015) that reviewed technology change in the irrigation industry found a large range in the actual irrigation application efficiencies for different irrigation methods:

- drip and micro-irrigation 75–95 percent;
- sprinkler 60–90 percent;
- surface 60–85 percent.

14 National irrigation modernization guideline(s) are needed to conceptually guide the potential modernization decisions, giving clarity to modernization objectives, presenting options and suggesting priorities. They are also required to rule out forms of modernization where suitability criteria are not met.

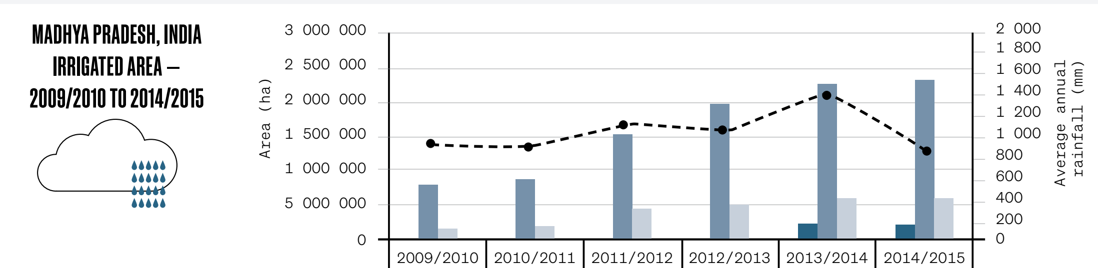
Box 6.3
Adoption of modern management practices in Madhya Pradesh, India

The irrigated area in Madhya Pradesh has increased threefold since 2010–11, largely due to dynamic leadership and the adoption of modern management methods. In 2009–10 and 2010–11 the rabi (dry season) irrigated areas were 803 ha, 488 ha and 890,226 ha respectively, by 2013–14 and 2014–5 the area had increased to 2.33 million ha and 2.39 million ha respectively, with the utilization efficiency of the irrigation commands increasing from 34 percent to 85 percent. Allied to the increase in irrigated area, food grain production rose from 1.4 million tonnes in 2010–11 to 37 million tonnes in 2015–16. Although there was higher rainfall during the 2011–2013 monsoons the very low rainfall in 2014 contributing to stored water for the 2014–15 rabi season demonstrated that the increase in the cropped area was not due to higher rainfall alone, but rather to modernized management interventions. An additional key factor was that the annual maintenance expenditure increased sevenfold from Rs 112/ha in 2009–10 to Rs 820/ha in 2015–16.

In 2010–11, under the direction of the new principal secretary of the Water Resources Department, and using modern information technology and communication systems installed by the World Bank funded MP Water Sector Restructuring Project (MPWSRP), modernized management procedures were adopted by the WRD. These measures included:

- Gate keepers sending daily reservoir water level gauge readings by SMS to the central web-based MIS where the depth readings are converted into stored volume based on reservoir specific depth volume curves.
- Based on these readings the senior management set reservoir-specific irrigated crop area targets for the coming rabi season at the end of the monsoon (mid-September). These figures are based on a rule of thumb figure of 1 million cubic metres being sufficient to irrigate 200 ha.
- Prior to the rabi irrigation season the district office staff inspect all systems and report back on repairs required and costs to ensure the system can function in the coming season. Senior management delegate authority for executive engineers (EEs) to execute the work they determine is required to achieve the required performance targets.
- Each week each EE enters the cumulative area irrigated on the MIS.
- Each week there is a video conference with the basin office chief engineers and superintending engineers, and the divisional EEs chaired by the principal secretary and engineer-in-chief to monitor and discuss the ongoing situation during the irrigation season.

At the end of the season the actual irrigated area is compared to the target area and deviations from the target values discussed during the video conference. Staff with well-performing schemes are rewarded with cash payments and certificates recognizing their contribution. Schemes where targets have not been met are discussed and causes identified, and where possible action taken to remedy identified causes.



	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015
MP Kharif	-	-	-	-	216.006	200.514
MP Rabi	803.488	890.226	1.559.61	2.020.66	2.330.43	2.392.03
MPWRSP Rabi	150.329	177.225	444.701	501.607	599.759	596.750
Average annual rainfall (mm)	960	916	1160	1092	1472	845

Source: Burton & Stoutjesdijk, 2017.

Box 6.4
Costs and benefits of reducing the inefficiency of pumped irrigation

A study conducted by the World Bank investigated the costs of irrigation inefficiency on pump schemes in Tajikistan. The study focused on the causes, costs, and solutions of low irrigation efficiency in Tajikistan's pumped irrigated agriculture. Six representative schemes were selected and the level of inefficiency, the costs of pumping and the costs of irrigation inefficiency determined.

The cost of pump irrigation to the country were found to be substantial. During the period 2005–13 the cumulative cost of pumping was USD 217.89 million or USD 95.54 per ha annually. This can be compared with an FAO estimate in 2011 of the income generated from one hectare of irrigated land of approximately USD 95. Cumulative paid and unpaid electricity costs and electricity subsidies from 2005–13 amounted to USD 139.48 million, or 69 percent of the total O&M costs. The cumulative cost of irrigation inefficiency at 72 percent was estimated at USD 100.43 million, which is USD 11.16 million/year on average or USD 44.11/ha annually.

As a result of the CASA-1000 power purchase agreement signed in 2016 between Afghanistan, the Kyrgyz Republic, Pakistan and Tajikistan, the excess summer energy from the Kyrgyz Republic and Tajikistan can be sold to Afghanistan and Pakistan. Accordingly, the opportunity cost of summer energy has risen, with exported energy being over 10 times the sum that the government of Tajikistan charge farmers for pumped irrigation water.

The study found that the current annual pumped irrigation cost to Tajikistan could be reduced by 62 percent from USD 31.09 million to USD 11.70 million, with earnings from power exports arising from improving irrigation efficiency accounting for some 57 percent of the cost reduction. In this scenario the cost of pumped irrigation would be reduced from USD 122.7/ha to USD 46.2/ha.

Source: World Bank, 2017.

Thus, the highest surface application efficiency (85 percent) was higher that the lowest sprinkler application efficiency (60 percent) and also higher than the lowest drip application efficiency (75 percent), which supports the argument that there is much to be gained by improving surface irrigation techniques. In some cases, education and training of farmers to change and improve their irrigation practices might be more cost-effective than physical interventions. Laser land levelling is a further beneficial and relatively low-cost activity that needs to be considered, with measurable improvements in application efficiencies and reduction in over-watering (Box 6.5).

There is a need to be careful how "saved" water is used. In some cases where water use efficiency gains are made the farmers may use the saved water to increase the irrigated area. Although this leads to an increase in production, it also results in increased ET and reduction of groundwater recharge. Where other farmers are pumping from groundwater the loss of this recharge fraction may impact on their water supplies and could result in a lowering of the groundwater table.

Box 6.5
Improving irrigation efficiency through land levelling

Land levelling can significantly improve the efficiency of water application and contribute to a reduction in water logging and salinization. Data from three separate studies identifies the range of opportunities that land levelling offers.

Land levelling for cotton production in Tajikistan. In this study conducted by the International Water Management Institute (IWMI) laser land levelled and non-level (control) plots were studied over three years (2004–2006). The results showed that laser land levelling reduced the water application rate for cotton by 593, 1 509 and 333 m^3/ha in each year compared to the non-levelled fields. These figures represent a reduction in water use of 8, 16 and 5 percent respectively from the control plot use. Deep percolation was on average 8 percent lower and runoff was 24 percent lower than the non-levelled field. The average annual income from the laser levelled field was 22 percent higher, whilst the gross margins were 16, 88 and 171 percent (average 99 percent) higher compared to the non-levelled field. Constraints on the application of technology were found to be the lack of initial capital for farmers and scattered plot locations.

Source: Abdullaev, I., Hassan, M. Ul and Jumaboev, K., 2007.

Precision land levelling in rice-wheat systems in north-western India. This study compared crop yield and total irrigation time required per season between laser levelled (LLL) and traditionally levelled (TLL) fields. Laser levelling in rice fields reduced irrigation time by 47–69 hours/ha per season and improved yield by approximately 7 percent as compared to traditionally levelled fields. For wheat, irrigation time was reduced by 10–12 hours/ha per season and yield increased by 7–9 percent in comparison of LLL with TLL. It was also found that laser land levelling was scale neutral (i.e. not biased towards large farmers). Overall, farmers benefitted by USD 143.5/ha annually through increased yields on rice-wheat (RW) systems. Importantly, electricity costs for pumping were reduced, saving up to USD 194/ha/year with a LLL field requiring 754 kWh/ha less than a TLL field. On a broader scale, in the case where 50 percent of the RW area in Haryana and Punjab were laser levelled, the additional production would be around 699 million kg of rice and 987 million kg of wheat, amounting to USD 385 million/year.

Source: Aryal, J.P., M.B. Mehotra, M.L. Jat and H.S. Sidhu, 2015.

Precision surface irrigation in Pakistan. WMI are supporting measures to increase the efficiency of surface irrigation through laser land grading, which demonstrate that application efficiencies of 80 percent can be achieved. Using computer modelling[15] fields are graded to match the predominant slope. The work is carried out using a simple tractor mounted grader with a receiver unit linked to a laser unit set up in the field. The land is graded and then furrows are formed, typically for cotton. The study found that land productivity (kg/ha) increased by 11 percent and water productivity increased by 12 percent. Actual field application and distribution uniformity were found to closely match with the computer modelling.

Source: IWMI, 2014.

15 WinSRFR, developed by the US Department of Agriculture.

Box 6.6
Capping ET to increase farmer incomes while reducing water withdrawals

Between 1970 and 2000 there was a rapid expansion of the irrigated land in Turpan Prefecture, China from 60 000 ha to 80 000 ha. To relieve the pressure on groundwater from this expansion and to conserve water, from 2000–2008 modern irrigation technologies were introduced, including drip and sprinkler irrigation. The anticipated water savings however did not materialize as farmers used the "saved" water to increase their irrigated area. The total area increased by 34 percent to 107 000 ha. The groundwater levels continued to decline by 1.5–2 meters per year. By 2008 groundwater in the basin was being over-exploited by 230 million m^3/year.

A policy decision was made to cap the water use by farmers by monitoring their crop water use using remote sensing technologies. This was achieved with five tasks:

Task 1: Conduct a water accounting assessment at the river basin level. From this exercise the available water resources, total water consumption and change in groundwater storage were determined.

Task 2: Determination of target water allocations. This process involved consultation with farmers and politicians to gain buy-in to the process of allocating water rights based on crop ET to WUAs. This water right was backed by a signed agreement between the government and each WUA.

Task 3: Revising the cropping pattern to fit within the allocated water right. Consultations were held with farmers and WUAs on: (i) changing of cropping patterns to higher value crops; (ii) checking that there were markets for the crops; (iii) checking the irrigable area within each WUA boundary; (iv) preparing a land use map within the WUA command; (v) checking that the revised cropping pattern ET is less than the target ET.

Task 4: Use remote sensing to monitor the actual ET. A Knowledge Management System was established to convert the target ET for each WUA into a water withdrawal target and then to monitor the actual water use by measuring the actual ET over the WUA command.

Task 5: Charge for over-use of water and take measures to bring the actual ET consumed within the target ET value. At the end of the season the actual ET is compared with the target ET. If the actual ET is the same or less than the target ET, the WUA (and thus farmers) pay the water charges only. If the actual ET is greater than the target ET, an additional charge is made. In this case, WUAs and farmers are provided with support to advise them on measures to reduce the actual ET yet still increase their income.

As a result of these measures the agricultural production was sustained while the groundwater situation and downstream environment was improved due to the (real) water savings made at farm level.

Source: Authors' own elaboration.

Box 6.7

The potential of managed aquifer recharge in the upstream of Fergana Valley, Uzbekistan

Climate change and the growing demand for food and energy increase the competition for water between upstream and downstream users in the Syr Darya River Basin. The change in the upstream reservoir operation from a conjunctive irrigation/hydropower mode to exclusively hydropower generation resulted in reducing the river flow downstream in the summer and increasing it in the winter. This phenomenon caused a downstream water shortage of 2000–3000 Mm^3/year in the summer and an excessive, often unutilized, flow of the same magnitude in the winter. A study conducted by IWMI examined the alternative approach of managed aquifer recharge (MAR) in the upstream of Fergana Valley with a view to adapt to new water management reality. The regional assessment shows that over 500 000 ha, or 55 percent of the currently irrigated land in the Fergana Valley, can be shifted from canal irrigation to conjunctive surface water-groundwater irrigation. This will reduce the return flow to the river by 30 percent (or by 1000 Mm^3/year), and form free storages of 500 Mm^3 in the command areas of main canals. Pilot-scale studies for Isfara and Sokh aquifers in the Fergana Valley support the results of the regional assessment. Overall, groundwater development for irrigation and MAR in the Fergana Valley is expected to reduce the winter flow of the Syrdarya River at the valley outlet by 1500 Mm^3/year, and consequently increase its summer flow by the same magnitude. The study proposes a major shift in the focus of development projects in the Fergana Valley, from rehabilitation of dense drainage systems to groundwater development for irrigation and MAR.

Source: IWMI, 2013. Karimov, A. *et al.*

This situation occurred in the Turpan Prefecture, China, where innovative measures were taken to address these issues (Box 6.6).

Conjunctive use of surface and groundwater resources may gain significance in some areas of Central Asia under the growing water scarcity. While some locations in Central Asia suffer from waterlogging, other locations might prove suitable for groundwater recharge (Box 6.7). Groundwater recharge could be developed as part of an overall basin-level integrated water resources management plan. On existing large scale irrigation schemes where applicable such as, for example, in the Ferghana Valley in Uzbekistan (World Bank, 2017b), conjunctive use should be part of the overall modernization programme to include changes required in the hydraulic structures, and system operations to accommodate the new water use configuration.

Pressure pipe water distribution. Reducing the agricultural land taken up by physical infrastructure using buried pipes instead of open channels at the on-farm level can have several additional benefits, including improved control and discharge measurement, and reduced conveyance losses and improved flow travel times (Box 6.8). In the case where there is available head due to the topography, low pressure gravity pipelines should be considered. In these types of circumstances there is further benefit from reducing the need for the drop structures required in open channels. In flat lands, buried pipe systems will need to be pressurized by pumps. This is an option where the additional costs of pumping are adequately compensated by the value of the crops grown and maintenance and periodic renewal of the pumps and motors is assured. In some cases, the buried pipe system may also require a storage reservoir from which to pump the required daily discharge.

Box 6.8

Pressurized pipe pilot studies in Kazakhstan

For canal systems in poor condition the choice is whether to retain, rehabilitate and possibly line existing canals, or switch to buried pressurized pipe systems for at least part of the system. Adoption of buried pipes may be justified for the following reasons:

- lower capital cost for small flows and HDP/uPVC pipe diameters < +350m. For large flows and diameters > +600mm canals will be cheaper. Provision of storage and/or back up groundwater supply may significantly increase costs;
- low maintenance costs and a longer service life than (lined) canals;
- higher efficiencies with lower conveyance and operational losses than canals;
- improved farmer service with water provided by hydrants, with farmers usually able to draw water on demand (within limits);
- accurate volumetric discharge measurement and transparent water charging become possible.

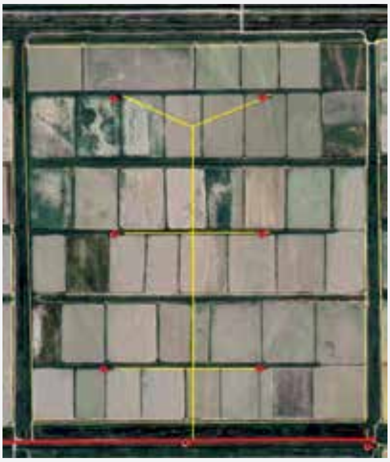
Under the FAO Stocktaking Study (FAO, 2019) outline designs for buried pipe pilots were prepared for three pilot schemes:

I. **Makhtaral Scheme:** Three medium (300–400 ha) closed pump-pipe systems taking off from a storage tank in the tail of the K18 secondary canal to supply 1090 ha has been proposed, costing about USD 2.6 million (USD 2400/ha). This system could be adopted for drip/ sprinkler if desired with filtration to prevent emitter clogging, but is proposed initially for furrow irrigation with hydrant-hose (hydro-flume) connections.

Concept for three pump-buried pipe systems covering 1090 ha pumping from a reservoir (tank) in tail of Secondary Canal, K18, Makhtaral Scheme

II. **Kyzylkum Scheme:** Several small (90–100 ha) closed pump-pipe systems along secondary canal 4R2 have been proposed, particularly at the tail end of the secondary canal, where a storage tank would be provided from which water would be pumped into the pipe systems. Pipe hydrants would provide water under sufficient pressure for furrow irrigation with hydrant-hose (hydro-flume) connections. The cost would amount to about USD 1200/ha, equalling a cost for each (100 ha) system of about USD 120 000.

Box 6.8
Pressurized pipe pilot studies in Kazakhstan (continued)



Concept for pump-buried pipe systems, each 90–100 ha, pumping from Secondary canal 4R2, Kzylkum Scheme

III. **Big Almaty Canal (BAC) Scheme:** One large (400–800 ha) gravity pipe distribution system with low pressure hydrants for hose (hydro-flume) connections, or discharging directly into field channels for furrow and/or basin irrigation. A ring and branch combination pipe system has been proposed. Including for various fittings and flow meter(s) the cost is likely to be about USD 1900/ha.

Concept for pump-buried pipe systems, each 90–100 ha, pumping from Secondary canal 4R2, Kzylkum Scheme

Adoption of pressure pipes for the BAC scheme is particularly attractive, as pumping is not required due to the quite steep (1.2 percent to 1.8 percent) slopes from the main canal and into the command area. As large pipes are costly compared to open channels, each pipe system would not be more than 800 ha in size.

A detailed proposal on piloting pressure pipe systems in the three schemes under IDIP-II project was formulated in this study's background paper "Irrigation modernization pilots under IDIP-2" (FAO/World Bank, 2018).

Source: Authors' own elaboration.

STRENGTHENING AGRICULTURE

To obtain maximum leverage from returns to modernization of the physical system farmers' agricultural practices need to be modernized. Following independence and the breaking up of the large state and collective farms into smallholdings, relatively few "new" farmers have received training or extension advice on crop husbandry and irrigated farming practices.[16] The agricultural advisory services and practices that existed in the Soviet period were set up for state and collective farming and not easily adaptable to smallholder farming. The lack of agricultural extension advice and training may be a key factor in the generally low levels of production, water use efficiency and water productivity.

The starting point for modernizing agricultural extension and training is found in the universities, technical and vocational education and training centres (TVETs) and research establishments. The understanding and knowledge of staff in these institutions needs to be modernized. This can be achieved through study tours and work assignments to respected establishments in other countries, and also twinning with international establishments and exchange of personnel. As part of this process university courses and curricula can be modernized incorporating international knowledge and experience.

Research establishments would benefit from strengthening and the adoption of modern approaches to research, including greater use of adaptive research. Research programmes should be developed to address issues faced by farmers and processes implemented to ensure robust research-education-extension-farmer linkages.

To transfer knowledge to farmers in the field there is a need for a well-articulated agricultural and extension strategy and implementation programme. Over the years a number of programmes have been created to strengthen these services in different countries (e.g. the Training and Visit (T&V) programme in India); some have been successful whereas others less so. Opportunities exist in Central Asia not only to build on these experiences but also to adopt modern ICT and to engage with the private sector of agricultural input suppliers, marketing organizations, machinery and equipment suppliers. Various apps are now available in many countries for the provision of advice and training to farmers that can be adapted to the conditions in Central Asian countries. IWMI's report on agricultural extension in Kyrgyzstan, Tajikistan and Uzbekistan (Kazbekov, J. and Qureshi A.S., 2011) provides useful guidance on opportunities as well as the measures that can be taken.

Precision agriculture is being used to reduce costs and increase the efficacy of in-field agricultural processes. It requires highly interconnected technologies, including remote sensing, GPS guidance systems, soil moisture sensors, and automated weather stations. A more recent innovation has been the development of systems for drones that can collect, process and analyse data closer to the farming unit. Such drone-based systems could be useful for irrigation agencies and WUAs alike to monitor cropping and water distribution.

16 Many of the smallholder farmers were not farmers before independence. They may have worked on the state or collective farms but in the capacity of a variety of jobs ranging from agricultural labourers to office workers. Although they may have been working in an agricultural setting, they were not necessarily involved in the day-to-day crop choice selection, crop husbandry and irrigation application practices, where they subsequently had to engage in as smallholder farmers (Kazbekov and Qureshi, 2011).

Box 6.9
The potential of adopting winter wheat varieties in Central Asia

Wheat, which accounts for 85 percent of all cereals in Central Asia is directly linked to food security in the region. However, substantial winter wheat production is regularly lost due to the effects of yellow rust disease common in the region. This is a problem that is expected to be further aggravated due to the predicted climate change conditions.

To address the problem, resistant varieties of winter wheat have been introduced into all countries in Central Asia. During 2016–2017, around 110 000 ha were planted with the resistant varieties of winter wheat, but the area could potentially be expanded to over 2 million ha in the region. This would reduce production costs by saving on fungicides and also help stabilize wheat production in the region, while protecting the environment and human health. Planned and accelerated seed multiplication and extensive farmer training are the necessary conditions for scaling up the plantation areas under the resistant winter wheat varieties. In Tajikistan, the adoption of three yellow rust resistant varieties by 4 000 small farmers have been achieved by establishing farmers' filed-based seed production and farmer-to-farmer distribution and sales. The objective is to reach at least 100 000 more farmers through an investment in training in: (i) seed production; (ii) small-scale seed processing equipment; (iii) farmers' fields- based seed production; and (iv) utilizing GO, NGO, CBO and farmers' organizations for distribution and marketing of the seeds.

Source: ICARDA, 2016.

Further areas for modernization include the provision of improved seed varieties and dressed seeds. This can either be a public or private sector activity or a mixture of each. Similarly, the provision of other inputs can be strengthened. Providing credit to farmers could be a key part of this process, which may require policy and legislative changes by the government. In the packages of credit of other countries, seed and key inputs have made significant contributions to improving agricultural production. Such measures may also be beneficial in that farmers are being encouraged to modify or adapt their cropping patterns (Box 6.9).

Controlled–environment agriculture includes water smart agriculture technologies that comprises horticulture production applying hydroponic systems that allow growing vegetables with significantly reduced water usage (80–95 percent), minimal land area and less inputs comparing to traditional farming. Hydroponics is used to grow tomatoes, cucumbers, peppers, leafy greens, and a variety of hers and crops. It generates employment opportunities with minimal land and water requirements (Box 6.10).

Marketing is another crucial area that will need to be addressed. Having good, reliable markets is a major driver for encouraging farmers to change their cropping and farming practices. Indeed, strengthening this sector may require changes in government policy and legislation, particularly if government seeks to encourage private sector engagement and provide security to farmers in the transaction process. Allied to this is the need to encourage the development of apps for provision of market information.

Box 6.10
Horticulture in Uzbekistan

Agriculture is an important source of income in Uzbekistan for the 4.7 million households that operate dehkan farms in rural and disproportionally poor communities. Horticulture was identified by the Government of Uzbekistan as an opportunity to reduce rural poverty among small farmers by increasing their farm productivity and incomes, thereby fostering greater and better rural jobs. Horticulture products are also grown in Uzbekistan on an additional 21 000 larger private farms as well.

Evidence suggests that growing fruit and vegetables is among one of the most profitable activities on both dehkan and private farms and, over the last ten years the incomes these activities have generated have comprised a growing share of the national GDP. Horticultural export earnings have also surged in recent years, growing from USD 373 million in 2006 to USD 1.16 billion in 2010. The horticulture subsector is supported by policies involved in research in agronomy and post-harvest technologies, private investment and efficient markets, and the good stewardship of natural resources.

Source: FAO, 2019.

Digital agriculture (also denominated ICT and/or E-agriculture) is a fast-growing technological area aiming at conceptualizing, designing, developing and applying innovative ways to use digital tools in the rural domain, with a primary focus on improving information and communication processes in agriculture. E-agriculture strategies are highly relevant in Central Asia and have strong potential to be further developed and widely implemented. However national strategies for e-agriculture should first adequately address the problem of a very low level of ICT and internet access in the countries. There are a few specific agriculture information portals in the region and also some mobile-phone and SMS based services for farmers, among other existing development projects in the field.

Climate resilient technologies. Weather forecasting is a crucial variable in light of adverse climate change impacts. Increasingly, accurate weather forecast services (medium and long-range forecast as well as snow cast) are being delivered through mobile networks to beneficiaries and/or are being associated with an agricultural extension package delivered through website or mobile phone. Hyperlocal weather advisories are a necessity to address the fast-changing weather patterns. Solar irrigation pumps are an emerging alternative to keeping costs of pumped irrigation affordable, while also minimizing its carbon footprint. Harnessing the innovation of solar irrigation pumping would require a nuanced approach to address specific objectives in each local context. The irrigation modernization process in the region can benefit from the wealth of research and pilot experiences carried out by national and international academic and research institutions (Annex V).

UPGRADING KNOWLEDGE AND INFORMATION

Modern ICTs are potentially one of the most powerful tools for modernizing the irrigated agriculture sector. A variety of technologies are available, including:

- **Remote sensing applications:** Remote sensing can be used for a range of activities, including water accounting, measuring crop type and area, crop evapotranspiration, water applications, and identifying areas of waterlogging and salinization. It has an application for water resources planning and management and in irrigation and drainage. If not already established, Central Asian governments would benefit from establishing a remote sensing centre with a remit to support water resources planning and management and I&D. It could be useful to establish such a centre in a university or for research.
- **Management Information Systems**: management information syMIS) are now standard practice in the MOM of I&D systems. Data can be sent by field staff via SMS or from automated systems in the field (e.g. weather stations, river and canal water level and flow recorders) to be automatically processed and presented to operators and managers.
- **Geographical Information Systems:** GIS are now an integral part of modern data collection, processing, analysis, and reporting procedures.
- **Smartphone applications (Apps):** smartphone applications are now widely used in the agriculture sector. These apps provide advice on a range of activities from crop selection to marketing. Furthermore, apps developed in other parts of the world can be adapted to suit the situation found in Central Asia. Several apps have been developed for use with drones fitted with cameras. This relatively low-cost technology provides significant opportunities in the I&D sector, ranging from remote canal inspections to identification of fertilizer needs on fields.

The development of online education and training programmes is a cost-effective way of upgrading knowledge for farmers and WRP&M and I&D professionals. These programmes can be developed with the assistance of university, training and research institutes as part of an external programme. Such programmes can be fee earning or subsidized by government or interested private sector organizations. Consideration should be given to supporting a regional institute to support the modernization programme and share knowledge and experience.

Digital Agriculture (DA) is an integral part of upgrading knowledge and information. DA includes data ecosystems to support the development and delivery of timely, targeted information and services to make farming, including irrigated agriculture profitable and sustainable while delivering safe nutritious and affordable food for all. It also helps to provide an overview of how digital technologies (DTs) are innovating food and farming systems today and digitalization, combined with the use of ICTs, can play a role in agricultural development.

The private sector can be engaged to assist in the provision of on-line advice, training, and information provision for farmers. A key role for the private sector in this context will be the extension and improvement of the internet and mobile phone communication network in rural areas. This will be an important area for public-private partnerships and external funding support.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Chapter 7
Tailoring modernization interventions

The previous sections have highlighted the many issues facing the irrigation and drainage sector in Central Asia. As outlined in these sections, each irrigation scheme is unique with different climatic and physical settings, cropping and farming practices.

In this context it is useful to consider a more nuanced approach to modernization applying different solutions to different situations. This introduces the concept of different levels of performance and different levels of intervention. Schemes that are in a low level of development may not be as suitable (or sustainable) for modernization as schemes at a higher level of performance. Furthermore less resources and effort are required to modernize a scheme that is already at a higher level of development. It then becomes important in the modernization process to categorize irrigation schemes and consider their potential for modernization, taking into account the costs and resources required to modernize, the benefits, as well as the likelihood of sustaining the changes brought about by the process.

Table 7.1 shows four possible levels of I&D scheme development. The table describes the physical status and the management, operation, and maintenance procedures contributing to the level of service provided and the potential production. As the level of technology and management increases, so too does the level of service and production. Simple uncontrolled flood irrigation systems transition through manually operated supply driven to automated on-demand systems where levels of service are optimum. It is feasible to expect that in a given scheme different technologies or management will occur at different levels. The main system may be operated at Level 2 whereas the on-farm system functions at Level 1. In this case the output (production) could still be at Level 1.

The acknowledgement of the different conditions and performance of I&D schemes leads to the need to tailor the modernization process according to the existing conditions. Some schemes in a country could be suitable for the introduction of high-tech operating systems, others might not. Recognizing this fact is key, after which schemes can be categorized according to their assessed condition, capability for modernization and likelihood of sustainability for the modernization process. Schemes not necessarily qualified for modernization should not be neglected, however, they might well benefit from investment in addressing specific issues arising from deferred maintenance (such as the repair/replacement of pumps, or repairs to the main canal system).

The conducted Rapid Appraisal Procedure (RAP) evaluations and results displayed in Table 7.1 illustrate the difficulty with selecting a one-size-fits all modernization strategy. The process is complex, and the issues must be dealt with at different levels (national, basin, off-farm, on-farm, field level, etc.). Moreover, it is difficult to assess the degree to which measures taken at different levels have an impact on the final outcomes (crop production, water use efficiency

Table 7.1
Possible categorization of I&D schemes and their level of performance

Level	Off/ on-farm	Physical	Management	Operation	Maintenance	Level of service	Production
1	Off	Open channel (unlined) Simple control structures No measurement	Low input No seasonal plans No service delivery contract Low fee collection Manual billing	Manual Simple rules Limited scheduling	Limited work done Manual vegetation and silt removal	Low	Low yields Low production Low cropping intensity Top-tail inequity
	On	Open channel (unlined) Ungated control structures No formal turnouts	Low input No seasonal plans Farmers organize water distribution Limited WUA involvement	Limited, farmers organize amongst themselves	Limited work done Manual vegetation and silt removal		
2	Off	Open channel (unlined) Simple control structures No measurement	Moderate input Seasonal plans No service delivery contract Mod. fee collection Manual billing	Manual More complex rules Scheduling based on norms	Work organized and done manually	Moderate	Moderate yields Moderate production Moderate cropping intensity Some top-tail inequity
	On	Open channel (unlined) Some control structures	Moderate input Seasonal plans WUA organizes water distribution WUA service fee charged	WUA field oversee water distribution	Work organized by WUA and done manually		
3	Off	Open channel (lined) Good control structures Measuring structures	High input Seasonal plans Service delivery contract High fee collection Manual billing	SCADA system ET-based scheduling Monitoring of supply vs demand	Maintenance scheduled and done Machinery and equipment used Contractors may be used	High	High yields High production High cropping intensity Limited top-tail inequity
	On	Open channel (lined) Good control structures	WUA has O&M staff WUA charges a fee	WUA field staff oversee water distribution	Work organized by WUA and done with some machinery		

Table 7.1

Possible categorization of I&D schemes and their level of performance (continued)

Level	Off/ On-farm	Physical	Management	Operation	Maintenance	Level of service	Production
4	Off	Piped system Automated control Flow meters	Highly technical input Seasonal plans submitted on-line On-demand irrigation Automated billing	Automated system Centralized control	Limited but expensive and high tech when it's needed Need reserve of spare parts Need good technical support	Optimum	Optimum yields' Optimum production High cropping intensity No inequity
	On	Piped distribution systems Full farmer-controlled turnouts with measurement	Low management input	Limited due to pressurized on-demand system	Very little required until pipes need replacement or are damaged		

Source: Authors' own elaboration.

and productivity, social equity, etc.). In this context, Table 7.2 provides some guidance on prioritizing scheme modernization activities in the case where not all components can be addressed simultaneously. This can occur, for example, where modernization of irrigation schemes is being carried out over a period of several years.

Table 7.2 is an evolution of the understanding of irrigation management, which began in the 1970s and 80s when researchers from a variety of organizations, including Colorado State University and Cornell University in the United States, and international organizations such as the International Rice Research Institute, started looking at the performance of I&D schemes. The importance of main system management was highlighted by several researchers, as being a key factor in farmers' management and the use of water at the tertiary unit and field level. Where main system supplies were found to be reliable, timely, and adequate, performance at the tertiary unit level was likely to be higher than where supplies from the main system were unreliable, untimely and inadequate.[17] In Table 7.2, having secured a reliable, timely, adequate, and equitable supply from the main system farmers and WUAs can focus on improving distribution at the on-farm level. Once supplies to the field can be trusted and relied upon, farmers can then start to plan ahead and consider investment in better seeds, fertilizer and pesticides, and/or alternative crop varieties which require a more reliable water supply regime. At this time reliable and trustworthy information, training and extension services will be required by farmers. Commensurate with the improvements in the agronomic practices and improved production,[18] improvements will be required for crop storage, transportation, and marketing. Moreover, improvements at the river basin level, including discharge measurement and flow prediction can further add to the reliability and trustworthiness of water supplies to the scheme and on down to the field level.

Table 7.3 provides a more detailed assessment of possible measures to modernize and upgrade I&D schemes incorporating many of the proposed measures outlined in previous chapters.

17 See Chambers. 1988. Main systems management: the central gap. Chapter 6.

18 Not only in terms of yields but also quality of produce. The quality and uniformity of potatoes, for example, is strongly correlated with the quality of the irrigation supply.

Table 7.2
Considerations in prioritizing modernization activities

Priority	Modernization component	Elements	Direct results	Desired outcomes
1	Get the main system functioning adequately in order to provide reliable, adequate and timely water supplies to the on-farm systems	Adequate supplies at intake Good control Measurement Adequate maintenance Good operation (scheduling)	Supplies to tertiary units are reliable, equitable, adequate and timely WUAs are prepared to collect the ISF	Higher water use efficiency and productivity Higher production
2	Next, focus on improving the water distribution at the on-farm level (includes WUA strengthening as this is central to good operation)	Lined channels Simple control structures Fixed outlets to fields Good operation by WUA (field staff essential)	Supplies to farmers' fields are reliable, equitable, adequate and timely Farmers trust the WUA on water management Farmers prepared to pay ISF	Higher water use efficiency and productivity Higher production
3	Next, focus on improving the agronomic practices and in-field water management (this may run concurrently with Priority 2)	Farmer training Improving timings and depths of application Improved agronomic practices (crop selection, seeds, spacing, weeding, fertilizer use) Land levelling and planning Hanging irrigation methods (e.g. furrow to border strip, surface to drip)	More efficient and productive water use More efficient use of nutrients Higher yields and higher and more uniform quality produce	Higher water use efficiency and productivity Higher production
4	Next, focus on the supply chain and marketing	Crop storage Improved access to markets Market information	Better prices Greater income	Greater income to farmers Quality products available in the market
5	Next, focus on river basin management (this may be a higher priority if water is scarce)	Measurement of river flows Creation of an information system Management decisions on seasonal allocations to I&D schemes	Formalized procedures for water allocation in river. basins based on sound data	Allocation of water based on agreed policies and priorities Matching allocations to licences

Source: Authors' own elaboration.

Table 7.3
Possible components for modernization of an irrigation and drainage scheme

	Component	Description	Remarks
A. Field level			
(I)	Improve field application efficiency	*For furrows and/or border strip* Amend furrow irrigation layout on steep slopes. Options: align furrows across the slope; shorten the furrows; change to border strip irrigation Land levelling and land planning to get uniform field slope (for furrow or border strip) Carry out studies to determine correct flow rates and field dimensions, for scheme soil types on typical slopes. Combine with computer modelling studies (BASCAD) Use header ditches and siphon pipes Train farmers to auger and check the soil pre- and post-irrigation to determine: (i) when to irrigate and (ii) how much to apply (by checking wetted depth post-irrigation) Keep number of irrigations per season for all crops to a minimum by encouraging deep rooting (basic principle – wet entire root zone by applying large amounts less frequently) Other irrigation methods For relevant crops and conditions convert furrow to drip irrigation (high value vegetables, orchard crops) For relevant crops and conditions convert furrow or border strip to sprinkler irrigation (relatively high value crops on undulating land)	Significant water savings can be made by relatively simple improvements to surface irrigation methods. Well-managed surface irrigation can be as efficient as poorly performing drip or sprinkler irrigation Too frequent irrigation results in higher volume of losses during the season
(ii)	Improve agronomic practices	Use quality dressed seed Use line sowing; correct crop spacing Use organic fertilizer where livestock are kept Improve land preparation, soil tillage, tilth creation	
(iii)	Capacity building of farmers	Improve understanding, knowledge and skills of farmers through training (Farmer Field Schools) Support adoption of innovations through lead farmers Develop distance learning apps for mobile phones or internet use	Given the generally low level of extension services since Independence the economic returns to farmer capacity building are considered to be high
B. On-farm level (managed by Water Users Associations)			
(i)	Establish, train and support WUAs	Form WUAs as the management interface between the agency-controlled main canal and the farmer-controlled field Train and build capacity in water management as the main priority, followed by maintenance, then fee collection and finally organization (conflict management, meetings) Train WUAs in performance management (how to measure and use performance, indicators)	WUAs are required to manage the water allocation and distribution at the on-farm level. The more organized the WUA, the better the level of production and the better the ISF collection and maintenance

Table 7.3
Possible components for modernization of an irrigation and drainage scheme (continued)

	Component	Description	Remarks
B. On-farm level (managed by Water Users Associations)			
(ii)	Improve control and measurement at tertiary unit intake	Install variable flow control gate to control flow entering the on-farm system. Depending on the size of the outlet, have slide or spindled gate. Can have simple on/off gate if rotated flow in parent canal and irrigation quantity supplied is based on duration of flow Install measuring structure at the intake. Replogle or Crump weirs are simple to construct and operate and reasonably efficient for passing sediment load. Flumes preferred if sediment load is high	Essential to have full variable control of the outlet in most systems, unless the parent canal operates on rotation Measurement is desirable, depends on operation policy
(iii)	Reduce distribution losses and travel times	Line canals. Consider a variety of options, inter alia: - line existing canal sections with concrete - build rectangular sections using steel shuttering - use precast parabolic sections In steep lands use gravitational pressure and install low pressure pipelines with gated turnouts For all groundwater systems install buried pipes or use lay-flat hose to convey water to fields	Lining reduces water losses but also significantly reduces water travel time for rotation of flows. Allows on-demand irrigation at the on-farm level. Maintenance considerably reduced as no vegetation in canal
(iv)	Improve water control	Construct distribution boxes, either gated or with checks. Proportion openings to command area served Construct formal outlets to fields (pluggable pipes) Have simple measurements at key division points (can be incorporated into distribution boxes) Provide on-farm storage to store water from the main system at night and to provide continuous flow at the on-farm level if/when main system flows are rotated or intermittent	Distribution boxes are required to head up the water. Formal outlets needed to reduce management losses
(v)	Consolidated crop types	Encourage groups of farmers with adjacent plots to share land and cultivate larger blocks of the same crops	Greatly simplifies irrigation scheduling, reduces losses, saves farmer time
(vi)	Train WUA field staff as extension agents	Train WUA field staff in on-farm water management (standard) Train selected WUA field staff in in-field water management (furrow flow rates, design furrow lengths, determining infiltration rates, measuring wetted profile using soil augers)	WUA field staff, if appropriately selected and paid, could advise individual farmers on irrigation methods. Avoids having to establish separate extension agents
(vii)	Improve irrigation timing and scheduling	Install Class A evaporation pans in each WUA to measure ET (or transmit daily data from local automatic weather station) Use check book method (water balance sheet) for demonstrating scheduling intervals and amounts for different crops Develop and publish indicative regional scheduling regimes for different crop types on different soils	Using a Class A pan is a practical way of showing farmers the daily ETo rates and irrigation water needs. Can then easily link to irrigation intervals for crops with different rooting depths

Table 7.3
Possible components for modernization of an irrigation and drainage scheme (continued)

	Component	Description	Remarks
C. Main system level (Physical measures)			
(i)	Control and measurement on the main system	Construct canal control structures on main and secondary canals. Check structures to maintain command at offtakes, gated offtake to control and regulate discharges Use overshot rather than undershot gates (with sediment flushing such as the Romijn gates) to improve to reduce impact of fluctuations in parent canal discharges Use long-crested weirs (with gate for flushing sediment) to maintain uniform off-taking flows Consider Neyrpic type gates for offtakes for ease of operation Construct measuring structures at division points and offtakes. Use Crump or Replogle weirs to allow passage of sediment, or flumes (such as cut-throat flumes) In advanced systems with established control and measurement structures and procedures install SCADA system for automated water level and flow data collection and transmission Construct in-line storage systems to stabilize flows in the main canal network	*Note:* Control means both water level and discharge, not just discharge
(ii)	Line canal cross sections offtake locations	If no cross regulator constructed provide a minimum length of canal lining upstream and downstream of offtakes in order to provide a defined cross section at the offtake point	Essential to have a defined section in the main canal in order to maintain command at the offtake
(iii)	Provide drop structures or energy dissipators in step canals	Construct drop structures and/or energy dissipators in steep canal sections	High velocity flows, even in lined canals, can be very damaging
D. Main system level (Management measures)			
(i)	Establish performance-based (p-b) management	Establish management processes and procedures for performance-based management. This entails setting targets for performance of irrigation schemes, monitoring performance, assessing performance at the end of the season and rewarding staff (and WUAs/farmers) for achieving high levels of performance Conduct training in performance-based management for all levels (agency staff, WUA management, farmers) Gain buy-in from all stakeholders on adopting performance-based management	If physical systems are to be modernized in order to improve system performance, it is important to also modernize the thinking of all stakeholders
(ii)	Determine indicators to be used in p-b management	Conduct a study to determine and test a suitable set of indicators for performance-based management	It is important to keep the indicators relatively simple and measurable
(iii)	Install automatic weather stations	Install automatic weather stations to be able to determine key variables, including temperature, rainfall and ET	An essential tool in moving to more responsive ET-based scheduling procedures

Table 7.3
Possible components for modernization of an irrigation and drainage scheme (continued)

	Component	Description	Remarks
D. Main system level (Management measures)			
(iv)	Adopt ET-based scheduling	In conjunction with the automatic weather data collection, adopt real-time ET-based scheduling Develop new procedures for estimating seasonal water requirements based on historical ET data then adjust the scheduling on a weekly, thrice per month (10–11 day) or twice per month (15–16 day) in-season water allocation schedule Set gates each time period according to calculated schedule and notify WUAs and water users Computerize the calculations, either using bespoke scheduling software or spreadsheets Carry out comprehensive training and capacity building of all agency staff	These procedures are central to improving performance by matching actual ET demands with irrigation supply Important to also link to monitoring of canal discharges in order to determine compliance but also canal losses (needed in the calculations)
(v)	Monitor performance	Monitor implementation of the planned water allocations to ensure compliance by field staff. Hold field staff accountable Carry out spot checks in the field to ensure compliance	
E. Basin level			
(i)	Strengthen river basin monitoring programme	Building on existing transboundary monitoring and regulation procedures establish monitoring programme for all river basins Establish database for recording and analysing river flows. Use the analysis to predict summer recession flows in catchments	Knowledge of river flows and ability to predict summer recession flows is an integral part of modernizing irrigation management
(ii)	Prepare and maintain river basin management plans	Each river basin and significant sub-basin or catchment should have a river basin plan that set out the current and future predicted water use together with the historical and predicted water resources	This plan should form the basis for planning and management of all water resource related activities
(iii)	Establish a digital Water Resources Information System	Data collection, processing and analysis are a central part of river basin planning and management. To this end a digital Water Resources Information System should be established, or where it already exists (as in Kyrgyzstan) it should be further strengthened	

Source: Authors' own elaboration.

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Chapter 8
Conclusions

As has been shown in this report, Central Asia is in a challenging situation in relation to its water resources and agricultural production. Although the agricultural sector has a more limited role in the national economies than in the past, it is still central to each nation's food production and national and rural economies. The agricultural sector is heavily dependent on irrigation, which consumes about 90 percent of the total abstracted water resources. Without irrigation, crop yields and agricultural production would be significantly lower. Many countries in the region however are facing already water scarcity situations and climate change is expected to aggravate this situation.

The irrigation sector in the region faces a number of challenges vis-à-vis scheme management, operation and maintenance – one of the key challenges being the large stock of irrigation infrastructure in the region, which continues to deteriorate due to the lack of adequate maintenance funding. Compounding the situation, the on-farm infrastructure in the region has not yet been adequately developed to support the division of large state-owned and communal farms into numerous smallholdings that followed Independence. Coupled with weak irrigation management institutions both at the off- and on-farm levels, this has resulted in high water loses in the systems, low water use efficiency, unsatisfactory services to farmers, low yields and greatly reduced overall production.

The emerging approach for addressing these challenges is to modernize the irrigation sector and transition from the traditional supply-oriented water delivery to more 'on demand' irrigation services. As opposed to mere rehabilitation, the concept of modernization applies technical, institutional, and managerial upgrading of irrigation schemes to improve resource utilization and water delivery service to farmers. Given that water is the main constraining factor in the region, improving water use efficiency and productivity is the main overarching objective of irrigation modernization in the region.

Irrigation modernization encompasses a variety of elements, including government policy, organizational and institutional reform, and management, operation and maintenance processes and procedures. The initial focus needs to be on modernizing the MOM procedures. These procedures are not only required to address changes made to the physical infrastructure, but also to improve the performance of existing systems. This is necessary, as there are insufficient funds to modernize all I&D systems. Key aspects of the modernization process are measures to improve the scheduling of irrigation water supplies to better match supply and demand. Allied to such improvements will be the need to improve the understanding, knowledge, and skills of both irrigation agency and WUA staff. In addition to improving scheduling and water delivery, there is the need to ensure that farmers have the necessary understanding, knowledge, and skills to use irrigation water and other inputs to obtain optimum production. This will include their improving the water application, crop and seed selection, agronomic practices (crop spacing, weeding, fertilizer use), crop storage and marketing.

The ongoing and planned irrigation investment projects funded by the governments as well as by the international financing institutions such as the World Bank, Asian Development Bank, and other development partners, provide the opportunity to pilot the approaches and develop 'advanced irrigation schemes', which will pave the way for future irrigation development in each country.

Government policy and regulation overlie all of the above-mentioned actions. If modernization is to proceed, it will require a clear policy and strategy from government. Mechanisms for adequately funding the MOM of the modernized and existing I&D systems will need to be a central part of any modernization policy. Currently, money is being loaned or granted from international agencies to make up for the backlog of maintenance, repair and replacement work required due to many years of maintenance underfunding. Modernization does not lessen the requirement for adequate and timely maintenance funds. Government policy will also be fundamental to making the necessary institutional and organizational changes required under any modernization programme. Actions taken here need to include support to irrigation agencies to upgrade the staff capabilities through training and continuing education programmes. It will also be important to consider how the private sector could effectively be involved in improving irrigation performance.

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Annex I
FAO Rapid Appraisal Procedure (RAP) evaluations and recommendations

Detailed studies of three irrigation schemes (Ershon and Dupulla in Tajikistan and the Gaznon scheme in Uzbekistan) were carried out in 2019 using the MASSCOTE methodology to assess each scheme's performance and help identify ways to achieve greater water use efficiency, equity and sustainability in irrigation systems. A RAP was used as a diagnostic tool to identify problems with system operation and their underlying causes. The findings of the analysis were done to improve the current understanding of the performance-related issues of irrigation schemes in the region and thereby contribute to formulating modernization interventions. The three schemes have different characteristics, the 668 ha Ershon scheme is mostly gravity-fed, the 810 ha Dupulla scheme is a pumped scheme and the 3,541 ha Gaznon scheme is supplied by surface and groundwater. Using the RAP the following data were collected and analysed:

- **water balance between water demand and supply, and between groundwater and surface water:** incorporating the climatic, agronomic, and hydrological data;
- **organizations and institutions of water management:** incorporating the organizational structures at each management level and evaluating the performance of the institutions;
- **water delivery service:** incorporating the data on conveyance, hydraulic structures, and their operation at each canal level.

The main findings from the studies were:

- water distribution in all three schemes is based on farmers' requests derived from their annual cropping patterns submitted to the WUA;
- there are significant differences between the calculated water supply based on the irrigation norms and the calculated demand based on seasonal crop ET calculations using FAO's CROPWAT model;
- on all three schemes the average yields are below potential values;
- on the Gaznon scheme the groundwater use has increased significantly in recent years due to recurrent droughts;
- conveyance efficiencies on all schemes are low, below 60 percent on Gaznon, below 40 percent on Ershon, and below 30 percent on Dupulla;
- the condition of the off-farm and on-farm systems is generally poor on all schemes due to lack of adequate maintenance. Canals are mostly earthen and lack uniform shape;
- the level of control on the off-farm and on-farm canals is also generally poor on all schemes, with few if any gates or formal division structures at the on-farm level. The lack of proper hydraulic structures and flow control decreases the conveyance efficiency and makes water distribution highly inefficient;

- there is no accurate measurement of discharge on the three schemes;
- the predominant irrigation method on all schemes is furrow irrigation;
- in all three systems management of the off-farm system is carried out by the government I&D agency while the on-farm systems are managed by WUAs in Tajikistan and WCAs in Uzbekistan. ISF collection levels are low and mostly used to pay salaries of the WUA or WCA;
- on all three schemes there is a lack of reliable irrigation supplies and unequal distribution between the head and tail of the system;
- agricultural production on all schemes is hampered by the lack of agricultural extension and advisory services.

Measures proposed for improving performance included:

- convert furrow irrigation to alternate furrow irrigation (AFI) with optimized discharge per furrow;
- compute the seasonal and in-season weekly or periodic irrigation water demand using daily determination of potential crop ET;
- install real-time water level monitoring in key locations and combine with ET-based irrigation scheduling procedures (e.g. AQUACROP, CROPWAT);
- modernize the operation procedures to more closely match irrigation water supply with calculated (ET-based) demand;
- formalise and strengthen the conjunctive use of surface and groundwater;
- introduce early warning systems for water scarcity;
- carry out water accounting studies and climate forecasting to prepare farmers against severe water scarcity and drought;
- install sediment exclusion/capture structures at the headworks;
- upgrade control and measurement structures, with automated monitoring at key locations;
- renew pumps to improve their pumping efficiency and replace open channels with buried pipes on pumped schemes to reduce conveyance losses;
- in Tajikistan, introduce separate accounting for each WUA and establish a more efficient fee collection mechanism;
- adopt volumetric charging based on actual water delivered. This requires accurate measuring systems (structures) at each WUA intake;
- establish WUA/WCA capacity development programmes to strengthen WUA/WCA's management, operation, and maintenance capabilities;
- support the development of private sector agricultural advisory services;
- establish a comprehensive agricultural support programme focused on the Department of Agriculture to introduce concepts of crop rotation and inter-cropping to improve soil fertility; direct mechanical seeding; facilitate access to quality seeds; direct seeding of winter cereals to allow double cropping in one year; establish greenhouses with local entrepreneurs; engage with local machinery providers to introduce new techniques and machinery; encourage farmers to group together to create storage facilities; support improved irrigation practices for furrow irrigation; introduce drip irrigation on steeper (8–12 percent) sloping lands to increase crop production, water use efficiency and reduce soil erosion.

Annex II
Tajikistan: issues and opportunities

Table II.1
Tajikistan: issues and opportunities

Background data	◆ Agriculture contributes 21 percent to the GNP and rural employment accounts for 46 percent of total employment. ◆ 953 441 ha are arable. ◆ 749 656 ha (79 percent) potentially irrigable. ◆ 742 100 ha developed for irrigation, only 473 022 ha currently irrigated. ◆ Out of 280 850 ha designed for pumped irrigation, only approximately 170 000 ha are still operational. About 74 percent pump lift less than 100 m, remainder has lifts of between 100 m to 300 m. ◆ surface irrigation is the most common irrigation method.
Issues	◆ Deterioration of I&D infrastructure. ◆ Pumped schemes have deteriorated more rapidly than gravity schemes. ◆ Many pumped irrigation schemes are unprofitable due to high energy costs and low market prices for crops grown. ◆ Pump stations account for significant fixed and annual O&M costs, estimated at USD 60–150 per ha depending on the lift. ◆ Waterlogging and salinization of irrigated land (about 10 percent of total irrigated area). ◆ Poor I&D sector management due to incomplete legal and regulatory framework. ◆ The I&D agency (ALRI) is under-staffed and under-financed. ◆ Expenditure on O&M has fallen from USD 88/ha in 1990 to USD 14/ha in 2017, versus requirement of USD 21–28/ha for gravity and USD 60–150/ha for pumped schemes. ◆ Electricity supplies are unreliable. ◆ Low efficiency of surface (flood) irrigation methods. ◆ Income from agricultural production are low due to lack of support, agricultural extension, financing, crop insurance, quality inputs and marketing. Farmer cooperatives require assistance in production management, know-how and marketing.
Opportunities	◆ Although many pumped irrigation schemes are not economically viable a 2003 World Bank study (World Bank, 2003) found that some could be viable with more changes to cropping patterns and improvement in water use efficiency. ◆ Economic liberalization, policy reforms and more efficient use of resources. ◆ Irrigation application efficiencies and low. Improving surface irrigation methods, scheduling and changing the irrigation method has significant benefits (World Bank, 2017a).

Table II.1
Tajikistan: issues and opportunities (continued)

Opportunities	◆ There is a high opportunity cost for electrical energy. Under the CASA-1000 power purchase agreement conserved energy can be sold to Pakistan. Efficiency improvements combined with growing higher value crops can improve the financial viability of some pumped schemes. ◆ Implementation of the Water Sector Reform (WSR) Program will facilitate I&D system modernization and rehabilitation together with outsourcing of some activities to the private sector, operation of schemes on commercial terms, introduction of asset and performance-based management and improvement in the quality-of-service delivery. ◆ Introduction of public-private partnerships (PPP), including greater contributions by farmers to MOM costs, however, without significant reforms private investment in the I&D sub-sector is unlikely (World Bank, 2012). ◆ Specific opportunities identified for donor-funded support include: the implementation of the WSR Program; MEWR and ALRI restructuring and development; continued support for agricultural reforms and liberalization (in conjunction with I&D scheme modernization/rehabilitation); improvement in agricultural productivity; raising water use efficiency and productivity, particularly for pumped schemes; strengthening WUAs (including specific legislation for WUAs); introduction and realization of a service delivery culture; establishment of a Water Information System (WIS) with associated information sharing remit; increase in the contribution paid by water users for the services provided.
Actions taken since independence	◆ Land reform – state and communal farms broken up and land allocated to smallholder farmers. ◆ WUAs have been formed at scheme level (but need continued support); ◆ Water sector reforms have been initiated through the WSR Program (2016–2025). The Ministry of Land Reclamation and Water Resources has been abolished and the Ministry of Energy and Water Resources (MEWR) created and a separate Agency for Land Reclamation and Irrigation (ALRI) was established for managing I&D schemes. ◆ Under the WSR Program integrated water resources management (IWRM) based on decentralization and devolution of service delivery was established. Four River Basin Organizations (RBOs) will be formed to formulate water policy and manage and co-ordinate all water-related activities in the river basin under the MEWR. River Basin Councils (RBCs) will also be formed. ◆ Introduction of asset management planning into the I&D sector.
Financing	◆ GOT has approved an Action Plan for implementation of the WSR Program during 2015–2025, which lists activities and investments in the water sector at USD 225.6 million including USD 140 million for the I&D sub-sector. It is anticipated that the donor sector will finance the majority (94 percent) of the I&D sub-sector investment. ◆ The USD 118 million for rehabilitation/modernization is a fraction of the estimated USD 700 million required.

Note: Adapted from World Bank. 2018. (unpublished) Tajikistan Irrigation Strategy: Challenges, Opportunities and Priorities for Assistance, World Bank, Washington D.C.

Annex III
Uzbekistan: issues and opportunities

Table III.1
Uzbekistan: issues and opportunities

Background data	◆ Total annual renewable water resource is 52 billion m3, of which only 20 percent is sourced within the country. 96 percent is surface water, 1 percent groundwater and 3 percent recycled water. ◆ The water availability per capita is 1 500 m3/capita per annum. Uzbekistan is the 25th most water stressed country in the world. ◆ 90 percent of water used by agriculture, 4.5 percent by municipalities, 4.3 percent by industry and 1.2 percent by fisheries. ◆ Water resources are unevenly distributed in the country. ◆ Domestic, industrial and energy use are growing, placing pressure on the irrigation sector for water. ◆ Total irrigated area 4.3 million ha. ◆ Agriculture's share of the GDP is 28 percent. ◆ Around 60 percent of the irrigated land is supplied by pumping from 1 687 main pumping stations operated by the Ministry of Water Resources (MoWR) and around 10 280 pumping units operated at the on-farm level. ◆ There are some 12 400 wells (4 049 operated by MoWR, the rest are private). ◆ Nearly half the population lives in the rural areas. ◆ Waterlogging and salinization are major issues. 1.95 million ha of the irrigated lands are saline to some degree. There are some 172 ameliorative pumping stations, 3 788 vertical drainage wells and 27 648 groundwater observation wells. ◆ Since 1990 some 298 500 ha of land has been abandoned due to system deterioration. ◆ The Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME) is the main education and training centre. Other key institutes include the Karshi Engineering and Economic Institute and the Tashkent Agrarian University. There are several research institutes.
Issues	◆ Key medium- and long-term issues in the water sector are reducing water availability due to climate change and increasing demand due to population increase, urbanization and economic development. ◆ By some estimates, due to climate change flow in the Syr Darya and Amu Darya rivers is expected to reduce by 55 and 15 percent respectively by 2050. In 2015 the total water shortage in Uzbekistan exceeded 3 km3. By 2030 this could reach up to 7 km3 and by 2050 up to 15 km3. Some models anticipate that the frequency and duration of droughts will increase. ◆ Uzbekistan is highly dependent on water resources from neighbouring countries. 80 percent of the total water resources comes from outside the country. Good relations with neighbouring countries are essential. ◆ Water resource planning and management is currently split between a number of government ministries and departments, with a lack of coordination amongst all of them.

Table III.1
Uzbekistan: issues and opportunities (continued)

Issues	◆ Low levels of remuneration lead to high staff turnover and difficulty in recruiting qualified personnel. ◆ Agencies lack adequate resources and equipment to perform their water management duties. ◆ A key issue in the I&D sector is inefficient water use, at the main system (off-farm) level and at the on-farm and field levels; ◆ State controlled cropping patterns. ◆ Lack of incentives for efficient water use by service providers and users. ◆ Lack of finances for water resources and I&D infrastructure. ◆ Little or no participation by water users in water resources and I&D management. ◆ Administrative (non-market) control of crop production and water allocation. Crop and wheat production planning is not based on maximizing economic benefits, increasing incomes, saving water or reducing the cost of water delivery. ◆ WCAs have not become sustainable self-management groups of water users. Due to poorly-functioning WCAs the condition and performance of on-farm infrastructure has deteriorated, service delivery has been poor, and fee recovery low. ◆ I&D infrastructure is outdated and dilapidated. I&D management practices are equally outdated. Pumping stations and pumped irrigation schemes are particularly badly impacted. Overall, this results in substantial water losses, unnecessary and costly pumping, inefficiencies in water allocation and distribution, unreliable, untimely and insufficient irrigation supplies and low levels of production. ◆ The financial and technical capacity of MOM units under the MoWR (Water Management Organizations (WMOs) and District Irrigation Departments is underdeveloped, with a lack of machinery and resources. ◆ The water-accounting network has deteriorated at all levels, with damaged or (now) non-existent structures, gauges. This is particularly the case with the interface of the service provider and water user. ◆ Staffing is a key issue. The national water management organizations are affected by a shortage of qualified personnel. Teaching and research institutes need modernizing and staff training in modern techniques. The exception is TIIAME, which still retains its position as one of the leading teaching and research institutes in the region. ◆ Salaries of WMO staff is low compared to other sectors, resulting in a perceived lower status and failure to attract new recruits or retain talented staff. ◆ A lack of coordinated funding for research and of field-based research does not facilitate the adoption of improved practices in the I&D sector.
Development objectives	◆ Create conditions for meeting the growing needs of people, the economy and the environment. ◆ Facilitate efficient water resources management and use and protect the condition of irrigated land. ◆ Achieve water and food security in the context of growing water scarcity and climate change.
Proposed activities	◆ Three key areas considered important: - adoption of market principles, improved water sector regulation and financing mechanisms; - improved water policy and water management mechanisms; - strengthening professional, research and innovative capacity in the water sector. ◆ Changes in agricultural policies to liberalize the agriculture sector, particularly phasing out of the state control of cotton and wheat production.

Table III.1
Uzbekistan: issues and opportunities (continued)

Proposed activities	◆ Adoption of the updated Water Code and introduction of integrated water resources management practices, including designating one single agency to be responsible for all water resources planning and management. ◆ Separation of water resources and I&D. Creation of separate ministries/agencies for water resources planning and management and I&D management, operation and maintenance. ◆ Increased engagement of the private sector, including PPP. ◆ Movement towards a service delivery culture in I&D water delivery and recovery of a larger proportion of the costs from water users. ◆ Rehabilitate, upgrade and/or modernize the I&D systems, particularly pumped systems. Utilize asset management planning techniques to quantify and cost the performance and condition of all assets, and formulate scheme-specific modernization plans. ◆ Upgrading of research capacity, training and knowledge development. ◆ Strengthening relationships with neighbouring countries, particularly in relation to a regional legislative framework for the region. ◆ Introduction of ICT into the water resources and I&D sectors.

Source: Adapted from Uzbekistan Government. 2020. Draft Concept Note of the State Program for Water Resources in Uzbekistan for 2020–2030.

Annex IV
Kazakhstan: issues and opportunities

Table IV.1
Kazakhstan: issues and opportunities

Background data	◆ Water resources are limited in Kazakhstan, with regional scarcity. ◆ Agriculture consumes approximately 64 percent of the available water resources. Industry uses 28 percent. ◆ There is expected to be a growth in water demand but a reduction in supply available due to climate change in six out of the eight water basins by 2040. The World Bank estimates that GDP could fall by 6 percent by 2050 due to water scarcity. ◆ The majority of the water resources come from surface water (101 km^3/year) with just over half (54.5 km^3/year) originating in the country. The remainder is derived from transboundary flows from China, Uzbekistan, Russia and Kyrgyzstan. Proven groundwater reserves 15 km^3/year.
Issues	◆ Provision of quality drinking water. ◆ Insufficient water for irrigation during the growing season. ◆ Depleted aquatic ecosystems (Aral Sea, Balkhash, Ural). ◆ Dependence on water resources use and management in neighbouring countries. ◆ Polluted wastewater discharged into rivers. ◆ Depletion of water bodies. ◆ Poor condition and performance of water infrastructure. ◆ High losses. ◆ Insufficient protection from floods and low flows. ◆ Low volumes of recycled water. ◆ Weak tariff systems. ◆ Shortage of qualified staff.
Opportunities and proposed actions	◆ Strengthening international agreements to secure water resources. ◆ Develop a water security strategy. ◆ Empower CWR as a regulator for industrial tariffs. ◆ Update and strengthen the Water Code. ◆ Reorganize the selected agencies into Joint Stock Companies (JSC); ◆ Construction of new, and modernization/rehabilitation of existing, I&D schemes.

Table IV.1
Kazakhstan: issues and opportunities (continued)

Opportunities and proposed actions	◆ Adopt "Smart Water" technology – automated control systems, GIS, remote sensing, Water Information System. Create a data information system based in Nur-Sultan. ◆ Implement water conservation practices. ◆ Create a flood management system. ◆ Upgrade education and training of water professionals – open specialist university/training centres, provide grants for overseas study and research, create a design and engineering bureau, modernize computer systems and software to international standards. ◆ Investigate and develop opportunities for public-private partnerships. ◆ Implement major projects for redistribution of water between river basins (transfer from surplus to deficit basins).
Objectives for development	◆ Preserve ecological flows. ◆ Guarantee provision of water to the population, the environment and sectors of the economy by increasing water saving measures and increasing the volume of available water resources. ◆ Improve the efficiency of water resources management. ◆ Key areas to focus on: - international cooperation; - updating the legal framework; - institutional reform; - modernization and reconstruction of water management infrastructure; - study into the water market; - digitalization, Smart Water, water saving; - environmentally smart water resources use; - training of water sector specialists with modern skills and scientific support; - development of public-private partnership; - implementation of global national projects.
Targets	◆ Maintain a water balance of 100 km^3 by locating additional surface water resources, building new reservoirs, reducing water wastage, increasing groundwater use. ◆ Decrease water consumption per unit of GDP from 91.2 to 73.0 m^3/1000 USD. ◆ Construct 26 major hydraulic works. ◆ Rehabilitate/modernize 182 state and 300 municipal hydraulic structures. ◆ Construct new I&D schemes to increase irrigated area from 1.7 to 3.0 million ha. Increase length of lines canals. ◆ Repair and modernization of data collection systems within basins to provide 100 percent coverage. ◆ Increase forest cover of catchments from 1 to 200 thousand ha.

Source: Adapted from Kazakhstan Government. 2020. Draft Concept Note of the State Program for Water Resources in Kazakhstan for 2020–2030.

Annex V
Climate resilient technologies and innovations

The collaborative research activities conducted by ICARDA and other centres of the consortium to date have resulted in the release of more resistant crop varieties and the development of various technologies and agricultural practices that lead to higher climate resilience. These innovations and technologies are mapped into five thrust areas, countries and research phases in Table V.1.

Table V.1
Climate resilient technologies and innovations

Climate-resilient technologies/ innovations developed by the consortium in proposed five thrust areas:	KAZ	KYR	TAJ	TKM	UZB
Varieties, seed systems and diversification					
Winter wheat varieties with high yield, quality traits and tolerance to drought, heat, salinity, pests and diseases (yellow rust)	S	S	S	S	S
Spring wheat varieties with high yield, quality traits and tolerance to drought and diseases (stem, leaf rust, *septoriosis*)	S	P	P	P	S
Maize varieties with high yield, tolerance to drought, heat, pests and diseases (for feed, food, biomass/biofuel)	S	P	P	P	P
Potato varieties with high yield, resistant to drought, heat, salinity and virus diseases	S		S		S
Vegetable varieties with high yield, quality and tolerance to drought, heat, salinity, pests and diseases, for year-round vegetable production; cultivation technologies	S	S	S	S	S
Barley varieties tolerant to drought and heat, suitable for marginal lands and rainfed conditions	S	S	S	S	S
Chickpea varieties tolerant to drought and heat, suitable for dual planting in autumn and spring under rainfed conditions	S	S	S	S	S
Early maturing varieties of winter wheat and mung bean allow inclusion of mung bean as an additional catch crop in wheat-cotton and wheat-wheat rotation			C		S
Fruit varieties with quality traits and tolerance to drought, heat, frost, salinity (planting material is available from nurseries; grafting material from matrix orchards)	S	S	S	S	S
Walnut varieties tolerant to frost for reforestation of degraded slopes in mountainous areas	D	S	P		S
Pistachio and almond varieties with drought resistance and high productivity for reforestation of degraded lands in dry foothills	P	S	S	S	S

Table V.1
Climate resilient technologies and innovations (continued)

Climate-resilient technologies/ innovations developed by the consortium in proposed five thrust areas:	KAZ	KYR	TAJ	TKM	UZB
Varieties, seed systems and diversification					
Salinity tolerant neglected and underutilized fruit tree species for establishment of plantations in areas with soil salinity (evaluated germplasm and planting material)	D			D	S
Drought, frost, pest and diseases resistant varieties of tree and shrub species for increasing productivity of desert rangelands	S			C	S
Sorghum and pearl millet-based crop-livestock feeding system for food security and income diversification on marginal lands	P			S	S
Virus free seed potato production technology			S		S
Tomato grafting technology for improved tolerance to biotic and abiotic stresses, salinity and drought					S
Cultivation of summer legumes as a second crop	S	S	S	S	S
Phyto-remediation of salt affected and waterlogged lands through seed multiplication of multi-purpose underutilized halophytic and salt-tolerant plants				S	S
Mobile applications for agribusiness		S	S		D
Vegetation change and land degradation analysis using satellite remote sensing	P	P	P	P	P
On-farm water use efficiency					
Groundwater quantity and quality models			P		P
Groundwater/artesian water use for irrigation of salt-tolerant horticultural crops, vegetables and arid fodder crops		P	C		P
Weather-based irrigation scheduling			P		P
Irrigation with the use of perforated polyethylene					S
Irrigation with the use of gated pipes					S
Improved furrow irrigation (alternate furrow irrigation)	S	S	S		S
Partial root-zone drying technique for water use efficiency at farm level			P		S
High Frequency Irrigation for potato crop			P		S
Drip irrigation for orchard, cotton and potato					S
Short furrow irrigation for major crops		S	S		S
Irrigation scheduling using irrometers		S	S		S
Irrigation scheduling using ET meter and ET pot					S
Laser levelling for improving irrigation efficiency			S		
Irrigation scheduling based on RS/GIS			P	P	P
Water cadastre for improving water use efficiency					P
Smart gauges for improving water use efficiency		S	P		P
Crop models for optimization of irrigation regimes					C
Mapping water and land productivity and spatio-temporal variability					C

Table V.1
Climate resilient technologies and innovations (continued)

Climate-resilient technologies/ innovations developed by the consortium in proposed five thrust areas:	KAZ	KYR	TAJ	TKM	UZB
On-farm water use efficiency					
Digital agricultural platform (beta) for agro-ecosystems mapping, monitoring and management					P
Conservation Agriculture					
Minimum/ no tillage (conservation tillage)	S	C	C	D	S
Raised-bed planting	P	P	C	D	P
Residue retention/ control	P	P	P		P
Laser-assisted land levelling	P			P	S
Application of phosphogypsum for increased water retention capacity (in soils with high magnesium contents)	S			D	
Integrated Pest Management packages for wheat, potato and tomato		S	S		S
Land degradation control through agro-forestry and rangelands management					
Inventory and classification of marginal lands prone to soil degradation					S
Establishment of native trees/shrubs on marginal land patches, use of winter/summer conventional and non-conventional crops and utilization of agricultural residues	C			P	C
Community-based, participatory models for afforestation of piedmont areas, pasture improvement and management	P			P	S
Integrated use of marginal mineralized water and salt-affected soils for food-feed crops and forage legumes in the local, smallholder crop-livestock farming system	S	P	P	P	S
Assessment of land degradation using satellite observation in central Asia.	P	P	P	P	P
Sustainable livelihoods in mountain areas					
Community-based models for genetic enhancement of local sheep and goat populations (through established nucleus flocks); value chain of livestock products and marketing analyses	C	C	S		C
Community-based fibre processing by artisan women's groups supported by improved sheep and goat fibre produced by smallholder farmers	D	P	P	D	D
Community-based models for sustainable use of limited water resources in rainfed areas	P		P	C	S
Water harvesting and revitalization of water storage technologies (*sardobo*; *cherle*; groundwater reservoirs)	P				P
True Potato Seed (TPS) production technology for small farmers access to quality potato seed			D		

Legend: Discovery phase (D) Proof of concept phase (C) Pilot phase (P) Scaling up phase (S)

Source: ICARDA Tashkent, November, 2020.

Annex VI
Approach to modernization: a performance-based management process

Modernization implies change – moving from one place to another. A classic set of questions in change management is:

- Where are we now?
- Where do we want to be? and
- How do we get there?

These three straightforward questions lay out the pathway for planning modernization, either of a countrywide programme, or of an individual scheme or group of schemes.

Traditionally, for individual schemes or a group of schemes, feasibility studies are carried out to answer these three questions. From these studies the current situation for the scheme(s) is assessed (condition of the infrastructure, management, operation, maintenance), improvement measures identified (repair or upgrade infrastructure, train I&D agency staff and farmers, establish WUAs) and potential outcomes postulated (increased yields, water use efficiency improved, farmer incomes raised).

A similar process can be followed by focusing on performance. What is the performance now, what could it be, and how might we achieve our targets? This approach is based on performance assessment and benchmarking (Figure VI.1) and, unlike the traditional feasibility study approach, is a continuous management process of assessing scheme performance, comparing it to 'best practice' schemes and identifying and adopting measures to 'close the (performance) gap'. Importantly, it is a management-centric rather than a technical or engineering-centric approach. Establishing a benchmarking (Malano and Burton, 2001) programme to identify best performing systems to which other systems can aspire can prove to be a valuable part of the performance-based management approach.

The advantage of using a management-centric approach to look at modernization of existing I&D schemes is that the assessment does not begin and end with a discrete modernization project – it is part of an ongoing management process focussed on maintaining and enhancing scheme performance over time.

Table VI.1 outlines a programme for benchmarking performance in the I&D sector incorporating identification of the objectives, performance indicators and key processes, including preparation of an action plan for improvement and liaison and agreement with water uses on implementing the plan.

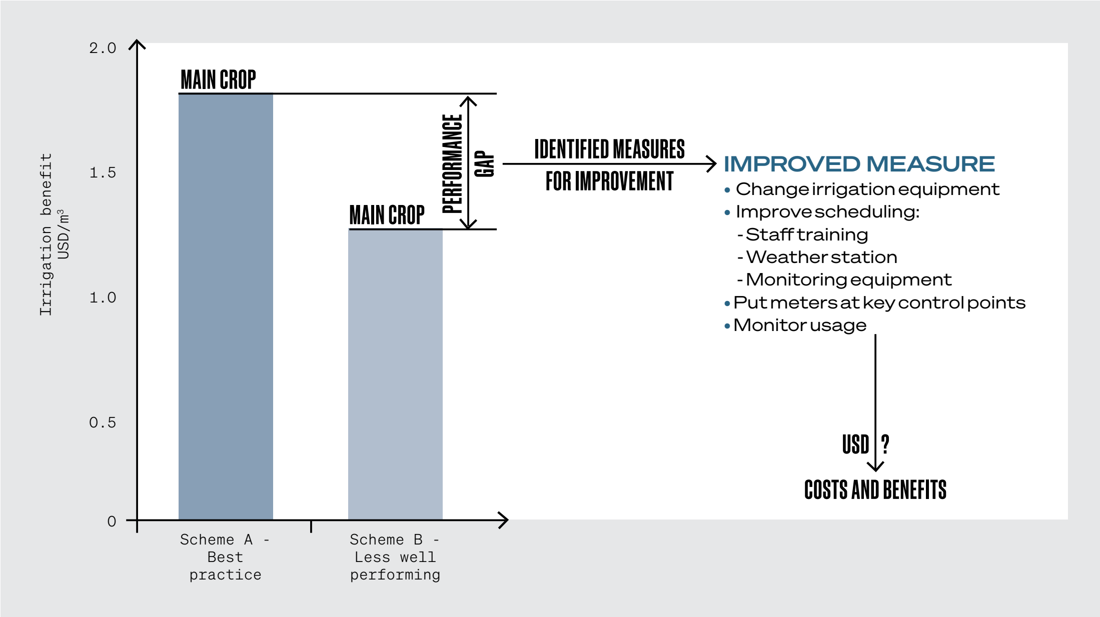

Figure VI.1
Benchmarking: closing the performance gap

Source: Authors' own elaboration.

Table VI.1
Programme for benchmarking performance in the I&D sector

No.	Activity	Example/Explanation
1	Identify the objectives of the total process.	◆ Increased agricultural production. ◆ Improved efficiency and productivity of water use. ◆ Minimising costs whilst maintaining adequate operation and maintenance standards. ◆ Sustain soil fertility and crop growth environment.
2	Identify the key outputs.	◆ Irrigation water delivery. ◆ Drainage water removal. ◆ Crop production.
3	Identify performance indicators for measurement of outputs.	◆ Crop production (in kg and MU[1]). ◆ Crop production (in kg and MU[1]) per unit area. ◆ Crop production (in kg and MU[1]) per unit water supply.

Table VI.1
Programme for benchmarking performance in the I&D sector (continued)

No.	Activity	Example/Explanation
4	Collect data for output indicators and benchmark performance against comparable units.	◆ Crop type, area, yield, input costs, market price, water supplied.
5	Quantify the gap in output performance.	This may be between total crop production on secondary canals, or between total crop production within tertiary canals.
6	Identify the key processes that contribute to the output performance.	◆ Irrigation water delivery (reliability, timeliness and adequacy). ◆ Drainage water removal (timeliness, adequacy, soil water quality). ◆ Maintenance of I&D system.
7	Identify performance indicators for these key processes.	◆ Seasonal relative irrigation water supply (supply/demand). ◆ Seasonal irrigation water supply per unit area (m3/ha). ◆ Main system water delivery efficiency. ◆ Pumping hours and discharge per unit area for tertiary canals in the head, middle and tail reaches. ◆ Seasonal average depth to groundwater (m). ◆ Seasonal soil and drainage water quality. ◆ Cost of irrigation water delivery and drainage water removal.
8	Collect data for these process indicators and assess and benchmark process performance against comparable processes.	◆ Compare performance of the following indicators between secondary canals and tertiary canals: - secondary canal water delivery efficiencies; - relative irrigation water supply; - tertiary canal pumping hours per unit area; - irrigation water supplies per unit area; - average depths to groundwater; - groundwater and soil quality.
9	Identify the gaps in process performance.	This may be between total crop production on secondary canals, or between total crop production within tertiary canals.
10	Identify the key factors that influence this performance, and propose remedies.	◆ Tail end tertiary canals, for example, may be getting less water per unit area than head-end tertiary canals. ◆ Groundwater levels and soil salinity levels may be high, thus reducing crop yields

Table VI.1
Programme for benchmarking performance in the I&D sector (continued)

No.	Activity	Example/Explanation
11	Prepare an action plan for introduction and implementation of the proposals.	The action plan might require senior management to take action, and/or for WUA representatives, or others, to take action. Need to specify who is involved, what resources are required (time, people, finances), and the programme for implementation.
12	Gain acceptance of the action plan by key stakeholders.	◆ Agreement from senior managers within irrigation and drainage agencies. ◆ Agreement between WUAs on a secondary canal.
13	Implement the Action Plan.	◆ Disseminate the details of the action plan widely to explain what is being done. ◆ Leadership will be required by key stakeholders to ensure the action plan is implemented properly. ◆ Make step-by-step improvements.
14	Monitor implementation and degree of change effected.	Monitoring data fed back to all key stakeholders, including senior management and to WUA representatives.
15	Evaluate implementation and degree of change on completion.	Senior management and WUA representatives to assess the change in performance as a result of implementing the action plan.

Note: 1. MU – Monetary Unit

Source: Burton, 2010.

Modernizing irrigation systems in Central Asia could increase the productivity of the irrigation sector to meet growing food and export demand, while also improving farmers' livelihoods. It could ensure greater irrigation efficiency and crop productivity amid growing water scarcity in the region and deliver cost-effective and reliable irrigation services to farmers. In addition, modernized systems could contribute to national development objectives such as climate resilient economic growth, food security and poverty reduction. This publication, geared to policy-makers, sector managers and technical experts, draws on the findings of a study carried out by an FAO team through the World Bank's regional assistance programme "Exposure and Practical In-Roads to Modernizing Irrigation in Central Asia". It is part of the Directions in Investment series under the FAO Investment Centre's Knowledge for Investment (K4I) programme.

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