Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn

Economic and ecological restructuring of
land and water use in the region Khorezm in Uzbekistan

Recognition, visibility, and the beacons set for a handover: Highlights of a decade of interdisciplinary research and education in the Aral Sea Basin in Central Asia

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1 Introduction

Creating resilient and sustainable agricultural and ecosystems is urgently needed in Central Asia. To achieve this, an over-arching concept, coordination, cooperation and vision for this region is required. Uzbekistan, as the other four countries in Central Asia, is confronted with the degradation of natural resources that is not likely to be arrested in the near future. In this sense, the ZEF/UNESCO project "Economic and Ecological Restructuring of Land- and Water Use in the Region Khorezm (Uzbekistan)" addressed challenging issues such as: How can science, knowledge, and innovation reduce the loss of natural resources and resource use inefficiencies, benefit livelihoods and sustain environmental health?

Sustainable use and management of natural resources in Khorezm, a region in the lower part of the Aral Sea Basin in Central Asia, was the overall goal of a research and education project - with a focus on land and water. ZEF's concept was guided by the principle of efficiency and aimed at defining sustainable options for land and water use: namely ecologically and economically sound practices to increase resources use efficiencies, fight land degradation, mitigate greenhouse gas emissions, and increase rural incomes. The project was developed and implemented by ZEF in cooperation with the science sector of UNESCO, German Space Agency (DLR), the University of Würzburg, and the State University of Urgench (UrDU), Uzbekistan. Next, KRASS (The Khorezm Regional Advisory Support Service), a project-initiated local NGO composed out of project alumni and employees of UrDU) supported dissemination activities.

ZEF's research aimed at the sustainable use of natural resources in Khorezm. Photo: ZEF

The research, aiming at providing sound, science-based policy recommendations, was funded by the Federal Ministry of Research and Education (BMBF), with Bonn University contributing too. The project had an interdisciplinary setup: More than 100 international researchers from social, natural and economic sciences have worked together during one decade to come up with solutions for the region's multi-faceted problems. The project was carried out in three phases (Table 1). Phase I (2001-2003) focused on the establishment of central databases and infrastructure and analyzed bio-physical and socio-economic data gaps. In Phase II (2004-2006) field surveys and trials on alternative water and land use options as well as studies to increase the understanding about institutions and processes on land and water use were conducted. During Phase III (2007-2011) the project's researchers tested an integrated concept for restructuring land and water use on a landscape segment (75 ha) provided by the regional authorities.

The evaluation and adaptation of innovations with stakeholders (farmers, water managers, policy makers), a method developed by the project and called 'Follow-the-Innovation' (FTI), was a crucial component of Phase III.

It is common that activities of research and education projects end with the research findings being published, without bringing them to practitioners and policymakers. The researchers and management of this project intended to act in a different way. They started disseminating (selected) innovations and findings in the last Phase III with the aim of translating these innovations into action and introducing them to national agricultural policy-makers. The project findings and highlights will be summarized hereafter according to seven categories: (section 2) Building infrastructure and institutional capacities, (3) human capacity building, academic qualifications and international recognition, (4) publications, (5) decision support tools, (6) reproducibility of project findings for out-scaling, (7) efficiency and criteria and (8) a post-project perspective.

Table 1: Project phases

Phase	Duration	Main activity
I	2001-2003	Inventory of natural resources and its documentation in Uzbekistan. Creation of project infrastructure (establishment of laboratories, office facilities, purchase of lab and field equipment, cars, recruitment of staff and students) and establishment of data banks in Urgench. Induction of the 1st batch of Ph.D. students.
II	2004-2006	Field experiments with the aim to understand processes; development of model approaches to increase the understanding of complexity and causality. Induction of the 2nd batch of Ph.D. students
III	2007-2011	Field experiments as the basis of an integrated concept to test restructuring of land and water use on a landscape segment (75 ha). Evaluation and adaptation of innovations with relevant stakeholders (farmers, water managers, policy makers), through the Follow-the-Innovation (FTI) process. Dissemination of selected innovations. Determination and implementation of hand-over strategy. Induction of the 3rd and 4th batch of Ph.D. students.

2 Building infrastructure and institutional capacities

The people leading and running this project did not focus merely on outputs, but also on the inputs that helped to get these outputs. Therefore, they set up a local infrastructure to support advanced research and education in natural and social sciences. An old training and education building (Figure 1a), made available by the University of Urgench UrDU, was refurbished with funds of BMBF and ZEF into a modern working space of 680 m^2 with a traditional exterior design

Figures 1a and 1b: The office building before (1a, above) and after (1b, below) the refurbishment. Photo: ZEF

(Figure 1b). The project's building included five up-to-date laboratories, a library, 14 office rooms and teaching facilities for about 30 scientists. The building was inaugurated in June 2003.

The project's office building included a GIS (Geographical Information System) laboratory, which was installed by the DLR. It became fully operational in September 2003 and provided services for the entire project by giving state-of-the-art, technical support for carrying out GIS and remote sensing (RS) activities. The GIS-lab was equipped for processing data that had been either collected from study sites in Khorezm directly or that were supplied by collaborating Uzbek institutions in the form of maps and other data sources. In June 2003, a UNESCO-funded virtual laboratory was established at UrDU permitting a direct link between this university and research groups dealing with large, "terminal" lakes (e.g. the Aral Sea, Dead Sea, Lake Tchad).

The offices, laboratories, library, computers, field and lab equipment for field experiments, databases and maps created by the project were shared also with partners such as UrDU. Further support to UrDU included hardware (computers, printers, laboratory equipment), which helped to develop and disseminate training and teaching materials which also leveraged the investments in institutional capacity building. Courses on GIS and RS, experimental statistics, crop production and economic modeling were conduced regularly to all-level students. The entire database, hardware, training materials and the infrastructure were handed over in 2011 to the partners KRASS and UrDU. The partnership between ZEF, UrDU and UNESCO resulted also in establishing a UNESCO Chair at UrDU for improving the education of young researchers on sustainable development issues.

3 Human capacity building, academic qualifications and international recognition

While recognizing that the future of the Aral Sea Region depends on knowledge and skills, which in turn depend on the quality of education, training researchers from Khorezm and Uzbekistan became one of the project's key objectives. To enhance the motivation of Uzbekistan's youth to engage in agricultural education and research, the project facilitated the collaboration between local and international (mainly German) institutions. Due to the unique learning atmosphere created by the project, young, talented people were linked to national and international institutions in addressing the intractable problems of natural resources degradation in the Aral Sea Basin. This was one mean to lure young talents from the region and support their integration in the local and international science community.

Facts and figures

Human capacity building was integrated into all levels of project activities. It aimed at different academic levels and graduating both women and men. Thus, a young and upcoming generation in Uzbekistan was prepared for becoming future teachers and decision-makers. Since the onset in 2002, 54 Ph.D. students (table 2), about half of them from Uzbekistan, completed their field research whilst 35 graduated successfully, 17 of them from Uzbekistan (as of April 2013). Noteworthy is that from these 53 Ph.D. students, 18 arranged partly their own finance and funding, including stipends from the DAAD (2 students), the DAAD-Stipend program at ZEF (3 students), Robert Bosch-Foundation (1 student), the "Studienstiftung des Deutschen Volkes" (1 student), and the IPSWaT-Program of BMBF (2 students). Two Ph.D. graduates were funded completely by external sources while using the facilities of the project. Two post-docs were supported by the INTAS program from the EU. One Ph.D. graduate from Uzbekistan was awarded a junior professorship by the Robert-Bosch-Stiftung in 2009. Four scientists from Uzbekistan obtained support to complete their habilitation in Uzbekistan. Two of them completed their academic qualification by the end of the project whereas the other two will complete their studies in 2013/14. Efforts to include female students coming from the region in the research proved to be successful (table2).

Skills and scope

During field studies and surveys in Khorezm, the Ph.D. candidates conducted not only their core research under supervision of local and foreign experts, but also supervised local and international M.Sc. (about 105) and B.Sc. (about 90) students. This locally-built pool of graduates also warrants sustainability. Furthermore, since 31 of the 105 M.Sc. students came from a wide range of countries, such as Germany, Finland, Italy, Czech Republic, The Netherlands, New Zealand, Vietnam, Hongkong, Iran, Afghanistan, Brazil, and Columbia, and completed their higher education within the project, these alumni represent a future international network. About 65 students were awarded scholarships from the project to complete their M.Sc. studies in Uzbekistan. In addition, about 40 M.Sc. students, were supported with external funds, but used the infrastructure and data of the project (Table 2). Local Ph.D. and M.Sc. students attended intensive English and computer courses for upgrading their skills needed for a successful completion of their theses. Project staff conducted various training courses and trained teachers of the partner UrDU.

Table 2: Academic qualifications in the ZEF/UNESCO-Project (Status 01.06.2013)

Phase		Uzbek students		Non-Uzbek students		Total
		Female	Male	Female	Male	
Ph.D.	Completed	9	7	8	11	35
	On-going	7	6	3	3	19
M.Sc.	Completed	30	40	15	20	105
B.Sc.	Completed	66	21	2	1	90
Habilitation	Completed	0	2	0	0	2
	On-going.	0	2	0	0	2
Total		112	78	28	35	253

GIS and remote sensing

Human capacity building activities not only comprised educating academic but also training technical and supporting staff. For example, human capacity for database management and GIS/RS software was built up by DLR and the University of Würzburg to increase project students' integration and enable them to share their data within the project. Establishing networks of the project's GIS/RS group with a large number of Uzbek GIS, RS and mapping organizations allowed enhancing scientific and academic capacity by the exchange of data, methods and expert knowledge on the agro-ecosystems in the Khorezm region. The activation of the Meta Data Base (MDB) permitted the project's participants to get an overview of available data, thus increasing work efficiency and facilitating inter-disciplinary integration. A database with actual data to which the MDB referred (Central Data Base - CDB) to was developed in the course of 2004. Secondary data provided by collaborating Uzbek institutions were quality-checked before being entered into the CDB.

Awards and recognition

With members of the Consultative Group on International Agricultural Research (CGIAR) the project was a 2008 co-recipient of "The King Baudouin Award" for Sustainable Agricultural Development in Central Asia and the Caucasus (CAC Program). In 2013, the project was distinguished by the "Energy Globe Award". The goal of this Award is to present successful sustainable projects to a broad audience (see www.energyglobe.info).

4 Publications

A decade of research has generated a catalogue of information on science, knowledge, and innovations, from improving land and water use to social, market and institutional development of the Khorezm region. The research findings were communicated in the first place through numerous journal articles, book chapters, conference and symposia contributions, discussion papers and short communications (table 3). As far as copy right agreements allow, these manuscripts can be downloaded from the project Website (http://www.khorezm.zef.de), or at least full references accessed. The knowledge which is documented in different languages (English, Russian, Uzbek, German), has thus been made accessible to a broad as well as academic public, which ensures a future use in regions with similar agro-ecological conditions.

Each dissertation permitted the elaboration of on average 2-3 scientiific publications. By the end of the project, 668 papers had been published, of which 206 in scientific, double peer-reviewed, international and national journals and books. Others are still under review, in press or planned. It is valid to assume that the numbers in table 2 are still to increase because some journal articles have been published after completing the dissertation and some authors who left the project have sometimes forgotten to report back.

Highlights

One publication was recorded in 2012 in the top10-Download-List of SSRN (Social Science Research Network) under the theme 'Development Economics'. An updated overview of the overarching project results can be extracted from three "Project Books" (section 9). Since its online publication on September 2011, there has been a total of 722 chapter downloads of the book from Martius et al. (2012) available on the online Springer platform. Two more project books are in preparation. A documentary film of the project (in Russian, German or English) can be watched at http://www.youtube.com/watch?v=FPxD0b4Cxnw&feature=plcp

Total > 668 scientific works	
Articles in international double peer reviewed journals	86
Articles in local journals	70
Working and discussion papers	25
Contributions to international und local conferences	204
Completed habilitations	2
Completed Ph.D. dissertations	35
Completed M.Sc. theses	105
Chapters in books	52
Project books	7
Science Briefs - ZEF-UNESCO Rivojlanishlari – ZUR	25

5 Decision support tools

Findings of individual work packages have also been used for a wide range of modeling approaches on various levels (see table 4). The objectives of modeling included (i) to integrate findings of different project components, (e.g. yield models, alternative crops, water productivity, agricultural sector) and (ii) to up- and out-scale project findings with the support of satellite images and extrapolation approaches.

GIS tools and computer models

GIS and RS supported information was used to estimate and predict crop yields (cotton, wheat, rice, maize) with a high accuracy or analyse the land use dynamics of the last decades. With the use of high resolution satellite images land use data could be linked to water management strategies and water distribution models. Social and economic studies covered a wide spectrum of topics including analyses of agro-service organizations and of the agricultural sector. Pivotal for the project was the combined modeling of economic and ecological processes to understand their dynamics and allow, through simulations, the development of scenarios for optimizing land and water use (table 4).

Computer models such as FLEOM (Farm-Level Economic Ecological Optimization Model) consist of spatially distributed sub-units for resource utilization, natural constraints, economics and human driving forces. These helped to understand the dynamics of long-term sustainability of ecological and economic conditions of Khorezm and Uzbekistan and support land use planning at the levels of farms and Water Users Associations (WUAs). The researchers concluded that economic and ecological sustainability could be achieved simultaneously when, for instance, farmers are allowed to take more flexible decisions at the farm level. However, it is cautioned that environmental deterioration may continue until farmers gain more flexibility in their decision-making.

Economic simulations and scenarios

Economists in the project simulated various scenarios for assessing the ecological and economic consequences of potential changes in policies such as the state order (area and production-quota fixed by the state for cotton and winter wheat), the upgrading of crop value chains, the water footprints of alternative crops, changing water prices, and innovations to increase water use efficiencies. For instance, a gradual adjustment of the present cotton policy (e.g. from area-based to quantity-based) would facilitate crop diversification and thus bears the potential to increase rural incomes as well as attract farmers' interests to invest in land and water improvement practices and to unfold their experience and creativeness. Unless the existing state procurement system is changed, pricing of irrigation water is likely to remain infeasible and farmers' interest in water-wise technologies will likely remain limited.

Value chain and water footprint

Linking the value chain and water footprint approaches of dominant crops such as cotton and winter wheat helped to identify water saving options and opportunities for improving water management. Reductions in water use can be achieved by diversifying the economy and moving from water intensive agricultural production to less water consuming industrial sectors, introducing water saving irrigation technologies and raising awareness in the population about the real value of water. The combined findings of the economic based value chain analysis and ecologically oriented water footprint analysis enabled better informed decision-making to reach land, water and ecosystem sustainability in the study region.

Understanding institutional setting

An increased understanding of formal and informal institutional arrangements and thus variants of differentiation in an Uzbek society in transition facilitated the implementation of informed decisions, by embedding the project knowledge of improved water and land management in the context of local practices ('doing things'). Analyzing the gendered nature of rural relations in agricultural production processes and the system of agricultural service provision in post-Soviet Uzbekistan contributed to a better understanding of local social structures, actors and processes of decision-making. Various models are made suitable also as an education and research-oriented open-source platform for integrating the various databases and identifying the relevant key processes. The management and administration of the project's central GIS facilities in Urgench continues to provide the platform for this task.

Laser-Leveling in Uzbekistan. Photo:Zef

Cotton production remains crucial to the Uzbek economy. Photo: ZEF.

Table 4: Overview of developed and applied models

Name	Type	Spatial level/ functional entity	Own development	Web-access	Stand-alone-tool	Validation	Further development necessary
			Economy				
KhoRasm	Agricultural sector model	Region/Khorezm	Yes	No	Yes	Yes	-
KhoRisk	Water & Risk mana-gement	Regional/Khorezm	Yes	No	Yes	Yes	-
KhoWadi	Water distribution	Khorezm	No	No	Yes	No	-
UzGem	General equilibrium model	Nationwide (Uzbekistan)	Yes	No	Yes	No	-
VCA	Value Added Chain analy-ses	Crops	Yes	No	Yes	Yes	-
FLEOM	Farm optimization	Farm level	Linking of Models	No	No	Yes	Yes (dynamic, addi-tional crops)
			Agronomy				
CropSyst	Crop growth and develop-ment	Crops (cotton, wheat, maize)	No	No	Yes	Yes	Yes
APSIM	Crop growth and develop-ment	Crop (Rice)	No	No	Yes	Yes	Yes
LUE model (Monteith)	Remote sensing based crop growth and yield modeling	Crops (Cotton, rice), field-based and regional	No	No	Yes	Yes	Yes (inclusion of the spatial variabil-ity of meteorological parameters over the region)
			Hydrology				
HYDRUS	Water dynamics, water and mineral transport (and bal-ances) in the soil	Field	No	No	Yes	Yes	-
FEFLOW	Groundwater dynamics	Water User Association: hydro-logic boundaries and sub-units of a drainage and irrigation systems;	No	No	Yes	Yes	-
Steady- and non-steady state drainage models	Design alternatives for drainage systems	Field level up to the level of discharge units of major col-lectors	No	No	Yes		Yes (Restructuring of drainage systems)
AquaCrop (Crop-wat)	Irrigation management/-planning for full and deficit irrigation	Field level	No	No	Yes	Yes	-
AquaCrop – Hydrus	Irrigation management and planning with consider-ation of the capillary rise from shallow groundwater in the Khorezm region	Field level	Linking with existing models	No	No	Yes	-
Cropwat-Hy-drus-Feflow	Management of surface water (canal system) and ground water	Units with a hydrological border	Linking with existing models	No	No	Yes	Yes (additional ap-plication for years with a high/low water supply)
IWRM-Kulawat	Water distribution for larger units with a high temporal and spatial resolution	Regions fed by primary chan-nels	Yes (Partner: SIC ICWC; Uni Würzburg; ZEF)	No	Yes	Yes for spe-cific mod-ules	Yes (application for other primary chan-nels; very close to practice due to the backward linkages with water and chan-nel managers and users)
SEBAL	Surface Energy Balance Algorithm for Land (Evapo-transpiration)	Regional model, spatial resolu-tion 1 km	No	No	Yes	Yes	Yes (improvements for the soil heat flux module, inclusion of the spatial variabil-ity of meteorological parameters over the region)

6 Reproducibility for out-scaling of findings

The innovative concept and approach used in the project was based on four pillars: (i) Integrating science, research and education at national and international levels, (ii) building human and institutional resources in the intervention areas and creating a center of excellence, (iii) a long-term commitment, and (iv) a science-based idea for improving land and water use. The project's multi-faceted approach has given it an advantage over other actors. Yet, with respect to the reproducibility of innovations and the innovative approach various lessons learned can be shared:

Innovative concept

The implementation of this research and educational concept in the intervention region was innovative in itself: the establishment of an extended research and educational infrastructure, including a well-equipped GIS laboratory with skilled staff which can serve as a centerpiece for offering services and products. The use of GIS, mathematical modeling, new analytical methods, household surveys, and a transdisciplinary process of innovation testing and further development together with local stakeholders offered a spectrum of different insights that led to an increase in knowledge and innovations of scientific novelty as well as local use.

Time, transition, and transfer

The time frame of the project was conducive for strategic capacity building. The early connection of the variety of research findings and data collected through multiple disciplines permitted an early and permanent cross-checking of information with the project objectives and an optimization of the applicability. As the project in Uzbekistan was implemented at a time of socio-economic transformation processes, the capacities built – among them the project's alumni – immediately fed into the shaping of these processes of change. Furthermore, the project concept and lessons learned can be reproduced in other regions without much restrictions while the experience and expertise are available in Uzbekistan, Germany (at ZEF) and with international collaborating organizations (such as UNESCO).

Database services

The concept of project data integration for enabling interdisciplinary research as well as the inclusion of data management into capacity building can be transferred to similar projects irrespective of their nature. The main components of a successful implementation of GIS and database services comprise i) a simple and applicable service concept (standardized data management, GIS/ RS applications at different user levels and scales, monitoring workflows), ii) adequate equipment including hardware, software, field devices and the databases (MDB, CDB), iii) defined applications and products (access rights for databases, scientific models, maps, etc.), and iv) human capacity building. One elementary step is thus the adaptation of standards to actual local knowledge. Depending on the country to which this concept will be transferred, these steps could help to reduce complexity, and increase the use of simple and understandable algorithms, and integration of the educational partner institutes.

The office in Urgench supported the project and the researchers. Photo: ZEF.

Outreach in Uzbekistan

The efforts made in the preparation and dissemination of training materials and enhancing local capacities greatly benefited the dissemination of project findings to a wider audience. Within the framework of a GEF/UNDP funded project in Uzbekistan, which aims at mainstreaming global environmental priorities into national development planning and management processes, the consortium ZEF/KRASS/UrDU was invited by the Academy of State and Social Construction to conduct trainings. This elite academy, the "Presidential Academy", is a special teaching and educational institution for the future high-level regional and national cadre of the Government of Uzbekistan. The special training course on environment and ecology was based on project findings. The course materials and project findings created not only visibility among the future decision-makers, but KRASS was asked to conduct similar trainings for students and faculty staff in agriculture specialized faculties in Fergana Valley such as the Namangan Engineering-Economic Institute and the Andijan Agricultural Institute.

Follow-the-Innovation

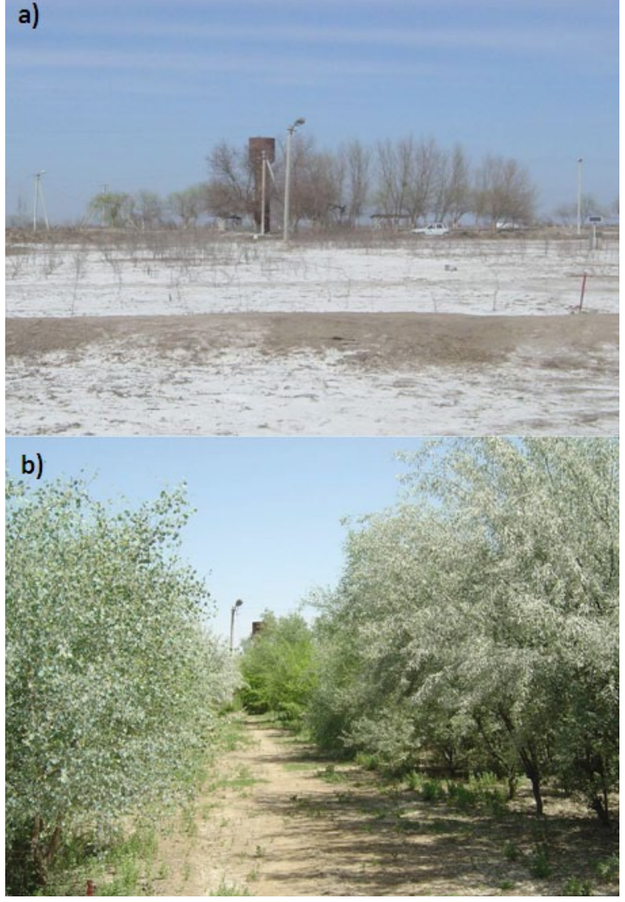
Various innovations, especially those that were subjected to the FTI-approach such as introducing laser-guided-land leveling, can be scaled out without much modifications. Important is that any out-scaling is guided by targeted training programs to improve the efficient use of this equipment. Other innovations and findings can be extrapolated to other regions with similar agro-ecological conditions, however with relevant modifications and preparations:

Afforestation

The afforestation research provided evidence of an ecosystem rehabilitation and potential financial benefits indicating that a conversion of the degraded cropland to a long-term use for forestry is a viable strategy that can be scaled out. The tree plantations can improve degraded soils through enhancing nitrogen and carbon stocks and provide fruit, fodder, timber and fuel wood (Pictures 2a and 2b). This option is applicable to regions beyond Khorezm, but with appropriate modifications such as for instance the choice of tree species.

Hydrological models

The comprehensive hydrological models and tools for irrigation water management developed (Table 4) can be applied for irrigation and drainage systems in other regions of Central Asia. But given that their development considered the shallow groundwater levels typical for Khorezm, these hydrological models consider also the interactions between surface water, soil and groundwater and are therefore comprehensive and mirror the complexity of the hydrological situation in the Khorezm region mainly. These specifications are not necessarily of importance in other regions.



PICTURE 2A AND 2B: ESTABLISHED TREE PLANTATION ON DEGRADED CROPLAND (RESPECTIVELY AFTER ONE AND THREE YEARS)
PHOTO: KHAMZINA ET AL. 2012

Water management

The water management tools developed comprise irrigation scheduling at field level, water distribution at the level of WUA, and water allocation at the Khorezm-wide level and enable the integrated use of surface and groundwater. These models are deterministic in structure and follow the hydrological process explicitly and consider the inter-relation between water stress and yield reduction. Methodologically, these models cover the situation of irrigation and drainage systems but when applying to other regions in Central Asia, the models need to be parameterized according to the given situation.

Follow-the-Innovation

The Follow the Innovation (FTI) approach for participatory testing and adaptation of agricultural innovations, developed by the project together with local stakeholders in 2012, was tested and developed further as part of a BMBF-funded and ZEF-implemented project in Tajikistan. It forms the methodological starting point for an innovation development component in a larger-scale BMBF-funded and ZEF-led research consortium in Ghana, Nigeria and Ethiopia.

Tools for tree plantation inventories

Both among the forest administration and the farming population a deficiency in knowledge and an inconsistency of inventory data on forests and tree plantations exist. Based on photogrammetry a key was developed for conducting tree plantation inventories as a suitable, easy-to-use, cheap, and quick but comprehensive methodology. This permitted the mapping of tree plantations and forests in the study region Khorezm and its assessment. This method could be extended to other low-land areas, but in case it is used in other areas, photographic indicators should be developed for tree species not included yet. The same is true in case of other parameters of interest.

Economic models

The economic models developed reflect the characteristics of the Khorezm region and country specific features such as state order, reduced land tenure, imposed land size etc. Whereas the theoretical background of these models will fit many regions in Central Asia, they will need adaptation to become of use for regions with frame conditions different from Uzbekistan.

Crop models

A parameterization is needed for the crop models developed with CROPSYST or APSIM (Table 4). An outscaling of these models therefore needs targeted preparations. With the support of the partner ICARDA, one version of CROPSYST was translated into the Uzbek language. This allowed a better access to this model to a research community till then deprived from such tools.

Integrated modeling

During a number of modeling studies different spatial scales (e.g. at field, farm, WUA, district and regional levels) were integrated (e.g., modeling crop development, alternative crops or water use efficiency) as well as used up-to-date satellite imagery to outscale the methods and outcomes to other regions. For instance, the remote sensing approach was used to accurately estimate regional cotton, wheat, and rice yields as well as accurately depicting changes in the agricultural system for a decade. New satellite imagery with high spatio-temporal resolution (RapidEye) covering entire Khorezm facilitated to accurately capture and forecast crop yields. Application of modeling techniques in water management based upon up-to-date land use maps derived from remotely sensed images indicated the potential of stabilizing agricultural yields for Khorezm under increasing water variability. These models, approaches and findings can be extrapolated to other regions although a groundtruthing of crops would be needed.

Several innovations were developed in the specific context of the study region Khorezm while taking into account specific frame conditions such as the state order, the varieties cropped for the determination of efficient N use but also others. These need to be fine-tuned to a new region if considered for out-scaling.

A MAJOR PART OF UZBEKISTAN'S AGRICULTURAL PRODUCTION IS STILL UNDER STATE ORDER.
PHOTO: ZEF

7 Efficiency and criteria

The research and educational goals have been in compliance with the UN Millennium Development Goals of eradicating poverty and hunger and achieving food and water security, but also with the United Nations conventions on desertification, land degradation and climate change as well as with the long-term strategic programs of the EU and Germany developed for Central Asia. Scientific research and technological development not only form a centerpiece for economic growth and development, but are also needed for responding to today's global challenges. The bilateral collaboration between Germany and Uzbekistan permitted the sharing of each other's (academic) strengths and resources and for preparing the ground for a joint transfer of scientific results into innovative applications.

Continuous support by BMBF

The project would not have existed if it were not for the persistent support from the BMBF. Their willingness to think long-term and agree in principle to support an ambitious and challenging program with a 10-year lifespan, is unique and highly appreciated in a development context. This support offered opportunities to engage in complex, inter and multi-disciplinary research. Time series analysis allowed for impact analysis as well as localized innovation development and uptake. Working across disciplinary boundaries comes with opportunity costs; yet to meet the complexity of reality also the approaches for developing alternative options or 'solutions' have to be inter and transdisciplinary in nature.

Some numbers

The efficiency of the project can be assessed by various indicators (Table 5). For instance, the accumulated mileage by the nine cars of the project during a decade of work equaled a distance of 55.5 times the earth's circumference (40,075 km), which illustrates the efficiency of the drivers and the care they took of the cars. With this, a total of 159 Ph.D. and M.Sc. students could collect the information that was made public through more than 668 different publications. When referring to the total project portfolio over 10 years, BMBF supported each student with on average 76,000 €. The average of 147,540 € per PhD student amounts to about 39,800 € per Ph.D. student and year. When taking into account that many more students and publications will follow even after the cessation of the project, these efficiency indicators would improve further.

Table 5: Relations of the different efficiency criteria

	Number	Unit	Amount per unit (€)
Total budget Jan 2002 - Dec 2011	7,967,209	10	Year 796,721
Students	159	Student	50,482
Ph.D.	54	Student	147,540
M.Sc.	105	Student	75,964
Publications	668	Publication	11,940
Contributions to books and confe rences	281	Publication	28,385
Articles	206	Publication	38,719
Final reports	199	Publication	40,081
Books	7	Books	1,139,458
Distance driven	2,226,910	Km	--
Contracts with third parties	57	Contract	139,933
Employees	762	People	10,467

8 A post-project perspective

Quantifying the efficiency of a project (table 5) remains a major indication of success. However, the sustainability of achievements can also be assessed by looking at the interest spurred and the attention received for ensuring the handover of results. By the end of Phase III, various beacons had been set for promoting project findings to practitioners, education and research institutes as well as policy makers. Therefore, governmental declarations, letters of intent from national institutions as well as invitations from national and international institutions and structures were arranged to collaborate with the project consortium and implement findings. Also a consortium was established through a Memorandum of Understanding between UNESCO, UrDU and KRASS for the period 2010-2020 to disseminate project findings in and beyond the Khorezm region. Recent experience shows that besides UrDU the NGO KRASS is capable of handling such challenges - although it still seeks support in organizational development and long-term planning, donor approach and networking. Dissemination activities that continued after the cessation of the project can be monitored on the Website of the NGO KRASS (www.krass.uz/news.html).

KRASS, a local NGO, will handle future challenges. Photo: Shtaltovna.

Summary of highlights:

- With the human and institutional capacity built at UrDU/KRASS and the creation of a **UNESCO chair for sustainable development at UrDU,** the way was paved for the introduction of innovative curricula on sustainable land and water management. The infrastructure established and handed over with a well-equipped GIS laboratory and skilled staff, can serve as a center for offering services and products.
- In 2010, the project partners submitted four selected innovations to the **Agrarian and Water Management Committee of the Lower House of the Legislative Chamber of Uzbekistan's Parliament (Oliy Majis),** including the use of EM-38 for rapid mapping of soil salinity, afforestation of marginal, salt-affected cropland in the irrigated areas for rehabilitation and enhancement of agro-ecosystem services, improved options for crop management and sustainable land use (including the laser-guided land leveling and the principles of conservation agriculture), and the introduction of dye-producing *Indigofera tinctoria* L. as a potential cash crop. In December 2010, the Ministry of Agriculture and Water Resources confirmed the scientific validity and endorsed the recommendations. The Government of Uzbekistan supported thus the spread of selected innovations.
- Key project research results and policy recommendations were shared with **international financial institutions** and development agencies active in Uzbekistan, including the World Bank (WB), German Technical Cooperation (GTZ – now GIZ), Swiss Agency for Development and Cooperation (SDC), Japan International Cooperation Agency (JICA), Korean International Cooperation Agency (KOICA), Organization for Security and Co-operation in Europe (OSCE), Israeli Agency for International Development Cooperation (Mashav), Europa House, United Nations Development Program (UNDP), United Nations Educational Scientific and Cultural Organization (UNESCO), and the International Center for Agricultural Research in Dry Areas (ICARDA).
- Since Phase III, ZEF and its partners have collaborated in joint proposal writing for various organisations such as Volkswagen Foundation, BMBF and others. Interna-

An Eddy covariance tower in Urgench
Photo: ZEF

tional institutions such as UNDP, UNESCO, GIZ (German Society for International Cooperation) in Uzbekistan have contracted the established **follow-up consortium for targeted mutual activities.** GIZ, UrDU, and KRASS agreed upon implementing a large scale afforestation project on ecologically based land use and conservation of biodiversity in Karakalpakstan and northern Turkmenistan. The project works on forest protection and afforestation in the lower reaches of the Amudarya and cooperates with an economic project on afforestation and the value chain of alternative energy.

- Since its establishment in November 2008, the **NGO KRASS** has conducted activities in the field of agricultural extension services, implementation of innovations and preparation of training materials for adults. KRASS has collaborated with local organizations such as the Farmers Association and the President's Academy but also with international organizations such as Cornell University, GIZ, ICARDA, UNDP, UNESCO, AIM and others. Substantiated by the governmental declaration as well as the invitations of national and international organizations for collaboration, the consortium has received official and clear commitments that the project findings are of interest to be shared. Also domestic organizations and institutions including the Oliy Majis have entrusted KRASS/UrDU with special tasks to disseminate selected findings.

The project's concept for integrating research and education for sustainable development has also been instrumental for the completion of:

- The **agreement between UrDU and the Returning Experts Programme of the "Centrum für internationale Migration und Entwicklung (CIM)"** concerning graduates from German educational institutions under the ZEF and Triesdorf programmes (BMZ/GTZ funded). This foresees a topping up of the local salary for teachers of UrDU returning from Germany. This should motivate them to remain at UrDU for the immediate future;
- The installation of a **UNESCO chair on education for sustainable development at UrDU.** This offers a platform for, advanced learning, implementing innovative curricula, modern technology and updated experiments;
- The funding by BMBF of a **modern GIS and soil laboratory at UrDU.** This is envisaged for state-of-the-art teaching, research and income generation.

Einstein once emphasized: *"Not everything that can be counted, counts; And not everything that counts, can be counted".*

Epilogue

During a field research stay in southern Tajikistan in 2012, one of the former ZEF/UNESCO project staff members was told by several small-scale farmers to go and visit one particular, very innovative and forward thinking farmer in a particular dry area of Sharituz District. Towards the end of the researcher's visit the innovative farmer mentioned a little tree plantation that he had started to reduce salinity in a particular part of his field. He explained:

"*In 2011 my son and I were invited to a* Ger*man project in Khorezm, Uzbekistan. They planted trees on saline soil. When I saw the trees in Khorezm on the salty land, I remembered our trees during USSR times. Our region is a very windy region. During USSR times we planted forests and a line of trees from here to the Afghan border. The forests protected us against the winds. But during and after the war, we had some very cold winters and people cut the trees. So now the wind is very strong again." He continued: "The trees that we planted will protect us, but they also help the soil to regenerate again. Because we have very saline soils so many trees will not grow. But these types will. And especially the Acacia will improve the soil again. Qayragoch [an Elm tree] grows very fast and is good for wind protection and later to use the wood as fire wood. The Acacia improves the soil and when they flower in May, the blossoms attract honey bees. […] The Russian Olive also assists the drainage. Fruits are very healthy, good to reduce blood pressure and can be used for the laundry. Poplar grows fast and if you cut it you can use the wood as building material or as fire wood. Poplar also grows better on the saline soil than Qayragoch. But actually Russian Olives are the best for reducing the salt in the soil."*

Step-by-step development processes take their time

Photo: Hornidge

This example of a farmer in Southern Tajikistan, who visited the ZEF/UNESCO project in Khorezm by chance, adopted some of the project's innovations and ideas, then adapted them according to his local situation and developed them further along the socio-economic and bio-physical needs of his and his colleagues farm enterprises, without ever reporting this back to the project of origin, stands for the diversity and multitude of the project's long-term and nearly untraceable local consequences. The ZEF/UNESCO project in Uzbekistan, while having ended in 2011, provided a fertile ground for many more seeds, trees, and creative ideas for a more sustainable water and land management to germinate.

Local farmer in Sharituz, Tajikistan.
Photo: Hornidge. ZEF.

9 For further reading

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