8-7

Managing Soil Salinity in the Lower Reaches of the Amudarya Delta: How to Break the Vicious Circle

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Executive Summary

Soil salinity is one of the critical factors responsible for the ongoing land degradation in the irrigated lowlands of Central Asia, including in the lower reaches of the Amudarya Delta. This land degradation hinders sustainable development and presents a major challenge for the area's rural population, whose livelihood security depends on irrigated agriculture. The factors causing soil salinity are multifaceted and interlinked; recent studies and interventions confirm that no one action alone will deliver a sustainable solution. Recommendations for alleviating soil salinity should take into account the complex interactions and can be formulated only once the interlinked factors causing soil salinity are understood. In the past, little attention was paid to creeping land degradation, which has resulted from soil salinization and waterlogging across huge agricultural and even nonagricultural areas.

This case study focuses on the vicious circle of soil salinization: agriculture's consumption of large amounts of water contributes to shallow groundwater, leading to recurring soil salinity, which in turn demands more water for leaching (flushing the salts out of the rooting zone). The situation is exacerbated when water is not available in sufficient amounts in time and in space. The seemingly stable present water flows in the major water source (the Amudarya River) since the major drought in 2000–01 is caused by increased glacier melting in upstream countries. This water supply in turn diverts attention from the strong need for improved irrigation and cropping practices. Efforts aimed at reducing the amounts of irrigation water use face the problem of the "devilish" vicious circle, which has not only technical but also financial and political dimensions.

Your assignment is to present policy options for managing soil salinity in a more sustainable way. Focus on incentives and instruments to solve the artificial water shortage problem.

Background

Irrigated agriculture has sharply increased food, feed, fuel, and fiber production worldwide and thus made a significant contribution to food security (Tanji and Kielen 2002). Nearly 40 percent of global food production is produced on about 280 million hectares (Mha) of irrigated cropland, which constitutes approximately 18 percent of the world's cropland (UNESCO-WWAP 2006). Irrigation has contributed to increases in cultivated area, cropping intensity, and yields and has thus helped stabilize and increase food production in spite of an enormous expansion in population and per capita food intake. But irrigated agriculture accounts also for almost 70–90 percent of freshwater use. This usage is highest in arid and semi-arid areas. The negative consequences of irrigation are land degradation through salinization[1] and waterlogging[2] and heavy use of land and available freshwater resources. In addition, the increasing pressure on these resources from the growing population and the consequences of climate change, which include uncertain water availability in recent and coming years, jeopardize the sustainability of agricultural production and in turn threaten the livelihoods of the local population (Glantz 2002).

These problems are acute in the Central Asian countries. The irrigation and drainage networks in these arid and semi-arid regions perform poorly compared with networks elsewhere. These systems suffer from high water inputs, low water use efficiency, and low yields and have severe impacts on water and soil resources, causing environmental deterioration and human health problems. Soil salinity, a well-known phenomenon in these irrigated areas, is associated with poor natural drainage. Irrigation water use in the lower reaches of the Amudarya River is a textbook example of the mantra "irrigate first, manage salinity later," which also burdens many other irrigation schemes worldwide. Agricultural productivity in the cropland areas in Central Asia has declined severely in recent decades. Salinity-affected areas are estimated at 40–60 percent of the total area; yield losses can reach 20–40 percent in slightly and moderately saline areas but can reach 80 percent or even

[1] Secondary salinization is defined here as the salinization that occurs when saline underground water levels rise to the soil surface and contribute to an accumulation of salts in the soil profile after the water is evaporated.
[2] Waterlogging is defined as excessive moisture content relative to air in the soil root zone.

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complete failure in severely saline areas (Ramazanov 2004).

Historical Background

Starting in the 1960s, the Soviet Union converted Central Asia in general, and Uzbekistan in particular, into an agrarian, cotton-producing area. This change was made possible with an expansion of agricultural area to 8 Mha (in 1999) that was irrigated with about 100 cubic kilometers (km^3) of river water transported through 323,000 km of irrigation channels (SIC-ICWC 2004). The water outflow was managed through 200,550 km of collectors and drains constructed between 1960 and 1990 (SIC-ICWC 2004). But this intensive land development program for irrigated agriculture demanded virtually all available water from the two principal Central Asian rivers, the Amudarya and Syrdarya, and all their tributaries. Little if any attention was paid to environmental degradation, caused by a rapid rise of the groundwater table. From a technical point of view, a rising water table demands a functional drainage network, but even with the large drainage works built in the area, salinization could not be arrested and reportedly even increased (Nasonov 2007). Currently, more than 50 percent of the irrigated areas in Uzbekistan suffer from soil salinization, while virtually all the downstream areas are saline to different degrees.

A dysfunctional drainage system is only one cause of the rise in land salinization and waterlogging. They have also been driven by excessive water inputs and seepage from the mainly earthen irrigation networks (Bucknall et al. 2003). Given that groundwater is a major source of drinking water in many rural areas, salinization of the land and water resources in turn causes the degradation of drinking water, leading to widespread health problems (Herbst 2005).

About 25–30 percent of all irrigation water is now used to flush salts from the soil profile, especially in downstream areas. The efficiency of this practice is questionable in, for example, the Khorezm province—a downstream area of the Amudarya River, representative of about 8 Mha of irrigated land in Central Asia (Figure 1). In-depth studies have shown that leaching merely reduces the concentration of salts and that the salts reappear in the soil profile in between the irrigation events or outside the growing periods (Forkutsa et al. 2009). This practice thus causes further soil degradation and significantly reduces crop yields. Finally, it endangers the sustainability of agriculture by reducing economic returns and threatening the livelihoods of the population.

Regional Characteristics of Khorezm

The salient changes since the 1960s, as well as the current problems of the interaction between land and water management in Uzbekistan have been widely studied. The case of the Khorezm province illustrates these issues.

The Khorezm province has a long history of agricultural activities, which have been reported in numerous documents from ancient times. Khorezm today is a 650,000-ha province in Uzbekistan: it is flat, with an average slope of less than 1 degree and elevations ranging from 75 to 138 meters above sea level (Ibrakhimov et al. 2007). The natural conditions are favorable for crop production. The soils and microtopography of the province were formed under the influence of the meandering Amudarya River. Soils are stratified; the upper soil texture is silt and sandy loam extending two to three meters deep and underlain by sand. Average temperatures recorded at the Urgench[3] Meteorological Station were –2.2°C. in January and +27.0°C. in July from 1980 to 2006 (Figure 2). Effective temperatures during growing periods allow the production of one to two crops per season. Because of the aridity of the continental climate, however, potential evapotranspiration (ET) amounts to 1,400–1,600 millimeters (mm), in contrast to the average precipitation of 100 mm (Mukhammadiev 1982). The ratio of ET and precipitation indicates the need for artificial irrigation of crop production.

The Amudarya River—the longest river in Central Asia with a length of 2,540 km—is the major source of irrigation water in Khorezm.[4] During 1911–2000 the entire Amudarya River basin generated an average annual flow of about 77 km^3, of which an average 14.8 km^3 were available to the Khorezm province and downstream Karakalpakstan (SIC-ICWC 2004).

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[3] Urgench is the regional capital of the Khorezm province.

[4] The Amudarya is in fact 1,415 km long, but its length is 2,540 km if measured from the sources of its headstream, the Panj River in neighboring Tajikistan.

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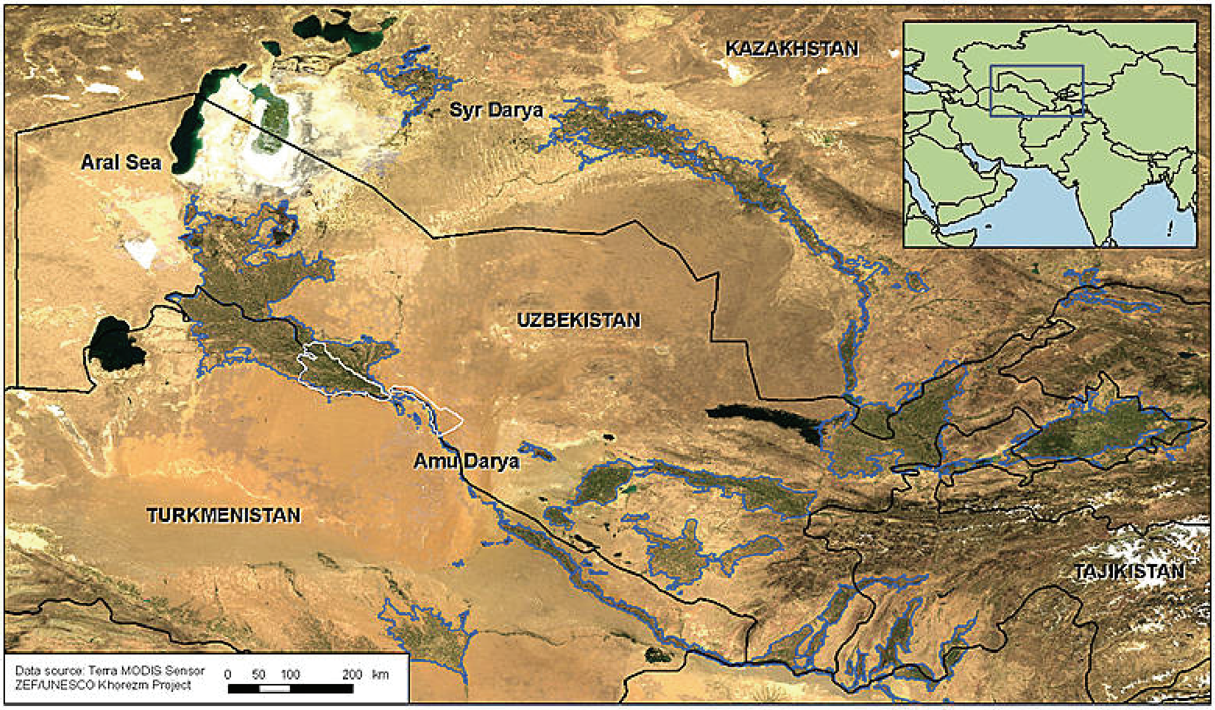
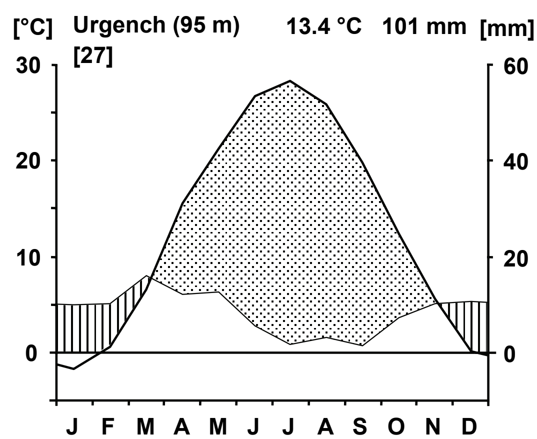
Figure 1: Map of Uzbekistan and the Irrigated Areas in the Southern Parts along the Amudarya River



Source: Terra MODIS Sensor, ZEF/UNESCO Khorezm Project.
Note: The Khorezm province is delineated with white boundary.

Figure 2: Monthly Mean Air Temperature (parabolic line, left axis) and Monthly Precipitation (right axis) in Khorezm, 1980–2006



Source: Forkutsa et al. (2009).
Note: Data along the top of the graph are location of the meteostation, elevation above mean sea level (meters), average temperature (Celsius), and precipitation (millimeters). Average maximum temperature is 27.

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The sources of water for the Amudarya River are snow and glacier melt and rainfall in the mountainous areas of the neighboring countries Tajikistan and Kyrgyzstan. The river carries sediments, which may raise soil fertility when they are deposited along with the irrigation water (Nurmanov 1966). At the same time, however, the salinity of the river water of about 0.2 grams per liter in the flow-formation zone (mountainous areas) increases in the transit and dissipation zone to 0.8–1.8 grams per liter (SIC-ICWC 2004) until it reaches the deltaic zone of downstream Khorezm and Karakalpakstan. Although the salinity level in the deltaic zone is higher than that in the upstream zones, the river's salinity level is not at present hazardous for crop production provided ameliorative measures are properly carried out.

The flat natural environment hinders effective drainage of agricultural fields. During leaching and irrigation events, the groundwater table rises, reaching one meter and less. The dynamic and moderately saline groundwater of 1.7–1.8 grams per liter mobilizes salts, which, following the capillary rise of groundwater and its evapotranspiration, remain in the soil root zone. The rate of salt transfer with groundwater ranges from 3 to 10 metric tons per hectare (Ibrakhimov et al. 2007). Apart from salinization, waterlogging affects more than 60 percent of cropped area (SIC-ICWC 2004).

To counterbalance the adverse effects of rising groundwater, an extensive network of drains and collectors was installed in Khorezm. Now, however, the discharge of drained water out of the area has created an outlet problem—there is no receiving water body with sufficient capacity to accept the vast amounts of drain water.

The frequent irrigation of water-intensive crops such as cotton and rice cultivated over vast areas causes the groundwater table and soil salinity to fluctuate within the first one to two meters of topsoil. Rice is not a state quota crop in Uzbekistan, but because rice consumes huge amounts of water, the government sometimes restricts its cultivation, much to the despair of the farming population, for whom rice is an extremely profitable crop giving the highest revenues. The growing seasons for cotton and rice coincide, resulting in potential competition for water, particularly in the lower reaches of Amudarya. Apart from consuming large amounts of water (up to 4,000 mm), the constant flooding of rice fields (to control weeds and reduce salinity) in the higher parts of the landscape causes the groundwater level to rise in adjacent fields and hence exacerbates the soil salinity problem. In times of low water availability, farmers even block the drains to raise groundwater tables, and this practice also leads to waterlogging in neighboring fields. By 1999, more than 90 percent of the area in the Khorezm province experienced groundwater table depths of less than two meters below ground (SIC-ICWC 2004). Although the effects of salinity are somewhat buffered by frequent surplus-irrigation and leaching events, the inadequate infrastructure and insufficient removal of salts contribute to advancing soil salinization. This situation in turn demands more water for leaching and more leaching events.

This vicious circle needs to be broken in favor of sustainable agriculture.[5] Land and water use are intermingled and cannot be regarded as isolated issues. Determining an entry point to break the vicious circle (if in fact it is possible to break it) requires an in-depth understanding of the issues at stake.

Policy Issues

To design an adequate policy for breaking the aforementioned vicious circle, it is important to take into account the many technical, financial, and political aspects of the issues.

The Agricultural Production System

Since independence in 1990, the Government of Uzbekistan (GoU) has adapted the main elements of the centralized Soviet system of planning and managing agricultural production units. Despite manifold reforms since independence, at present farmers hold only lease contracts to their land. Furthermore, for cotton and wheat production, the GoU prescribes crop varieties, amounts of seed and expected yields, timing and supplies of fertilizers and chemicals, timing and amounts of water

[5] Sustainable agriculture is defined here as agriculture capable of being continued with minimal long-term effects on the environment (http://www.thefreedictionary.com).

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for leaching and irrigation, and many more agronomic practices. The omnipresent national administration observes the entire agricultural production process but pays particular attention to the state quota crops cotton and wheat, which occupy 70 percent of the cropland and for which the GoU also regulates the purchase prices. At the same time, the state subsidizes the production chains of these strategic crops and bears the maintenance and operation costs of the relevant infrastructure, including main and interfarm irrigation and drainage networks, dams, reservoirs, and pumping stations. The on-farm irrigation infrastructure[6] costs are born by water user associations (WUAs). Because of the difficulty of collecting fees from their farmer-members, however, WUAs tend to transfer responsibility for maintaining drains and irrigation channels directly to farmers.

At present, the operation and maintenance of the huge network of irrigation and drainage channels are centrally managed. The state's tight control of the farming sector means that the state rather than the farming population is largely responsible for the success or failure of crop production, the dynamics of environmental change, the provision of employment, and other agricultural outcomes. Although it is repeatedly mentioned that state control in Uzbekistan hampered the development of agricultural production, it is also generally accepted that the economy of Uzbekistan has been more stable and less prone to collapse than other former Soviet Union republics in the aftermath of their independence thanks to its agricultural production policies (Spoor 1999).

The government's strict management and governance of the water supply to the production regions and individual fields offers the possibility of allocating the approximate amounts of water for the entire season and in the future. Since water is one of the common, transboundary resources of the five Central Asian countries, the potential to allocate and proportionally share freshwater is important for conflict resolution. It is also an effective means of controlling overuse of water at local, district, and regional levels.

Since the entire agricultural production chain provides job security and eases social tension (Müller 2006), the national administration is not yet considering waiving jobs in this chain. For farmers, the advantages of the state-controlled value chain include guaranteed, subsidized advance payments in the form of, for example, diesel, fertilizer, and tax reductions. The negative consequences of this management are, among other things, low returns, farmers' weak financial status and reduced options, and their low capacity for building farm capital. Farmers also lack incentives to save water and to achieve higher yields for the state quota crops cotton and wheat, because of the low purchase prices determined and imposed by the national administration. Farmers are obliged to grow cotton and wheat, and their performance is assessed according to whether they fulfill the state quota.

Because of the national administration's heavy involvement in crop production, policy recommendations have the highest chances of success when they are made through this institution. Thus, initiatives and eventual implementation of recommendations must come from the national administration. The scope for farm-level decision making for cotton and wheat is limited; farmers do not have to make decisions themselves, they do not directly pay for the water they use, and they do not need to respond to market signals. Therefore much responsibility lies with the national administration as a prime decision maker.

Water

Overall water distribution in the Aral Sea Basin is coordinated by the Interstate Commission for Water Coordination (ICWC) with a number of executing agencies. The ICWC was established by the five Central Asian states after the disintegration of the Soviet Union to coordinate water resource management, water allocation, the setting of limits on water withdrawals, and accounting. The Basin Water Organization (BWO) for the Amudarya is one of these executing agencies of the ICWC and is mandated to, among other things, ensure the timely and reliable supply of water to water users according to limits set by the ICWC. The ICWC reached a water-saving policy agreement to decrease the common water intake by all five Central Asian countries, and water intake consequently fell from 116 km^3 in 1990 to 105 km^3 by 2000 (Dukhovny and Sokolov 2002). Although these water savings were meant to help rehabilitate

[6] Since the ending of the collective farm period, when the collective farms were converted into private farms, on-farm irrigation canals have been called "interfarm canals."

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or maintain the Aral Sea, much of this water does not reach the increasingly desiccated sea.

The Khorezm province is within the BWO Amudarya. The permanent uncertainty of water allocation is one characteristic of the lower reaches of the Amudarya. During the Soviet era, *kolkhoz*[7] units handled irrigation water in a relatively uncomplicated arrangement. Land and water use reforms, which resulted in the creation of many small farms, complicated water distribution because the system was originally developed for large-scale production units.

The contribution of shallow groundwater to secondary soil salinization is well recognized in the Khorezm province, but less well known is groundwater's contribution to satisfying crop water requirements (Forkutsa et al. 2009). For example, although a groundwater table below two meters would significantly reduce soil salinity (Forkutsa et al. 2009), given the present inefficiencies in irrigation application, surface water applications in the Khorezm province would need to be virtually doubled to match the present groundwater contribution to satisfying crop water demands. Such large additional quantities are presently unavailable, and they are highly unlikely to become available given the predicted impact of climate change on water availability in the region (Chub 2007). Hence the management of groundwater demands a careful and balanced approach in time and space and needs to be taken into account when reflecting about increasing the efficiency of the drainage network in the region.

Despite the time and resources that farmers have already spent to secure the supply of irrigation water in time and space, this supply remains uncertain. This uncertainty not only limits planning, but it also means that once irrigation water becomes available, farmers tend to use as much as possible, explaining the frequent overuse of this precious natural resource. Furthermore, a major cause of the too-shallow groundwater is heavy irrigation, resulting in high losses of irrigation water in fields and seepage from the irrigation network, although these "losses" do percolate back into the groundwater.

Local officials see improvement of the drainage network as the best option to reduce soil salinity and waterlogging and in turn increase the sustainability of production. But the amount to be drained out of the Khorezm province has created an "outlet problem"—there is no sufficiently large water or land body with adequate capacity to accept the vast amounts of water to be drained. The area used currently is the Sarikamysh depression, which is shared by Turkmenistan and Uzbekistan. Effluent water from the irrigated areas must cross the border into Turkmenistan to reach this large lake for disposal. At present the water in this lake has a very high salt content and cannot be reused unless vast amounts of funds are devoted to cleaning and purifying it. The authorities of Turkmenistan, however, presently have no incentive to improve the outlet. Thus, although the outlet problem is technically solvable, it has a political and social dimension and involves a very high cost.

As long as this outlet problem exists, it will not be possible to arrest or alleviate soil salinization in the Khorezm area by lowering the groundwater table depth by lengthening and deepening the existing drains and collectors. Furthermore, increasing drain capacity without easing the outlet problem does not address the pressing issue of overuse of irrigation water. Finally, establishing a functional drainage network is expensive and risky, given the uncertainty about whether it will ease the problem. Alternative options for improving the drainage network are to widen the drains (because introducing tile drains is economically costly) or to increase drainage density. These options, however, would come at the expense of field area and would thus reduce total production while failing to address the problem of water overuse.

Current practices have derailed the massive development of land for irrigation. The entire system must be modified or adapted to the emerging situation of many farmers and producers. However, as Glantz (2002) depicted, it is easy to offer solutions for others to put into action, but the "ordeal of change" has psychological as well as political and socioeconomic constraints. To make policies operational and useful, policy recommendations should take into account these aspects as well.

[7] *Kolkhoz* is a short form of "collective farm," which is the communal production enterprise formed during Soviet times.

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Stakeholders

In Uzbekistan's state-managed agricultural production system, the government is the principal stakeholder in terms of decision-making power. Yet many water-related organizations are engaged in planning, regulating, distributing, and monitoring, starting with the Ministry of Agriculture and Water Resources (MAWR). The Hydro-Melioration Department, within the MAWR and its regional branches, is responsible for monitoring soil salinity. These regional and national branches of the department conduct yearly interventions in soil salinity management and assess their impact. Currently, however, the department does not have the capacity and resources to handle intensive and large-scale monitoring activities. The introduction of modern soil salinity assessment tools and methods could solve this lack of capacity (Akramkhanov 2005). Updated and timely information on soil salinity can help officials make necessary adjustments in leaching or irrigation water amounts.

National- and regional-level WUAs and water management organizations (WMOs) established to manage irrigation water use are responsible for allocating water at the farm and interfarm level, respectively (Pender, Mirzabaev, and Kato 2009). They are also responsible for maintaining irrigation infrastructure and for handling water management among a large number of small-scale farms,[8] which were established when the *kolkhozes* were abolished. One of the first WUAs in Uzbekistan was established in the Khorezm province in 2000, and the current number of WUAs in the republic is close to 1,700 (MAWR 2010). Despite the progress in establishing WUAs, their effectiveness is currently limited by numerous factors, such as top-down establishment, lack of recognition of legitimacy by water users, low level of irrigation service fees and lack of payments by many farmers, lack of management capacity, and unclear roles and responsibilities. Nevertheless, there is evidence that the management of the WUAs is improving, for example, the equity of water distribution among farmers (Pender, Mirzabaev, and Kato 2009).

Another stakeholder is the Land Reclamation Fund (LRF). The Government of Uzbekistan, alarmed by the increasing land degradation, adopted a special program to develop the agricultural sector. The program, which runs from 2008 to 2012, prioritizes the improvement of irrigated lands. The LRF was established in 2007 and started its activities in 2008 with the objectives of (1) reclaiming land; (2) improving the irrigation drainage network, including commissioning new drains and maintaining existing drains; and (3) building capacity. Through the LRF the GoU therefore made available about 75 billion soums in 2008 (when US$1 = 1,350 soums) and 135 billion soums in 2009 (when US$1 = 1,500 soums), and a further 20 percent increase in funding was expected in 2010. The fund also acts as an investor by procuring equipment and leasing it to other organizations engaged in land reclamation. In addition, the LRF funds the mapping and assessment of several soil indicators.

Because soil salinity is tightly linked to water resource management, the governments of the other Central Asian countries, as well as local and regional governments, are stakeholders. The case of Turkmenistan illustrates the difficulties of managing these multiple stakeholders. The outlet problem, for example, cannot be solved unilaterally because the drainage water is disposed of in a depression shared by Uzbekistan and Turkmenistan.

The main stakeholders are of course the farmers and the rural population, which account for about 60 percent of the total population and whose livelihoods depend on agriculture. In particular, during drought years, maintaining a minimum level of food security has been a major challenge, considering the low mobility of the rural population.

The impact on the environment includes a heavy toll on people's health, particularly in the downstream areas. Drinking water supply is in place for most of the urban centers, but the rural population relies mainly on groundwater and shallow groundwater sources. The latter vary in quality, and the lack of sanitation and hygiene increases the incidence of disease. The Ministry of Health is the most important stakeholder addressing health issues.

[8] Since November 2008 the GoU has initiated a process of farm optimization for farms engaged in crop production. This process involves consolidating small-scale farms into large farms. Small farms of less than 10 ha were deemed suboptimal, and by 2009 the number of farms fell from 220,000 to 105,000, with average farm size of 57 ha (http://www.agro.uz/rus/ekonomika_selkogo_xozyaystva).

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Policy Options

Most of the options considered here target ways to stimulate water saving and increase water productivity among water users and organizations responsible for water distribution.

Tax Exemption and Bonus Provision

Authorities could impose water taxes or tariffs, perhaps on a progressive scale depending on land conditions and water use, which are mixed in this region. Currently, there is no water fee directly charged to farmers. Fixed service fees (or membership fees) for the WUAs pay for pumping costs, irrigation canal maintenance, and staff members. Farmers recognize that they are getting poor service from the WUAs and consequently delay paying their membership fees, and the WUAs in turn have moved to transfer pumping costs and canal maintenance directly to farmers.

One suggested scheme for incentives and disincentives to improve soil salinity and water use efficiency is summarized in Table 1. Farmers who use large amounts of water that lead to poor land conditions would be subject to a heavier tax. In contrast, farmers who use low amounts of water and generate good land conditions would earn a tax reduction or even a financial bonus. Hence, farmers who choose to invest in their land or increase water use efficiency by making use of options to reduce soil salinity would be subject to monitoring before and after these measures, at determined intervals and at a given period of the year.

Establishing a transparent and comprehensive set of incentives and disincentives would in the medium term reduce soil salinity, increase water use efficiency, increase agricultural production, and potentially increase rural livelihoods. Those farmers who invest in their land and in improved water use would reap real benefits, which may well overcome the often-cited apathy with regard to such investments under a situation of insecure land ownership or isolated measures (Rudenko and Lamers 2006). This approach would demonstrate not only national concern with improving environmental policy, but also appropriate action. It may even count as a contribution to the regional or national action plans for combating desertification that countries are to present to the United Nations Convention to Combat Desertification (UNCCD). It may restore some responsibility for agricultural sustainability to farmers, thus boosting their self-esteem, their satisfaction with the government, and rural empowerment.

On the other hand, the creation of such schemes requires the establishment of updated criteria for irrigation or withdrawal norms for water users at different tiers or canal levels. The introduction of updated or modified norms and criteria should be based on minimum water withdrawal restrictions, taking into account long-term data on actual water supply in different reaches of the Amudarya and crop biological water requirements. Finally, these criteria should, when possible, be based on the perception and understanding of the producers and with options for own monitoring to become transparent.

Table 1: Potential Scheme of Incentives and Disincentives for Water and Land Management

	Farmers without increase in water use efficiency	**Farmers who increase water use efficiency**
Farmers who increase soil salinity	Increased taxation	Reduced tax bonus
Farmers who maintain good land conditions or decrease soil salinity	Medium tax bonus	High tax bonus

Source: Authors.

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Water Pricing

Studies conducted by Djanibekov (2008) show that introducing water prices would likely encourage agricultural producers to shift their cropping patterns toward crops that require less intensive use of water, such as fodder crops. Water pricing as an isolated measure could reduce production of rice, the most water-intensive crop in the region. Given that rice is the region's major cash crop, reduced rice production would lower farm income.

The introduction of water charges as a standalone policy would also decrease regional income, although expansion of the livestock sector could compensate for this reduction (Djanibekov 2008). Because the introduction of water prices directly and negatively affects the incomes of agricultural producers, various issues may need to be considered before widespread implementation. First, a water-pricing mechanism can be introduced gradually over time to allow water users to adjust to higher production costs. Second, water pricing could be differentiated according to the growing season. For example, during periods when water is scarce and the intensity of water use is the highest, agricultural producers should be charged the highest water price. Water prices could also be varied between crops to promote crop diversification. In setting an appropriate price for water, care must be taken to ensure that the districts located farthest from the water source are not prevented from meeting their irrigation water needs. Next, water policies should be set to protect the poor—in other words, rural households should get a "free" allowance of irrigation water and be required to pay only for water for cash crops such as rice. Finally, the introduction of water pricing must be accompanied by other measures to solve the qualitative and quantitative water resource management problems in the region. Better management of the irrigation and drainage system resulting from investment of the collected payments for water use can provide a more responsive physical environment for farmers who wish to adopt new production technologies and new crop varieties to take advantage of opportunities for double cropping in Khorezm (Djanibekov 2008).

Improved Water Distribution Network

Given the high seepage losses in the canals that divert river water to the fields for irrigation, improving the water distribution infrastructure could become a priority. The goal would be to reduce seepage losses, which are currently estimated at 20–30 percent for the lower reaches of the Amudarya. Lining the canals would entail large investments and subsequent high maintenance costs. Studies have shown that the rehabilitation, renovation, and concrete lining of canals in all Central Asian countries may save as much as 10–22 km^3 of water a year (Micklin 1988) but would require human and financial resources valued at an estimated US$16 billion (Micklin 2002). On the other hand, findings in Pakistan showed that lining alone will be insufficient (Murray-Rust and Vander Velde 1994). To maximize investments in reducing water losses through lining canals, water management control needs to be strengthened, but no cost estimates are presently available for this action.

Groundwater Table Deepening and Water Use Restrictions

The preferred option of the GoU is to adopt any policy that minimizes the groundwater contribution to soil salinity, such as deepening the drainage network. Hence large efforts are currently underway in many regions suffering from soil salinity. Because of the underlying sandy soils, however, the maximum depth of the drainage network in the Khorezm province, for instance, ranges from 1.5–2 meters (field ditches) to 2–2.5 m but is rarely deeper than 3 m (major collector drains), with the ditches spaced 400–500 m apart. It is commonly understood that drainage capacity in Khorezm is limited and contributes to the secondary land salinization that is widespread throughout the region. The current effluent disposal depression is shared with Turkmenistan, and the collector passes across the two countries' border. Thus a policy of deepening the drainage network can be effective only with the approval of Turkmenistan. As mentioned earlier, however, these technical improvements address only one side of the coin.

Instead of or in addition to bringing more water into the region or improving drainage to discharge more drainage water out of the region, policy makers could focus on limiting water-related human activities in the region. Such limits would mainly concern agriculture, which accounts for up to 85–95 percent of all water consumption. The diversion of river water could be reduced by, for example, reducing the scale of irrigated agriculture, improving watershed management, introducing water-wise technologies such as drip or subsoil

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irrigation (see below), or eliminating the cultivation of water-intensive, low-profit crops. The selection of suitable crops could be guided by the water footprint of each crop along the entire value chain, as recently proposed (Rudenko, Djanibekov, and Lamers 2009). By taking into account virtual and actual water use estimates along the entire chain, this indicator could provide information useful for restructuring regional agriculture.

Water-saving Technologies

Because agricultural production is possible only with irrigation, another policy option is to change and adapt irrigation practices. Guidelines for the timing and amounts of preseason leaching and irrigation events were developed for the large production units of the 1960s at the onset of the rapid expansion of the irrigation network, but they have not been updated since. Also, during the Soviet era, when resources such as water and funds were abundant, the notion of saving natural resources was not prioritized, perhaps as a result of the centralized command system and the lack of ownership.

Financial mechanisms to support the introduction of water-wise technologies may in the end also result in lower irrigation water applications at the field level. There is scope for achieving improvement in water use efficiency this way because the large expansion of the irrigated areas in the past was achieved mainly by adopting cheap, inadequate irrigation technologies (Glantz 2002). The International Center for Agricultural Research in the Dry Areas (ICARDA) has tested several water-saving technologies, including drip irrigation, sprinklers, alternate-furrow irrigation, bed and furrow, laser-assisted land leveling, contour furrows, mulching, and plastic chutes (Pender, Mirzabaev, and Kato 2009). A simple shift to alternate-furrow irrigation, which pushes application efficiency to 85 percent on average, could result in water savings of 44 percent (Horst et al. 2005). This example demonstrates that substantial savings in water use and increases in water use efficiency (production per unit of water) could be achieved (Pender, Mirzabaev, and Kato 2009). At the same time, comparing different water-saving techniques taking into account two additional criteria—financial viability and economic efficiency—reveals a proportional relationship between the water use reduction rate and the capital requirement (Figure 3). Alternate-furrow irrigation showed the highest impact of techniques that require low investments (Bekchanov, Lamers, and Martius 2010). Water-saving technologies with a high potential for reducing water needs, such as drip or sprinkler installations, require large investments that are presently out of reach of farmers. In the context of Uzbekistan, the question arises whether the government is willing and able to provide sufficient financial support to implement and distribute these techniques.

Integrated Packages

Stepping up support for the cotton-processing and industrial sectors has the potential to maintain the share of agriculture in regional income generation but with less land and water resources than presently used (Rudenko, Djanibekov, and Lamers 2009). Regional agriculture could, on the other hand, be restructured by improving agricultural practices on more fertile land and using alternative crops on poor and less fertile lands. More diversified land use can be achieved by introducing alternative but useful income-generating crops, such as sorghum or indigo, on marginal, salt-affected croplands or by afforesting such marginal lands (Lamers et al. 2008).

The use of trees within the irrigated land use systems, where secondary soil salinization is chiefly responsible for cropland degradation, can reduce the elevated groundwater tables through biodrainage.[9] Recent studies on selecting appropriate species showed that the annual stand transpiration averaged 1,250, 1,030, and 670 mm for *Elaeagnus angustifolia* L., *Popular euphratica*, and *Ulmus pumila* L., respectively (Khamzina et al. 2009). But despite the ample water use and vigorous juvenile growth, the groundwater drawdown effect was less than one meter over five years of forest growth. At present, therefore, this option has limited scope given that the lowered groundwater tables are refilled each year by underground inflow because of the overuse of irrigation water on croplands (Khamzina et al. 2009).

[9] Biodrainage uses the transpirative capacity of trees to control the recharge or enhance the discharge of the shallow groundwater.

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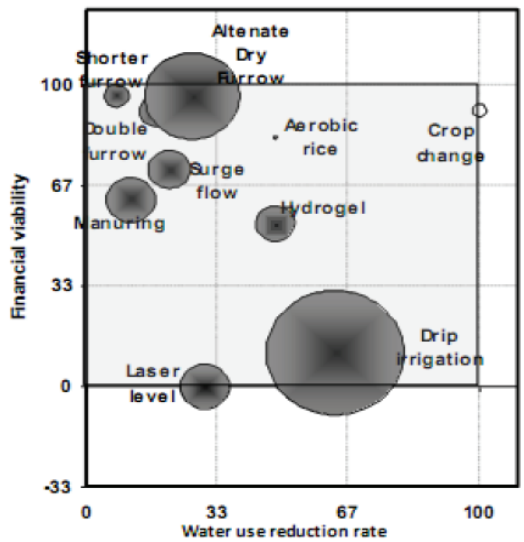
Figure 3: Water Use Reduction Rate (in percent), Economic Efficiency, and Financial Viability (in percent) of Water Conservation Techniques



Source: Bekchanov, Lamers, and Martius (2010).
Note: The size of the bubble corresponds to economic efficiency. Crop change is left blank since it gained negative gross margins.

Options for the selection of crops and products generated in the region could be based on their "water footprint," encouraging a shift from more water-intensive to less water-intensive products. Such a shift would affect total water demand in the region and subsequent water distribution and effects from water usage. This shift would, however, require a fundamental change in agricultural strategies and government policies, including giving farmers greater autonomy in, for example, deciding what crops to grow. It also would demand increased knowledge about the cultivation of alternative crops and the establishment of facilities for advisory services to farmers. It would require all of the auxiliary organizations needed for modern farming of alternative crops, such as laboratories, research stations, machinery sales points, food safety and phytosanitary controls, credit, and insurance schemes, which are at present mainly focused on supporting cotton and wheat producers. The agencies responsible for monitoring land and water use would need to be reinforced. Of the two organizations currently engaged in monitoring soil salinity, only one is directly involved in annual assessments. Empowering and legalizing WUAs may also be important in ensuring that water users gradually wean themselves off of the state-supported maintenance of the irrigation and drainage network and move to a user-based system.

There may also be a number of options that are not elaborated here but that have been successfully implemented within other irrigation networks worldwide.

Assignment

Your assignment is to present policy options for managing soil salinity in a more sustainable way. Focus on incentives and instruments to solve the artificial water shortage problem.

Additional Readings

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