RESEARCH
REPORT

67

Water Productivity in the Syr-Darya River Basin

Hammond Murray-Rust, Iskandar Abdullaev, Mehmood ul Hassan
and Vilma Horinkova

IWMI
International
Water Management
Institute

FUTURE HARVEST
IWMI is a Future Harvest Center
supported by the CGIAR

Research Reports

IWMI's mission is to improve water and land resources management for food, livelihoods and nature. In serving this mission, IWMI concentrates on the integration of policies, technologies and management systems to achieve workable solutions to real problems—practical, relevant results in the field of irrigation and water and land resources.

The publications in this series cover a wide range of subjects—from computer modeling to experience with water user associations—and vary in content from directly applicable research to more basic studies, on which applied work ultimately depends. Some research reports are narrowly focused, analytical and detailed empirical studies; others are wide-ranging and synthetic overviews of generic problems.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI's own staff and Fellows, and by external reviewers. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

Research Report 67

Water Productivity in the Syr-Darya River Basin

Hammond Murray-Rust, Iskandar Abdullaev, Mehmood ul Hassan and Vilma Horinkova

International Water Management Institute
P O Box 2075, Colombo, Sri Lanka

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Ghana, Pakistan, South Africa, Sri Lanka, and Thailand.

This research was made possible through generous support from the Ford Foundation, New Delhi, SIDA (Swedish International Development Agency) and the Dutch Government.

The authors: Hammond Murray-Rust is the Theme Leader of Integrated Water Resources Management in Irrigated Agriculture and a Principal Researcher of the International Water Management Institute (IWMI). Iskandar Abdullayev is a Researcher and Water Management Specialist, Vilma Horinkova is a Principal Researcher and Director for the Central Asia and Caucasus IWMI sub-office, and Mehmood Ul Hassan is a Regional Researcher, all of the IWMI Central Asia and Caucasus sub-office.

Murray-Rust, H.; Abdullaev, I.; ul Hassan, M.; Horinkova, V. 2003. *Water productivity in the Syr-Darya river basin*. Research Report 67. Colombo, Sri Lanka: International Water Management Institute.

/ water management / water use / water allocation / water supply / water demand / water delivery performance / water resources / irrigation water / irrigated farming / irrigation schemes / river basins / cropping systems / soil salinity / crop yield / land / agriculture / environment / organizations / performance evaluation / Central Asia / Syr-Darya /Aral sea /

ISBN: 92- 9090- 509- 3

ISSN 1026-0862

Please send inquiries and comments to: *iwmi-research-news@cgiar.org*

Contents

Summary *vii*

Mitigating the Effects of Irrigation on the Aral Sea *1*

Water Management Institutions and Policies in the Syr-Darya River Basin *2*

Water Allocation *6*

Assessment of Irrigation Performance in the Syr-Darya Basin *11*

Conclusions *22*

Annex *27*

Literature Cited *75*

Abbreviations

BVO	Basin Valley Organization
CCF	Collective and Cooperative Farms
DWMO	District Water Management Organization
IWMI	International Water Management Institute
ICWC	Interstate Commission on Water Coordination
IWD	Irrigation Water Demand
IWS	Irrigation Water Supply
IWL	Irrigation Water Limit
O&M	Operation and Maintenance
PPF	Private and Peasant Farms
SRB	Syr-Darya River Basin
SANIRI	Central Asia Research Institute on Irrigation
SIC	Scientific Information Center of the Interstate Commission on Water Coordination
WUA	Water Users Association

Summary

This report analyses the water productivity and water-saving initiatives in the Syr-Darya river basin (SRB) of Central Asia. The report presents institutional and political aspects of water resources management in the basin—particularly a brief description of pre- and post-soviet developments in water management. Water allocation elements principles for different hierarchical levels in the basin are also discussed. The assessment of the performance of irrigation in SRB is presented as an analysis of the water-saving competition, funded by the World Bank (from 1999 to 2000). The competition itself is no longer operational, but the International Water Management Institute (IWMI) and the Scientific Information Center of the Interstate Commission on Water Coordination (SIC) based in Tashkent are funding the collection of data on water use.

Water delivery, crop yields (cotton, wheat and rice) and water productivity were used as major indicators of performance for the irrigation system of the basin. The analysis was done for different levels of water use and management—farm, irrigation-system and basin levels were studied. The study was conducted for the head, middle and tail reaches of the basin. This analysis can be used by water managers, policymakers and potential donors as a tool for identifying the hierarchical levels and areas of the basin, where water management needs to be improved and water conservation is a possible solution for the existing water-related environmental problems.

Water Productivity in the Syr-Darya River Basin

Hammond Murray-Rust, Iskandar Abdullaev, Mehmood ul Hassan and Vilma Horinkova

Mitigating the Effects of Irrigation on the Aral Sea

Irrigation extractions from both the Syr-Darya and the Amu-Darya rivers have contributed significantly to the problems of the Aral Sea. During the summer months, when demand for irrigation is at its highest, little water reaches the sea. Not only diversions for irrigation, but also relatively large amounts of water used up in leaching and use of water by upstream reservoirs for production of electricity have reduced important winter flows to the sea. Therefore, it is inevitable that agriculture must consume less water if the volume of water in the sea can be conserved or augmented.

Critics of irrigation claim that irrigation water use is wasteful, and that improper management of irrigation systems has resulted in excess withdrawals above the level needed to meet food and fiber production targets. Yet these claims tend to be based on observations of the impact of water extractions on the sea level rather than on accurate data on irrigation water consumption and institutional and governance inadequacies.

As a part of its substantial effort to reverse some of the adverse impacts of irrigation on the hydro-ecology of the Aral Sea, the World Bank sponsored a water-saving competition among different water users throughout the Syr-Darya basin (which is discontinued now, but IWMI and SIC are funding the collection of data on water use). The objective of this competition was to reward, with prizes and other forms of recognition, water users who could demonstrate that they had reduced irrigation water use. This paper is based on data collected from the beginning of 1999 to the end of 2001. This data gives insights into actual water use in different locations in the basin and helps to identify where there is potential for further improvement in water productivity.

Because the main rivers that feed the Aral Sea flow across several countries in Central Asia, it is necessary to understand some history of both irrigation and institutional development and changes that occurred over the region during Soviet rule and since the establishment of the newly independent republics. This is covered next.

The basis for water allocation within the basin is examined next. These allocation principles have their roots in the Soviet period, particularly in terms of assessing the overall demand for water, but they have been modified to some extent to include allowances for non-crop factors such as soil and salinity amelioration with adjustments for leaching in areas prone to salinization.

The details of the water-saving competition are presented next, including the criteria for selecting the competitors. Three categories have been used for the competition: water management districts that supply and distribute water—typically over 20,000 ha or more in extent; cooperative or communal farms that cover about 1,000-2,000 ha of land and private farms which are a few hectares in size. This section also analyses the data collected from 1999-2001. The focus is on water productivity because, if food and fiber targets are to be met with less water usage, productivity of water is a more meaningful performance parameter than simple yield per hectare. Factors used in the analysis include, location within the basin, location within a province, size of the unit under investigation, and the effect of salinity in the lower reaches of the basin. Private farms appear to under-perform compared to communal systems.

Finally the paper focuses on conclusions and recommendations. This includes a comparison of performance parameters from the SRB with other data from South Asia. These comparisons indicate that Central Asian systems perform at similar levels.

The competition appears to have sparked interest among both water users and policymakers, and it is recommended that this activity be continued in the future. There appears to be significant scope for performance improvement at all levels, particularly in private farms.

Water Management Institutions and Policies in the Syr-Darya River Basin

General Background and Problems

The Aral Sea basin, covering the territories of Tajikistan, Uzbekistan, Turkmenistan, some parts of Afghanistan, Kyrgyzstan and Kazakhstan, is located in the heart of the Euro-Asian continent. Its territory is located between longitudes 56^0 and 78^0 east and latitudes 33^0 and 52^0 north, and covers about 1.55 million square kilometers of Central Asian and 0.24 million square kilometers of Afghan territory.

Diverse terrain and altitudes ranging from 0 to 7,500 m above the mean sea level are responsible for the diversity of the microclimate. The average temperatures range from 0-4^0 C in January and 28-32^0 C in July. However, summers in some parts of the area can be as hot as 52^0 C and winters can be as cold as -16^0 C, making the overall climate of the basin a sharply contrasting one, with hot summers and cold winters. The two main rivers, the Amu-Darya and the Syr-Darya, together with some thirty primary tributaries, feed the basin (figure 1). However, many of the tributaries now flow only seasonally—drying up before reaching the main rivers. The main rivers originate in mountainous regions that have surplus moisture (precipitation of 800-1,600 mm and potential evapotranspiration of 100-500 mm) resulting in permanent snowfields and glaciers (the Pamir and Tien Shan ranges). Annual precipitation in the lowland deserts of the basin ranges from 100 mm in the southwest to 200 mm in the foothills of southeastern mountains, and to 30 mm in the Hungry Steppe, southwest of Tashkent. The moisture coefficient[1] in the basin ranges from 0.1 to 0.6 (Micklin 1991). Thermal conditions in the basin are favorable for crops such as cotton and cereals.

[1]Precipitation divided by potential evapotranspiration.

FIGURE 1.
The Aral Sea basin.

The SRB covers an area of 444, 000 km^2 and is home to about 18 million people, with an overall population density of 19 people per square kilometer. The Syr-Darya originates in the Tien Shan mountains and runs through the upstream countries of Kyrgyzstan and Tajikistan, and through Uzbekistan and Kazakhstan into the Aral Sea (approximately 2,500 km).

In the early 1960s, the former Soviet Union launched efforts to divert almost all water from the two main rivers (Amu-Darya and Syr-Darya). The diversion of millions of cubic meters of water to irrigate cotton fields and rice paddies through massive infrastructure development helped increase the command area from 5 mha (million hectare) in the 1950s to 8 mha in the 1990s. The water development system of the region is described as “one of the most complicated human water development systems in the world” (Raskin et al. 1992) because human interventions have gradually modified the natural water flow and the environment along the river’s banks. The Aral Sea basin system now has highly regulated rivers with 20 medium- and large-sized reservoirs and around 60 diversion canals of different sizes. In all, the two rivers have some fifty dams of varying sizes. The diversions of water for agriculture from the Syr-Darya are almost equal to its total annual inflow and the annual diversions from the Amu-Darya are around 45 km^3 of its annual inflow of 70-80 km^3. However, because virtually all of the available surface water is diverted for irrigation, there is very little scope for further expansion of command areas. Better water management to improve productivity, therefore, is the only option to guarantee food security in the region.

The conveyance system of the two rivers consists of a complex web of canals, impoundments, tributaries, irrigation fields, distribution systems and municipal and industrial facilities (Micklin 1991). The drainage infrastructure is designed in such a way that it discharges most of its effluent into the two rivers, thus gradually aggravating the downstream water quality. As a result, soil salinity in the downstream areas is emerging as a major problem. While cotton was the main crop in the region during former Soviet Union rule, a new trend of crop diversification is emerging.

The diversion of the inflow to the Aral Sea basin has led to a gradual deterioration of the environment. In 1965, the Aral Sea received about 50 km^3 of freshwater per year—a value that fell to zero by the early 1980s. Consequently, concentrations of salts and minerals began to rise in the shrinking body of water causing severe soil salinity problems, especially in the downstream areas of the region. The water salinity has increased from around 0.5-0.8 grams per liter to 2 grams per liter in the deltas of the Amu-Darya and the Syr-Darya. Presently 31 percent of the irrigated area has a water table within 2 m of the surface and 28 percent of the irrigated area suffers from moderate to high salinity levels. Crop yields in those areas have declined by 20-30 percent. An estimated 137 million tons of salt was the average discharge from the irrigated lands for the past 20 years (SIC 2000).

This change in the water chemistry of the river has led to alterations in the Aral Sea's ecology, causing reductions in fish population and thereby threatening a previously thriving commercial fishing industry, which employed roughly 60,000 people in the early 1960s. By 1977, the fish harvest was reduced by 75 percent and deteriorated to a virtual elimination of the industry by the early 1980s. The shrinking Aral Sea has also had a noticeable effect on the region's climate. The growing season is now shorter, causing many farmers to switch from cotton to rice, demanding even more diverted water. Salinization effects are even threatening the cultural heritage of Central Asia; high groundwater levels and salinity are affecting historic monuments in the famous towns of Bukhara and Khiva (Razakov et al. 1999).

A secondary effect of the reduction in the Aral Sea's overall size is the rapid exposure of the sea bed. Strong winds that blow across this part of Asia routinely pick up and deposit tens of thousands of tons of exposed soil every year. This process has not only contributed to a deterioration of the air quality for nearby residents, but has also reduced crop yields due to heavily salt-laden particles falling on arable land (Mirzaev 1998).

Institutional Structure of Water Management and Changes Since Independence

The independence of the five Central Asian states in 1991 led to institutional changes in water resources management. Soon after independence, in 1992, the heads of the five newly independent states (Tajikistan, Uzbekistan, Turkmenistan, Kyrgyzstan and Kazakhstan) signed interstate agreements on water sharing, use, conservation, financing and management. The first of these agreements established the Interstate Commission on Water Coordination (ICWC) appointing relevant deputy ministers for water as its members. The ICWC was entrusted with the responsibilities of policy formulation and allocating water to the five states (Bandaragoda 1999).

The ICWC comprises leaders of water management organizations (deputy ministers for water) of the Central Asian states and is the highest decision-making body concerned with the regional water supply. The ICWC annual planning meeting is scheduled towards the end of each calendar year, with high-level government representatives (prime ministers or deputy prime ministers and relevant ministers) of Central Asian states participating to discuss preliminary plans and agreements for the following year's water supply.[2] Plans for water supply and mutual agreements regarding all commodities are confirmed at an ICWC meeting in March of the following year. Subsequently, the ICWC conducts working meetings approximately once in every three months to discuss the monitoring of water deliveries and any problems with water supply, as well as compliance with agreements (ICWC 1992).

The ICWC operates through four executive bodies, the Amu-Darya and the Syr-Darya basin valley organizations (BVOs), the Scientific Information Center (SIC), and the ICWC secretariat. The ICWC secretariat is responsible for facilitating the ICWC meetings, preparation of programs and projects with the other sister organizations and financial control of the BVOs. The BVOs are responsible for the technical aspects of water allocation, distribution and management at the basin scale and among republics. The SIC, with its 14 regional branches, is responsible for creating an information base, analysis, and supporting and carrying out programs to enhance water conservation measures.

Later, with the initiation of the Aral Sea basin program by the World Bank, the United Nations Development Programme (UNDP) and the United Nations Environmental Programme (UNEP), two special bodies were created—the International Fund to Save the Aral Sea (IFAS) and the Interstate Council for the Aral Sea (ICAS). The ICAS subsequently merged into the IFAS in 1997. The IFAS is headed by one of the presidents of the five states on a rotation basis. The executive committee of IFAS, comprising the prime ministers of the five states, carries out the functions.

In the present context, the institutional framework for water management in the region is a hierarchy with five levels of authority/responsibility. The levels of management responsibility are interstate or regional, state, provincial, district and farm.

The regional/interstate level organizations work in two different aspects. While one set of organizations (IFAS and ICWC) deals with macro-level water resources, environmental management, funding decisions and political decisions, the other set (BVOs) deals with technical aspects of water regulation among the states. However, most of the regional/interstate arrangements suffer from a lack of financial commitment from the member states and do not perform optimally.

At the country level, ministries in charge of water resources are responsible for management of the water resources within their country boundaries. These ministries focus on planning and policies and delegate most of the allocation, regulation and distribution tasks to the respective provinces. At the provincial level, provincial water managing organizations (*Oblvodkhozes*) distribute and deliver water to major irrigation schemes. Oblvodkhozes control main and distributary canals and their area of control typically ranges from 300,000 to 600,000 ha. Likewise, district water management organizations (*Rayvodkhozes*) are responsible for water distribution to various sets of farms. They operate and maintain inter-farm canals up to the gates of the collective farms or water users associations (WUAs). A typical area of responsibility for a rayvodkhoz is around 20,000 to 25,000 ha.

[2]The water management staff from south Kazakhstan, Kzylorda and Shymkent is also invited to this meeting in situations where urgent problem-solving is necessary.

The farm structure within each of the five independent states varies, depending on the level of progress in land privatization. *Kolkhozes* or collective/cooperative farms which existed under Soviet rule devolved in to WUAs. Each WUA comprises several PPFs. The WUAs are responsible for water distribution and operation and maintenance (O&M) of the infrastructure within the boundaries of their farm. Initiatives are underway in each country on different scales and with different speeds to privatize land and reorganize the private farms into WUAs. The impact of land privatization and farm integration initiatives on improvements in water management depends on a host of policy, socio-political, institutional and market factors that are yet to be determined (IWMI 2000).

Water Allocation

Water Allocation Elements and Principles

During the Soviet era, the state of water resources use in Central Asia was evaluated by applying the delivery efficiency coefficient (DEC) in calculations to determine how much water from the higher level of the system reaches the lower level (e.g., from main canal to inter-farm canal, from inter-farm to on-farm canal and from on-farm canal to irrigated field). The DEC calculations represent the share of losses at each level of the system. However, these calculations do not reflect how water resources are used for producing agricultural crops. The DEC is calculated as follows:

DEC	=	(Wapp/Wwith)x100
Where:		
Wapp	=	volume of water applied for irrigation, m^3
Wwith	=	volume of water withdrawal for irrigation, m^3
Note:		
DEC< 50%	-	irrigation system is technically poor
50<DEC<70%	-	irrigation system is technically moderate
DEC>70%	-	technically good conditions

The assessment of water use through DEC calculations was well suited to the environment of the economic system of the former Soviet Union. As in all socialist economies, the natural resources, including scarce water resources, were rarely properly valued, regulated or managed. In such an economic environment, water use in all sectors of the economy was not related to the end product of the sector. However, in municipal and industrial sectors, there are legally imposed nominal fees for water supply and severe penalties for unregistered and untreated discharge of sewage water. But, all industrial sectors are state owned, and the regulations are rarely implemented. The few attempts to introduce water fees in irrigated agriculture failed after one to two years of experimentation.

In irrigated agriculture, the main aim of water management units at all levels is to deliver water according to the user demand. The demand for water in irrigated agriculture is estimated by DWMOs at the beginning of each irrigation season (there are two irrigation seasons in Central Asia: vegetation, April-September; and non-vegetation, October-March). The demand for water was determined according to climatic zone, size of irrigated area, crop type and soil and groundwater conditions. There are so-called "hydromodule districts" within the irrigated zones of Central Asia. For each type of crop, within each hydromodule district, recommended water demand norms are calculated. The collective demand for water includes all losses above the on-farm level (in main and secondary canals). However, the DECs of the systems are not properly monitored, and only "normative" values are used for the calculations. The water allocation principles applied during Soviet rule (and are still continuing) have no incentive for conserving and saving water. In many cases the real water supply rates are two to three times higher than the recommended water demands. The absence of incentives for conserving water resources has led to an overexploitation of irrigation water.

In the late 1980s, the irrigation water limit (IWL) was introduced to Central Asia because the water demand almost matched the available water resources of the region. Under IWL the demands of users were adjusted in accordance with water availability in the sources (rivers, reservoirs, etc.).

After the collapse of the Soviet Union, the Central Asian states did not change these water allocation principles at all. Only in Kyrgyzstan, an upper-reach country, the limits were abolished, and water is now being delivered according to user demand. In the water-scarce states of the region (Uzbekistan, Kazakhstan and Turkmenistan) the IWL is still operational.

The IWL made the process of water allocation more complicated. In reality there are two separate processes for planning and allocating water in irrigated agriculture in Central Asia. The first process consists of estimating the demand from water users, collective/cooperative and private farms, or from WUAs by the higher water management levels (district/province/state). The second process includes the preparation of limits for users—this is calculated by the higher levels of water management (ministries of agriculture and water management in the respective counties) and communicated to lower units (district water management organizations). The "limit" demands and the estimated demands are translated into water-use plans at the district level, according to which water is allocated to the users.

In Central Asia/Aral Sea basin, the present water allocation rules and governing elements are similar to what existed during Soviet rule. Water allocation has to follow several steps in the organizational structure. In the first step, interstate water allocation agreements have to be implemented, considering water allocation from the sources (rivers, water reservoirs and interstate canals) to each state. The Syr-Darya BVO and Amu-Darya BVO, respectively, are responsible for water allocation from the two main rivers (Amu-Darya and Syr-Darya) within the region. The second step constitutes water allocation in the irrigation systems within each state, including interstate, inter-district and inter-farm canals. For this step, the water-related ministries of each state, the Ministry of Agriculture and Water Management or special water resources committees, are responsible.

The next three steps constitute distribution at and below the provincial level—from the province (locally referred to as *oblast*) management unit via district management unit to the farm. Management units for provinces are called oblvodkhozes; they distribute water further amongst the districts (*rayons*). Water resources at the district level are managed by rayvodkhozes, which are responsible for water delivery to all farm units. Farm management is then responsible for distributing the water within the farm boundaries. Generally, in all five Central Asian states allocations follow similar steps. In Uzbekistan, the *shirkats* (form of collective-cooperative unit) are responsible for on-farm water distribution. Private farms have to sign an agreement on water supply with the shirkats.

There are three elements or indices of water allocation used in Central Asia as a whole, including the SRB. These are: irrigation water demand (IWD), irrigation water limit (IWL) and irrigation water supply (IWS). Each of these elements has a water application purpose. The IWD is calculated as demand for water, taking into account crop type and climatic and soil conditions. There is no guarantee that a volume of water equaling the IWD will be supplied. It is an optimal volume of water, calculated for a given type of crop and the conditions of the area. Research institutions project a mean IWD with a long-term validity. The last calculation of the IWD for Uzbekistan was done in the 1990s and is still in use. Research on projecting the IWD is still going on, but the main principle has so far remained the same.

The IWL is the restricted amount of water to be supplied to the irrigated area after taking in to account the forecasted water availability of the water source. In fact the IWL is an adjusted IWD, taking into account the availability of water in the source. This index was introduced at the end of the 1980s, because of environmental changes in the Aral Sea basin and a relatively high deficit of water resources. The IWL, to some extent, provides a water right for users. The IWL is calculated seasonally for the vegetation period (April-September) and for the winter season (October-March) and must be approved by the authorities at different levels: at the interstate level by ICWC, at the state level by the relevant Ministry, and at the provincial and district levels by governors.

The irrigation water supply (IWS) represents the real water supply to the user at a given time (day, week, month, season and year). The IWS is actually the IWL adjusted according to the real water supply. The IWS can be higher than the IWL (predicted water availability < actual water availability), equal to the IWL (predicted water availability = actual water availability), or less than the IWL (predicted water availability > actual water availability). The principles or methods of determination of the IWD, the IWL and the IWS are given next.

Technical Basis for Determining Water Allocation Principles

As mentioned earlier, the basic water allocation principles in Central Asia today are basically the same as those during the Soviet era. The three governing indices, the IWD, IWL, and IWS had no solid documentation until the 1970s, when the technical basis for determination of water shares in Central Asian irrigated agriculture was worked out. They were mostly built on the method developed by the research institute called Sredazgiprovodkhlopok[3] (1970).

According to the manual developed by Sredazgiprovodkhlopok, the irrigated areas of the Syr-Darya and the Amu-Darya river basins fall into three latitude zones and five altitude zones. Within the different climatic zones, there are “hydrogeological” and “soil-meliorative” regions. These regions are defined on the basis of the conditions for groundwater recharging:

a: impression region—groundwater is not impacting soil formation, the groundwater outflow is secure and the groundwater table is deep within the territory

b: discharge region—intensive inflow and a very difficult groundwater outflow; persistently high groundwater table, which impacts soil formation

c: depression region—impeded inflow and outflow of groundwater, with fluctuating groundwater depth and regime

[3]Sredazgiprovodkhlopok—Central Asian research institute on cotton irrigation, which existed until 1993. It was later renamed Uzdavmeliosuvlouiha and carried out designing of most of the irrigated projects in the Central Asian region.

To calculate the IWD for irrigated areas, nine hydromodule districts were considered. However, irrigated agriculture was not possible in two of them because of the soil conditions.

Calculation of Irrigation Water Demand (Crop Water Requirement)

The demand for irrigation water was calculated for the vegetation period (April-September) and the non-vegetation period (October-March). During the vegetation period demand on irrigation water was calculated using equation 1:

$$M = 10 \times K1 \times K2 \times (E-O) \qquad (1)$$

where:

M = crop water requirement (m^3/ha)
E = potential evaporation from April to September (mm)
O = precipitation for the same period (mm)
K1 = coefficient, related to the type of crop
K2 = coefficient, related to the hydrogeological and soil-meliorative conditions of irrigated areas

In equation 1, the monthly mean of E and O are determined through the formula developed by N. N. Ivanov (Sredazgiprovodkhlopok 1970).

$$E = 0.0018 \times 0.8 \times (25+t)^2 \times (100-a) \qquad (2)$$

where:

E = potential evapotranspiration (mm)
t = monthly average of air temperature (^{o}C)
a = monthly average of humidity (%)

The means of K1 and K2 coefficients were calculated by a series of experiments for each zone by researchers (this was done in tabular format, but due to size restrictions they are not presented here). The monthly irrigation water demand was calculated through equation 3 using the climatic data from all of the hydromodule districts. However, it does not include the losses from the irrigation system nor is it considered a field-level IWD. The demand of the irrigation system on water should include the losses (50 to 75% of calculated water demand) during the delivery from head to intakes.

$$IWD = M/h \qquad (3)$$

where:

IWD = irrigation water demand (m^3/ha or m^3)
M = crop water requirement (m^3/ha or m^3)
h = delivery efficiency (portion of water reaching the irrigation system)

Calculation of the Irrigation Water Limit (IWL)

There are no clearly defined methods for the IWL calculation, and the method used by water managing entities depends on the forecasted water availability in the river or other water sources. However, there are two basic methods for the calculation of water limits. The first method is based on the determination of the coefficient of water availability by comparing the water volume of a river or other water source with the IWD. The second method is based on the comparison of potential irrigated areas with cultivated irrigated areas.

Method one—comparison of the water volume of a river or other water sources with IWD:

$$K_{b.o} = W_r\ h / IWD \qquad (4)$$

where:

$K_{b.o}$ = forecasted coefficient of water availability
W_r = forecasted river water volume, 75% probability (m^3/ha or m^3)
IWD = irrigation water demand (m^3/ha or m^3)
h = delivery efficiency (amount of water reaching the irrigation system)

If the mean of $K_{b.o} < 1$, limited water would be supplied to the area. $K_{b.o}$ determines the IWL of each irrigation system and the principle for all areas:

Limit = IWD $K_{b.o}$ (5)

where:

Limit = IWL (m^3/ha or m^3)

Method two—comparison of potential irrigated areas with planted irrigated areas:

wir = Qr h/qir (6)

where:

wir = potential irrigated area under the forecasted water availability of water sources—rivers or other sources (ha)

Qr = forecasted river discharge—average for long period, calculated from river hydrography (m^3/s)

h = delivery coefficient (amount of water, reaching the irrigation system)

qir = hydromodule discharge of irrigation system—calculated from IWD, in liters per second per one hectare water supply (l/s ha)

$K_{b.o}$ = wir/wp (7)

where:

wp = planted irrigated area (ha)

Again, if $K_{b.o}$<1, the IWL is calculated through equation 5.

Actual Water Distribution (IWS)

If the region is under pressure from water shortage, the actual water supply is less than the demand and therefore limits have to be imposed on the amount of irrigation water supplied. The principles applied for the determination of the actual water supply for irrigated agriculture are similar to the IWL calculation. The data on available water in the source is used as basic information to determine the irrigation water supply. The available water resources are distributed among water users by the use of a sufficiency coefficient:

Df = Wav/ åWlimit (8)

where:

Df = coefficient, which shows water sufficiency in the source

(<1, deficit or >1 ,more than IWL)

Wav = volume of available water in the source (km^3)

åWlimit = summarized volume of the limits of the different water users of the irrigation system (km^3)

The irrigation water supply of each water user is determined by the equation given below:

IWS_I = $Limit_I$ Df (9)

where:

IWS_I = irrigation water supplies for water user i

$Limit_I$ = Limit of water user i

Assessment of Performance in the Syr-Darya Basin

The Water-Saving Competition Sponsored by the World Bank/IWMI

The water-saving competition was initiated as part of the Global Environment Facility's (GEF's) water and environmental management project, which combined the need to increase productivity of irrigation water under the increasingly worsening conditions of water scarcity. One component of the project, rewarding winning water users of the competition, was aimed at stimulating a wider circle of water users and involving them in water savings. The competition monitoring was begun in 1999 and was supported by the World Bank for two successive crop-growing seasons till the year 2000. Its primary strategy was to propagate the application of inexpensive technical and managerial methods and measures to save water by users themselves (GEFPA et al. 2000).

Various groups of water users and water supplying organizations (collective farms, farmers and WUAs) participated in the competition. In total, some 144 water-savings initiatives (different measures for reduction of water use in agriculture) participated in the competition. All together, 30 district water management organizations (DWMOs), 8 WUAs, 58 collective-cooperative farms (CCFs) and 61 private-peasant farms (PPFs) from 8 provinces in the Aral Sea basin took part in the water-saving competition (figure 2). In the water productivity analysis, only the water management institutions located in the SRB were taken into account. These were: 24

FIGURE 2.
Map of project locations.

DWMOs, 8 WUAs, 43 CCFs and 47 PPFs from the 6 provinces (2 from Kyrgyzstan, 1 from Tajikistan and Uzbekistan and 2 from Kazakhstan) of the 4 states of the SRB. Head, tail and middle reaches of the SRB were represented by an equal number of provinces (2 provinces in each reach). Table 1 and figure 2 present the location of the project provinces within the SRB and the Central Asian region.

Most significant in this competition was the fact that water-savings approaches by water users were not experiments "forced from top down by officials," but actual and concrete practices and measures undertaken by participants themselves. During the competition it became evident, that some demonstrated water-saving practices that existed before the competition. Self-monitoring of water use and productivity by the participants themselves remained the key strategy. Competitions were organized within the province level and by the type of participants (DWMOs, WUAs, CCFs and PPFs). There was no competition among the same type of management institutions within the same region (whole SRB or Aral Sea Basin or interstate level). This was mainly due to the political reasons (the questions of "who is using water more economically" or "who is conserving more water?"). The payoff to land ($/ha), payoff to water ($/1000m^3) and payoff to investments ($/$) were the indicators used for selecting the winners. There were two prizes (1 and 2) for DWMOs and WUAs and three prizes for CCFs and PPFs within each province. However, during year 2001, the World Bank decided to withdraw its support for the competitions. Though the participants of the competitions kept on saving water, the competition itself was discontinued.

However, IWMI together with SIC-ICWC decided to build on the previous work and continue to strengthen the monitoring of water-saving practices—though on a much smaller scale. The initiative focuses on reaching and convincing a wider public to adopt basin-wide water conservation practices through the joint adoption of the "best practices for water conservation" project. The overarching goal of the project is to forge a gradual change in attitude of water users and water managers at all levels in the hierarchy towards water as a limited resource and prepare indicative recommendations for policymakers regarding irrigation water allocations within the region.

The strategy is to select the best management institutions from the previous competition, monitor their water use, productivity and salinity situation and encourage other water users through field demonstrations to conserve water. In this process, local NGOs are to be involved in promoting the water-savings campaign and disseminating water conservation results to the public at large. The selection of best practices in the IWMI-SIC project is different to the previous system. The number of participants has decreased to 9 DWMOs, 8 WUAs, 15 CCFs and 19 PPFs in the 6 provinces of the SRB. This is due to financial limitations and the reliability of the data collected. The project outcomes are based on general data collection and on calculations of water productivity. Also, the earlier competitive attitude has changed into a more participatory approach towards water saving. Participants of the project (DWMOs, WUAs, CCFs and PPFs) are receiving

TABLE 1.
List of project locations.

River reach	Syr-Darya basin	
	State	Province
Upper	Kyrgyzstan	Osh Djalalabad
Middle	Uzbekistan	Fergana
	Tajikistan	Sogd
Lower	Kazakhstan	South-Kazakhstan
		Kzylorda

a guaranteed amount of money (DWMOs and WUAs US$150; CCFs US$100 and PPFs US$50) for submitting data on the amount of water used, quantities of agricultural inputs, outputs, etc. However, after discussions with the participants in year 2001, it was concluded that for making water-saving methods sustainable it is crucial to have at least one prize for each type of organization (DWMO, WUA, CCF and PPF). In other words, according to the participants, the competition played a key role in promoting water savings.

There is sufficient data from the various organizations that entered the competition to make some estimation of the overall performance (water delivery, crop yields and water productivity). The following section examines the performance in three main dimensions: between the six different provinces in the basin; between the different types of participating units and between units in the head, middle and tail of each province.

Research Methods

The monitoring of the competition was carried out by trained field observers for agricultural enterprises (one for each CCF or PPF) and by district observers for water management organizations (one observer for each DWMO). The field and district observers were trained at three special training workshops on data collection procedures.

The observers conducted the following observations in the fields/farms/WMOs:

1. monitoring of the crop development/ yields—planting dates, type of seeds, cultivations, crop development stages, stresses in crop development, diseases, harvesting and crop yield determination

2. water accounting/balance monitoring—pre- and post-sowing irrigations, inflow-outflow discharges (hourly), drainage inflow, soil moisture check three days prior to irrigation and three days after irrigation, groundwater level (daily monitoring)

3. agro-economic monitoring of crop growing and associated expenses—agricultural practices, applied with dates, amounts, expenses for such practices, water conservation practices and expenses for application, fertilizer/ pesticide/herbicide applied, dates and expenses, etc.

4. monitoring of salt balance—salt content of irrigation, drainage and groundwater and soil salt content

The quality of the recorded data was regularly checked on site. The water measurement was performed using measurement devices. The devices were installed at the inlet and outlet of each sample field, farm and irrigation system/canal. The observers/monitors recorded the readings and monitored the irrigation schedule accordingly. During irrigation, the observers took hourly records of water depth or discharge. Records were logged into a special monitoring form developed by the SIC-ICWC research team.

Observers/monitors collecting the data on yields were properly trained on how to determine the crop yield. Cotton yield in Syr-Darya is the average weight of cotton (in tons) that is harvested from the field. This very definition is more of a "seed cotton yield" than of the refined or final product-related yield (lint). Data collection for sample fields was carried out using the square method. Ten squares of 1 m^2 were selected in the diagonals of the sample field. In each square cotton was picked and measured. The average yield per hectare was calculated from the average square yield. In addition to the field data, the crop statistics per farm and districts were collected.

The database on the project was developed in MS Access and MS Excel. For the analysis in the paper, data from this database is used—extracts from the database are given in the annex.

Water Delivery Performance

The average demand for the entire area in year 2000 was 1,189 mm (1 mm = 10 m^3/ha) for the April-October period. The IWL, based on an early assessment of water availability, was slightly higher at 1,220 mm, but the actual water deliveries only averaged 913 mm. Table 2 shows that there are very large differences in the demand calculated for the different provinces. This reflects the combination of temperature, cropping pattern and soil/salinity conditions used in determining what the crop water requirements are. Four of the six provinces requested less than 750 mm—Sogd had a demand of 1,421 mm, while Kzylorda requested 2,537 mm, much of which was for leaching of salts. In so far as the demand is based on an agreed set of calculations, there is no dispute that this is an unfair distribution of water.

The IWL for the three upper provinces was lower than the IWD, but was higher in the lower three provinces. This reflects the hydrologic topology of the basin—the lower three areas get water from more than one tributary valley of the basin, while the upper three provinces are all served from a single branch of the Syr-Darya.

However, the IWS was lower, as was the IWD and the IWL in all locations except in south Kazakhstan where supply exceeded the initial demand. This reflects on both the overall availability of water and the efforts by the competing units to use less water than in the past.

The average supply was approximately 70 percent of the IWL except for Fergana, which received 90 percent of the IWL but still received the lowest average supply. This indicates that there is considerable control over water at province level, which reflects the degree of coordination among the different countries and administrative units in the basin.

In terms of location within each province there are some significant differences in water distribution between head, middle and tail units (table 3). Overall, tail-end units tend to get more water than head- or middle-end units, irrespective of whether they are large rayons, intermediate cooperative farms or small private farms. This reflects a deliberate effort to avoid wasting water at the head end of a province and making sure that water is distributed as fairly as possible. This policy appears to be too severe,

TABLE 2.
Average water delivery within each province for the year 2000 (mm/season).

	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Kzylorda	Average
Demand	696	741	644	1,421	499	2,537	1,189
Limit	696	702	525	1,519	863	2,576	1,220
Supply	480	584	464	1,078	576	1,933	913

TABLE 3.
Water deliveries to different types of units and different locations for the year 2000 (mm/season).

Location	CCF	PPF	DWMO	WUA	Average
Head	986	498	934	483	831
Middle	862	949	1,123	482	961
Tail	1,883	870	1,122	782	974
Average	966	831	1,080	525	913

with quite large increases in deliveries to tail-end areas where waterlogging is more likely to develop. Table 3 also shows that, as expected, large units have higher supplies than small ones, presumably to compensate for losses within the area being irrigated. Rayons get about 11 percent more water per unit area than cooperative farms and 30 percent more than small private farms.

Cropping Patterns

For the purposes of the water-saving competition, the focus is on the productivity of the three major crops (cotton, wheat and rice). While there are several other crops, their area is less significant and does not significantly affect values.

The basin is dominated by cotton, which accounts for 55 percent of the three major crops (table 4). It is grown in all provinces except Kzylorda, although the amount in the Osh province is much lower than in the others. There is a general increase in the importance of cotton towards the north of the basin.

Wheat is the second-most favored crop, covering nearly 30 percent of the area. It cannot be grown at the same time as cotton because cotton planting has to be completed before wheat can be harvested. As a result many units adopt a two-year rotation system, planting wheat after cotton and leaving the field fallow, planting maize or another short-growing crop after the wheat has been harvested. Wheat is more important in upper parts of the basin where the climatic conditions are more favorable due to greater winter rain. Rice dominates Kzylorda, covering 81 percent of the reported area, but is insignificant elsewhere.

Yields

Yields of cotton average around 2.9 t/ha, generally higher in the upper parts of the basin, and decline towards the tail (table 5). Fergana gets the highest average yields (3.4 t/ha) while south Kazakhstan averages just under 2.0 t/ha even though it has by far the largest area under cotton in the basin.

Wheat yields are very similar. They average 2.8 t/ha throughout the basin, with Sogd getting the highest average yields of 4.1 t/ha. Both tail-end provinces get low wheat yields—2.0 t/ha in south Kazakhstan and 0.9 t/ha in Kzylorda. These low yields reflect high summer temperatures and widespread salinity, and it is questionable whether the nearly 40,000 ha in these two provinces should really be growing wheat at all.

Table 6 presents information on salinity in the project locations. In the tail reach (Kzylorda) 100 percent of the irrigated area is moderately or highly saline. In the upper reach (Osh and Djalalabad) only 2.3-5.0 percent of the irrigated land is saline.

TABLE 4.
Total area of major crops by province and type of unit for year 2000 (ha).

Type of water users	Crop	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Kzylorda	Total
Collective/ cooperative	Cotton	274	71	6,905	5,739	5,901		18,890
	Wheat	575	66	4,018	1,794	985	2,910	10,348
	Rice		8		323	300	10,345	10,976
Private	Cotton	37	18	276	68	63		462
	Wheat	63	23	188	23		420	716
	Rice			1			900	901
Rayon	Cotton	18,040	10,728	30,755	25,633	124,600		209,756
	Wheat	16,707	25,954	19,934	7,296	22,172	11,953	104,016
	Rice					2,000	54,481	56,481
WUA	Cotton	1,585	948			1,900		4,433
	Wheat	2,252	3,235			15		5,502
	Rice							
Total cotton		19,936	11,765	37,936	31,440	132,464		233,541
Total wheat		19,597	29,278	24,140	9,113	23,172	15,283	120,582
Total rice		8	1	323	2,300		65,726	68,358

TABLE 5.
Cotton, wheat and rice yields in provinces (t/ha), all lands.

Crop	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Kzylorda	Average
Cotton	2.75	3.17	3.42	2.80	1.95		2.89
Wheat	3.48	3.83	4.12	2.36	2.02	0.91	2.82
Rice		1.76	2.98	3.24	2.69	4.26	3.99

TABLE 6.
Soil salinity in the project locations: percentage of total irrigated area.

Province	Non-saline	Moderately saline	Highly saline
Kzylorda	0	68.1	32.9
South Kazakhstan	32.3	39.2	28.6
Djalalabad	95	4.5	0.5
Osh	97.7	1.8	0.5
Sogd	62.1	33.0	4.9
Fergana	42.3	36.6	21.1

Rice yields in Kzylorda average 4.3 t/ha. Other provinces grow little or no rice and comparison is meaningless.

From the perspective of unit location within a province (table 7) there are no significant differences.

However, the type of unit does have an impact on yields. Private farmers almost always get better yields than cooperative farms, except for wheat, where cooperatives do a little better.

The interpretation of these differences is not simple. Private farmers are not always free to make cropping choices (private referring more to land ownership than to freedom from state policies) and do not have access to inputs from the market. Cooperatives can get inputs from the state sector, which vary in reliability among the different countries. Nevertheless, the implication is that private land is farmed more productively.

These differences cannot be attributed to the size of holding. Figures 3 and 4 show that for both cotton and wheat, yields are similar for all holdings between 6 and 6,000 ha. Rayon-level yields are lower but as these are not production-level units, it is not really fair to include them in an analysis of yields in relation to size.

What figure 3 shows clearly is that wherever salinity has been reported, yields are very low for wheat, irrespective of the size of the unit. Average wheat yields in the basin are 3.4 t/ha in non-saline areas. This data again leads to the conclusion that growing wheat in these saline areas is a waste of water and most clearly in Kzylorda where almost all areas are saline.

FIGURE 3.
Relationship of cotton yields to type and size of unit.

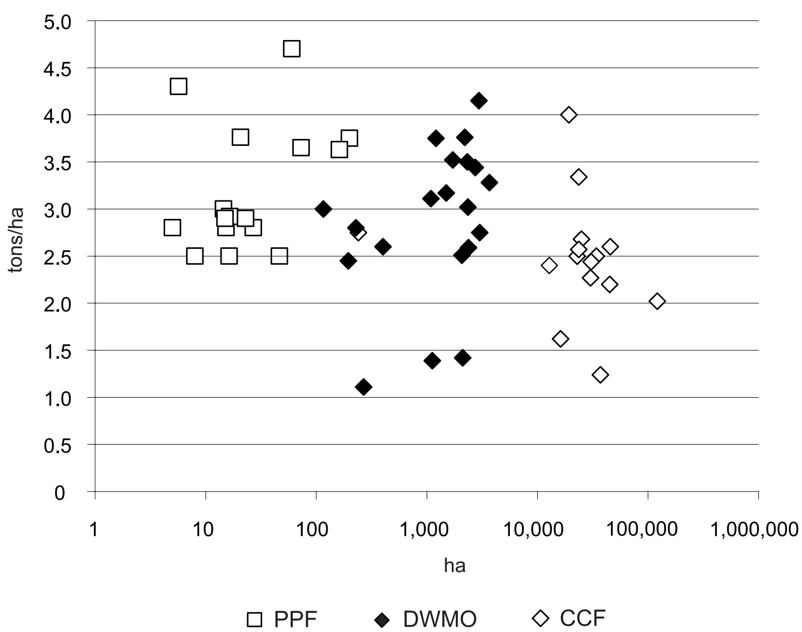
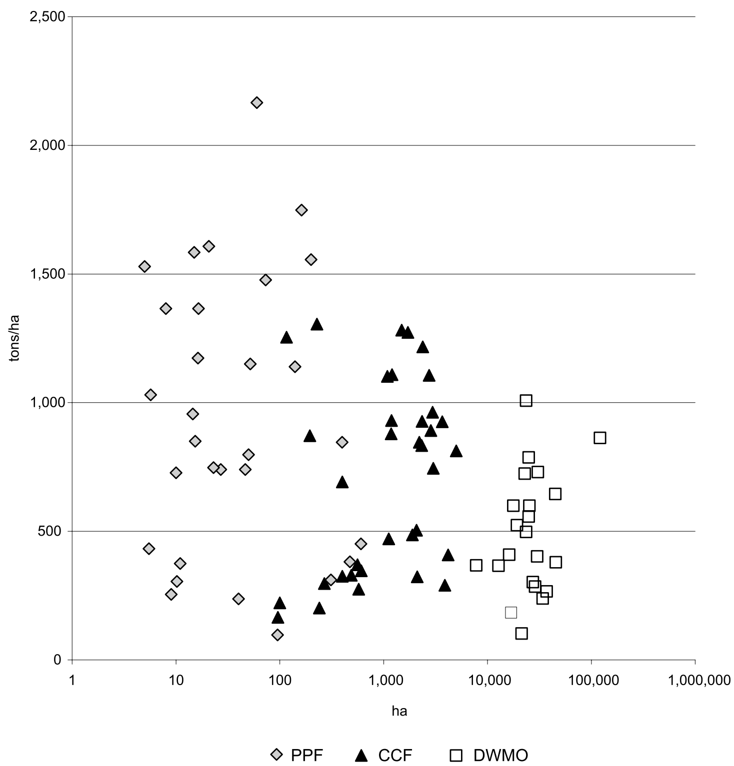


FIGURE 4.
Relationship of wheat yields to type and size of unit.



In non-saline areas, rayons perform less well. Private cotton farmers outperform cooperative cotton farmers but cooperative wheat farmers outperform private wheat farmers.

Productivity of Land

Productivity of land has been calculated in terms of gross value of production in US$ per hectare on the basis of the three major crops combined and using the standard gross value of product (SGVP) approach to standardize prices.

The average productivity of land is US$736, ranging from US$524 in Djalalabad province, the headmost part of the basin, to US$1,076 in Fergana valley (table 8). These province-based differences may reflect not only actual productivity but also the variation in prices and exchange rates in different countries.

Productivity by type of unit shows the same pattern as for yields. Private farms do best in every province, averaging US$938 per hectare, cooperative farms average US$714 per hectare, while rayons do worst in every province, averaging only US$511 per hectare.

Somewhat unexpectedly, however, there is a significant impact of location on productivity of land. Average productivity of tail-end farms is nearly US$1000 per hectare, while head-end farms only gross slightly over US$600 per hectare (table 9). Given that yields are not significantly different by location, it suggests that the cropping mix is more profitable in tail-end locations.

Salinity has an effect on the productivity of land. In the higher and middle reaches this effect is not much, but in lower reaches it is serious (tables 9 and 10). This means that although wheat produces almost no real value for farmers, rice does, and due to this they continue to

TABLE 7.
Cotton, wheat and rice yields by location, all lands (t/ha).

Crop	Head	Middle	Tail	Total
Cotton	2.81	2.94	2.90	2.89
Wheat	2.82	2.90	2.61	2.82
Rice	4.09	3.71	4.48	3.99

TABLE 8.
Productivity of land by province and type of unit, all lands (US$/ha).

Type	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Kzylorda	Average
CCF	452	710	1,031	916	599	552	714
PPF	608	763	1,208	1,251	1,475	725	938
DWMO	378	452	842	436	591	452	511
WUA	670	615					642
Total	524	656	1076	877	791	577	736

TABLE 9.
Productivity of land by province and location in province, all lands (US$/ha).

Location	Djalalabad	Osh	Fergana	Sogd	SouthKazakhstan	Kzylorda	Average
Head	435	470	1,013	868	642	541	613
Middle	615	880	1,011	873	722	539	764
Tail	605		1,315	893	1,584	719	955
Total	524	656	1,076	877	791	577	736

TABLE 10.
Productivity of land by province and type of unit, non-saline land (US$/ha).

Type	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Average
CCF	515	710	1,054	916	599	786
PPF	608	763	1,208	1,251	1,475	1,003
DWMO	425	452	1,008	436	591	522
WUA	763	615				674
Total	567	656	1,139	877	791	807

cultivate the saline lands in Kzylorda and can gross US$577 per hectare on average.

Productivity of Water

The final performance indicator is the value of water. This also uses the standard gross value of product (SGVP) approach to generate gross farm income, and considers the volume delivered to the head of each unit. The results show quite large differences that are important for assessing water management strategies.

The average productivity of water in the Syr-Darya basin is US$0.11/$m^3$. Three provinces perform more or less at the average level. Fergana and south Kazakhstan are significantly higher at US$0.20 and US$0.16/m^3, while Kzylorda manages only US$0.03/$m^3$ (table 11). This reflects the huge water deliveries to this area for salinity amelioration.

If we ignore the data from Kzylorda, the overall basin-level productivity rises up to US$0.14/$m^3$, indicating that water use in non-saline areas is roughly five times more productive than in saline areas (table 12).

In terms of farm type, a similar trend to the one seen in land productivity is evident. Rayons have the lowest water productivity while private farms slightly outperform cooperative farms. However, it is only in the two tail-most provinces that private farms have any noticeable improvement over cooperatives.

However, from all the data it appears that farm size does have some influence on water productivity. In private farms, water productivity is much higher for larger farms than for smaller ones. The reason for this is not immediately clear, but one possibility is that on larger farms there is greater opportunity for reuse, so less water flows into drains and into other unproductive uses.

In terms of location within a province there is no clear trend. This suggests that there is no overall influence that merits managerial attention (table 13).

Institutional Implications for Improving Water Productivity

The water users and managers in the Syr-Darya river basin are faced with the challenges posed by the transition to a market economy. For managers, decaying water delivery infrastructure, unavailability of funds for proper O&M of the infrastructure, poor salary levels, etc., are the main constraints to efficient management of water resources. The sanction and reward mechanisms for water managers do not generate enough motivation for improving irrigation-system performance. Once water is diverted and delivered to the off-takes, the responsibility of the canal managers ends. Any attempt to improve the productivity of water, except physical improvements and rehabilitation of the system would, therefore, have no major and sustained impacts on the current methods of water management at the higher levels of the system. The water-saving competition has provided temporary incentives for canal managers by offering an opportunity to win a prize and earn recognition for better performance. The competing WMOs have mostly introduced managerial measures like rotation of canals, fixing water turns for farms and promoting night irrigation among farmers. These attempts are, however, unlikely to be sustained when the competition is withdrawn. Therefore, any serious attempt to improve water productivity should focus on bringing about institutional changes, which link water performance of the canal managers with the sanction and reward mechanisms.

TABLE 11.
Productivity of water by province and type of unit, all lands (US$/$m^3$).

Type	Djalalabad	Osh	Fergana	Sogd	SouthKazakhstan	Kzylorda	Average
CCF	0.12	0.12	0.21	0.10	0.15	0.03	0.11
PPF	0.10	0.11	0.23	0.16	0.22	0.04	0.14
DWMO	0.05	0.06	0.13	0.03	0.14	0.02	0.06
WUA	0.13	0.09					0.11
Total	0.10	0.10	0.20	0.10	0.16	0.03	0.11

TABLE 12.
Productivity of water by province and type of unit, non-saline lands (US$/$m^3$).

Type	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Average
CCF	0.12	0.12	0.22	0.10	0.15	0.15
PPF	0.10	0.11	0.23	0.16	0.22	0.17
DWMO	0.06	0.06	0.14	0.03	0.14	0.08
WUA	0.16	0.09				0.12
Total	0.11	0.10	0.22	0.10	0.16	0.14

TABLE 13.
Productivity of water by province and location in province, non-saline lands (US$/$m^3$).

Location	Djalalabad	Osh	Fergana	Sogd	South Kazakhstan	Average
Head	0.09	0.07	0.27	0.09	0.19	0.12
Middle	0.14	0.13	0.17	0.10	0.15	0.14
Tail	0.10		0.30	0.10	0.13	0.18
Total	0.11	0.10	0.22	0.10	0.16	0.14

For the farmers, however, there are more incentives than for canal managers. The water is provided in limited amounts and often less than the required quantity. Therefore, there is a theoretical incentive to conserve water. However, the profits of farmers depend more on the prices of non-water inputs and the functioning of the markets. In Uzbekistan, for example, farmers in many areas are forced to grow cotton due to the state order system. The state provides subsidized inputs for cotton cultivation and purchases the produce at a set price, which is far below the cost of production—so much so that in certain parts of the country farmers are not motivated to pick their own cotton and the state has to send students and state employees to pick it. Even if the farmer produces excess cotton, the state is the only buyer. Thus, farmers do not recover even the cost of production. In some of the other states, for example, in Kazakhstan, farmers are relatively free in making marketing decisions.

The political economics of water pricing suggests that water prices do not form a significantly sufficient part of the production costs to be an effective instrument for water conservation. Technological interventions for significantly improving water productivity at farm level, such as drip and trickle irrigation, are too expensive for farmers to switch over from flooding and furrow irrigation. Therefore, in the absence of effective market instruments and appropriate technologies, the only way to improve water productivity is to provide water in limited amounts to the users, and let them fine-tune their management practices in view of the limited availability. Therefore, more emphasis needs to be placed on institutional interventions like improving water allocation methods and enforcing effective water rights at all levels of water management.

A comparison of the water performance of the Syr-Darya irrigation system with other irrigation systems in Asia (table 14) shows considerable possibility to conserve/save available water. However, high productivity per evapotranspiration in all reaches of the Syr-Darya shows high reuse of the return flows from irrigated areas in the upper reach, which makes water conservation efforts very difficult.

Conclusions

The Water-saving Competition

The water-saving competition among different types of water management agencies in the Syr-Darya basin has proved to be a valuable activity. It appears to have sparked an interest in the issue of trying to be more water efficient, and it is encouraging that, despite the current lack of financial incentives, the number of participants remains high.

A second significant element of the water-saving competition is that it has started to develop an important database. Prior to the competition there was little access to information about water use at different levels in the basin. The current data set, now in its third year, allows similar methodologies to be adopted in over a hundred different units in four separate countries. It has potential to be applied in other, larger and water-scarce basins to promote transparent exchange of information.

The data is not without problems. Large areas of all units are either in private holdings or left fallow and there is no way of distinguishing between water deliveries to the main crops and to the extensive area of “other” crops. This problem has been addressed in the 2001 season and will make it easier to determine the true productivity of the different major crops.

Comparison of Performance Within the Basin

The performance data from the different locations show, as can be expected, a considerable variation in performance from one location to the next.

The unit-size analysis suggests that smaller units are more productive than larger ones. This is certainly true when comparing data from rayons to both collective/cooperative and private

TABLE 14.
Performance comparison of Syr-Darya basin with other irrigated regions in Asia.

Item	Unit	Bhakra (India)	Chishtian (Pakistan)	Huruluwewa (Sri Lanka)	Krindi Oya (Sri Lanka)	Upper reach (Kyrgyzstan)	Middle reach (Uzbekistan)	Lower reach (Kazakhstan)
SGVP	Million US$	2,146.30	41.36	5.90	14.52	7.70	19.06	19.6
Land productivity	SGVP/cropped area (US$/ha)	728.00	398.00	761.00	842.00	313.00	732.00	433.00
Water productivity per available water	SGVP/AWirr. US$/$m^3$	0.15	0.06	0.04	0.06	0.05	0.12	0.05
Water productivity per process consumption	SGVP/ETa US$/$m^3$	0.17	0.07	0.10	0.15	0.14	0.12	0.12

units, but there is much less difference in performance levels between collective/cooperative and private units. Yields are more or less the same and land and water productivity show slightly better performance in privately operated units but is not significant. In terms of water productivity, larger private farms seem to do better than smaller ones, suggesting better opportunities for re-use of drainage water within the farm boundaries, but again the differences are not significant.

We cannot therefore make any direct recommendation about the size or ownership of different units—believing that state policies towards inputs and outputs are probably more influential.

The other major influence is the environmental variation in the basin and most notably the influence of salinity on performance. By all criteria, Kzylorda province in Kazakhstan performs less well than any other province and it is only because rice prices are roughly double than those of wheat that performance based on value produced per hectare are comparable. Productivity of land is below average, but productivity of water is unacceptably low, even allowing for leaching and other soil amelioration practices.

One final observation is that there is no clear head-tail trend within provinces. This speaks well for the process of allocation and delivery of water between units, and indeed represents a deliberate policy in some countries to minimize head-end water use so as to allow more water to tail areas.

Comparison of Performance with Other Regions

In comparison with several systems from India, Pakistan and other areas of South Asia, the Central Asian data is neither better nor worse on average. This indicates that there is nothing exceptional about the water management conditions in the area: the motivation to improve water management comes because the Aral Sea is drying up.

The comparison with India is least favorable because yields in India are better than those from Central Asia, but are generally much more favorable than for Pakistan, where the data comes from an area subject to some salinity. Comparison with Sri Lankan data is more complicated, because of the greater overall water availability in Sri Lanka from rain and irrigation. Central Asia, in this context, performs much better from the perspective of water productivity from available water, but obtains similar values for productivity of depleted water.

Agriculture and the Environment

The desiccation of the Aral Sea dominates the issue of water productivity, water saving and water allocation between sectors in the Syr-Darya basin. Although the performance data presented here cannot give a hard and fast answers to policy makers, it does provide a clearer basis for making water-allocation decisions.

The most obvious issue is the nature and type of water use in Kazakhstan, particularly in saline areas. Within Kzylorda province there are six rayons that have a total arable area of 132,000 ha, of which 55,000 ha are in rice production and another 11,000 ha in wheat (the remainder are either fallow or are farmed individually). The average income in these six rayons is US$450/ha, while the average water productivity is US$0.02/$m^3$. Although on average the production of rice from these rayons is almost 4 t/ha, amounting to a total annual production of 220,000 tons of rice, they receive almost 2000 mm/year of irrigation deliveries—some 2.64 km^3 of water. While some of this water returns to the Syr-Darya as drainage (albeit saline drainage) it has to be compared with the needs of the Aral Sea and the ecological value of this water.

In 1999-2000 a total of 2.8 km^3 of water reached the Aral Sea, while 21.57 km^3 was withdrawn—Kazakhstan diverted 8.2 km^3 of this. If at least some of the saline rice producing areas in the Syr-Darya basin are taken out of production it would be possible to double the flows into the Aral Sea. The net cost of taking out of production the six rayons in the study would be less than US$30 million in terms of the gross value of production of cotton and wheat, but would presumably have a far higher value for the Aral Sea.

Upper areas in the Syr-Darya basin should become more water efficient and thereby conserve more water. However, at the same time there is a danger that the conserved water might be used to increase the irrigated area. If this happens production will increase because water is used more effectively, but it will not result in water savings that can be transferred to the Aral Sea. The data from the water-saving competition does not provide us with an opportunity to determine whether the water saved as a result of management improvements is turned into an actual saving. The risk to the Syr-Darya basin is that upstream savings will merely mean more water for downstream irrigators and not for the Aral Sea.

TABLE 1.
Codification of water-saving competitors.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Sheili	111	DWMS	1	R
LR	Kazakhstan	1	Kyzil Orda	11			FLR Akmaya-2	2	C
							FLR Gigant	3	C
							Peasant farm Jety againi	4	P
							Ps.F Izgilik	5	P
							Ps.F Maksat	6	P
							Ps.F Akniyet	7	P
							PF Sapar	8	P
							FLR Nartay	9	C
							FLR Bikmenbet	10	C
							FLR Talaptan-2	11	C
					Janakurgan	112	DWMS	12	R
							S/f Togusken	13	C
							Ps.Jana Jol Az	14	P
					Syrdarya	113	Kzylorda DWMS	15	R
							Syrdarya DWMS	16	R
							FLR Shagan	17	C
							FLR N.Ilyasov	18	C
					Karmakchi	114	Karmakchi DWMS	19	R
							RPC Jonajol	20	C
							PC Dostyk &C	21	C

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Jalagash	115	Jalagash DWMS	22	R
							PC Shamenov	23	C
							Ps.F Algabas	24	P
			South Kazakhstan	12					
					Makhtaaral	121	Makhataral DWMS	25	R
							APC Rakhat	26	C
							WUA Aray	27	W
							WUA Makhtaly	28	W
							PC Dostyk	29	C
							PC Ketebai	30	C
							PF Abildayev	31	P
					Turkestan	122	Turkestan DWMS	32	R
							PC Farkhad	33	C
							PC Koktondy Ata	34	C
					Shardara	123	Kyzylkum DWMS	35	R
							RSCE Komsomol	36	C
							SCE Jaysan	37	C
							PF Janibek	38	P
							PF Asem	39	P
					Sayram	124	PC Yassavi	40	C
UP	Kyrgyzstan	2	Osh	21					

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Karasu	211	Karasu RDWM	41	R
							WUA Rakhmat	42	W
							WUA Jany Aryk	43	W
							JSC Uch Kairagach	44	C
							Ps.F Mungush	45	P
							PF Maksat	46	P
					Nookat	212	Nookat RDWM	47	R
							Ps.F A.Salieva	48	P
					Aravan	213	Aravan RDWM	49	R
							WUA Sakhy Darya	50	W
							PF Ogalik	51	P
					Uzgen	213	Uzgen RDWM	52	R
							JSC Bee Brooder	53	C
							PF Shabadan	54	P
							PF Ak Emgek	55	P
					Karakuljan	214	PF Kok Jar	56	P
			Djalabad	22					
					Alabuka	221	Alabuka RDWM	57	R
							SSGF Ak Korgan	58	C
							Ps.F Jenish	59	P
							Ps.F Kulet Ata	60	P
							Ps.F Naimetov	61	P

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Aksy	222	Aksy RDWM	62	R
							Ps.F Intymak	63	P
					Suzak	223	Suzak RDWM	64	R
							AC Akykat	65	C
							AC Toktosunov	66	C
							SSGF A.Yunusov	67	C
							WUA Bulak Suu	68	W
					Nooken	224	Nooken RDWM	69	R
							WUA Nooken-K	70	W
							WUA Kyzyl Ai	71	W
							AC Kench	72	C
					Toktagul	225	Ps.F Chychkan	73	P
					Bazar Korgan	226	Ps.F Alatoo	74	P
							Ps.F Kyzyl ata	75	P
					Suzak	223	Ps.F Ak Tilek	76	P
							Jigach Korgon	77	P
							Ps.F Jaichi	78	P
MR	Tadjikistan	3	Sogd	31					
					Kanibadam	311	Kanibadam WMA	79	R
							JSC Iram	80	C
							JSC Boimatov	81	C

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Djabbar Rasulov	312	Djabbar Rasulov WMA	82	R
							K-z Samadov	83	C
							AC Digmay	84	C
					Bobojan Gafurov	313	Bobojan Gafurov WMA	85	R
							JSC A.Rakhimboyev	86	C
							JSC Jumayev	87	C
							K-z Rasulov	88	C
					Matchi	314	AC Zarifiyen	89	C
							PF Gafforien	90	P
					Zafarabad	315	DF Davronien	91	P
							PF Obidjon	92	P
							PF Yusufi	93	P
URA			Khatlon	32					
					Bokhtar	321	Bokhtar HAPROA	94	R
							K-z Kommunizm	95	C
							S-z F.Saidov	96	C
					Khodjamston	322	OD Shurabad IN	97	R
							K-z Lenin	98	C
							K-z Komsomol	99	C
							PF Ismat	100	P
					Vaksh	323	OD Vaksh IN	101	R
							PF Safari	102	P

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Gozimalik	324	S-z Bobjonov	103	C
							DF Radjab	104	P
							PF Shukhrat	105	P
							PF Firuz	106	P
					Sarband	325	K-z R.Odinayev	107	C
					Kolkhozabad	326	K-z Jumayev	108	C
							K-z Lenin	109	C
MR	Uzbekistan	4	Fergana	41					
					Kuva	411	Kuva RDAWM	110	R
							K-z Navoi	111	C
							K-z Khakikat	112	C
							K-z Rakhmatov	113	C
							PF Akhmad ata	114	P
							PF Mirkhamid	115	P
							PF Kosimkarvon	116	P
					Oltiaryk	412	Oltiaryk RDAWM	117	R
							K-z Al Fargoni	118	C
							K-z Navoi	119	C
							PF Khadji	120	P
							PF Odiljan	121	P

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Besharyk	413	Besharyk RDAWM	122	R
							K-z Rapkon	123	C
							K-z Dustlic	124	C
							K-z Uzbekistan	125	C
							PF Zarbulok	126	P
							PF Otajon	127	P
							PF Kora Jida	128	P
							PF Yangi Khayet	129	P
MRA			Kaskadarya	42					
					Kamashi	421	Kamashi RDAWM	130	R
							K-z Karabag	131	C
							K-z Chimkurgan	132	C
							PF Diyer	133	P
							PF Tabbaruk Zamin	134	P
							PF Mamat	135	P
					Shakhrizabz	422	Shakhrizabz MCDM	136	R
							K-z Ulugbek	137	C
							K-z Amir Timur	138	C
							K-z uzbekistan	139	C
							PF Suluv Momo	140	P

continued

TABLE 1.
Continued.

Location in the basin	Republic	Republic code	Province (Oblast)	Province code	District (Rayon)	District code	Type of water user	Competitor ID number	Type of competitor
					Karshi	423	Karshi RDAWM	141	R
							K-z Yakshi Omonov	142	C
							PF Faiz	143	P
					Kasbi	424	K-z Kh.Khujakulov	144	C
							PF Khakkulobrui	145	P
						425	PF Ruzimat	146	P
					Kasan		PF Koson	147	P
							PF Maidanak	148	P
							PF Tulga	149	P

Note:

LR = Lower reach
UP = Upper reach
MR = Middle reach
URA = Upper reach Amu-Darya
MRA = Middle reach Amu-Darya
R = District water management unit
C = Collective/cooperative farms
P = Private/peasant farms
W = Water users association
DWMS = District water management service

TABLE 2.
Cropping intensity for district water management units (Rayvodkhozes), collective/cooperative farms and private/peasant farms.

Competitor ID number	Type of competitor	Cropping intensity
41	R	93.39
49	R	59.16
52	R	100
57	R	100
62	R	100
64	R	100
69	R	100
79	R	100
82	R	100
85	R	100
79	R	100
82	R	100
85	R	100
110	R	100
117	R	100
122	R	100
1	R	100
12	R	95.30
15	R	100
16	R	100
19	R	100
22	R	100
25	R	100
32	R	100
35	R	100
44	C	100
53	C	30.3
58	C	100
65	C	100
66	C	100
67	C	100
72	C	100
80	C	100
81	C	100
84	C	100
86	C	100
87	C	100
88	C	100
111	C	100

continued

TABLE 2.
Continued.

Competitor ID number	Type of competitor	Cropping intensity
112	C	100
113	C	100
118	C	99.7
119	C	100
123	C	100
124	C	100
125	C	100
2	C	100
3	C	100
9	C	100
10	C	100
11	C	87.5
13	C	78.5
17	C	100
18	C	100
20	C	100
21	C	100
23	C	100
26	C	100
29	C	100
30	C	100
33	C	100
34	C	75.7
36	C	100
37	C	100
45	P	100
46	P	100
51	P	100
54	P	100
55	P	100
56	P	100
59	P	80.39
60	P	100
61	P	100
63	P	92
45	P	100
46	P	100
51	P	100
54	P	100

continued

TABLE 2.
Continued.

Competitor ID number	Type of competitor	Cropping intensity
55	P	100
56	P	100
59	P	80.39
60	P	100
61	P	100
63	P	92
73	P	100
74	P	100
75	P	103.43
76	P	0
77	P	0
78	P	0
90	P	100
91	P	100
92	P	120
93	P	
114	P	100
115	P	100
116	P	100
120	P	100
121	P	100
126	P	100
127	P	100
128	P	100
129	P	100
4	P	100
5	P	100
6	P	100
7	P	100
8	P	100
14	P	100
24	P	100
31	P	100
38	P	100
39	P	100

Note:

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

TABLE 2a.
Data on crop patterns.

				Crop pattern (ha)											
Reach	Competitor ID number	Type of competitor	Irrigated area (ha)	cotton	wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vines	Vegetables	Others
UR															
	41	R	45,452	7,918	13,015						1,098				20,421
	42	W	3,229	450	1,845		204			45	120				565
	43	W	1,000	18	430						14			102	436
	44	C	116	71	45										
	45	P	5.7	2.5					3.2						
	46	P	27	9	8		5							5	
	47	R													
	48	P													
	49	R	19,229	2,810	6,496		1,261				810				
	50	W	1,626	480	960						80			100	6
	51	P	15.3	6.3	9										
	52	R	21,341		6,443	3,784					1,424				9,690
	53	C	95.7		21			8							
	54	P	5.5		5.5										
	55	P	10.4						10.4						
	56	P	5							5					
	57	R	16,863		7,157		2,180				1,193			1,706	4,627
	58	C	575		318				45		50			10	152
	59	P	10.2		6				2.2						0
	60	P	11		8				1	2					0
	61	P	46.5	17	21									2.5	6
	62	R	12,792	2,160	1,920	72	1,273			1,000	900				5,467
	63	P	12.5							8.5	3				
	64	R	34,032	5,533	1,330		1,017				1,000			1,025	24,127
	65	C	100		55				27		5			3	10
	66	C	240	24	22						20				174
	67	C	400	175	65										160
	68	W	359	85	77		24				18				76

continued

TABLE 2a.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area (ha)	Crop pattern (ha) cotton	wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vines	Vegetables	Others
	69	R	22,900	10,347	6,300				1,325		367			1,415	3,146
	70	W	2,417	950	1,175		178				20			18	76
	71	W	2,298	550	1,000		80		426					60	182
	72	C	195	75	115										5
	73	P	95		20		35		40						
	74	P	16.3	14		2.3									
	75	P	14.5	6	8										1
	76	P	29												
	77	P	8												
	78	P	10												
MR															
	79	R	23,600	8,364	1,700	2,268						7,371		271	3,626
	80	C	3,673	1,820	493		109							81	1,170
	81	C	2,322	952	313	309						707		41	
	82	R	16,180	7,480	4,320	2,086						884		1,410	
	83	C													
	84	C	2,075	480	946	350						134		156	
	85	R	30,169	9,789	1,276							8,223		674	10,207
	86	C	1,491									1,050	441		
	87	C	2,377	1,790		156	76	323						32	
	88	C	1,087	697	42	124	50							26	148
	89	C													
	90	P	73	53	15									5	
	91	P	23	10	8	2	2							1	
	92	P	5	5										1	
	93	P													
	110	R	24,941	9,865	5,704	370	296					3,802		920	3,984
	111	C	2,348	1,000	434		1					182		22	709
	112	C	1,206	490	143	15	5					26		2	525

continued

TABLE 2a.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area (ha)	cotton	wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vines	Vegetables	Others
	113	C	1,713	780	476	5	145							2	305
	114	P	10		5			1						3	1
	115	P	200	85	100							4		11	
	116	P	60	44	14									2	
	117	R	23,589	9,600	6,860	997	326					1,429		153	4,224
	118	C	1,494	755	520	16	5					48		1	144
	119	C	2,740	1,270	643	12	5					140			670
	120	P	40		16	7	15							2	
	121	P	162	120	42										
	122	R	30,614	11,290	7,370	1,039	963					3,036		257	6,659
	123	C	2,955	905	617	125	29					451		11	817
	124	C	3,009	1,044	750	40	198					159		10	808
	125	C	2,202	661	435	6	49					419		9	623
	126	P	11.5			5	6.5								
	127	P	9		5							4			
	128	P	16.5	11	5.5										
	129	P	20.7	16.2		4.5									
	1	R	28,720		2,187	7,540	291	8,500	195	2,097		485		6,368	1,057
LR	2	C	3,880		430	1,320		1,443						687	
	3	C	609		100	200		202						107	
	4	P	398		110	45		220	20					3	
	5	P	310		70	50		130						10	50
	6	P	50					50							
	7	P	474		100	125		170						49	30
	8	P	52					50						2	
	9	C	560		130	130		300							
	10	C	488		110	200		100						78	
	11	C	400		40	100		100						110	
	12	R	27,411		4,400	9,600	302	8,365	182	227		300		700	2,049

continued

TABLE 2a.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area (ha)	Crop pattern (ha)											
				cotton	wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vines	Vegetables	Others
	13	C	4,171		900	900		1,400	59					14	
	14	P	605		140	280		160							25
	15	R	7,790		421	1,060		2 ,580		680		300		700	2,049
	16	R	25,340		3,550	8,427		12,836						508	19
	17	C	5,000		1,000	1,500		2,500							
	18	C	1,890		150	470		1,200		30				40	
	19	R	17,779		895	6,200		9,200	30	676				351	427
	20	C	2,850		30	1,260		1,055						10	
	21	C	1,180			416		750						14	
	22	R	24,976		500	7,220		13,000		1,120				840	2,296
	23	C	1,192		20	302		800						70	
	24	P	140			20		120							
	25	R	121,402	91,200	9,320	14,247			400	46				6,189	
	26	C	5,077	4,400	50	24	220	100							283
	27	W	2,147	1,900	15	80						18		55	
	28	W													
	29	C	228	191	12	25									
	30	C	1,200	926	60	125		20							69
	31	P	8	8											
	32	R	37,125	11,400	9,452	600									15,673
	33	C	2,103	700	710	350								40	303
	34	C	268	100	63	20	20								
	35	R	45,000	22,000	3,400	8,500	700	2,000						5,000	3,400
	36	C	3,900	2,172	145	641		735				33	14	160	
	37	C	1,120	510	150	130		200	100			18		12	
	38	P	15	15											
	39	P	40	40											
	40	C													

Note:

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

w = Water users association

TABLE 3.
Analysis of water supply in the Syr-Darya river basin water-saving competition.

Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (from IWL)	Relative irrigation water supply (from IWD)
R	45,452	566.13	566.13	474.76	0.84	0.84
W	3,229	29.27	29.27	19.74	0.67	0.67
W	1,000	13.92	9.2	4.72	0.51	0.34
C	116	1.1	1.1	0.71	0.65	0.65
P	5.7	0.04	0.04	0.04	1.00	1.00
P	27	0.21	0.21	0.21	1.00	1.00
R	19,229	152.19	152.19	128.59	0.84	0.84
W	1,626	12.75	11.25	12.83	1.14	1.01
P	15.3	0.13	0.13	0.13	1.00	1.00
R	2,1341	200.23	200.23	149.63	0.75	0.75
C	95.7	0.65	0.65	0.52	0.80	0.80
P	5.5	0.03	0.03	0.03	1.00	1.00
P	10.4	0.03	0.03	0.03	1.00	1.00
P	5	0.03	0.03	0.03	1.00	1.00
R	16,863	145.6	145.6	86.4	0.59	0.59
C	575	4.08	4.08	1.72	0.42	0.42
P	10.2	0.08	0.08	0.08	1.00	1.00
P	11	0.05	0.05	0.03	0.60	0.60
P	46.5	0.45	0.45	0.32	0.71	0.71
R	12,792	111.00	111.00	89.5	0.81	0.81
P	12.5	0.08	0.08	0.06	0.75	0.75
R	34,032	338.9	338.9	273.4	0.81	0.81
C	100	0.65	0.65	0.47	0.72	0.72
C	240	0.59	0.59	0.43	0.73	0.73
C	400	2.62	2.62	1.31	0.50	0.50
W	359	3.51	3.51	3.09	0.88	0.88
R	22,900	180.3	180.3	168.2	0.93	0.93

continued

TABLE 3.
Continued.

Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (from IWL)	Relative irrigation water supply (from IWD)
W	2,417	15.15	15.15	10.54	0.70	0.70
W	2,298	22.87	22.87	12.18	0.53	0.53
C	195	1.91	1.91	1.15	0.60	0.60
P	95	0.69	0.69	0.29	0.42	0.42
P	16.3	0.19	0.19	0.13	0.68	0.68
P	14.5	0.14	0.14	0.09	0.64	0.64
P	29	0.16	0.16	0.1	0.63	0.63
P	8	0.05	0.05	0.03	0.60	0.60
P	10	0.06	0.06	0.05	0.83	0.83
R	23,600	327.76	454.71	318.9	0.70	0.97
C	3,673	31.58	31.58	23.15	0.73	0.73
C	2,322	47.5	47.5	19.98	0.42	0.42
R	16,180	243	303	189.5	0.63	0.78
C	2,075	33.1	33.01	17.93	0.54	0.54
R	30,169	582	702.46	548.75	0.78	0.94
C	1,491	34.02	34.02	38.29	1.13	1.13
C	2,377	49.68	49.68	36.55	0.74	0.74
C	1,087	16.31	16.31	10.98	0.67	0.67
P	73	0.975	0.975	0.569	0.58	0.58
P	23	0.156	0.156	0.101	0.65	0.65
P	5	0.087	0.087	0.067	0.77	0.77
R	24,941	237.05	170.06	172.4	1.01	0.73
C	2,348	18.43	14.3	14.12	0.99	0.77
C	1,206	10.01	9.54	9.54	1.00	0.95
C	1,713	13.1	9.88	9.88	1.00	0.75
P	10	0.185	0.143	0.128	0.90	0.69
P	200	0.896	0.812	0.812	1.00	0.91

continued

TABLE 3.
Continued.

Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (from IWL)	Relative irrigation water supply (from IWD)
P	60	0.329	0.286	0.273	0.95	0.83
R	23,589	237.05	170.06	172.06	1.01	0.73
C	1,494	11.32	7.47	5.38	0.72	0.48
C	2,740	19.7	12.7	10.5	0.83	0.53
P	40	0.3	0.255	0.245	0.96	0.82
P	162	1.085	0.892	1.006	1.13	0.93
R	30,614	234.78	183.12	162.8	0.89	0.69
C	2,955	20.76	16.32	12.86	0.79	0.62
C	3,009	25.66	20.18	18.34	0.91	0.71
C	2,202	18.59	14.67	12.12	0.83	0.65
P	11.5	0.106	0.142	0.069	0.49	0.65
P	9	0.055	0.045	0.034	0.76	0.62
P	16.5	0.117	0.09	0.082	0.91	0.70
P	20.7	0.173	0.145	0.133	0.92	0.77
R	28,720	724.84	644.1	508.52	0.79	0.70
C	3,880	97.95	98.45	89.71	0.91	0.92
C	609	17.36	16.91	14.38	0.85	0.83
P	398	11.2	8.41	5.3	0.63	0.47
P	310	8.34	11.31	7.92	0.70	0.95
P	50	1.14	3.02	2.1	0.70	1.84
P	474	13.5	9.16	5.96	0.65	0.44
P	52	0.91	2.53	1.41	0.56	1.55
C	560	14.25	13.47	8.08	0.60	0.57
C	488	13.92	16.9	9.29	0.55	0.67
C	400	11.4	13.37	8.02	0.60	0.70
R	27,411	748.9	640	435.6	0.68	0.58
C	4,171	118.87	50.15	46.4	0.93	0.39

continued

TABLE 3.
Continued.

Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (from IWL)	Relative irrigation water supply (from IWD)
P	605	16.53	5.14	4.45	0.87	0.27
R	7,790	222.02	185	152.19	0.82	0.69
R	25,340	722.19	630	621.8	0.99	0.86
C	5,000	142.5	104.77	94.77	0.90	0.67
C	1,890	53.86	57.78	52.13	0.90	0.97
R	17,779	448.36	530	425.44	0.80	0.95
C	2,850	81.23	60	54.21	0.90	0.67
C	1,180	33.63	24.29	20.6	0.85	0.61
R	24,976	711.82	750	574.38	0.77	0.81
C	1,192	31.98	28.449	26.2	0.92	0.82
P	140	3.99	4.94	3.54	0.72	0.89
R	121,402	652.17	572	323.69	0.57	0.50
C	5,077	27.27	18.06	12.39	0.69	0.45
W	2,147	11.53	12.49	7.22	0.58	0.63
C	228	1.22	1.1	0.82	0.75	0.67
C	1,200	6.45	10.02	5.06	0.50	0.78
P	8	0.042	0.037	0.035	0.95	0.83
R	37,125	199.44	474	251	0.53	1.26
C	2,103	11.3	5.98	4.03	0.67	0.36
C	268	1.43	1.43	1.49	1.04	1.04
R	45,000	241.74	815	493.34	0.61	2.04
C	3,900	20.95	86.85	52.65	0.61	2.51
C	1,120	5.43	25.7	15.56	0.61	2.87
P	15	0.081	0.234	0.18	0.77	2.22
P	40					

Note:

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

TABLE 3a.
Analysis of water supply in the Syr-Darya river basin—district water management units/Rayvodkhozs.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply RIS_D from IWD	Average RIS_L	Average RIS_D	IWD m^3/ha	IWL m^3/ha	IWS m^3/ha	Cropping intensity	RIS_D	RIS_L
	41	R	45,452	566.13	566.13	474.76	0.84	0.84	0.78	0.85	12,456	12,456	10,445	93.4	0.84	0.84
UR	49	R	19,229	152.19	152.19	128.59	0.84	0.84	0.78	0.85	7,915	7,915	6,687	59.2	0.84	0.84
	52	R	21,341	200.23	200.23	149.63	0.75	0.75	0.78	0.85	9,382	9,382	7,011	100	0.75	0.75
	57	R	16,863	145.6	145.6	86.4	0.59	0.59	0.78	0.85	8,634	8,634	5,124	100	0.59	0.59
	62	R	12,792	111	111	89.5	0.81	0.81	0.78	0.85	8,677	8,677	6,997	100	0.81	0.81
	64	R	34,032	338.9	338.9	273.4	0.81	0.81	0.78	0.85	9,958	9,958	8,034	100	0.81	0.81
	69	R	22,900	180.3	180.3	168.2	0.93	0.93	0.78	0.85	7,873	7,873	7,345	100	0.93	0.93
	79	R	23,600	327.76	454.71	318.9	0.70	0.97	0.78	0.85	13,888	19,267	13,513	100	0.70	0.97
MR	82	R	16,180	243	303	189.5	0.63	0.78	0.78	0.85	15,019	18,727	11,712	100	0.63	0.78
	85	R	30,169	582	702.46	548.75	0.78	0.94	0.78	0.85	19,291	23,284	18,189	100	0.78	0.94
	110	R	24,941	237.05	170.06	172.4	1.01	0.73	0.78	0.85	9,504	6,818	6,912	100	1.01	0.73
	117	R	23,589	237.05	170.06	172.06	1.01	0.73	0.78	0.85	10,049	7,209	7,294	100	1.01	0.73
	122	R	30,614	234.78	183.12	162.8	0.89	0.69	0.78	0.85	7,669	5,982	5,318	100	0.89	0.69
	1	R	28,720	724.84	644.1	508.52	0.79	0.70	0.78	0.85	25,238	22,427	17,706	100	0.79	0.70
	12	R	27,411	748.9	640	435.6	0.68	0.58	0.78	0.85	27,321	23,348	15,891	95.3	0.68	0.58
	15	R	7,790	222.02	185	152.19	0.82	0.69	0.78	0.85	28,501	23,748	19,537	100	0.82	0.69
LR	16	R	25,340	722.19	630	621.8	0.99	0.86	0.78	0.85	28,500	24,862	24,538	100	0.99	0.86
	19	R	17,779	448.36	530	425.44	0.80	0.95	0.78	0.85	25,219	29,810	23,929	100	0.80	0.95
	22	R	24,976	711.82	750	574.38	0.77	0.81	0.78	0.85	28,500	30,029	22,997	100	0.77	0.81
	25	R	121,402	652.17	572	323.69	0.57	0.50	0.78	0.85	5,372	4,712	2,666	100	0.57	0.50
	32	R	37,125	199.44	474	251	0.53	1.26	0.78	0.85	5,372	12,768	6,761	100	0.53	1.26
	35	R	45,000	241.74	815	493.34	0.61	2.04	0.78	0.85	5,372	18,111	10,963	100	0.61	2.04

continued

TABLE 3a.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply RIS_D from IWD	Average RIS_L	Average RIS_D	IWD m^3/ha	IWL m^3/ha	IWS m^3/ha	Cropping intensity	RIS_D	RIS_L
	41	R	45,452	566.13	566.13	474.76	0.84	0.84	0.78	0.85	12,456	12,456	10,445	93.4	0.84	0.84
UR	49	R	19,229	152.19	152.19	128.59	0.84	0.84	0.78	0.85	7,915	7,915	6,687	59.2	0.84	0.84
	52	R	21,341	200.23	200.23	149.63	0.75	0.75	0.78	0.85	9,382	9,382	7,011	100	0.75	0.75
	57	R	16,863	145.6	145.6	86.4	0.59	0.59	0.78	0.85	8,634	8,634	5,124	100	0.59	0.59
	62	R	12,792	111	111	89.5	0.81	0.81	0.78	0.85	8,677	8,677	6,997	100	0.81	0.81
	64	R	34,032	338.9	338.9	273.4	0.81	0.81	0.78	0.85	9,958	9,958	8,034	100	0.81	0.81
	69	R	22,900	180.3	180.3	168.2	0.93	0.93	0.78	0.85	7,873	7,873	7,345	100	0.93	0.93
	79	R	23,600	327.76	454.71	318.9	0.70	0.97	0.78	0.85	13,888	19,267	13,513	100	0.70	0.97
MR	82	R	16,180	243	303	189.5	0.63	0.78	0.78	0.85	15,019	18,727	11,712	100	0.63	0.78
	85	R	30,169	582	702.46	548.75	0.78	0.94	0.78	0.85	19,291	23,284	18,189	100	0.78	0.94
	110	R	24,941	237.05	170.06	172.4	1.01	0.73	0.78	0.85	9,504	6,818	6,912	100	1.01	0.73
	117	R	23,589	237.05	170.06	172.06	1.01	0.73	0.78	0.85	10,049	7,209	7,294	100	1.01	0.73
	122	R	30,614	234.78	183.12	162.8	0.89	0.69	0.78	0.85	7,669	5,982	5,318	100	0.89	0.69
	1	R	28,720	724.84	644.1	508.52	0.79	0.70	0.78	0.85	25,238	22,427	17,706	100	0.79	0.70
	12	R	27,411	748.9	640	435.6	0.68	0.58	0.78	0.85	27,321	23,348	15,891	95.3	0.68	0.58
	15	R	77,90	222.02	185	152.19	0.82	0.69	0.78	0.85	28,501	23,748	19,537	100	0.82	0.69
LR	16	R	25,340	722.19	630	621.8	0.99	0.86	0.78	0.85	28,500	24,862	24,538	100	0.99	0.86
	19	R	17,779	448.36	530	425.44	0.80	0.95	0.78	0.85	25,219	29,810	23,929	100	0.80	0.95
	22	R	24,976	711.82	750	574.38	0.77	0.81	0.78	0.85	28,500	30,029	22,997	100	0.77	0.81
	25	R	121,402	652.17	572	323.69	0.57	0.50	0.78	0.85	5,372	4,712	2,666	100	0.57	0.50
	32	R	37,125	199.44	474	251	0.53	1.26	0.78	0.85	5,372	12,768	6,761	100	0.53	1.26
	35	R	45,000	241.74	815	493.34	0.61	2.04	0.78	0.85	5,372	18,111	10,963	100	0.61	2.04

TABLE 3b.
Analysis of water supply in the Syr-Darya river basin—collective/cooperative farms.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply (RIS_D) from IWD	Average RIS_L	Average RIS_D	IWD m^3/ha	IWL m^3/ha	IWS M^3/ha	Cropping intensity	RIS_D	RIS_L
	44	C	116	1.1	1.1	0.71	0.65	0.65	0.76	0.78	9,483	9,483	6,121	100	0.65	0.65
	53	C	95.7	0.65	0.65	0.52	0.80	0.80	0.76	0.79	6,792	6,792	5,434	30.3	0.80	0.80
	58	C	575	4.08	4.08	1.72	0.42	0.42	0.76	0.79	7,096	7,096	2,991	100	0.42	0.42
UR	65	C	100	0.65	0.65	0.47	0.72	0.72	0.76	0.79	6,500	6,500	4,700	100	0.72	0.72
	66	C	240	0.59	0.59	0.43	0.73	0.73	0.76	0.79	2,458	2,458	1,792	100	0.73	0.73
	67	C	400	2.62	2.62	1.31	0.50	0.50	0.76	0.79	6,550	6,550	3,275	100	0.50	0.50
	72	C	195	1.91	1.91	1.15	0.60	0.60	0.76	0.79	9,795	9,795	5,897	100	0.60	0.60
	80	C	3,673	31.58	31.58	23.15	0.73	0.73	0.76	0.79	8,598	8,598	6,303	100	0.73	0.73
	81	C	2,322	47.5	47.5	19.98	0.42	0.42	0.76	0.79	20,457	20,457	8,605	100	0.42	0.42
	83	C														
	84	C	2,075	33.1	33.01	17.93	0.54	0.54	0.76	0.79	15,952	15,908	8,641	100	0.54	0.54
	86	C	1,491	34.02	34.02	38.29	1.13	1.13	0.76	0.79	22,817	22,817	25,681	100	1.13	1.13
	87	C	2,377	49.68	49.68	36.55	0.74	0.74	0.76	0.79	20,900	20,900	15,377	100	0.74	0.74
	88	C	1,087	16.31	16.31	10.98	0.67	0.67	0.76	0.79	15,005	15,005	10,101	100	0.67	0.67
	89	C							0.76	0.79						
MR	111	C	2,348	18.43	14.3	14.12	0.99	0.77	0.76	0.79	7,849	6,090	6,014	100	0.99	0.77
	112	C	1,206	10.01	9.54	9.54	1.00	0.95	0.76	0.79	8,300	7,910	7,910	100	1.00	0.95
	113	C	1,713	13.1	9.88	9.88	1.00	0.75	0.76	0.79	7,647	5,768	5,768	100	1.00	0.75
	118	C	1,494	11.32	7.47	5.38	0.72	0.48	0.76	0.79	7,577	5,000	3,601	99.7	0.72	0.48
	119	C	2,740	19.7	12.7	10.5	0.83	0.53	0.76	0.79	7,190	4,635	3,832	100	0.83	0.53
	123	C	2,955	20.76	16.32	12.86	0.79	0.62	0.76	0.79	7,025	5,523	4,352	100	0.79	0.62

continued

TABLE 3B.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply (RIS_D) from IWD	Average RIS_L	Average RIS_D	IWD m^3/ha	IWL m^3/ha	IWS M^3/ha	Cropping intensity	RIS_D	RIS_L
	124	C	3,009	25.66	20.18	18.34	0.91	0.71	0.76	0.79	8,528	6,707	6,095	100	0.91	0.71
	125	C	2,202	18.59	14.67	12.12	0.83	0.65	0.76	0.79	8,442	6,662	5,504	100	0.83	0.65
	2	C	3,880	97.95	98.45	89.71	0.91	0.92	0.76	0.79	25,245	25,374	23,121	100	0.91	0.92
	3	C	609	17.36	16.91	14.38	0.85	0.83	0.76	0.79	28,506	27,767	23,612	100	0.85	0.83
	9	C	560	14.25	13.47	8.08	0.60	0.57	0.76	0.79	25,446	24,054	14,429	100	0.60	0.57
	10	C	488	13.92	16.9	9.29	0.55	0.67	0.76	0.79	28,525	34,631	19,037	100	0.55	0.67
	11	C	400	11.4	13.37	8.02	0.60	0.70	0.76	0.79	28,500	33,425	20,050	87.5	0.60	0.70
	13	C	4,171	118.87	50.15	46.4	0.93	0.39	0.76	0.79	28,499	12,023	11,124	78.5	0.93	0.39
	17	C	5,000	142.5	104.77	94.77	0.90	0.67	0.76	0.79	28,500	20,954	18,954	100	0.90	0.67
LR	18	C	1,890	53.86	57.78	52.13	0.90	0.97	0.76	0.79	28,497	30,571	27,582	100	0.90	0.97
	20	C	2,850	81.23	60	54.21	0.90	0.67	0.76	0.79	28,502	21,053	19,021	100	0.90	0.67
	21	C	1,180	33.63	24.29	20.6	0.85	0.61	0.76	0.79	28,500	20,585	17,458	100	0.85	0.61
	23	C	1,192	31.98	28.449	26.2	0.92	0.82	0.76	0.79	26,829	23,867	21,980	100	0.92	0.82
	26	C	5,077	27.27	18.06	12.39	0.69	0.45	0.76	0.79	5,371	3,557	2,440	100	0.69	0.45
	29	C	228	1.22	1.1	0.82	0.75	0.67	0.76	0.79	5,351	4,825	3,596	100	0.75	0.67
	30	C	1,200	6.45	10.02	5.06	0.50	0.78	0.76	0.79	5,375	8,350	4,217	100	0.50	0.78
	33	C	2,103	11.3	5.98	4.03	0.67	0.36	0.76	0.79	5,373	2,844	1,916	100	0.67	0.36
	34	C	268	1.43	1.43	1.49	1.04	1.04	0.76	0.79	5,336	5,336	5,560	75.7	1.04	1.04
	36	C	3,900	20.95	86.85	52.65	0.61	2.51	0.76	0.79	5,372	22,269	13,500	100	0.61	2.51
	37	C	1,120	5.43	25.7	15.56	0.61	2.87	0.76	0.79	4,848	22,946	13,893	100	0.61	2.87

TABLE 3c.

Analysis of water supply in the Syr-Darya river basin—private/peasant farms.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply (RIS_D) from IWD)	Average RIS_L	Average RIS_D	IWD M^3/ha	IWL m^3/ha	IWS M^3/ha	Cropping intensity	RIS_D	RIS_L
	45	P	5.7	0.04	0.04	0.04	1.00	1.00	0.79	0.84	7,018	7,018	7,018	100	1.00	1.00
	46	P	27	0.21	0.21	0.21	1.00	1.00	0.79	0.84	7,778	7,778	7,778	100	1.00	1.00
	54	P	5.5	0.03	0.03	0.03	1.00	1.00	0.79	0.84	5,455	5,455	5,455	100	1.00	1.00
	55	P	10.4	0.03	0.03	0.03	1.00	1.00	0.79	0.84	2,885	2,885	2,885	100	1.00	1.00
UR	56	P	5	0.03	0.03	0.03	1.00	1.00	0.79	0.84	6,000	6,000	6,000	100	1.00	1.00
	59	P	10.2	0.08	0.08	0.08	1.00	1.00	0.79	0.84	7,843	7,843	7,843	80.39	1.00	1.00
	60	P	11	0.05	0.05	0.03	0.60	0.60	0.79	0.84	4,545	4,545	2,727	100	0.60	0.60
	61	P	46.5	0.45	0.45	0.32	0.71	0.71	0.79	0.84	9,677	9,677	6,882	100	0.71	0.71
	63	P	12.5	0.08	0.08	0.06	0.75	0.75	0.79	0.84	6,400	6,400	4,800	92	0.75	0.75
	73	P	95	0.69	0.69	0.29	0.42	0.42	0.79	0.84	7,263	7,263	3,053	100	0.42	0.42
	74	P	16.3	0.19	0.19	0.13	0.68	0.68	0.79	0.84	11,656	11,656	7,975	100	0.68	0.68
	75	P	14.5	0.14	0.14	0.09	0.64	0.64	0.79	0.84	9,655	9,655	6,207	103.45	0.64	0.64
	76	P	29	0.16	0.16	0.1	0.63	0.63	0.79	0.84	5,517	5,517	3,448	100	0.63	0.63
	77	P	8	0.05	0.05	0.03	0.60	0.60	0.79	0.84	6,250	6,250	3,750	100	0.60	0.60
	78	P	10	0.06	0.06	0.05	0.83	0.83	0.79	0.84	6,000	6,000	5,000	100	0.83	0.83
	90	P	73	0.975	0.975	0.569	0.58	0.58	0.79	0.84	13,356	13,356	7,795	100	0.58	0.58
	91	P	23	0.156	0.156	0.101	0.65	0.65	0.79	0.84	6,783	6,783	4,391	100	0.65	0.65
	92	P	5	0.087	0.087	0.067	0.77	0.77	0.79	0.84	17,400	17,400	13,400	120	0.77	0.77

continued

TABLE3C.

Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Irrigation water demand (IWD) million m^3	Irrigation water limit (IWL) million m^3	Irrigation water supply (IWS) million m^3	Relative irrigation water supply (RIS_L) from IWL	Relative irrigation water supply (RIS_D) from IWD)	Average RIS_L	Average RIS_D	IWD M^3/ha	IWL m^3/ha	IWS M^3/ha	Cropping intensity	RIS_D	RIS_L
	114	P	10	0.185	0.143	0.128	0.90	0.69	0.79	0.84	18,500	14,300	12,800	100	0.90	0.69
MR	115	P	200	0.896	0.812	0.812	1.00	0.91	0.79	0.84	4,480	4,060	4,060	100	1.00	0.91
	116	P	60	0.329	0.286	0.273	0.95	0.83	0.79	0.84	5,483	4,767	4,550	100	0.95	0.83
	120	P	40	0.3	0.255	0.245	0.96	0.82	0.79	0.84	7,500	6,375	6,125	100	0.96	0.82
	121	P	162	1.085	0.892	1.006	1.13	0.93	0.79	0.84	6,698	5506	6,210	100	1.13	0.93
	126	P	11.5	0.106	0.142	0.069	0.49	0.65	0.79	0.84	9,217	12348	6,000	100	0.49	0.65
	127	P	9	0.055	0.045	0.034	0.76	0.62	0.79	0.84	6,111	5000	3,778	100	0.76	0.62
	128	P	16.5	0.117	0.09	0.082	0.91	0.70	0.79	0.84	7,091	5455	4,970	100	0.91	0.70
	129	P	20.7	0.173	0.145	0.133	0.92	0.77	0.79	0.84	8,357	7005	6,425	100	0.92	0.77
	4	P	398	11.2	8.41	5.3	0.63	0.47	0.79	0.84	28,141	21131	13,317	100	0.63	0.47
	5	P	310	8.34	11.31	7.92	0.70	0.95	0.79	0.84	26,903	36484	25,548	100	0.70	0.95
	6	P	50	1.14	3.02	2.1	0.70	1.84	0.79	0.84	22,800	60400	42,000	100	0.70	1.84
	7	P	474	13.5	9.16	5.96	0.65	0.44	0.79	0.84	28,481	19325	12,574	100	0.65	0.44
LR	8	P	52	0.91	2.53	1.41	0.56	1.55	0.79	0.84	17,500	48654	27,115	100	0.56	1.55
	14	P	605	16.53	5.14	4.45	0.87	0.27	0.79	0.84	27,322	8496	7,355	100	0.87	0.27
	24	P	140	3.99	4.94	3.54	0.72	0.89	0.79	0.84	28,500	35286	25,286	100	0.72	0.89
	31	P	8	0.042	0.037	0.035	0.95	0.83	0.79	0.84	5,250	4625	4,375	100	0.95	0.83
	38	P	15	0.081	0.234	0.18	0.77	2.22	0.79	0.84	5,400	15600	12,000	100	0.77	2.22
	39	P	40											100		

Note:

LR = Lower reach

UR = Upper reach

MR = Middle reach

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

TABLE 4.
Data on irrigation water demand (IWD), limit (IWL) and supply (IWS).

Reach	Competitor ID number	Type of competitor	Irrigated area ha	IWD million m^3	IWL million m^3	IWS million m^3
UR						
	41	R	45,452	566.13	566.13	474.76
	42	W	3,229	29.27	29.27	19.74
	43	W	1,000	13.92	9.2	4.72
	44	C	116	1.1	1.1	0.71
	45	P	5.7	0.04	0.04	0.04
	46	P	27	0.21	0.21	0.21
	47	R				
	48	P				
	49	R	19,229	152.19	152.19	128.59
	50	W	1,626	12.75	11.25	12.83
	51	P	15.3	0.13	0.13	0.13
	52	R	21,341	200.23	200.23	149.63
	53	C	95.7	0.65	0.65	0.52
	54	P	5.5	0.03	0.03	0.03
	55	P	10.4	0.03	0.03	0.03
	56	P	5	0.03	0.03	0.03
	57	R	16,863	145.6	145.6	86.4
	58	C	575	4.08	4.08	1.72
	59	P	10.2	0.08	0.08	0.08
	60	P	11	0.05	0.05	0.03
	61	P	46.5	0.45	0.45	0.32
	62	R	12,792	111	111	89.5
	63	P	12.5	0.08	0.08	0.06
	64	R	34,032	338.9	338.9	273.4
	65	C	100	0.65	0.65	0.47
	66	C	240	0.59	0.59	0.43
	67	C	400	2.62	2.62	1.31
	68	W	359	3.51	3.51	3.09
	69	R	22,900	180.3	180.3	168.2
	70	W	2,417	15.15	15.15	10.54
	71	W	2,298	22.87	22.87	12.18
	72	C	195	1.91	1.91	1.15
	73	P	95	0.69	0.69	0.29
	74	P	16.3	0.19	0.19	0.13
	75	P	14.5	0.14	0.14	0.09
	76	P	29	0.16	0.16	0.1
	77	P	8	0.05	0.05	0.03
	78	P	10	0.06	0.06	0.05
MR						
	79	R	23,600	327.76	454.71	318.9
	80	C	3,673	31.58	31.58	23.15
	81	C	2,322	47.5	47.5	19.98
	82	R	16,180	243	303	189.5

continued

TABLE 4.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	IWD million m^3	IWL million m^3	IWS million m^3
	83	C				
	84	C	2,075	33.1	33.01	17.93
	85	R	30,169	582	702.46	548.75
	86	C	1,491	34.02	34.02	38.29
	87	C	2,377	49.68	49.68	36.55
	88	C	1,087	16.31	16.31	10.98
	89	C				
	90	P	73	0.975	0.975	0.569
	91	P	23	0.156	0.156	0.101
	92	P	5	0.087	0.087	0.067
	110	R	24,941	237.05	170.06	172.4
	111	C	2,348	18.43	14.3	14.12
	112	C	1,206	10.01	9.54	9.54
	113	C	1,713	13.1	9.88	9.88
	114	P	10	0.185	0.143	0.128
	115	P	200	0.896	0.812	0.812
	116	P	60	0.329	0.286	0.273
	117	R	23,589	237.05	170.06	172.06
	118	C	1,494	11.32	7.47	5.38
	119	C	2,740	19.7	12.7	10.5
	120	P	40	0.3	0.255	0.245
	121	P	162	1.085	0.892	1.006
	122	R	30,614	234.78	183.12	162.8
	123	C	2,955	20.76	16.32	12.86
	124	C	3,009	25.66	20.18	18.34
	125	C	2,202	18.59	14.67	12.12
	126	P	11.5	0.106	0.142	0.069
	127	P	9	0.055	0.045	0.034
	128	P	16.5	0.117	0.09	0.082
	129	P	20.7	0.173	0.145	0.133
	1	R	28,720	724.84	644.1	508.52
LR	2	C	3,880	97.95	98.45	89.71
	3	C	609	17.36	16.91	14.38
	4	P	398	11.2	8.41	5.3
	5	P	310	8.34	11.31	7.92
	6	P	50	1.14	3.02	2.1
	7	P	474	13.5	9.16	5.96
	8	P	52	0.91	2.53	1.41
	9	C	560	14.25	13.47	8.08
	10	C	488	13.92	16.9	9.29
	11	C	400	11.4	13.37	8.02
	12	R	27,411	748.9	640	435.6
	13	C	4,171	118.87	50.15	46.4
	14	P	605	16.53	5.14	4.45

continued

TABLE 4.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	IWD million m³	IWL million m³	IWS million m³
	15	R	7,790	222.02	185	152.19
	16	R	25,340	722.19	630	621.8
	17	C	5,000	142.5	104.77	94.77
	18	C	1,890	53.86	57.78	52.13
	19	R	17,779	448.36	530	425.44
	20	C	2,850	81.23	60	54.21
	21	C	1,180	33.63	24.29	20.6
	22	R	24,976	711.82	750	574.38
	23	C	1,192	31.98	28.449	26.2
	24	P	140	3.99	4.94	3.54
	25	R	121,402	652.17	572	323.69
	26	C	5,077	27.27	18.06	12.39
	27	W	2,147	11.53	12.49	7.22
	28	W				
	29	C	228	1.22	1.1	0.82
	30	C	1,200	6.45	10.02	5.06
	31	P	8	0.042	0.037	0.035
	32	R	37,125	199.44	474	251
	33	C	2,103	11.3	5.98	4.03
	34	C	268	1.43	1.43	1.49
	35	R	45,000	241.74	815	493.34
	36	C	3,900	20.95	86.85	52.65
	37	C	1,120	5.43	25.7	15.56
	38	P	15	0.081	0.234	0.18
	39	P	40			
	40	C				

Note:

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

W = Water users association

TABLE 5.
Irrigation water supply indecies.

Competitor ID number	Irrigation Water Demand million m3	Water Limit, (Planned Water Supply) million m3	Irrigation Water Supply million m3	Relative Irrigation (Water) Supply (from Planed Water Supply) RIS_L	Relative Irrigation (Water) Supply (from Irrigation Water Demand) RIS_D
41	566.13	566.13	474.76	0.83	0.83
42	29.27	29.27	19.74	0.67	0.67
43	13.92	9.2	4.72	0.51	0.33
44	1.1	1.1	0.71	0.64	0.64
45	0.04	0.04	0.04	1	1
46	0.21	0.21	0.21	1	1
47					
48					
49	152.19	152.19	128.59	0.84	0.84
50	12.75	11.25	12.83	1.140	1.00
51	0.13	0.13	0.13	1	1
52	200.23	200.23	149.63	0.74	0.74
53	0.65	0.65	0.52	0.8	0.8
54	0.03	0.03	0.03	1	1
55	0.03	0.03	0.03	1	1
56	0.03	0.03	0.03	1	1
57	145.6	145.6	86.4	0.59	0.59
58	4.08	4.08	1.72	0.42	0.42
59	0.08	0.08	0.08	1	1
60	0.05	0.05	0.03	0.6	0.6
61	0.45	0.45	0.32	0.71	0.71
62	111	111	89.5	0.806	0.80
63	0.08	0.08	0.06	0.75	0.75
64	338.9	338.9	273.4	0.80	0.80
65	0.65	0.65	0.47	0.72	0.72
66	0.59	0.59	0.43	0.728	0.72
67	2.62	2.62	1.31	0.5	0.5
68	3.51	3.51	3.09	0.88	0.88
69	180.3	180.3	168.2	0.93	0.93
70	15.15	15.15	10.54	0.69	0.691
71	22.87	22.87	12.18	0.53	0.53
72	1.91	1.91	1.15	0.60	0.60
73	0.69	0.69	0.29	0.42	0.42
74	0.19	0.19	0.13	0.68	0.68
75	0.14	0.14	0.09	0.64	0.64
76	0.16	0.16	0.1	0.625	0.625
77	0.05	0.05	0.03	0.6	0.6
78	0.06	0.06	0.05	0.83	0.83
79	327.76	454.71	318.9	0.70	0.97
80	31.58	31.58	23.15	0.73	0.73

continued

TABLE 5.
Continued.

Competitor ID number	Irrigation Water Demand million m3	Water Limit, (Planned Water Supply) million m3	Irrigation Water Supply million m3	Relative Irrigation (Water) Supply (from Planed Water Supply) RIS_L	Relative Irrigation (Water) Supply (from Irrigation Water Demand) RIS_D
81	47.5	47.5	19.98	0.42	0.42
82	243	303	189.5	0.62	0.77
83					
84	33.1	33.01	17.93	0.54	0.54
85	582	702.46	548.75	0.78	0.94
86	34.02	34.02	38.29	1.125	1.12
87	49.68	49.68	36.55	0.73	0.73
88	16.31	16.31	10.98	0.67	0.67
89					
90	0.975	0.975	0.569	0.58	0.58
91	0.156	0.156	0.101	0.64	0.64
92	0.087	0.087	0.067	0.77	0.77
110	237.05	170.06	172.4	1.01	0.72
111	18.43	14.3	14.12	0.98	0.76
112	10.01	9.54	9.54	1	0.95
113	13.1	9.88	9.88	1	0.75
114	0.185	0.143	0.128	0.89	0.69
115	0.896	0.812	0.812	1	0.90
116	0.329	0.286	0.273	0.95	0.82
117	237.05	170.06	172.06	1.01	0.72
118	11.32	7.47	5.38	0.72	0.47
119	19.7	12.7	10.5	0.82	0.53
120	0.3	0.255	0.245	0.96	0.81
121	1.085	0.892	1.006	1.12	0.92
122	234.78	183.12	162.8	0.88	0.69
123	20.76	16.32	12.86	0.78	0.61
124	25.66	20.18	18.34	0.90	0.71
125	18.59	14.67	12.12	0.82	0.65
126	0.106	0.142	0.069	0.48	0.65
127	0.055	0.045	0.034	0.75	0.61
128	0.117	0.09	0.082	0.91	0.70
129	0.173	0.145	0.133	0.91	0.76
1	724.84	644.1	508.52	0.78	0.70
2	97.95	98.45	89.71	0.91	0.91
3	17.36	16.91	14.38	0.85	0.82
4	11.2	8.41	5.3	0.63	0.47
5	8.34	11.31	7.92	0.70	0.94
6	1.14	3.02	2.1	0.69	1.84
7	13.5	9.16	5.96	0.65	0.44

TABLE 5.
Continued.

Competitor ID number	Irrigation Water Demand million m3	Water Limit, (Planned Water Supply) million m3	Irrigation Water Supply million m3	Relative Irrigation (Water) Supply (from Planed Water Supply) RIS_L	Relative Irrigation (Water) Supply (from Irrigation Water Demand) RIS_D
8	0.91	2.53	1.41	0.55	1.54
9	14.25	13.47	8.08	0.59	0.56
10	13.92	16.9	9.29	0.54	0.66
11	11.4	13.37	8.02	0.59	0.70
12	748.9	640	435.6	0.68	0.58
13	118.87	50.15	46.4	0.92	0.39
14	16.53	5.14	4.45	0.86	0.26
15	222.02	185	152.19	0.82	0.68
16	722.19	630	621.8	0.98	0.86
17	142.5	104.77	94.77	0.90	0.66
18	53.86	57.78	52.13	0.90	0.96
19	448.36	530	425.44	0.80	0.94
20	81.23	60	54.21	0.90	0.66
21	33.63	24.29	20.6	0.84	0.61
22	711.82	750	574.38	0.76	0.80
23	31.98	28.449	26.2	0.92	0.81
24	3.99	4.94	3.54	0.71	0.88
25	652.17	572	323.69	0.56	0.49
26	27.27	18.06	12.39	0.68	0.45
27	11.53	12.49	7.22	0.57	0.62
28					
29	1.22	1.1	0.82	0.74	0.67
30	6.45	10.02	5.06	0.50	0.78
31	0.042	0.037	0.035	0.94	0.83
32	199.44	474	251	0.52	1.25
33	11.3	5.98	4.03	0.67	0.35
34	1.43	1.43	1.49	1.04	1.04
35	241.74	815	493.34	0.60	2.04
36	20.95	86.85	52.65	0.60	2.51
37	5.43	25.7	15.56	0.60	2.86
38	0.081	0.234	0.18	0.76	2.22

TABLE 6.
Data on production of agricultural crops.

				Production t/ha									
Reach	Competitor ID number	Type of competitor	Irrigated area ha	Cotton	Wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vegetables
UR	41	R	45,452	2.6	3.2		6.28		1.28		3		
	42	W	3,229	2.5	4.3		6.94			17.3	2.63		
	43	W	1,000	2.5	4.4						3.71		17.5
	44	C	116	3	4.5								
	45	P	5.7	4.3					1.5				
	46	P	27	2.8	5.4		5.4						25
	47	R											
	48	P											
	49	R	19,229	4	4.2		6.28				3.5		14.8
	50	W	1,626	4	4.2						3.5		31.5
	51	P	15.3	2.8	2.6								
	52	R	21,341		2.36		5.9				2.51		2.45
	53	C	95.7		4			1.76			1.62		
	54	P	5.5		3								
	55	P	10.4						1.8				
	56	P	5							15			
	57	R	16,863		3		4.7				2.3		13
	58	C	575		3.45				1.4		2.7		22.5
	59	P	10.2		3.6				1.2				13
	60	P	11		3.58				1.8	11.8			
	61	P	46.5	2.5	3.7								12
	62	R	12,792	2.4	6.7		4.5				2.2		
	63	P	12.5				4.9			12	2.5		
	64	R	34,032	2.5	3		5.5				2.5		8
	65	C	100		2.8				2		2.4		18
	66	C	240	2.75	3.9						2.9		
	67	C	400	2.6	3								

continued

TABLE 6.
Continued.

				Production t/ha									
Reach	Competitor ID number	Type of competitor	Irrigated area ha	Cotton	Wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vegetables
	68	W	359	2.8	4		5.8				2.6		17.6
	69	R	22,900	2.5	2.7								
	70	W	2,417	3.1	2.56		4.8				2.4		1.5
	71	W	2,298	3.9	2.72		4.3		1.8				2
	72	C	195	2.45	4.2								
	73	P	95		3.2		5.8		1.8				
	74	P	16.3	2.5		6							
	75	P	14.5	3	3.5								
	76	P	29				4.9			12	2.5		
	77	P	8		3.3		6.2		1.5		2.8		
	78	P	10				5.1		1.3				
					3.12	6.8			1.4				
MR	79	R	23,600	2.57									
	80	C	3,673	3.28	2.37		19.5						20.59
	81	C	2,322	3.5	3.07	26.59						3.06	38.77
	82	R	16,180	1.62									
	83	C											
	84	C	2,075	2.51	3.41	15.24						1.18	3.49
	85	R	30,169	2.27									
	86	C	1,491									8.48	
	87	C	2,377	2.59		37.42	35.13	3.24					32.31
	88	C	1,087	3.11	2.71	9.4	6.4						36.54
	89	C											
	90	P	73	3.65	1.2								10
	91	P	23	2.9	1.4	3	8.5						8.5
	92	P	5	2.8									
	93	P											
MR													

continued

TABLE 6.
Continued.

Reach	Competitor ID number	Type of competitor	Irrigated area ha	Production t/ha Cotton	Wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vegetables
	79	R	23,600	2.57									
	80	C	3,673	3.28	2.37		19.5						20.59
	81	C	2,322	3.5	3.07	26.59						3.06	38.77
	82	R	16,180	1.62									
	83	C											
	84	C	2,075	2.51	3.41	15.24						1.18	3.49
	85	R	30,169	2.27									
	86	C	1,491									8.48	
	87	C	2,377	2.59		37.42	35.13	3.24					32.31
	88	C	1,087	3.11	2.71	9.4	6.4						36.54
	89	C											
	90	P	73	3.65	1.2								10
	91	P	23	2.9	1.4	3	8.5						8.5
	92	P	5	2.8									
	93	P											
	110	R	24,941	2.68	3.37	4.68	2.7						5.8
	111	C	2,348	3.02	4.5		28						9.05
	112	C	1,206	3.75	8.64	15	4.4						50.5
	113	C	1,713	3.52	5.3	27.2	26						5
	114	P	10		4			2.98					
	115	P	200	3.75	5.08								9.18
	116	P	60	4.7	4.5								13
	117	R	23,589	3.34	3.38	0.1	1.01						6.34
	118	C	1,494	3.17	4.33	6.63	20						
	119	C	2,740	3.44	3.72	7.5	10						
	120	P	40		2.2	12	23.33						60
	121	P	162	3.63	4								

continued

TABLE 6.
Continued.

				Production t/ha									
Reach	Competitor ID number	Type of competitor	Irrigated area ha	Cotton	Wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vegetables
	122	R	30,614	2.44	3.67	0.93	4.35						
	123	C	2,955	4.15	4.77	15.72	24.83						6
	124	C	3009	2.75	3.33	19.88							10.2
	125	C	2202	3.76	4.31	12	2.9						16.37
	126	P	11.5			49.4	13.85						
	127	P	9		1.7								
	128	P	16.5	2.92	3.36								
	129	P	20.7	3.76		46.44							
	1	R	28,720		0.86		4	3.5	2.2	10.2			12.20
LR	2	C	3,880		1.07	0.51		2.76					6.80
	3	C	609		0.93	0.47		3.68					7.10
	4	P	398		0.1	0.27		5.73					
	5	P	310		1.14	1.6		2.46					4.50
	6	P	50					3					
	7	P	474		0.1	1		3.97					
	8	P	52					4.5					
	9	C	560		1.14	2.51		2.33					
	10	C	488		1.29	1		5.27					
	11	C	400		1.18	1.8		4.64					
	12	R	27,411		0.8		4	3.5	2.2	10.2			12.2
	13	C	4,171		1.9	3.76		3.91					
	14	P	605		0.53	0.79		6.16					5.8
	15	R	7,790		0.81	1		4.1		8.7			9
	16	R	25,340		1.01	2.03		4.3		10.9			11.6
	17	C	5,000		0.78	1		5.94					
	18	C	1,890		0.7	0.83		2.83		11.2			11.5
	19	R	17,779		1.05	0.28		4.3	0.2	8.3			11.3

continued

TABLE 6.
Continued.

				Production t/ha									
Reach	Competitor ID number	Type of competitor	Irrigated area ha	Cotton	Wheat	Lucerne	Maize	Rice	Sunflower	Potato	Tobacco	Orchards	Vegetables
	20	C	2,850		0.53	0.79		6.16					5.8
	21	C	1,180			0.53		5.01					2.86
	22	R	24,976		1.21	0.27		4		10.4			11.82
	23	C	1192		1	0.5		5.2					
	24	P	140			0.5		5					
	25	R	121,402	2.02	3.08	2.4	3.3			10.56			20.74
	26	C	5,077										
	27	W	2,147										
	28	W											
	29	C	228	2.8	3.18	10.4							
	30	C	1,200	2.53	3.2	10	35						
	31	P	8	2.5									
	32	R	37,125	1.24	1.58	1.86	2.26			6.72			22.7
	33	C	2,103	1.42	1.33	2.93							5
	34	C	268	1.11	2.09	4.4							4.23
	35	R	45,000	2.2	1.84	1.2	2.81	3.17		10.9			31.08
	36	C	3,900	1.56	0.94	0.9		2.04					
	37	C	1,120	1.39	1.05	4.62		2.2				2.22	25
	38	P	15	2.9									
	39	P	40										
	40	C											

Note:

R = District water management unit

C = Collective/cooperative farms

P = Private/peasant farms

W = Water users association

FIGURE 1.
Analysis of relative irrigation supply in the Syr-Darya river basin.

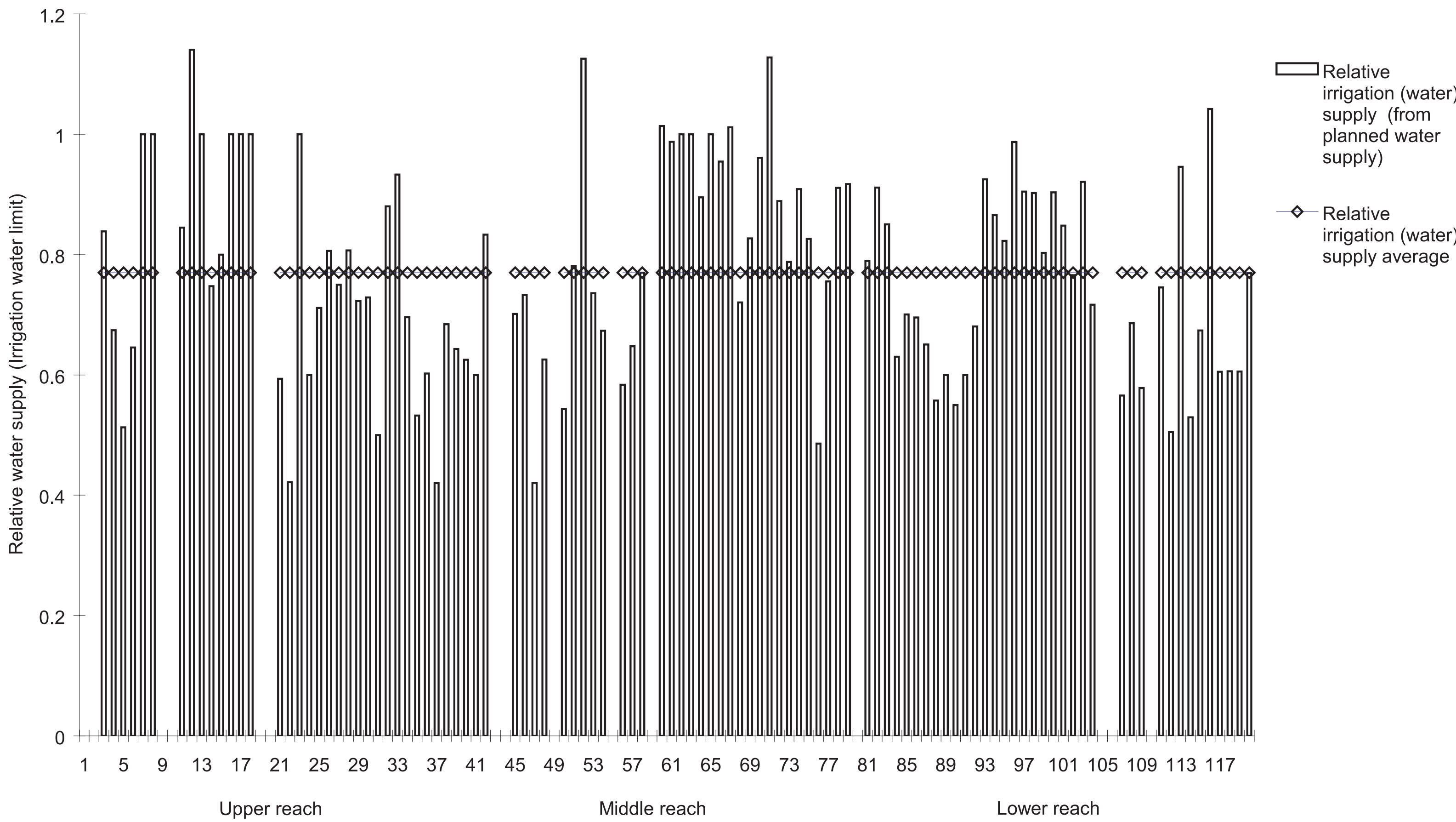


FIGURE 2.
Analysis of Irrigation water demand, supply and relative irrigation supply in the Syr-Darya river basin.

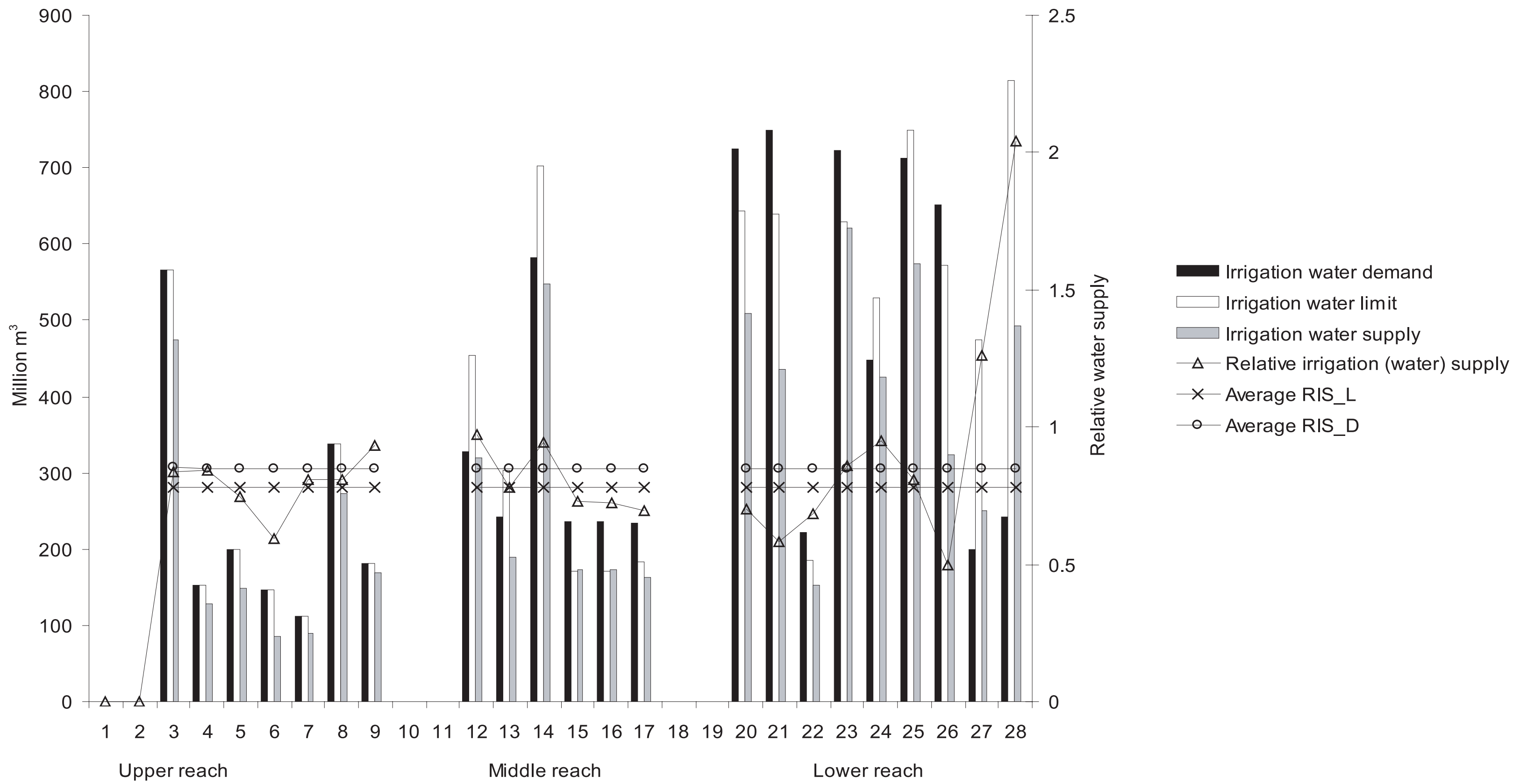


FIGURE 3.
Analysis of relative water use (WUAs).

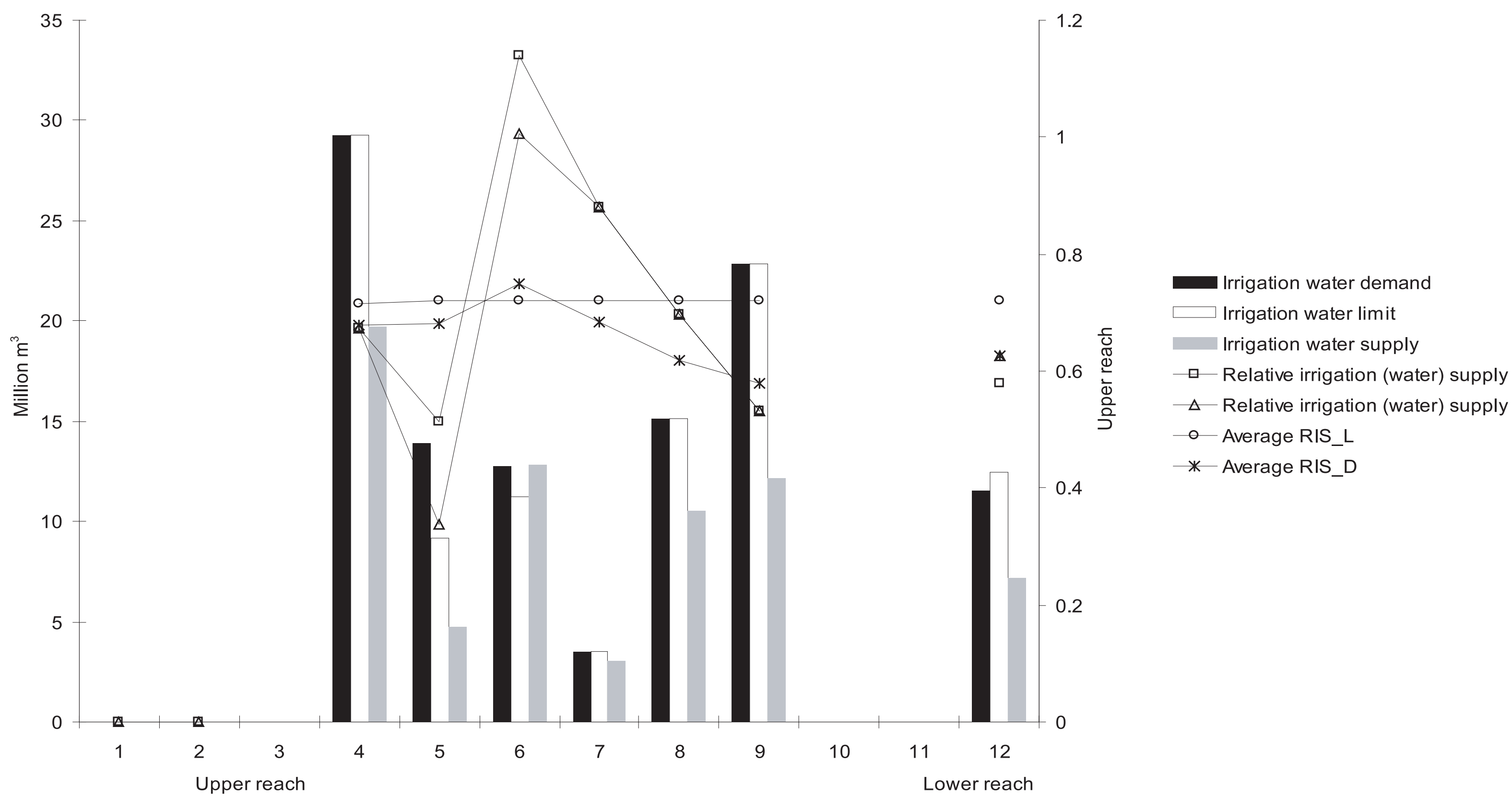


FIGURE 4.
Analysis of irrigation water demand, limit and supply and relative water supply in the Syr-Darya river basin (collective and cooperative farms).

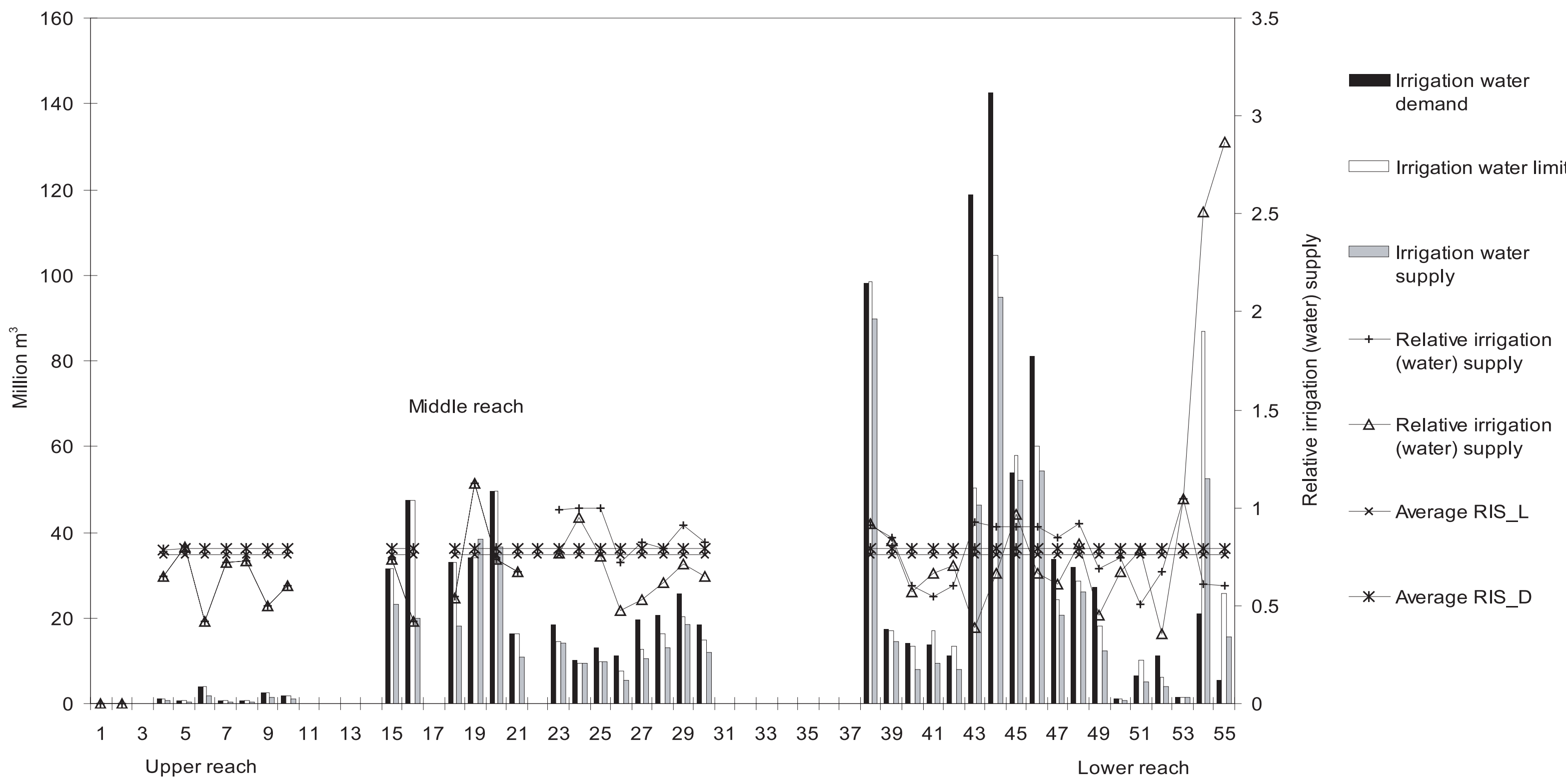


FIGURE 5.
Irrigation water demand, limit and supply in the Syr-Darya river basin at Rayvodkhoz level.

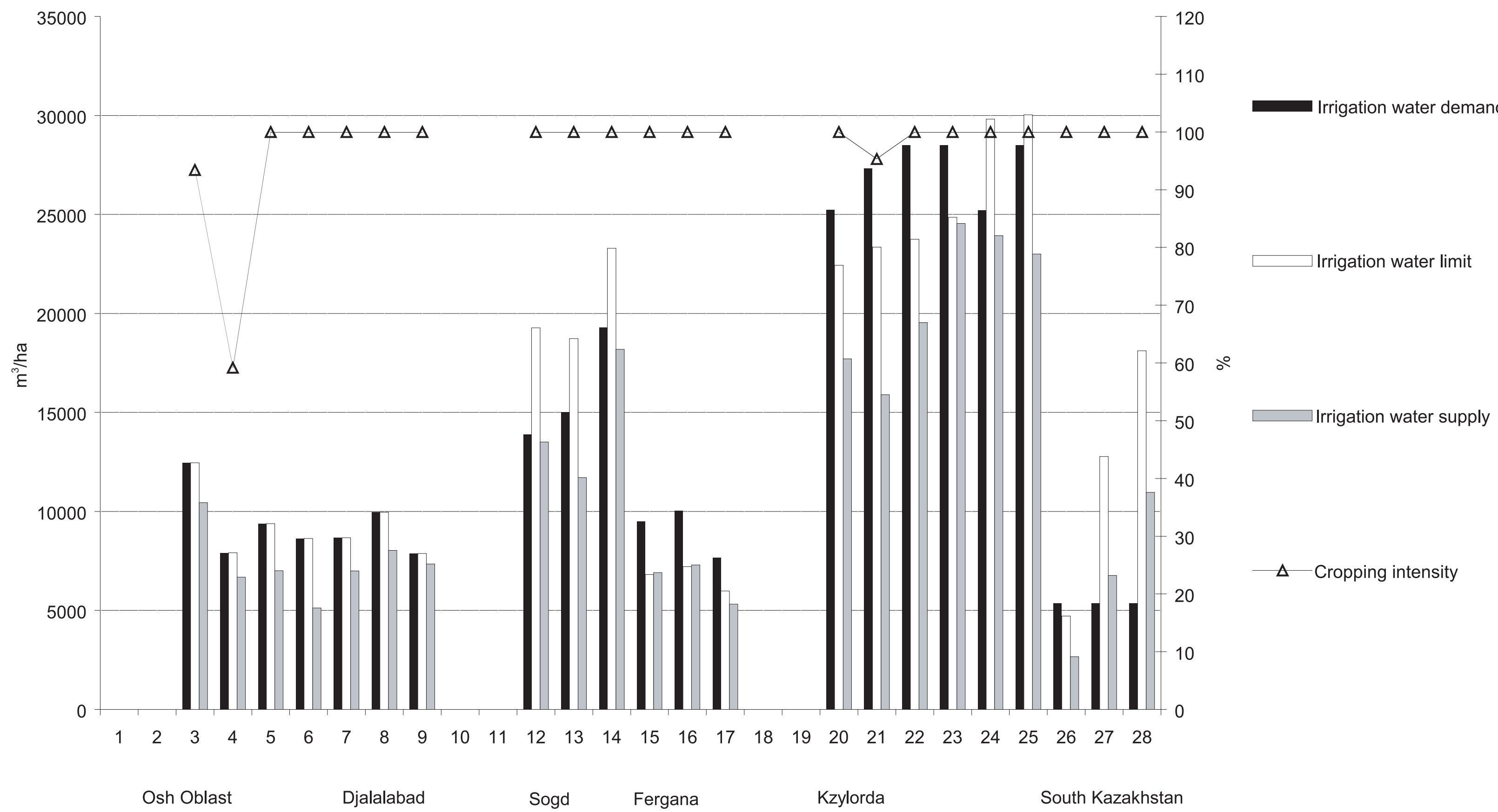


FIGURE 6.
Analysis of irrigation water demand, limit and supply and relative irrigation supply (private and peasant farms).

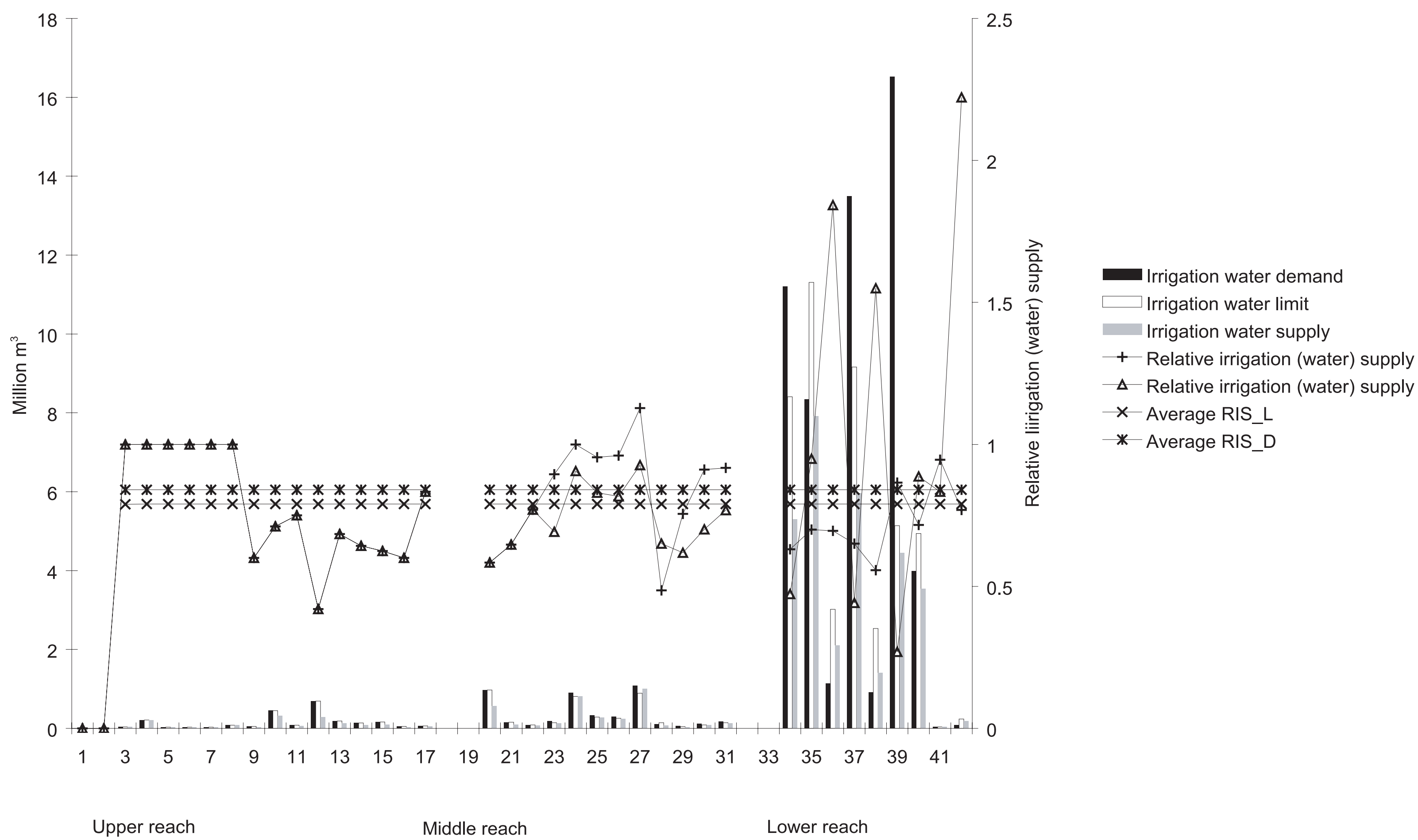


FIGURE 7.
Analysis of irrigation water demand, limit and supply and relative water supply (private and peasant farms).

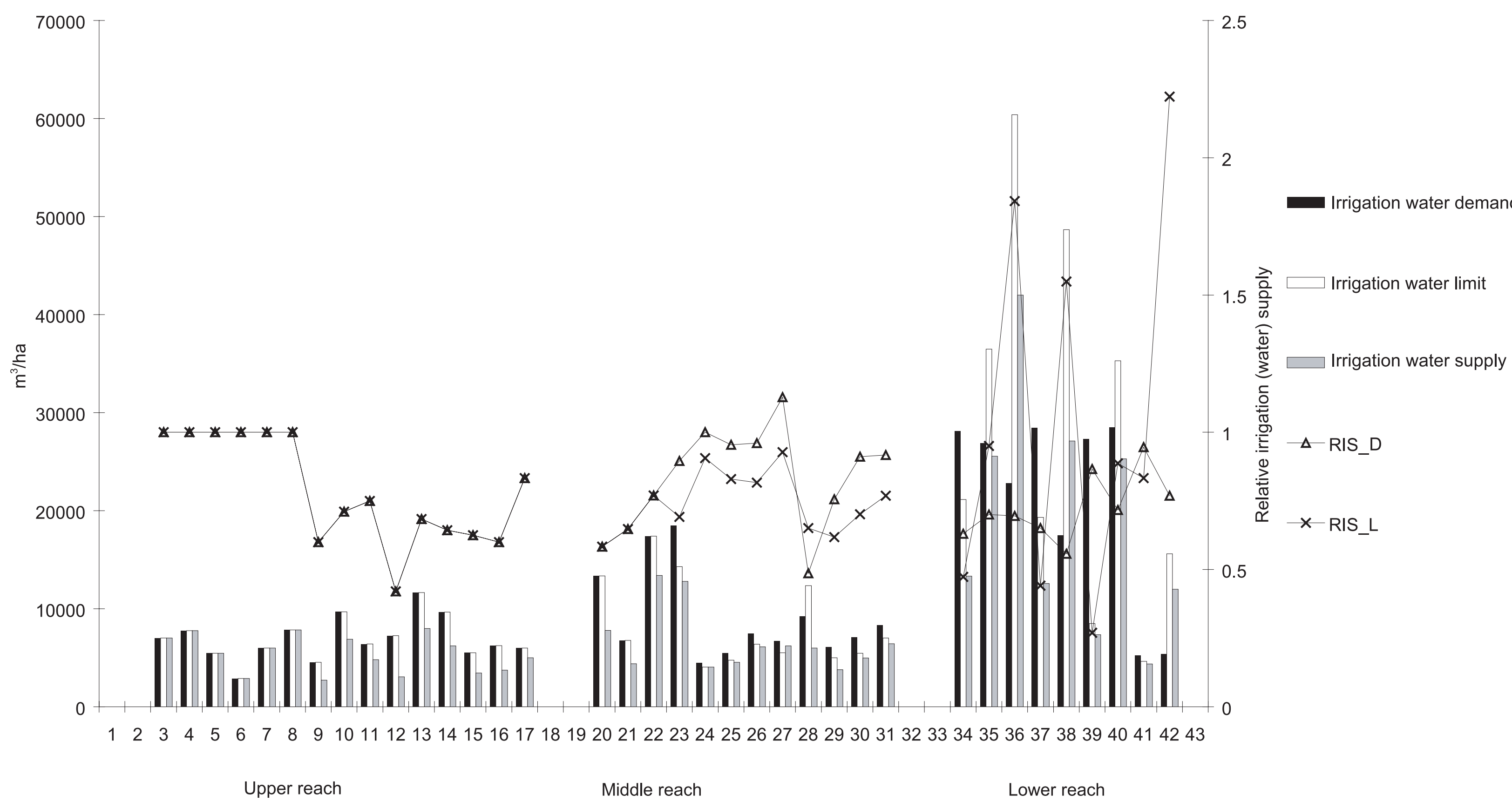


FIGURE 8.
Analysis of irrigation water demand, limit and supply and relative water supply in the Syr-Darya river basin (collective and cooperative farms).

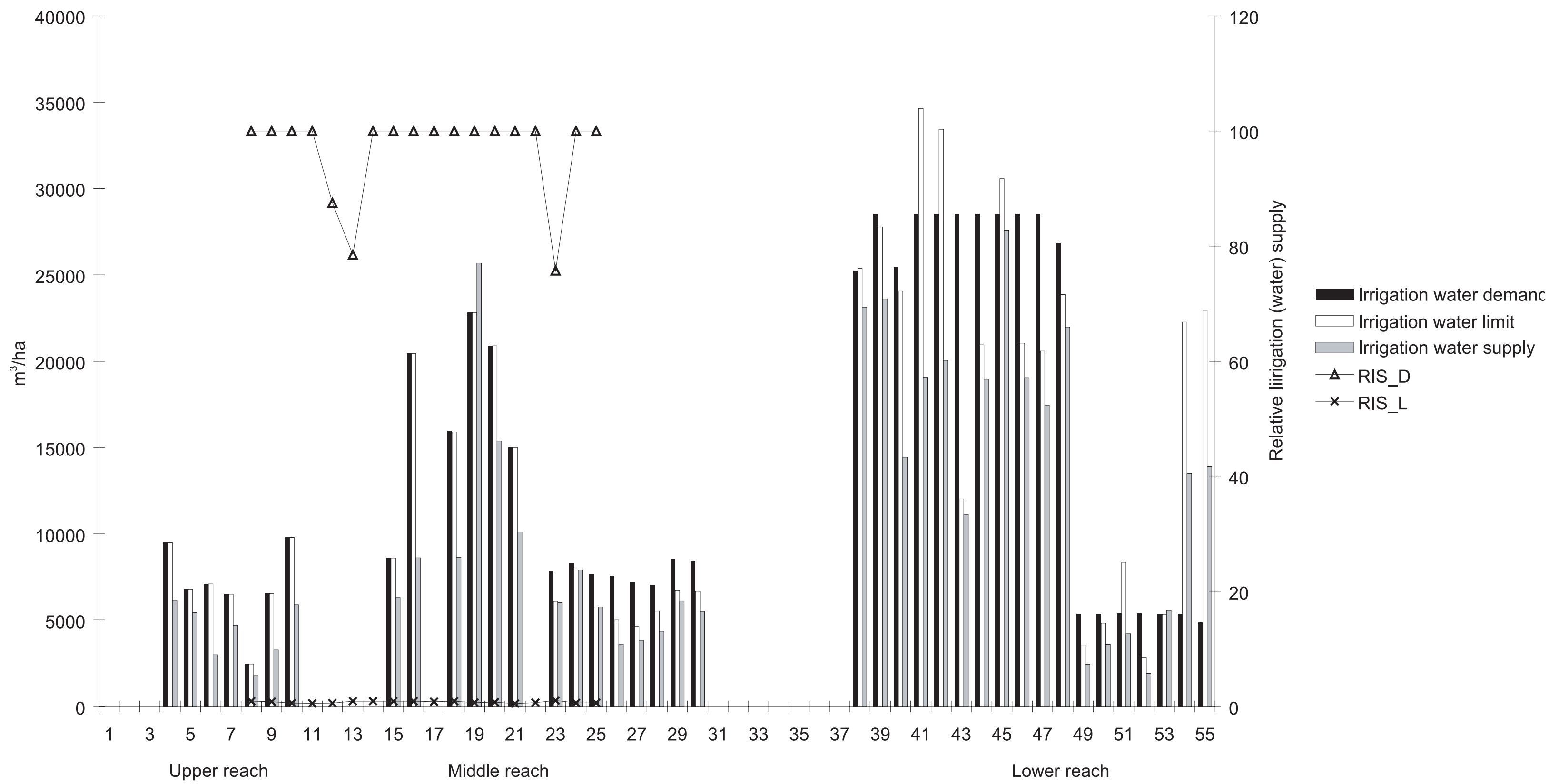


FIGURE 9.
Analysis of irrigation water demand, limit and supply and relative water use in the Syr-Darya river basin (Rayvodkhozs).

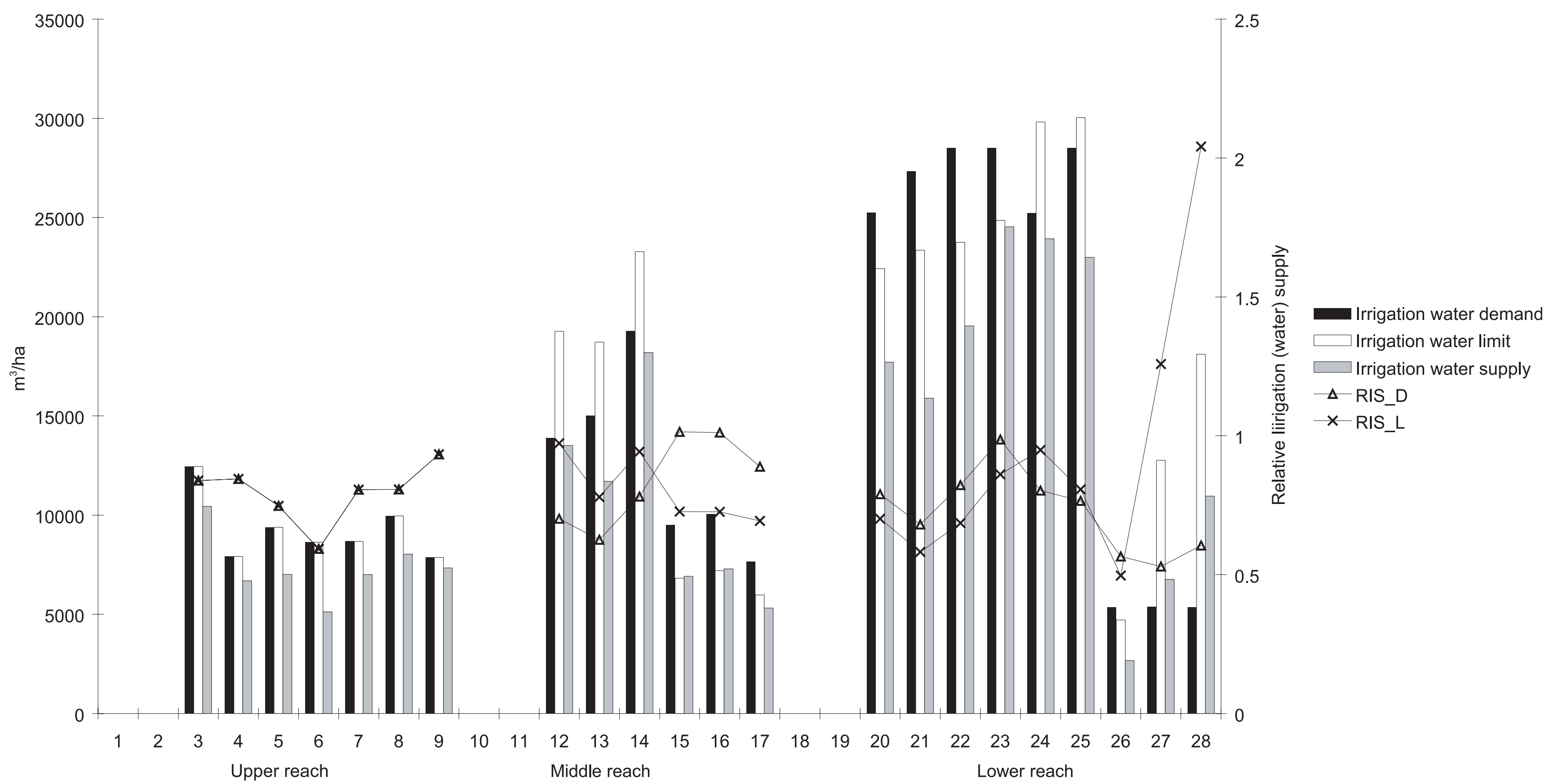


FIGURE 10.
Irrigation water demand, limit and supply in the Syr-Darya river basin at private- and peasant-farm level.

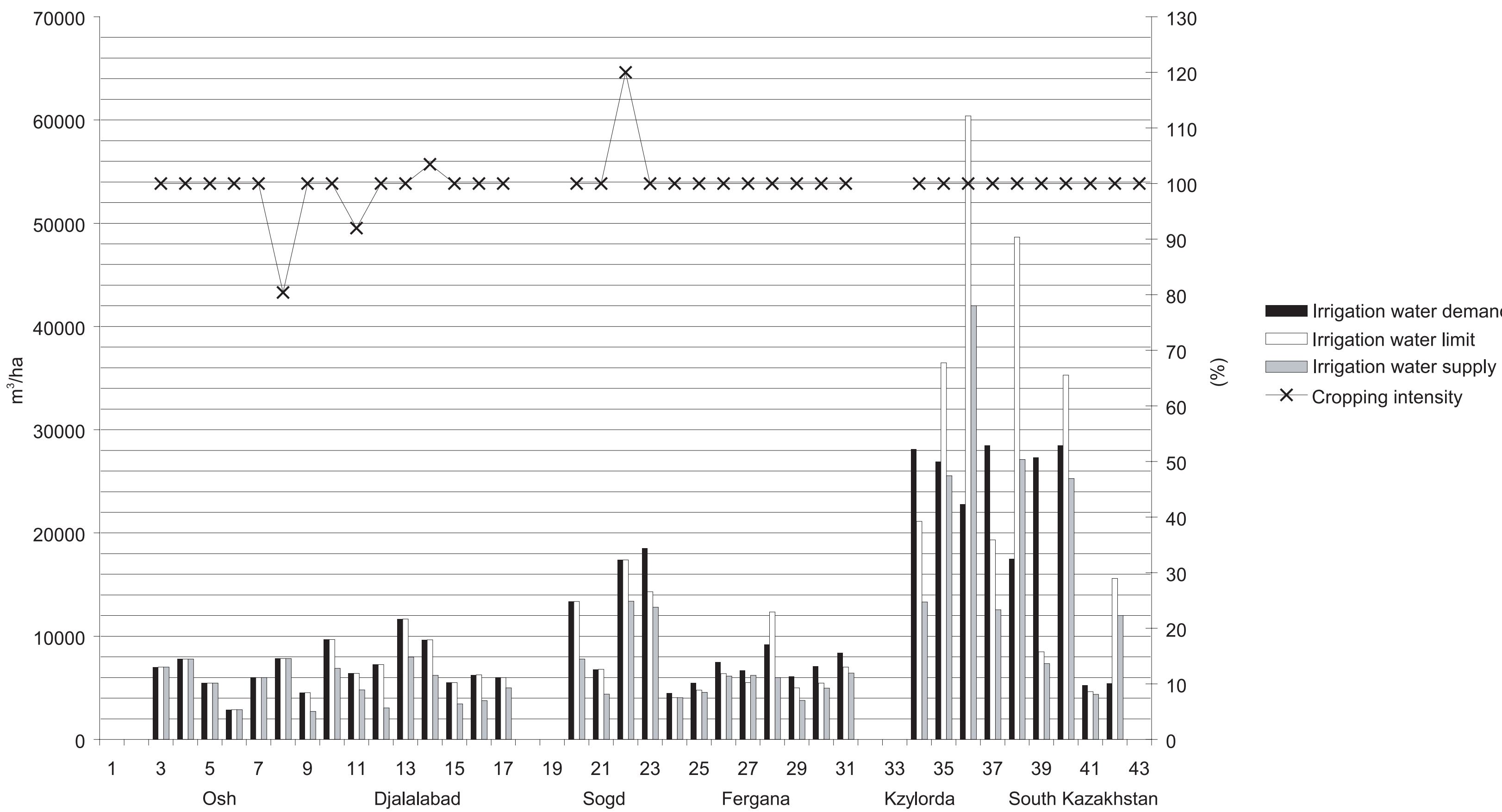
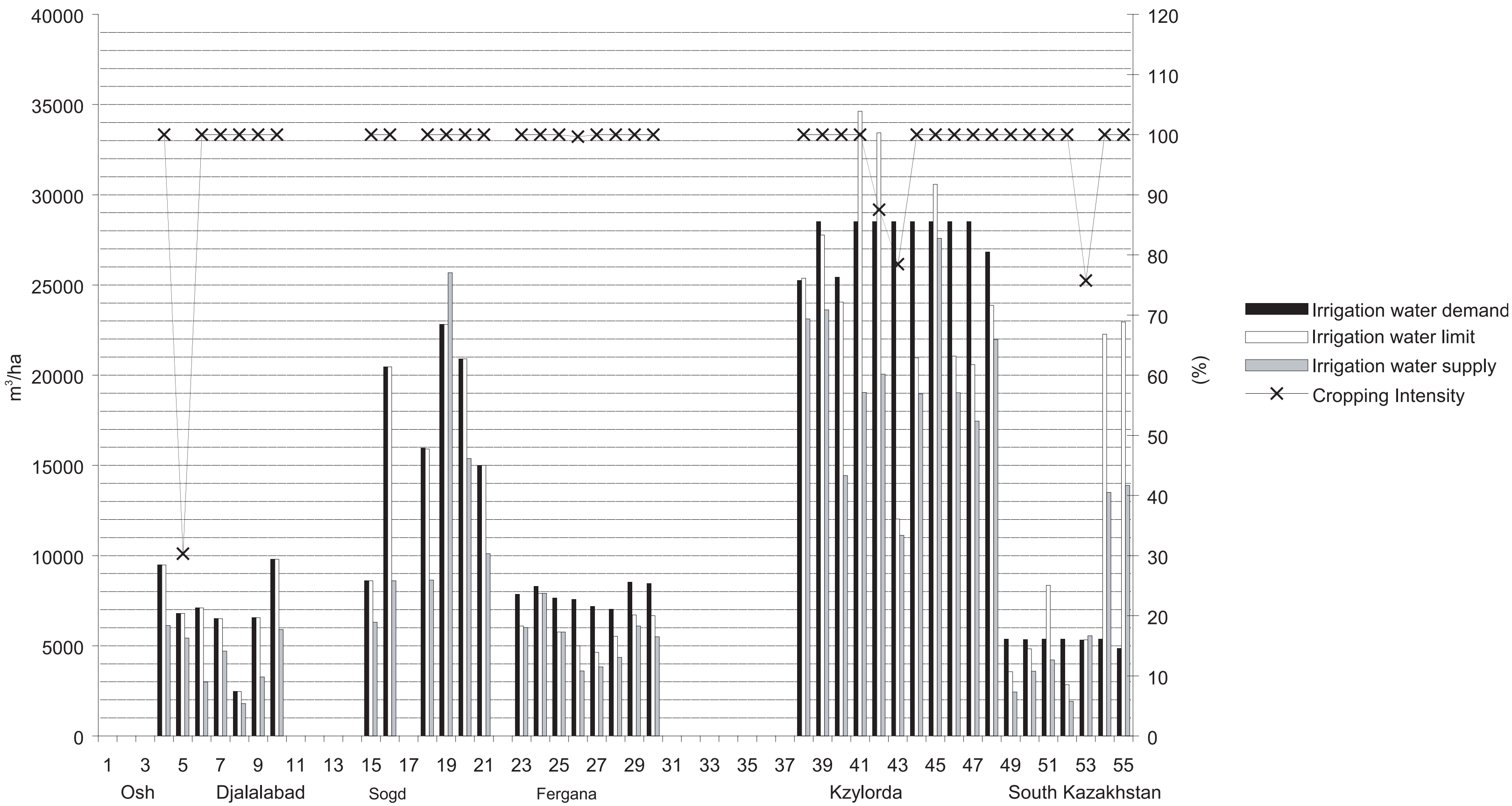


FIGURE 11.
Irrigation water demand, limit and supply in the Syr-Darya river basin at collective- and cooperative-farm level.



Literature Cited

Bandaragoda, D. J. 1999. *Institutional implications of water resources management in Central Asian republics*. Internal Report. Lahore, Pakistan: International Water Management Institute.

GEFPA (Global Environment Facility Project Agency); DHV Consultants BV; Landell Mills; ICWS. 2000. *Report on participation in water saving*. NP: GEFPA. pp.185

IWMI (International Water Management Institute). 2000. *The institutional, financial, and organizational arrangements for water management in Central Asia*. Draft Consultancy Report. NP.

Micklin, P. P. 1991. *The water management crises in Soviet Central Asia*. The Carl Beck papers in Russian and East European Studies. Pittsburg, USA: University of Pittsburg, Center for Russian and East European Studies.

Mirzaev, S.1998.*The impact of the Aral Sea crisis on water resources of Central Asia*. Report. Tashkent: Meeting of the Independent Panel on Aral Sea.123 pp.

Raskin, P.; Hansen, E.; Zhu, Z. 1992. *Simulation of water supply and demand in the Aral Sea region*. *Water International* 17(15-30).

Razakov, R. B.; Alihanov, B.; Rahmonov, B.A.; Kosnazarov K. A.1999. The Aral Sea problems and mitigating measures. Unpublished Report. pp.2. (in English)

SIC (Scientific Information Center of the Interstate Commission on Water Coordination). 2000. Bulletin No. 24. Tashkent: SIC. pp.23.

Sredazgiprovodkhlopok. 1970. *Calculated mean of irrigation norms of agricultural crops in the Syr-Darya and Amu-Darya river basins*. Tashkent: SIC. pp.292.

Research Reports

55. *Water Scarcity and Managing Seasonal Water Crisis: Lessons from the Kirindi Oya Project in Sri Lanka.* R. Sakthivadivel, Ronald Loeve, Upali A. Amarasinghe, and Manju Hemakumara, 2001.

56. *Hydronomic Zones for Developing Basin Water Conservation Strategies.* David J. Molden, Jack Keller, and R. Sakthivadivel, 2001.

57. *Small Irrigation Tanks as a Source of Malaria Mosquito Vectors: A Study in North-Central Sri Lanka.* Felix P. Amerasinghe, Flemming Konradsen, Wim van der Hoek, Priyanie H. Amerasinghe, J. P. W. Gunawardena, K. T. Fonseka and G. Jayasinghe, 2001.

58. *Fundamentals of Smallholder Irrigation: The Structured System Concept.* B. Albinson and C. J. Perry. 2001.

59. *A Gender Performance Indicator for Irrigation: Concepts, Tools and Applications.* B. van Koppen. 2001.

60. *Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer.* Tushaar Shah, Barbara van Koppen, Douglas Merrey, Marna de Lange and Madar Samad. 2002.

61. *Poverty Dimensions of Irrigation Management Transfer in Large-Scale Canal Irrigation in Andra Pradesh and Gujarat, India.* Barbara van Koppen, R. Parthasarathy and Constantina Safiliou. 2002.

62. *Irrigation Sector in Sri Lanka: Recent Investment Trends and the Development Path Ahead.* M. Kikuchi, R. Barker, P. Weligamage and M. Samad. 2002

63. *Urban Wastewater: A Valuable Resource for Agriculture.* Wim van der Hoek, Mehmood Ul Hassan, Jeroen H. J. Ensink, Sabiena Feenstra, Liqa Raschid-Sally, Sarfraz Munir, Rizwan Aslam, Nazim Ali, Raheela Hussain and Yutaka Matsuno. 2002.

64. *Use of Untreated Wastewater in Peri-Urban Agriculture in Pakistan: Risks and Opportunities.* Jeroen H. J. Ensink, Wim van der Hoek, Yutaka Matsuno, Safraz Munir and M. Rizwan Aslam. 2002.

65. *Land and Water Productivity of Wheat in the Western Indo-Gangetic Plains of India and Pakistan A Comparative Analysis.* Intizar Hussain,R.Sakthivadivel, Upali Amarasinghe, Muhammad Mudasser and David Molden. 2003.

66. *Agro-well and Pumps in Irrigation Schemes in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects.* M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono and H.M. Somaratne. 2003.

67. *Water Productivity in the Syr-Darya River Basin.* Hammond Murray-Rust , Iskandar Abdullaev, Mehmood ul Hassan, and Vilma Horinkova. 2003.

Postal Address:
P O Box 2075
Colombo
Sri Lanka

Location:
127, Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Tel:
+94-1-787404

Fax:
+94-1-786854

E-mail:
iwmi@cgiar.org

Website:
http://www.iwmi.org

International Water Management Institute

FUTURE HARVEST
IWMI is a Future Harvest Center supported by the CGIAR

ISSN 1026-0862
ISBN 92-9090-509-3