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John P. A. Lamers / Asia Khamzina /
Inna Rudenko / Paul L. G. Vlek (eds.)

Restructuring land allocation, water use and agricultural value chains

Technologies, policies and practices for the lower Amudarya region

With numerous figures

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Foreword (Dr. Georg Schütte)

Central Asia is one of the largest irrigated zones worldwide. For centuries, irrigated agriculture has been the most important economic basis in the Khorezm Province in northwestern Uzbekistan. Unsustainable land management practices introduced during the soviet era combined with outdated and inefficient irrigation and drainage infrastructures inevitably led to wide-spread soil degradation and low-productivity systems. The overuse of water resources has been exacerbating the desiccation of the Aral Sea. For that reason the German engagement in the Aral Sea region in research and capacity development aimed to make an important contribution to economic and social development while simultaneously safeguarding water and land resources in the region.

Under the funding initiative "Integrated Water Resources Management (IWRM) – From Research to Implementation" of the German Federal Ministry of Education and Research (BMBF), new approaches and concepts have been developed and adapted to the different natural and socio-economic conditions in cooperation with emerging and developing countries. The strategic framework for this IWRM funding initiative was set in the BMBF funding programme entitled "Research for Sustainable Development – FONA", which includes the funding priority "Sustainable Water Management – NaWaM". With these measures, German research contributes innovatively to the design and implementation of solutions for better water resources management worldwide. Precondition for these research projects was the active participation and cooperation of industrial partners and stakeholders from Germany and the respective countries. Besides the development and testing of technological solutions to improve water use efficiency, all projects had to consider the enabling institutional and policy environment. An important aspect of all project's activities was local capacity development to strengthen participants and stakeholders to secure sustainable project continuation in the future. The Khorezm project in Uzbekistan was one of seventeen research projects that developed and implemented IWRM concepts.

The aforementioned key elements of IWRM guided the activities of the German-Uzbek project entitled "Economic and ecological restructuring of land and water use in the Khorezm region of Uzbekistan – A pilot project in development research". It has been led by the Center for Development Research (ZEF) on the German side, the State University of Urgench (UrDU) on the Uzbek side and UNESCO at the international level. Activities started in 2001 and project results were delivered to the local institutions until 2011. In the process, a sustainable structure of local institutions and the UNESCO has been established to take over the project after its lifetime and to disseminate project findings in and beyond the model region Khorezm. The results achieved within one decade of interdisciplinary research to improve land and water management in agriculture demonstrate the enormous efforts of the bilateral project team.

The project recommended a range of technical innovations to improve irrigation water use efficiency supported by economic tools and improved enabling institutional and policy environments. A number of these innovations are being adopted by farmers and found their way into national agricultural policies. Moreover, a modern GIS and soil laboratory at UrDU funded by BMBF supports the state-of-the-art research and education in natural and social sciences at UrDU for future generations. The partnership between ZEF, UrDU and UNESCO resulted in the establishment of a UNESCO Chair on Education for Sustainable Development at UrDU, which ensures the transfer of scientific methods and research findings from the project into teaching. More than 50 PhD students and more than 100 MSc students, most of them from Uzbekistan, have become experts and decision makers assuring a broad communication of research findings to regions with similar agro-ecological conditions.

For Germany, the improvement of the environment, particularly of water resources is of highest importance. That is why BMBF engages with local partners in research projects worldwide. Thus it contributes to the development of sustainable solutions in water management for a better future for all. In the geographically strategic region of Central Asia, Germany promotes security and stability, supports economic development and sustains water and land resources. This book aims to share the experiences gained in the Khorezm project with you and is testimony of the BMBF commitment to integrated water management.

In addition to scholarly and scientific insight, this book may also raise your interest in our BMBF research initiatives. I certainly hope that it triggers also new ideas for future research activities on all levels. Thus I wish you a pleasant time while reading this publication.

Dr. Georg Schütte, State Secretary
German Federal Ministry of Education and Research

Foreword (Ruzumbay Eshchanov)

Uzbekistan needs cooperation for research and higher education development.

Seven decades of integration in the Soviet Union have brought our country not only laureates. No doubt, the expansion of irrigated agriculture to produce cotton throughout much of Central Asia has been of paramount social and economic importance. Cotton revenues still account for a considerable share in foreign exchange revenues and national income, and employment and income security for rural families. However, the (ab)use of the natural resources for irrigated crop production has also had ecological and social consequences: the desiccation of the Aral Sea, land degradation and desertification arising from soil erosion, salinization, overgrazing of pastures, unsustainable agricultural practices, sand encroachment, seasonal drought, and more. The implementation of the ZEF/UNESCO project in the Khorezm region aiming at good governance of natural resources in general but especially of land and water management in the irrigated areas of the Aral Sea Basin came, therefore, just at the right time.

We knew some facts. Between 1950 and 1990, the irrigated cropland areas in Central Asia grew from 2 to ca. 8 million ha, and between 1950 and 2000 the population increased by about 300 %. Irrigated agriculture became the keystone for the welfare of the region and its rural population. Modern means of production replaced traditional crop rotations. Only later were we confronted with widespread land and ecological degradation of the irrigated dryland ecosystems. We were convinced that fertilizers, seeds, machinery, pesticides, water schemes, etc., were all that was needed. However, the consideration given to the environment and to our farmers did not match these efforts; a high price is being paid for this.

The texts of the Avesta, the sacred book of the Zoroastrians, teach us that one should be committed to a life based on good thoughts, good words and good deeds. In this context, the ZEF/UNESCO project was exemplary for us in various ways. It combined the best knowledge, experience and approaches from both worlds, the east and the west, together with local and international views. In light of our immense need for trained and educated people in sustainable development, the initiative by the German Federal Ministry of Education and Research (BMBF) and ZEF/Bonn boosted education in the region. The project served as an example of educational structures spreading their outputs for sustainable development throughout Uzbekistan. The reputation of our regional university, the number of internationally accepted publications, the number of international collaborations, all increased dramatically. The spread of innovations and insights benefited both the environment and the population of the region already during the lifetime of the project.

This unique partnership in higher education and research and science development resulted in extensive media coverage and parliamentary support. It also contributed to the development of options for the use of our natural resources and markets that will be sustainable for a long time, and be acceptable to farmers, decision makers, and those worrying about the environment. This book provides an overview of these important aspects.

Ruzumbay Eshchanov
Rector State University of Urgench,
Chairman Khorezm Mamun Academy

Section 1: Introduction

Paul L. G. Vlek, John P. A. Lamers, Asia Khamzina, Inna Rudenko, Christopher Martius, Bernhard Tischbein, Ruzumbay Eshchanov

Restructuring land allocation, water use and agricultural value chains. Technologies, policies and practices for the lower Amudarya region

Abstract

During the seven decades of the Soviet Union (SU), the irrigated farming areas in Central Asia became some of the largest in the world. Though highly lucrative due to the cultivation of cotton, the introduced agricultural practices ended up being the cause of severe environmental degradation. The loss of the natural resources base during the SU period could not be arrested despite post-independence reforms. The Khorezm region, covering part of the lower reaches of the Amudarya River, is a typical example of this phenomenon, with land users and managers struggling to find efficient and environmentally friendly options for sustainable management of land and water resources. These "sustainable intensification" options must, on the one hand, help reverse land degradation and, on the other hand, ensure sufficient production to meet increasing demands and secure livelihoods. In 2000, the Center for Development Research (ZEF) at the University of Bonn accepted the offer from the German Federal Ministry of Education and Research (BMBF) to develop and implement a research and education program to serve as an example of international cooperation in the field of higher education in Uzbekistan. The aim was to address the necessary restructuring of the economic and ecological management of this Aral Sea region. The development of governance and incentive structures as well as sustainable intensification measures that spare the natural resources base, yet provide for sustainable livelihoods, were the overarching goals pursued through an interdisciplinary program. This approach implied realigning the land and water resources in such a way as to render farming profitable, sustainable, and acceptable to the local land users and managers. Policy makers are facing tough decisions in forging this transition and accommodating the concerns of producers and environmentalists alike. This chapter summarizes the overarching findings of the last phase of this project, and concludes with the lessons learned over a decade of research and educational activities.

1.1 Introduction

The development of irrigated agriculture in Central Asia has contributed to the reign of the various khanates in this region, which today is known as the Aral Sea Basin (ASB). The ASB used to be a vital and vibrant part of the famous Great Silk Road that brought Chinese silk, bronze ware, cosmetics, paint, rice, and tea to the West, whilst glassware, dried fruits, vegetables, cotton, horses, and semi-precious stones were brought to the East (Tolstov 1948). But since the days of the Great Silk Road, the ASB has served as a crossroad not only for trade, but also for cultures, ideas and agricultural development with impressive achievements as exemplified by irrigation and drainage networks, which were created along with the establishment of the khanates such as Kokand, Khiva and Bukhara.

In the arid environment of the ASB, only irrigated agriculture is possible. During the SU era (ca. 1925 – 1991), but particularly since the 1960s, about 8 million ha of land, including natural forest and desert biomes, were put under irrigation in the ASB. This required an annual supply of 96 km^3 of irrigation water conveyed through 323,000 km of channels (Orlowsky et al. 2000). To date, the irrigation and drainage infrastructure established during the SU period is used for the cultivation of cotton, wheat, rice and some other crops (Bobojonov et al. 2012). However, the present management of irrigated cropland is becoming increasingly unsustainable, as evidenced by a widespread land degradation that threatens the ecological and economic sustainability of the agricultural sector and the livelihoods of the local population. In the Khorezm region of Uzbekistan, with an average annual rainfall of ca. 100 mm, unsustainable land and water management practices have caused widespread waterlogging and soil salinization and a consequent decline in agricultural productivity.

During 2000 – 2012, the Center for Development Research (ZEF) at Bonn University, Germany, in collaboration with the Science Sector of UNESCO, the Urgench State University (UrDU) in Khorezm, Uzbekistan, and the German Space Agency (DLR) with the University of Würzburg conducted a research and education project in the ASB, funded by the German Federal Ministry of Research and Education (BMBF). The study region Khorezm covers 6,800 km^2 located in northwestern Uzbekistan, approximately 250 km upstream of the present shores of the Aral Sea. Roughly 270,000 ha are under irrigated agriculture. The Khorezm region is an over-seeable unit of management owing to its well delineated borders, which facilitates the calculation of regional balances for water, salinity, produce and the economy. Of the 1.7 million people that live in Khorezm, about 70 % are rural dwellers. The project focused on Khorezm located in the lower Amudarya Basin rather than on the entire ASB, which comprises a string of similar oases. It is widely recognized that reducing or shutting down the irrigation water supplies to re-fill the Aral Sea would create immense human suffering, potential unrest and conflicts, and is therefore only theoretically an option. The only viable option is to render irrigated agriculture sustainable, thus making it possible for millions of farm families to make a living while having access to sufficient drinking water and healthy food. The project aimed, therefore, to define and test sustainable options for land and water use, develop ecologically and economically sound practices to increase the resource use efficiency, combat land degradation, mitigate greenhouse gas emissions, and increase rural incomes. The innovative concept and approach was based on four cornerstones: (i) development of science-based options for improving land and water use; (ii) building human and institutional capacity in the intervention area and creating an educational center of excellence; (iii) integrating research and education at national and international levels; and (iv) long-term commitment and policy outreach.

This book is the fourth contribution of the project's research findings focusing on options and policies for sustainable agricultural intensification in the lower Amudarya region. It is a companion to the documentation of the social and economic findings (mainly Phase I of the project) covered by Wehrheim et al. (2008), and to the overview by Martius et al. (2012) on cropping and irrigation management and land-use systems in the given biophysical, economic and anthropological context (covering Phase I and II). The third book by Ul-Hassan et al. (2011) offers a guide for researchers and practitioners for conducting participatory testing and adaptation of agricultural innovations (part of Phase III).

1.2 The ZEF/UNESCO project in Khorezm

In Phase III (2007–2011), the ZEF/UNESCO project aimed at providing comprehensive, science-based options for *restructuring land and water use and governance* at three nested levels: policies, institutions, and technologies. The project intended to provide decision support for effective agricultural policies at the regional and national levels.

Only few youngsters in Central Asia are attracted to an education in science (Mukhammadiev 2010). The growing lack of qualified people in the agricultural and environmental sectors motivated the project to help change this situation. This called for a long-term collaboration between local and international (German) institutions aiming at the education of a larger group of Uzbekistan/Khorezmian researchers. The demand for education was fulfilled by creating a unique and conducive learning atmosphere that prepared young, talented people to get embedded in the local and international science community. Linking national and international institutions for addressing the intractable problems of natural resources degradation in the Khorezm region was thus used as a means to lure young talents from the region and expose them to international scientific standards.

The education of a new generation of scientists was integrated into all levels of project activities. During the decade of collaboration, 53 Ph.D. candidates, of whom more than half came from Uzbekistan, participated. By the end of 2012, 33 students (14 females), of whom 15 came from Uzbekistan (7 females), completed their doctoral degree. The Ph.D. candidates, who conducted their core research under the supervision of local and foreign experts, in turn supervised a large number of M.Sc. and B.Sc. students. For example, 105 M.Sc. students, of whom 31 came from a wide range of countries[1], completed their higher education in this intercultural and international cooperation program. The alumni also represent a future network of international collaboration.

ZEF successfully conducted an inter-disciplinary research and education program that, with active participation of the students, pioneered a series of innovations for increasing the sustainability of land and water resource use. An international partnership in research and education was fostered with members of the Consultative Group on International Agricultural Research (CGIAR) for which the project became a co-recipient of "The King Baudouin Award" for Sustainable Agricultural Development in Central Asia and the Caucasus in 2008. In 2013, the project was awarded the national Energy Globe Award for Uzbekistan by the Energy Globe Award[2].

A suitable and necessary infrastructure was set up to support advanced research and education. The capacity building was not limited to individual people, but also involved institutions such as educational organizations by supporting the development and dissemination of training and teaching materials. Also senior local scholars were involved in collaborative research and joint scientific publications, and offered opportunities for further academic promotion. Special training courses previously uncommon in the higher education system included Geographic Information Systems (GIS) and remote sensing methodologies, advanced statistical analyses, and linear programming.

1 These included Germany, Finland, Italy, Czech Republic, The Netherlands, New Zealand, Vietnam, Hong Kong, Iran, Afghanistan, Brazil, and Columbia.

2 The goal of the Globe Energy Award is to present successful sustainable projects to a broad audience, guided by the conviction that many of the environmental problems already have good, feasible solutions. Projects which conserve and protect resources or that employ renewable energy can participate (see www.energyglobe.info).

1.3 Overview of this book

This book is grouped into five sections covering the main themes policies, institutions, and technologies, and a final summary section. The five sections cover production systems (part 2), natural resources management (part 3), production and resource economics (part 4), society, policy and institutions (part 5) and the conclusions and options for actions section (part 6). The summaries of the contributions to each of these sections are presented in the following.

1.3.1 Part 2: Production systems

The agricultural production systems during the SU era relied on large farms that were managed by well-trained agronomists who put a large number of laborers to work largely according to their individual skills. After independence, the inherited production units were supposed to have been broken up, but the government dithered until 2001, and then the land reform was poorly conceived and even worse in its implementation and management. The lack of farming skills among the many new small farmers threatened the cotton crop and food security and, according to **Djanibekov et al.** (**Chapter 2.1**), the Government of Uzbekistan (GoU) thus had to reverse various land reforms and upscale the individual farm size. The land fragmentation that started after independence was reversed in 2008. The authors concluded that farmers presently often do not know how to manage their newly gained land. The authors also argued that as long as the benefits of overall economic growth remain out of reach of the rural population, the optimization of farm sizes for improving production efficiency will be stifled.

After dismantling the collective farms in 1996 – 2002, irrigated crop production in Khorezm as in most of Uzbekistan, was mandated to two types of production units: rural households (*dehqons*) and private farmers (*fermers*). The *dehqons* account for the largest share in horticultural and animal husbandry production (i. e., dairy, eggs, etc.) whereas the *fermers* mainly fulfil the state-ordered production of cotton and wheat. **Conliffe (Chapter 2.2)** differentiates and analyzes irrigation-based agricultural livelihoods in rural Khorezm. She groups smallholder (*dehqon*) households around cropping, entrepreneurship, and migration as rural livelihood types. She argues that spatial location even within one relatively small agro-climatic zone such as the Khorezm region is an important but often overlooked factor influencing livelihood opportunities. She furthermore illustrates convincingly that livelihood strategies vary between upstream and downstream locations and are associated with the location along irrigation channels. Also, household cropping decisions are influenced by access to natural resources and by the availability of male labor, propensity to take risks, and access to niche markets. Upstream households are able to double-crop the staple crop wheat with the region's most lucrative and water-intensive crop, rice. In contrast, downstream households have to engage in seasonal migration because they are doubly hard-hit, i. e., by inferior agricultural potential due to a poorer access to natural resources such as water, and by their remoteness, which reduces market access. Spatial differentiation and stratification thus impacts the households' abilities to respond to shocks that adversely affect livelihoods. Although **Conliffe (Chapter 2.2)** cautions against the use of geography in a rigid manner, she underlines that when broadly interpreting the findings in a geographical context a better understanding emerges about the abilities of rural households to respond to political and environmental change.

Flooded rice production in the Khorezm region has been controversial: "income generation but water waste". For many outsiders, paddy rice production in an arid region suffering from regular irrigation water shortages is incomprehensible given the huge water demands. Despite the notoriously unreliable regional statistics about rice production, paddy rice seems to occupy annually ca. 10 % of the arable land but consumes up to 30 % of the total water resources (Bekchanov et al., 2012). But in some regards, this is putting a magnifying glass on a small part of the picture thereby ignoring the whole: paddy rice is the most remunerative crop in the entire crop portfolio of the Khorezm farming population (Bobojonov et al., 2012). Since rice cultivation can therefore hardly be reasoned away, **Devkota et al. (Chapter 2.3)** examined a series of innovations to meet present rice yields with water-saving approaches including water-saving irrigation methods combined with conservation agriculture practices. The latter reduced water demand but also yields, which is thus unlikely to be acceptable to rice producers. Additional approaches dealt with seeding/planting methods (transplanted versus wet-direct seeding), rice varieties (short- and middle-duration rather than long-duration varieties) and optimal seeding date taking into account the type of rice and climatic conditions. Some of these innovations are best recommended as stand-alone measures (e.g., rice transplanting), some in combination with others (e.g., short-duration varieties and transplanting date), some only when accompanied by additional changes in cultivation practices (e.g., yield reductions under conservation agricultural practices can be reduced when flood irrigation is applied till the grain-setting phase). But since all measures bear the potential to reduce irrigation water input for rice production, they merit further attention.

Improved water management options were also assessed through value chain analysis (VCA) combined with a water footprint analysis (WFA) for identifying options to improve water use efficiency **(Rudenko et al. (Chapter 2.4)).** This analysis was completed for different management levels and different sectors of the economy, with a special focus on the most prominent agro-industrial cotton sector. The approach considered simultaneously financial and ecological aspects of regional development, and thus accounted for the present socio-ecological challenges. The combined findings indicate two paths for reducing water use and coping with water scarcity with lowest possible detriment to the regional economy. One is to reduce agricultural water use (because agricultural production of raw cotton uses the most water along the cotton value chain) through upgrading irrigation and drainage networks, and to introduce innovations that have a high potential for increasing water use efficiency on the field. The other is to shift water use from the high water-demanding agricultural sector (such as raw cotton) to the less water consuming industrial sector, such as the cotton processing industry. The latter in particular suggests the production and subsequent export of cotton yarn, which would allow the reduction in water use but could maintain the same or even increase export revenues over those presently gained with raw cotton. This shift should, however, be made with care to keep the untreated waste water (grey water component) from the cotton processing (textile) industry at a minimum level.

1.3.2 Part 3: Natural resources management

Irrigation water use efficiency elsewhere is better than that in Uzbekistan, and this by large margins (WWF 2002). The low irrigation water use efficiency both at on-farm and perimeter level remains the prism through which outsiders view Uzbekistan's irrigated agriculture. In **Chapter 3.1, Tischbein et al.** present numerous options for improving this low efficiency by employing alternative irrigation practices. The focus is on technological improvements, which is the language most easily understood by the national administration in Uzbekistan. The authors show that with relatively simple technological improvement, the efficiency of water use can be drastically increased to the benefit of the farmers and society. They argue that the present low level of water use efficiency should be considered a floor rather than a ceiling, which thus leaves ample room for improvement.

In downstream and lowland regions, adequate management of shallow groundwater is essential in the irrigated agriculture context. The ancient khanate system had mastered the management of land and water resources with a variety of land use and water management systems to suit the lay of the land. They understood that the depth of the groundwater table affects not only crop growth but also soil salinity. The oasis was finely tuned to maximize the returns on the land with a minimum of salt damage (Rakhmatullaev et al., 2003; O'Hara 1997; Kats 1976). This traditional practice was largely ignored and then lost as the SU reformed and extended the irrigation systems in the region, which led to large-scale cropping, inefficient water use and, consequently, rising groundwater table and soil salinization of considerable portions of the land (O'Hara 1997). **Ibrakhimov et al.** (**Chapter 3.2**) concluded from an analysis of multi-locational monitoring of groundwater salinity over a period of 16 years that knowledge of the spatial variability of groundwater salinity, which can vary from 1.3 to 15 $g\,l^{-1}$ (average is not more than 1.75 $g\,l^{-1}$), can help identify the areas where conjunctive use of ground and surface water is an effective way of meeting crop water demand. Although this information is being collected by regional water managers, it is not made use of by farmers and irrigation channel managers to increase overall efficiency of irrigation water, as traditional systems of learning and knowledge sharing have disappeared. To this end, an advisory institution needs to be put in place that can serve the community in improving the use of its water resources.

Khorezm is fighting a continuous battle to avoid an environmental crisis caused by water insecurity and soil degradation. **Akramkhanov et al.** (**Chapter 3.3**) illustrate that the dominating practice of pre-season leaching for soil salinity removal is far less effective and efficient than might be expected when considering the high amounts of fresh water applied (400 – 500 mm). The present leaching rarely results in the intended salt removal but rather shifts the salts from upper (20 cm) to lower soil layers. Much higher efficiencies were obtained when using an accurate, high-resolution, pre-leaching map of soil salinity at field level and a consequent timely targeting of site-specific leaching. Even though the necessary infrastructure is not available yet for implementing this combination of measures, the modest costs per hectare should be a stimulus to farmers and governmental officials alike to improve leaching effectiveness and avoid further salt accumulation during the vegetation periods.

Even during the SU era, the importance of protecting natural resources was recognized. This led to such practical measures as the establishment of tree hedgerow systems to combat wind erosion and improve the microclimate of the protected fields. Yet the lack of funds after independence limited the regular monitoring and evaluation of such hedges resulting in a knowledge gap about the condition and functioning of these protective systems. To fill this gap, **Tupitsa et al.** (**Chapter 3.4**) developed a cost-effective methodology combining photogrammetry with GIS technology and field surveys to assess the state of hedgerows. The findings illustrate that the hedgerow structure in the study region Khorezm needs to be improved by better design and maintenance as well as by introducing specific harvesting techniques to support the windbreak structure and function. The developed method could be transferred to other regions with similar agro-ecology.

The traditional multi-storey cultivation of crops and trees in the Khorezm oasis has been abandoned over the past century. In fact, laws exist that limit the coverage of trees. However, it was proven by Khamzina et al. (2012) that highly salinized cropping sites characterized by low yields of common crops could be made productive through the re-introduction of trees and with minimal irrigation input, as the trees rapidly reached shallow groundwater. In **Chapter 3.5, Djumaeva et al.** provide evidence that afforestation of degraded croplands could benefit from localized additions of phosphorus, thus enhancing N_2 fixation rates and tree growth. Consequently, the nitrogen and carbon stocks of the agro-ecosystems can be increased. Afforesting saline, degraded croplands is thus an option for (a) rehabilitation of nutrient-poor soil and carbon sequestration; (b) provision of benefits to the land owners and households due to increased land value and aesthetics; and (c) generation of alternative income and livelihood security for the land users (farmers) engaged in forest harvesting activities. Uzbekistan, a signatory to the desertification convention, is however slow when it comes to implementing sustainable land-use measures. But by adopting afforestation as a rehabilitation measure and land-use option for degraded croplands, Uzbekistan could set an example for Central Asia, where many similar agro-ecological landscapes exist.

If measures are to be taken to ameliorate the areas of low productivity, decision makers need to know where such hot-spots or unproductive areas are located. To enhance awareness of the spatial distribution of marginal croplands, **Fritsch et al. (Chapter 3.6)** elaborated a methodology based on GIS and remote-sensing data for detecting degraded areas through a weighted, multi-criteria analysis. The resulting maps can be used as land-use planning tools and strategic priority setting. The approach developed thus supports land users and land-use planners alike by not only targeting afforestation activities (Khamzina et al, 2012; **Chapter 3.4, 3.5**), but also by implementing measures to improve the distribution of irrigation water (**Chapter 3.1**) and innovative practices to increase water use efficiencies (**Chapter 2.3**, **4.1, 4.3**). However, for a widespread use of this technology, investments in human capital are needed.

The potential of lakes, another underused natural resource in the water-scarce study region of Khorezm, was analyzed by **Ginatullina et al. (Chapter 3.7)** concerning its potential for aquaculture development. This could not only support families in their quest to meet nutritional needs but also could increase their economic viability. Therefore, as a first step in the exploration of this potential, the food supply by lakes and its availability to fishes was assessed. The findings show the presence of a large number of zooplankton taxa. Their density/biomass, diversity and composition were impacted by the salinity level of the lake water, but subject to temporal and spatial variability. The lake temperatures affected the seasonal cycles of zooplankton in abundance and community composition. The salinity level of the examined lakes periodically appeared to override temperature as the dominant factor when salinity became high. The authors concluded that, due to the unpredictable fluctuations in salinity and its potential influence on zooplankton biomass and seasonal declines in the zooplankton communities, fisheries in the lakes of the Khorezm region may be more likely to succeed when cultivating fishes that do not rely directly on zooplankton.

1.3.3 Part 4: Production and resource economics

Regional statistics on water supply are hardly suitable for reflecting water use and water use efficiency as they do not account for conveyance losses. This gap was filled by the analyses of **Bekchanov et al.** (**Chapter 4.1**). Although water use usually lags behind water supply, the evidence indicates that in years of water scarcity, water use efficiencies turned out to be higher. Since the present state-order strategy makes the GoU the main body accountable for the water management institutions, the authors argue that it has a major role to play in supporting farmers to shift to more water-wise technologies and ensuring that water management institutions become more accountable to farmers.

The need for introducing and applying efficient irrigation technologies, especially at the field level, has been clear from various studies included in this book (e.g., **Chapter 3.1, 3.3**). This finding is further confirmed by farmers' perceptions as well as by the rate of acceptance and adoption of irrigation technologies by the farming population. **Bhaduri and Djanibekov (Chapter 4.2)** investigated different institutional and economic factors that may induce farmers to adopt water efficient technologies in the irrigated agriculture of Uzbekistan. The authors analyzed several scenarios with respect to water price flexibility, cotton policy restrictions, land tenure security and stability of the water supply. Their findings underline that a more flexible mechanism of water pricing holds the potential for increasing adoption rates of efficient irrigation technologies by 20 % compared to the fixed water price levels presently applied and foreseen in future policy measures. On the other hand, variability in water supply, restriction in decision making with regard to cotton production and land use slow down technology adoption and are inversely proportional to the adoption rate of efficient irrigation technologies by farmers. These findings thus confirm earlier suggestions that water pricing in Uzbekistan can be a viable tool for increasing the efficiency of water use. However, the absence of strong institutional arrangements and insufficient farm capital remain a constraint to the implementation of such water-pricing instruments. Hence, water-pricing measures must match the agricultural policy set-up, infrastructural capacities and the capital availability of farming entrepreneurs.

Not only irrigation water use efficiency on field and network level has been assessed as low (**Chapter 3.1**). **Karimov and Zarazúa** (**Chapter 4.3**) see room also for output gains when increasing the overall technical efficiency of the current production technologies. However, options for implementation differed according to region, crop growing area, location and soil fertility. Based on surveys conducted before land consolidation in 2008 (Djanibekov et al. 2012, **Chapter 2.1**), the findings show that gaps between present and attainable yields do not stem from scale differences, although increasing farm size has been an important argument by the GoU for introducing land consolidation in 2008. Furthermore, as long as farm-level management does not improve, overall technical efficiencies are likely to remain low. This supports the conclusion by the authors that the on-going land consolidation must be accompanied by measures such as farmer education. Noteworthy is the great difference in technical efficiency on land with different fertility levels, which indicates that farms operating on nutrient-poor land are relatively more efficient in the use of resources should they need to use them. Furthermore, differences in technical efficiency between regions and between different locations within regions indicate that advice to farmers must become differentiated. Two decades of farming have created a diversity of farms that consequently have different advisory needs and conditions.

The findings of a number of studies (e.g., **Chapter 4.1, 4.2, 4.3**) are based on production functions that are rooted in bio-physical and economic relationships used to estimate water productivity. Yet production functions alone are insufficient to determine water productivity, as they do not account for the interplay between the endowment and contextual factors that influence a production function. Therefore, water productivity assessments must be complemented by water profitability estimates as argued by **Saravanan et al.** (**Chapter 4.4**), who defined this as the *net value of products per unit of consumed water.* This approach allows including and thereby understanding a farmer's choice of water management practices to maximize profit given the physical and bio-physical settings. The authors argue that water profitability could be estimated through the Bayesian Network analysis, which helps identify factors other than bio-physical and economic ones, since annual farm profit over a longer period is only a part of a farmer's business objective. While taking endowment and contextual factors into consideration, the authors concluded that agricultural water profitability cannot be explained by the optimization of a single objective, but rather by a trade-off by the farmers between multiple objectives. The combination of endowment, contextual and production factors thus determines the space within which a farmer operates.

Clement et al. (Chapter 4.5) analyzed the seasonal and inter-annual price movements to pinpoint the factors influencing price fluctuation. In transition countries like Uzbekistan that pursue food self-sufficiency policies (indicated by the proportion of food import to total consumption), the effects of local factors on price formation are expected to be dominant. Various studies have looked at food security concerns in Uzbekistan, but very few have addressed food price variability and its determinants at the local level, which is necessary to understand household welfare impacts. As the income of households to a large extent depends on agricultural production, and since the largest share of the budget is spent on food consumption (WFP, 2008; Musaev et al., 2010), the fluctuations in prices will have a considerable effect on the level of both production and consumption, and thus on the overall welfare of the population in the region. The authors used price behavior of ten agricultural commodities, collected weekly from local markets in the Khorezm region during 2002 – 2010. The results show two general patterns of agricultural price fluctuations: (i) price fluctuations of rice, meat and wheat are more sensitive to external factors such as their respective international prices, market exchange rate and oil prices; (ii) the price movements of apple, onion, potato, and tomato are more locally determined, and particularly affected by seasonal patterns where the minimum price occurs during the harvest season and the maximum during off-season. To reduce the fluctuation of food prices, the authors argue for the creation of storage and processing facilities. These have deteriorated following independence, and should be given more attention in national policies.

1.3.4 Part 5: Society, policy and institutions

After a decade of interdisciplinary research, it has become clear that the expansion of land and water use undertaken during the SU era has been fraught with miscalculations, bureaucracy and lack of commitment. Furthermore, the many layers of decision making combined with the institutional distance between the decision makers and the farming population have resulted in an inability to reply quickly to the farming reality. The present irrigation water distribution system and network in the Khorezm region still has the capacity to convey adequate water supplies, but it is not a sustainable system yet. Steps to eliminate the present inefficiencies of natural resource use are needed. Science and technology research has indicated various pathways that could be followed to increase the efficiencies of natural resources use, but their adoption needs to be facilitated by laws and institutions. These institutions should provide the farming population with incentives to implement water-wise technologies as is argued by **Bekchanov et al.** (**Chapter 5.1**). This would also benefit the state and thus create a win-win situation. Institutional measures such as guaranteeing timely water availability, introducing adequate water pricing measures, and creating an environment for capital investments were seen to be less promising in the short term, as they do not address the high conveyance losses, which require costly infrastructural improvements. Instead, various water-saving measures that increase water use efficiencies (e.g., crop diversification), and technical innovations (e.g., drip irrigation for selected crops such as vegetables) could be implemented by the farmers and reduce conveyance needs, thus benefiting regional income as a whole.

The overall findings illustrate that a region-wide implementation of innovations necessitates investments and institutional changes, which would be substantial, but so would be the consequent pay-offs. Based on this view, **Shtaltovna et al.** (**Chapter 5.2**) point out that, of the nationwide changes so far, the machine tractor parks are among the most prominent in reaching the agricultural goal of modernization. Such parks had been mandated following independence and agricultural reforms, but the remaining state controls actually prevent these from becoming financially independent service providers. According to the authors, loosening this tight grip would demand a substantial shift in the mind-set of administrators, but the potential gains could be enormous.

The overarching challenge in the study region is not a straightforward issue of water scarcity even though it is perceived as such by farmers and others (Oberkircher et al., 2012). As seductively simple as this might sound, it is not helpful when searching for solutions to overcome the water crises in the region. The generation of farmers that emerged after independence and land consolidation has been seen to lack experience as private farm entrepreneurs. The same farmers are also overwhelmed in the face of the recurrent economic water scarcity and soil salinity. In fact, the entire region is wrestling with the rising demands for water and a generally declining supply caused by humans and nature. The older (farming) generations of Uzbekistan grew up during a time when many, if not all, innovation choices were made by the state or by the working place. This situation has in many ways not changed in Uzbekistan. **Hornidge et al.** (**Chapter 5.3**) report on the experiences of a Follow-the-Innovation (FTI)-approach developed and implemented over three years with four FTI-teams. The key of these experiments was to illustrate the gains possible when introducing project-based water and land-use innovations. It was demonstrated that innovation must be more than merely creating an environment in which such innovations are perceived as benefitting the adopter. Participation and democratic principles form a pillar in the FTI approach, conditions that the post SU period have yet to create.

1.3.5 Part 6: Conclusions

The approach selected by the project for the development of sustainable agricultural intensification options in Uzbekistan has been innovative in various ways. For example, the establishment of an extended research and educational infrastructure in the region, including a well-equipped GIS laboratory with skilled staff, which serves as a centerpiece for offering services and products. The project benefited from the trans-disciplinary view and approach used. The combined use of GIS, mathematical modelling, new analytical methods, and household surveys offered a spectrum of different visions for progress, which is broader than what specialized projects usually can do. The time frame of 10 years was shown to be conducive for strategic capacity building. The early connection of the research findings and data collected through multiple disciplines permitted a timely and permanent cross-checking of information with the project objectives and an optimization of the applicability of any of the proposed solutions. Linking the integrated research findings with practice further enhanced their usefulness for the end users. There were many lessons learned, and many are yet to be learned. It is imperative that the work started in this project be taken up by regional authorities and international donors, as failure to do so may one day lead to a breakdown in the agricultural sector and instability in the region.

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Section 2: Production Systems

Nodir Djanibekov, Ihtiyor Bobojonov, Kristof Van Assche,
Inna Rudenko, Kudrat Nurmetov, John P. A. Lamers

2.1 Farm restructuring in Uzbekistan through fragmentation to consolidation

Abstract

The state-induced farm consolidation in 2008 for boosting agricultural production in Uzbekistan was examined with a focus on the presently experienced opportunities for rural development. Farm consolidation as a stand-alone measure under the current constraints, e.g., infrastructure and policy regulations, is an insufficient incentive for increasing farm efficiency. In fact, the process can be referred to as "farm consolidation" rather than as a comprehensive land consolidation process as observed elsewhere. It is argued that the consolidation process is likely to improve and advance rural development only when a number of supplementing policies are introduced to relax existing production constraints, such as reducing the extent of the state procurement system, ensuring land ownership, and increasing access to auxiliary farm services.

Keywords: farm consolidation, farm efficiency constraints, Khorezm region, Central Asia

2.1.1 Introduction

The transition from a centrally planned towards a market economy, which Uzbekistan pursued after gaining independence from the former Soviet Union in 1991, has proceeded by what is assessed by many as a "gradual" reform path (Bloch 2002). In a nutshell, this path can be characterized as maintaining economic and social stability in the short run whilst taking advantage of operating market forces in the long run. Although the reformation targeted many sectors of the Uzbek economy, in particular the agricultural sector was restructured (Djanibekov 2008), with the objective to maintain the provision of income, food, feed, fiber and fuel for most of the rural households as well as to support a range of industries beyond the agricultural sector. The various stepwise land reforms divided, e.g., the large, previously inefficient agricultural production units into a large number of smaller, privately operated farms (Khan 2007). In effect, however, the farm restructuring did not meet the expectations of increasing land and water productivity, but rather illustrated the unsuitability of the existing irrigation and drainage infrastructure for the new form of farms (Djanibekov et al. 2012c). As a result, in 2008, a reverse reform, i.e., farm optimization resulting in farm consolidation, was initiated. This study analyzes the most recent (2008–2009) process of farm restructuring in Uzbekistan, extending the analyses of the latest farm restructuring process by Djanibekov et al. (2012a) with particular emphasis on the consolidation process.

2.1.2 Process of farm restructuring in Uzbekistan

2.1.2.1 First three stages of farm restructuring

The process of farm restructuring in Uzbekistan has been the subject of previous studies (e.g. Lerman 2009; Djanibekov 2008; Veldwisch, Spoor 2008; Djanibekov et al. 2012a). Table 2.1.1 summarizes the four stages of the farm and land reform process since 1991 namely: (i) transformation of state farms into collective units, and later (ii) into agricultural shareholding cooperatives, (iii) partial and continued disaggregation of large farms into smaller individual (private) farms, and (iv) consolidation of small farms into larger ones.

The farm restructuring process initiated and guided by the state was gradual. At the onset, the state-owned large-scale farms (*sovkhozes*) were transformed into collective farms (*kolkhozes*). Following this, *kolkhozes* were transferred into agricultural producer cooperatives (*shirkats*)[1] distributing and sharing property rights over agricultural income and output (except for cotton and part of the wheat harvests) with its members. Concurrently, the Uzbek legislation for the first time defined private farming as an individual ownership of agricultural income, output, and inputs with the exception of water and land. Furthermore, the legislation defined three types of private farms based on their production specialization: (i) cotton and wheat farms (the largest and dominant farm type) that also produce rice and vegetables on a small share of their farmland, (ii) horticultural and gardening farms (specialized in fruits, grapes and vegetables production), and (iii) livestock-rearing and poultry farms. The latter two farm types are not part of the state procurement system (Djanibekov et al. 2012a).

1 Law “on Agricultural Co-operatives (*Shirkats*)” (1998).

In all stages of the farm restructuring process, cropland remained under state ownership, meaning that no legal private land ownership has been introduced. To run a farm enterprise, individuals lease land from the state at zero rent with long-term usufruct rights. This implies that farmers cannot use their leased land, for instance, as collateral for accessing credit.

Table 2.1.1: Important characteristics of the farm restructuring stages in Uzbekistan since 1991

	First stage 1991 – 1997	Second stage 1998 – 2002	Third stage 2003 – 2007	Fourth stage 2008 – 2009	2009-present
	Transformation	Partial disbandment of large-scale farms	Complete disbandment of large-scale farms	Farm consolidation	
Main trans-formation process	Transfor-mation of *sovkhozes* into *kolkhozes*	Transfor-mation of *kolkhozes* into *shirkats*. Partly land leased from *shirkats* to private farms	Complete transfor-mation of *shirkats* into private farms	Amalgama-tion of small farms into medium-sized farms	Amalgama-tion of medium-sized farms
Dominant farm types	*Kolkhozes*, *sovkhozes*	*Shirkats*, private farms	*Shirkats*, private farms	Private farms	Private farms
Land ownership	State ownership	State ownership and land lease			

Source: Updated from Djanibekov (2008)

The lease agreements also constrained market-driven changes in farm sizes. In the first stages of farm restructuring, private farms were established through the lease of the unproductive land of *shirkats*[2]. As the reform progressed, the pace of fragmentation of *shirkats* into smaller farms was accelerated. By the end of 2007, Khorezm experienced a dramatic shift towards the above-mentioned three types of private farms, which were allotted 87 % of all arable land (Djanibekov 2008). Concurrently, the agricultural equipment of the *shirkats* was transferred to machinery and tractor parks (MTPs)[3], whilst water distribution and canal management was (partially) transferred to water users associations (WUAs)[4]. The state continued to coordinate the distribution of other agricultural inputs,

2 Law "on Private Farm" (1998).

3 Decree of the Cabinet of Ministers of Uzbekistan "on Measures for Strengthening Operating Efficiency of Machinery and Tractor Parks" (1997).

4 Decrees of the Cabinet of Ministers of Uzbekistan "on Measures for Reorganization of Agricultural Co-operatives into Private Farms" (2002). From the end of 2009 onwards they were officially called Water Consumers Association.

and maintained the procurement system for cotton and wheat (Pomfret 2008). This meant that with the progress of farm restructuring, state-mandated production targets were fully transferred to private farms, and cotton and wheat production in 2007, for instance, was allotted to roughly 70 % of the farm land.

2.1.2.2 Fourth stage: "Consolidation" (end of 2008 until today)

The first steps of farm restructuring thus resulted in a vast number of small farms. Also, the idea of a farm as one production unit in the sense that parcels are located next to each other to form a single territory of a farm unit was not promoted. Instead, a private farm could consist of several scattered fields often far from each other. The parcels were 2–3 ha (from 5 to 20 ha in the case of cotton and wheat farms) of various soil qualities and shapes Djanibekov et al. 2012c).

To counterbalance the adverse effects of a large number of small-scale production units that were to operate within an infrastructural setup designed for a small number of large production units, WUAs were established for increasing irrigation performance. Yet the irrigation water supply to, for example, tail-end users in the irrigation system and administrative districts further away from the water source, was often delayed (Abdullaev, et al. 2008). The reconstruction of the existing irrigation system to suit the numerous small farms would have required large investments.

At the same time, the availability of a farm-serving infrastructure fell behind the demands of the large number of newly established farms (cf. Djanibekov et al. 2012c; Niyazmetov et al. 2012). As a consequence, and similar to the situation in central and eastern European countries (Pašakarnis, Maliene 2010), it became evident from the third stage of reforms onwards, that, due to the initial set-up of the infrastructure (roads, canal and drainage system) for the large-scale farms, the stability of agricultural production was endangered by the vast number of small farms with insecure access to key resources. In 2008, to cope with the problem of the unsuitable infrastructure, the state reversed the previous reforms. With the declared aim of the "optimization" of farm sizes, farm consolidation was rapidly implemented by merging small farms into large units (Fig. 2.1.1). At the end of 2008, the first phase of the consolidation process began[5] followed by a second phase[6] in 2009. The aim was to increase the economic

5 Decree of the President of Uzbekistan "on Special Committee for Elaboration of Recommendations for Optimization of Fields of Private Farms" (2008).
6 Decree of the President of Uzbekistan "on Measures for Further Optimization of Private Farms Fields" (2009).

efficiency of private farms by increasing farm size and in the process to reduce the problem of the widely scattered private farm fields. The driving force behind the consolidation of these fields into larger production units was to increase the profitability of agricultural production. Hence, lease contracts for small farms were revoked, and the lands were re-allotted and became part of larger production units, resulting in a greater concentration of production by fewer, but larger farms. Concurrently, the minimum size of cotton and wheat farms, as well as that of gardening and horticulture farms[7], was re-defined in the Uzbek legislation. The minimum size of cotton and wheat farms increased from 10 to 30 ha, and of horticultural and gardening farms from 1 to 5 ha. During the first phase of farm consolidation, the number of private farms in the Khorezm region reduced from 19,000 to around 10,000 by the end of 2008 and to 5,760 at the onset of 2010. The average farm area increased from 13 ha in 2007 to 24 ha in 2008 and more than 40 ha in 2010 (Fig. 2.1.1, left Y-axis).

Hence between 2005, i. e., the middle of the reforms when *shirkats* were to be abolished, and 2010, which represents the second phase of the consolidation process, the farm groups and land distribution among farm groups had changed significantly. Two farm sizes then dominated (Fig. 2.1.2). About 50 % of all farms in Khorezm in 2010 were less than 10 ha in size and leased about 5 % of all farmland, mainly specializing in gardening and horticulture. The second group (37 % of all farms occupying 87 % of all farmland in 2010) comprised farms larger than 50 ha. These were mainly cotton- and wheat-producing farms. The private farms with a size of 10 – 50 ha, prior to consolidation the main group, lately accounted for only 13 % of all farms and occupied the remaining 7 % of all farmland.

The consolidation process in Uzbekistan differed considerably from that in Western European (e. g., in The Netherlands known as "ruilverkaveling", in France as "remembrement", and in Germany as "Flurbereinigung") and in central and eastern European countries (van Dijk 2007). The consolidation process in Uzbekistan was implemented in the first place by rapidly optimizing farm size without addressing other infrastructural changes typical for the land consolidation processes elsewhere. Since the average size of farm fields before consolidation was about 2 – 3 ha, the consolidation of these fields into larger ones was not necessary. Hence, this process can be referred to as "farm consolidation" and not so much as the comprehensive land consolidation process as observed elsewhere.

7 Law "on Introduction of Changes and Additions to Legislative Acts of the Republic of Uzbekistan in Connection to Deepening of Economic Reforms in Agriculture and Water Sector"(2009).

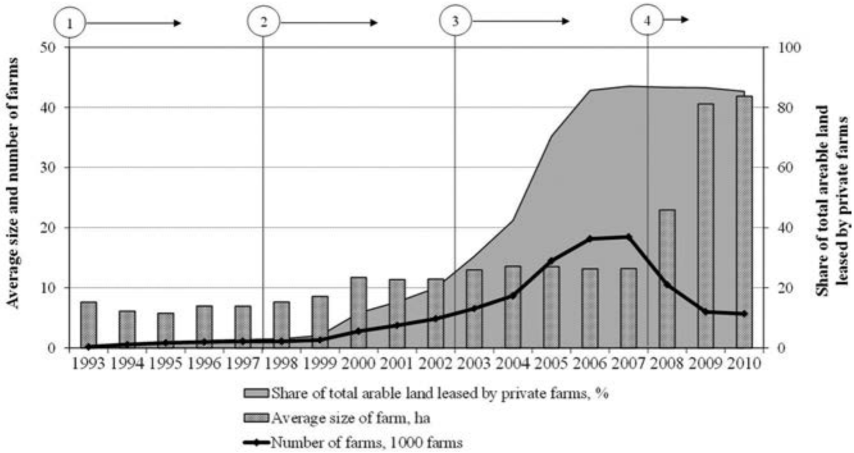

Figure 2.1.1: Evolution of size and number of private farms in Khorezm

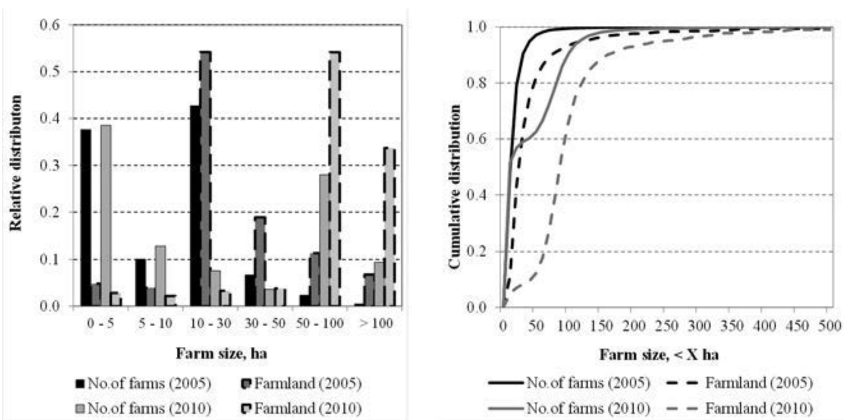

Figure 2.1.2: Relative (left) and cumulative (right) distribution of farms by size and number before and after farm consolidation in Khorezm

2.1.3 Farm sizes and productivity

The Uzbek legislation intended to provide equal access to land by rural households to prevent an increase in the number of rural, landless poor and to contribute to an increase in food and cotton production. As a result, since 2010 the agricultural production system in Uzbekistan has mainly consisted of a combination of large cotton and wheat farms. These have advantages regarding access to markets, infrastructure, and technology. The rural households, on the other hand, have the advantages in own-family labor and intensive production of vegetables, fruits and animal products (Djanibekov 2008). This combination of large farms and rural households can provide considerable benefits in terms of rural employment, income and food security and of the adoption of new agricultural technologies and maintenance of desired levels of cotton production.

Despite their important role in food security and poverty alleviation, rural households lack the ability to cope with an increasing variability of commodity prices and increasing input prices for which they do not have sufficient capital (Hazell et al. 2010). As a result, they may fall into what is called the "poor but efficient" trap (Fan,Chan-Kang 2010). In Uzbekistan, rural households heavily depend on earnings from employment in private farms in addition to the income from the non-agricultural sector (Veldwisch, Spoor 2008). In this respect, the economic performance of the private farms is essential in providing not only rural employment, but also in securing the rural sources of income and the food situation in rural households.

It recurrently has been argued that an increase in farm size may improve agricultural productivity (Deininger et al. 2004; Lerman, Cimpoies 2006; Lerman, Shagaida 2007; Eastwood et al. 2010; Fan, Chan-Kang 2010; Hazell et al. 2010). Although a generalization, this seems to have favored the recent farm optimization process in Uzbekistan. Yet there still is a recurring debate on the roles of small vs. large farms in fostering agricultural growth and economic development on which the empirical literature has failed to reach a consensus. The worldwide promotion of small, family-operated farms comes from their responsiveness to new markets and technologies and better development outcomes in terms of overall economic growth, employment generation, and poverty reduction. This places their productivity at the center of the development agenda (Fan, Chan-Kang 2010). Based on the experience worldwide it is recognized that small farms use their variable resources more efficiently and produce higher output per hectare compared to their larger counterparts (Hazell et al. 2010).

However, agriculture in Uzbekistan has a long history of collective farming based on intensive input use, employment of trained farm managers and engineers, and of operating within a specially designed infrastructure of irrigation canals and roads. Following several decades of collective farms, agricultural production in Uzbekistan became intensive in the use of machinery and chemical fertilizers. Moreover, the application of expensive inputs and machinery also caused the positive relationship between farm size and productivity. As a result, during the transition period and in the first years of private farm establishment, the economic efficiency of farms in Uzbekistan depended largely on access to more expensive inputs, and new sources of capital and extension services, which previously were subsidized by and provided through the central budget.