ADB TA 6357: Central Asian Countries Initiative for Land Management Multi-country Support Project

CACILM Multi-country Partnership Framework

Support Project on Sustainable Land Management Research

Sustainable Land Management Research Project 2007-2009

Final Report

Part I (DRAFT)

Regional Office of ICARDA for Central Asia and the Caucasus (CAC), Tashkent Uzbekistan

October 2009

Contributors

Kirsten Kienzler, Alisher Mirzabaev, Eddy de Pauw, Oksana Tsay , Tulkun Yuldashev, Dilafruz Tursunova, and Raj Gupta

International Center for Agricultural Research in the Dry Areas (ICARDA)

Abdulla Saparov (Kazakhstan), Malik Bekenov (Kyrgyzstan), Bobisho Kholov (Tajikistan), Muhammet Nepesov (Turkmenistan), and Rakhimjan Ikramov (Uzbekistan)

National Agricultural Research Systems in Central Asia

Rasulmat Khusanov (Uzbekistan)

Non-governmental Organization "Agribusiness and Entrepreneurship"

The photo on the front cover was taken at the final SLMR workshop in Tashkent, Uzbekistan, in August 2009.

To be cited as:

Kienzler, K., A. Saparov, M. Bekenov, B. Kholov, M. Nepesov, R. Ikramov, R. Khusanov, A. Mirzabaev, E. de Pauw, and R. Gupta 2009. Sustainable Land Management Research Project 2007-2009. Final Report – Part I. ICARDA Central Asia and Caucasus Program. Tashkent, Uzbekistan. 133p.

ICARDA Tashkent, P.O. Box 4564, Tashkent, 100000, Uzbekistan

Tashkent 2009

Abbreviations

ADB	Asian Development Bank
Asl	Above sea level
ARD	Agricultural Research for Development
ARP4	Fourth Assessment Report of the Intergovernmental Panel on Climate Change
ARI	Advanced Research Institute
AVRDC	The World Vegetable Center
CAC	Central Asia and the Caucasus
CACAARI	Central Asia and the Caucasus Association of Agricultural Research Institutions
CACILM	Central Asian Countries' Initiative for Land Management
CATCN-PGR	Central Asian and Trans-Caucasian Network for Plant Genetic Resources
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIESIN	Center for International Earth Science Information Network
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CIP	Centro Internacional de la Papa (International Potato Center)
CP	Challenge Program
CSO	Civil Society Organization
ctn	Centners (common agricultural unit; 10 centner = 1 t)
CWANA	Central and Western Asia and North Africa
DSR	Direct Seeding of Rice
EM	Electromagnetic
FAO	Food and Agriculture Organization of the United Nations
FESLM	Framework for Evaluating Sustainable Land Management
FTI	Faculty Training Institute
FDEM	Frequency Domain Electromagnetic
GEF	Global Environmental Facility
GHG	Greenhouse gas
GIS/RS	Geographic Information System and Remote Sensing
GFAR	Global Forum for Agricultural Research
GLP	Good Laboratory Practice
GNI	Gross National Income
GPR	Ground penetrating radar
HQ	headquarters
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
ICM	Integrated Crop Management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICRAF	The International Centre for Research in Agroforestry
IIWG	Intercessional Intergovernmental Working Group

IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
ICWC	Inter-State Commission for Water Coordination
IMPACT	International Model for Policy Analysis of Commodities and Trade
IPCC	Intergovernmental Panel for Climate Change
IPGRI	The International Plant Genetic Resources Institute
IPM	Integrated Pest Management
IPTRID	International Program for Technology and Research in Irrigation and Drainage
IRRI	International Rice Research Institute
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
KRII	Kyrgyz Research Institute for Irrigation
MAWMPIK	Ministry of Agriculture and Water Management and Processing Industry of Kyrgyzstan
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
Mha	Million hectares
MRWF	Medium Range Weather Forecast
MSEC	Multi-Country Secretariat
MTP	Medium Term Plan
NARS	National Agricultural Research System
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NIDFF	National Institute of Deserts, Flora and Fauna, Turkmenistan
NRM	Natural Resource Management
NSRDRI	Natural Resources and Sustainable Development Research Institute, Kazakhstan
NSEC	National Secretariat
PFU	Program Facilitation Unit
PMI	Policies, Markets and Institutions
PGRFA	Plant Genetic Resources for Food and Agriculture
PRIAA	Pri-Aral Research Institute of Agroecology and Agriculture, Kazakhstan
PSC	Program Steering Committee
PSR	Production System Research
RCT	Resource Conserving Technology
R&D	Research and Development
RI	Research Institute
RNA	Research Needs Assessment
RS	Reflectance Spectroscopy
SANIIRI	Central Asian Scientific Research Institute for Irrigation
SASRI	Soil and Agrochemistry Science Research Institute, Kazakhstan
SLM	Sustainable Land Management

SLM-IS	Sustainable Land Management-Information Systems
SLM-CB	Sustainable Land Management – Capacity Building
SLM-KM	Sustainable Land Management – Knowledge Management
SLM-R	Sustainable Land Management Research
SPAOPIF	Scientific Production Association of Ornamental Plant Industry and Forestry, Uzbekistan
SSSARI	State Soil Science and Agrochemistry Research Institute, Uzbekistan
SWEP	System-Wide Eco-regional Program
SWSRPCA	South-Western Scientific Research Production Center for Agriculture, Kazakhstan
TAC	Technical Advisory Committee
TDEM	Time Domain Electromagnetic
ToT	Transfer of Technology
TSSRI	Tajik Soil Science Research Institute
UCRI	Uzbek Cotton Research Institute
UNCCD	The United Nations Convention to Combat Desertification
UNCED	The United Nations Conference on Environment and Development
UNDP	United Nations Development Program
UNEP-GEF	United Nations Environment Program-Global Environment Facility
UNESCO	United Nations Educational Scientific and Cultural Organization
UNCCC	United Nations Framework Convention on Climate Change
URIAME	Uzbek Research Institute of Agricultural Mechanization and Electrification
URIKSBDE	Uzbek Research Institute of Karakul Sheep Breeding and Desert Ecology
USDA	United States Department of Agriculture
WUA	Water Users Association
WWF	World Wildlife Fund
ZEF	Zentrum für Entwicklungsforschung (Center for Development Research), University of Bonn, Germany

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1 Summary

Land degradation is particular acute and widespread in the Central Asian countries Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan, and is evidenced in rising groundwater tables, increasing land salinization, erosion and loss of soil fertility. This is particularly precarious in the context of global warming and climate change, which affects the Central Asian region above average along with more frequently occurring seasonal droughts. Research efforts in the frame of the Central Asian Countries' Initiative for Land Management (CACILM) have been made to develop sustainable land management options as strategic platform to combat land degradation, and increase the livelihoods of the poor farming population.

The Sustainable Land Management Research (SLMR) project, financially supported by the Global Environmental Facility (GEF), is part of the framework of the Central Asian Countries' Initiative for Land Management (CACILM), a 10-year program where all 5 Central Asian countries with the support of several international donors engage in combating land degradation and improve rural livelihoods in the region.

The SLMR project with its focus on research for development was commissioned in five Central Asian countries from July 2007 to August 2009 not only to promote sustainable land management research, but also to contribute to restoration, maintenance and enhancement of the productive functions of land to improved the economic and social well-being of the population while preserving the environmental functions of these areas.

Covering rainfed and irrigated agriculture, mountain areas and rangeland/pastures, 12 research sites were selected where sustainable land management options were tested in close collaboration with the national research institutions of the five Central Asian republics.

Laser-assisted land leveling, irrigation with plastic chutes and conjunctive use of drainage and irrigation water were tested and showed to increase water productivity by 15-25% in Kyrgyzstan, Turkmenistan and Uzbekistan. Raised-bed seeding improved seed germination rates, halved (wheat and rice) seeding rates, reduced water use by 10%, and allowed for diversifying the cropping geometry in Kazakhstan, Kyrgyzstan and Uzbekistan. Intercropping of cotton with legumes, maize with legumes, or sainfoin with barley proved highly profitable for farmers in Kyrgyzstan, Tajikistan and Uzbekistan. Also planting into standing stubble, or applying mulch were tested, and especially in the mountainous regions of Kyrgyzstan and Tajikistan, residues on sloped land and terraces successfully reduced erosion and increased soil moisture content in the topsoil. Rangeland productivity and fodder availability could be increased by planting suitable salt-tolerant fodder crops such as alfalfa, Sudan grass, triticale and sorghum, and licorice. Saxaul and other halophyte species were found to be highly suitable for diversifying the rangeland plant population and increase the pasture quality for the livestock herds. Different sources of income generation for the livestock farmers in the region could be encouraged. Using GIS-based similarity analyses environments similar to the SLMR project sites could be identified for potentially outscaling of the developed technologies.

The results have thus abundantly demonstrated that adoption of improved technologies of soil and water management could enhance productivity, resulting in higher rural incomes and household food security, and contribute to the conservation of natural resources and the sustainability of agricultural production in the region.

However, the adaptation of sustainable land management practices and modifying conventional crop production technologies has to be considered an innovation process by itself. This requires not only a shift in the local research paradigms but also demands the support of extension-type structures for awareness creation among the population and trainings for the successful implementation of improved land management practices with benefits for people and nature alike.

2 The Sustainable Land Management Research project

1. Land degradation is particular acute and widespread in the Central Asian countries Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan. Defined as 'a reduction or loss of the biological or economic productivity and complexity of rain-fed and irrigated croplands, rangelands, pastures, forest, and woodlands', land degradation in these countries is caused by a larger number of complex factors including low rainfall and droughts, extreme rainfall variability, and heat and cold stresses, climate change effects above global average. But also faulty land-use and water-use decisions, i.e. the strong focus of the Soviet system on maximizing production instead of production efficiency, had enormous negative implications on the ecosystem sustainability leading to water and wind erosion, loss of plant cover and soil organic matter, nutrient depletion, soil compaction, waterlogging and land salinization.

2. Furthermore, a wide range of unprecedented agricultural reforms in the Central Asian countries shortly after their independence from the USSR in 1991 has exposed rural smallholders to changes, which directly impacted on their livelihood. Although at different pace and intensity, in each of the five republics the 'collective farms' were transferred into smaller farm holdings. With the dissolution of the Soviet structure of the rural production system, these small farmers are facing increased input prices such as fertilizers, pesticides and machinery while this increase has not been compensated for by higher farm gate prices for the produced commodities. The change in the geo-political situation has moreover led to the disruption of former trade arrangements and economic linkages for production and distribution of farm products in the region. With the collapse of such arrangements, the Central Asian republics have been left with a major task of developing self-reliant agriculture for food security and improved livelihoods of their rural communities.

3. Inadequate cropping systems and unsustainable agricultural practices further constrain agricultural production. The large-scale and heavily mechanized production practices introduced during the Soviet era with its specialization on strategic crops such as cotton or wheat provoked a creeping reduction of soil fertility. Yields have become extremely unpredictable given the insecure input supply (e.g., shortages of pesticide supply) and increased probability of water scarcity during the vegetation season (e.g. for irrigation water), so that the conventional farming systems and land management practices alone cannot support larger households anymore.

4. To ensure long-term sustainable development and reduce land degradation and livelihood vulnerability, scientists and farmers have been turning their attention to more integrated land and water management systems. Developing sustainable land management (SLM) options in this region must take into stable and healthy food supply under changing environmental and socio-political conditions while protecting the multi-functional role of the ecosystems (see also Gupta et al. 2009). Improving the productivity of land and social well-

being of the population in Central Asia through sustainable land and water management is therefore an urgent task for the nations and calls upon the national and international research communities to act.

5. Under the umbrella of the Central Asian Countries' Initiative for Land Management (CACILM), a two-year multi-country research project commissioned in five Central Asian countries was initiated with financial support from the Global Environmental Facility (GEF). The so-called Sustainable Land Management Research (SLMR) Project with the International Center for Agricultural Research in the Dry Areas (ICARDA[1]) as the implementation agency focused on promoting sustainable land management research options through the research-for-development continuum, with qualitative and quantitative analyses of land, water and plant resources as an integral part of the project approach. By implementing research activities at 10 + 2 benchmark sites (two were added later), the SLMR project covered the four main agro-ecological zones, i.e. the rainfed, irrigated, mountain and rangeland areas and a range of Central Asian farming situations that include both medium and small farms. All research activities were conducted in close collaboration with the Central Asian National Agricultural Research Systems (NARS).

6. During the SLMR project phase, a large variety of the approaches and technologies were examined ranging from conservation agriculture under raised-bed planting practices with and without residue retention, using improved varieties and intercropping practices for rotation diversification, applying water-wise technologies leaching and irrigation practices to reduce drainage volumes, mountain erosion control measures and agro-forestry practices, strategies to increase the rangeland diversity and productivity, to GIS similarity analyses. Parallel, a socio-economic survey was conducted on all research sites, capturing the farmers' perception on land degradation and cropping-related issues.

7. The final SLMR project report summarizes the research activities and results of the time period January-October 2009. The report is split into three parts due to the length of the respective country reports, and the socio-economic literature review. The current document, *Part I*, thus comprises the research locations and people involved in the activities. Also, the results of the Greenseeker activities as well as of the socio-economic survey are presented. The final chapters of Part I summarize the achievements of the project according to the research topic. Part I closes by summarizing the potential and challenges the project faced and concludes with further research needs. The appendices of Part I contain the financial status and

[1] ICARDA collaborates with the National Agricultural Research Systems (NARS) of Central Asia since 1995. In September 1998, the regional office of for Central Asia and Caucasus (CAC) was established in Tashkent, Uzbekistan. ICARDA serves as a convening center for the Consultative Group of International Agricultural Service Program (CGIAR) on sustainable agricultural development in Central Asia and Caucasus. The program goal is to develop pathways to sustainable agriculture and land use in the region, to counterbalance the efforts of global change, and the food and fuel crisis. For further information please see also the website: www.icarda.org/cac

expenditure statement for the project period, the overall program schedules of the research activities as well as an overview about the trainings and workshops held. Detailed research reports of the respective country are provided in *Part II*. *Part III* contains the full socio-economic literature review on drivers of land degradation and their systemic interactions.

3 Research sites and research teams

8. The location of the SLMR research project sites are presented in Table 1 and Figure 1. The two research sites that were added later are not shown in Figure 1 but are located in the extended boundaries of the Tashkent city. For further details on the location and description of the sites, their characterization, similarity indices and the methods of the analyses have been described in the first annual SLMR report of 2008 as well as in the following scientific publications

De Pauw, E., F. Pertziger and L. Lebed. 2004. *Agroclimatic mapping as a tool for crop diversification in Central Asia and the Caucasus*. In J. Ryan, P. Vlek, and R. Paroda (Eds.). Agriculture in Central Asia: Research for Development. ICARDA, Aleppo, pp. 21-43.

De Pauw, E. 2007. *Principal Biomes of Central Asia*. In R. Lal, M. Suleimenov, B.A. Stewart, D.O. Hansen, P. Doraiswamy (Eds). Climate Change and Terrestrial Carbon Sequestration in Central Asia. pp.3-24. Taylor & Francis, ISBN 978-0-415-42235-2

9. All GIS-related data collected during the SLMR project were handed over to the SLM-IS unit of MSEC in Bishkek for further use. All maps that were prepared by the GIS unit of ICARDA have been put also on ICARDA's website:

http://geonet.icarda.cgiar.org/geonetwork/srv/en/main.home.

Table 1. Location of the SLMR research sites

COUNTRY	Site No.	Site name	LAT	LONG
Kazakhstan	25	Abylay	43.91667	69.83333
Kazakhstan	26	Kaptagay	44.33333	66.75000
Kyrgyzstan	27	Daniyar	42.90861	74.36306
Kyrgyzstan	28	Kenenbay	42.73556	74.50056
Tajikistan	29	Faizabad	38.58218	69.37572
Tajikistan	30	Vakhsh	37.85703	68.77853
Turkmenistan	31	Bugdaily	37.83878	58.75688
Uzbekistan	32	Sherzod Samandar Birligi ("Kushmanata")	40.36667	68.40000
Uzbekistan	33	Esanboi-ota ("Pakhtakor")	40.33333	67.96667
Uzbekistan	34	Kyzylkum ("Kyzlkesek")	41.04937	64.87753
Uzbekistan*	35	Akkavak (UCRI)	41.4222	69.491783

**This site was added later and therefore has not been included in the map and in the GIS analysis. It is located on the grounds of the Uzbek Cotton Research Institute (UCRI)*

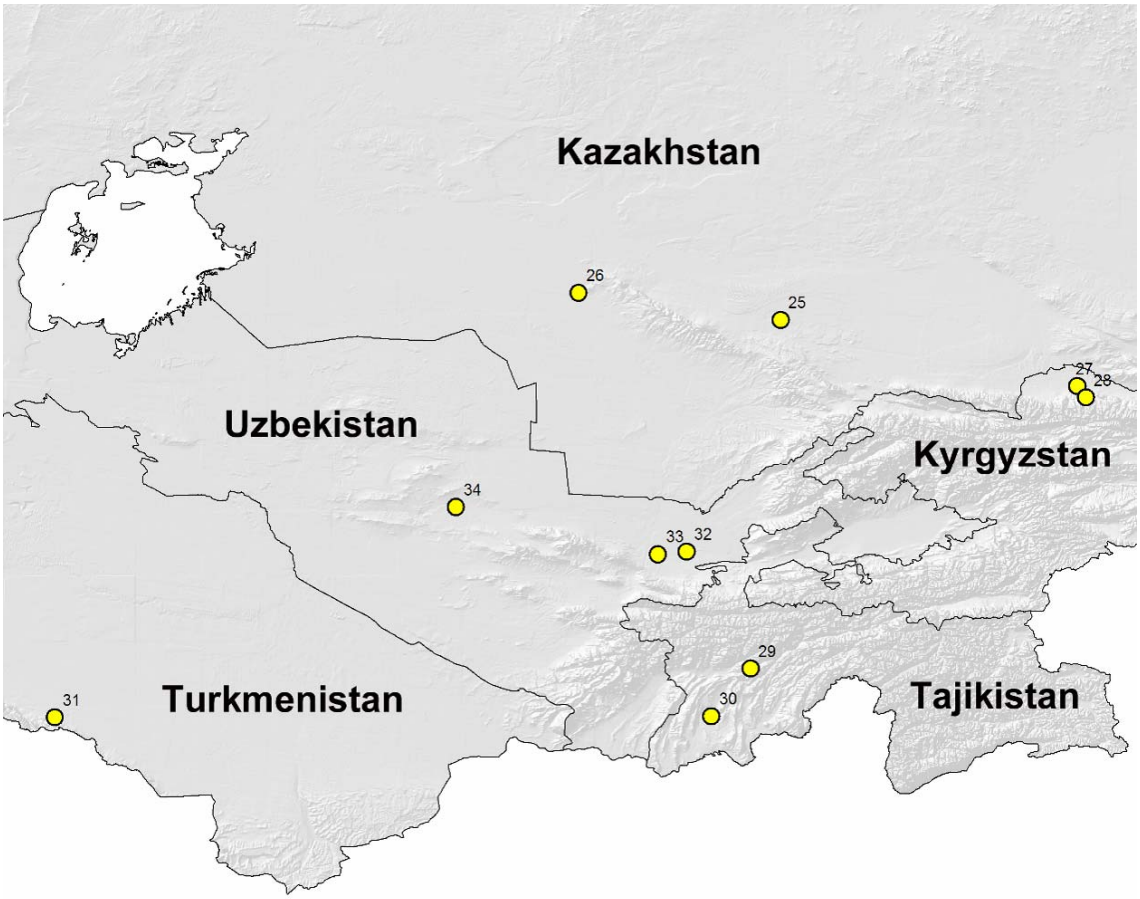

Figure 1. Location of the SLMR research sites

3.1 Kazakh research team

3.1.1 Benchmark site 25 and 26 (Abylay and Kaptagay)

National Coordinator, Soil Scientist, Soil and Agrochemistry Science Research Institute after U.U. Uspanov (SASRI) under the Ministry of Agriculture of the Republic of Kazakhstan	A. Saparov
Site Coordinator, Soil Scientist, Chief Research Officer, SASRI	A. Otarov
Responsible Investigator, Ecologist, Ex-Director of Priaral Research Institute of Agroecology and Agriculture (PRIAA) under authority of South-Western Scientific Research Production Center for Agriculture	T. Karlikhanov
Responsible Investigator, Soil Scientist, Head of Reclamation Division, Chief Research Officer, SASRI	M. Ibraeva
Responsible Investigator, Hydraulic Engineer, Head of Department, Natural Resources and Sustainable Development Research Institute (NRSDRI) under Kazakh National Agrarian University	A. Rau
Senior Scientist, Rice Breeder, PRIAA	K. Bakiruli
Senior Scientist, Agrochemist/Soil Scientist, PRIAA	X. Jamantikov
Senior Scientist, Soil Chemistry Scientist, PRIAA	M. Vilgelm
Senior Scientist, Hydraulic Engineer, NRSDRI	E. Kalibekova
Senior Scientist, Hydraulic Engineer, NRSDRI	R. Kablanov
Junior Research Assistant, Geographer, SASRI	A. Virakhmanova
Site Coordinator, Plant Specialist, Chief Research Officer, South-Western Scientific Research Production Center for Agriculture (SWSRPCA)	A. Seitkarimov
Head of Jambyl Department, SWSRPCA	A. Karinbaev
Senior Scientist, SWSRPCA	S. Kusherbaeva
Agricultural Economist, Deputy Governor of Sarysui district of Kazakhstan	S. Tokaev
Farmer of Abylay farm	K. Ayapova

3.2 Kyrgyz research team

3.2.1 Benchmark site 27 (Daniyar)

National Coordinator, Department of Agrarian Policy and Strategic Research, Ministry of Agriculture and Water Management and Processing Industry of Kyrgyzstan (MAWMPIK)	M. Bekenov
Site Coordinator, Agronomist, Kyrgyz Farming Research Institute	L. Martynova
Soil Scientist, Agronomist, MAWMPIK	G. Elemanova
Hydraulic Engineer – Irrigator, Head of the Laboratory, Kyrgyz Research Institute for Irrigation	P. Jooshev
Plant Protection Specialist, Plant Chemicalization, Quarantine and Protection Department, MAWMPIK	N. Mokshina
Senior Researcher, Biologist, Biotechnology Institute	B. Asanakunov

Farmer-Agronomist of the Daniyar farm	O. Mamaev

3.2.2 Benchmark site 28 (Kenenbay)

Site Coordinator, Irrigation Specialist, Kyrgyz Research Institute for Irrigation (KRII)	A. Atakhanov
Principal Scientist, Irrigation Specialist, KRII	A. Naloychenko
Senior Scientist, Agronomist, KRII	S. Pismenniy
Senior Scientist, Hydraulic Engineer, KRII	R. Madumarov
GIS Laboratory Specialist, KRII	N. Zemlyanskaya

3.3 Tajik research team

3.3.1 Benchmark site 29 (Faizabad) and 30 (Vakhsh)

National Coordinator, Tajik Soil Science Research Institute (TSSRI) under Tajik Academy of Science	B. Kholov
Site Coordinator, Head of the Soil Erosion Department, TSSRI	R. Kabilov
Site Coordinator, Plant Scientist, Vakhsh branch of NGO (Scientific Production Association) “Zemledelie”	T. Gulov
Site Coordinator, Plant Scientist, Director of Vakhsh branch of NGO “Zemledelie”	M. Abdullaev
Senior Scientist, Irrigation Specialist, Vakhsh branch of NGO “Zemledelie”	O. Rakhmonov
Senior Scientist, Plant Specialist, Vakhsh branch of NGO “Zemledelie”	A. Yorov
Land Management Scientist, Head of Laboratory, Institute “Tochikzaminsoz”	A. Khakimova
Chemical Industry Worker, Institute “Tochikzaminsoz”	T. Sladkova
Principal Scientist, Head of Soil Fertility Enhancement and Assessment Department, TSSRI	Sh. Karaev
Senior Scientist, Head of Soil and Plant Nutrients Department, TSSRI	N. Ibragimov
Senior Scientist, Department of Land Amelioration, TSSRI	S. Hodjaev
Research Officer, Soil Scientist, TSSRI	Sh. Kabilova
Post-Graduate Student, Soil Scientist, TSSRI	D. Jumaev

3.4 Turkmen research team

3.4.1 Benchmark site 31 (Bugdaily)

National Coordinator, National Institute of Deserts, Flora and Fauna (NIDFF), Ministry of Nature Protection of Turkmenistan	M. Nepesov

Senior Researcher, Agronomist, NIDFF	H. Charyev
Site Coordinator, Geographer/Soil Scientist, Farming Research Institute under the Ministry of Agriculture of Turkmenistan	K. Rejepbayev
Responsible Investigator, Mechanical Engineer, Turkmen Research Institute of Cereal Crops "Turkmengallaonumleri"	A. Annaev
Hydraulic Engineer, Turkmen State Institute for Designing of Water Management and Amelioration Systems "Turkmensuvylymtaslama" under the Ministry of Water Economy of Turkmenistan	O. Nazarmamedov
Responsible Investigator, Forestry Engineer, Kopetdag State Reserve of the Ministry of Nature Protection of Turkmenistan	A. Kuliyev
Forestry Engineer, Association "Grain Belt" of Turkmenistan	M. Akmuhammedov

3.5 Uzbek research team

3.5.1 Benchmark site 32: (Sherzod Samandar Birligi /"Pakhtakor"), 33 (Esanboi-ota /"Kushmanata"), and 34 (Kyzylkum)

National Coordinator, Head of Laboratory, Central Asian Research Institute of Irrigation (SANIIRI) under Ministry of Agriculture and Water Management of the Republic of Uzbekistan	R. Ikramov
Responsible Investigator, Irrigation Specialist, SANIIRI	L. Shezdyukova
Responsible Investigator, Irrigation Specialist, SANIIRI	Dj. Narziev
Senior Scientist, Irrigation Specialist, SANIIRI	G. Basteev
Researcher, Irrigation Specialist, SANIIRI	R. Rakhimov
MSc. Student, Socio-Economist, SANIIRI	F. Yusupova
Site Coordinator, Agronomist, Uzbek Cotton Research Institute (UCRI)	Kh. Maksadov
Responsible Investigator, Irrigation Specialist, UCRI	G. Bezborodov
Responsible Investigator, Agronomist, UCRI	F. Khasanova
Senior Scientists, Agronomists, UCRI	J. Shadmanov, I. Karabaev, B. Khalikov, M. Esanbekov
Site Coordinator, Livestock Specialist, Uzbek Research Institute of Karakul Sheep Breeding and Desert Ecology (URIKSBDE)	S. Yusupov
Responsible Investigator, Agronomist, URIKSBDE	A. Rabbimov
Senior Scientists, Agronomists, URIKSBDE	T. Mukimov, B. Bekchanov
MSc student, rangelands ecology department, URIKSBDE	F. Rabbimov
Farmer and guard, URIKSBDE	O. Khudjanov
Principal Scientist, Mechanization Specialist, Uzbek Research Institute of Agricultural Mechanization and Electrification (URIAME)	R. Baimetov
Senior Scientist, Mechanical Engineer, URIAME	A. Khadjimuratov
Principal Scientist, Soil Scientist, State Soil Science and Agrochemistry Research Institute (SSSARI)	A. Tursunov
Senior Scientists, Soil Scientists, SSSARI	D. Satarov, D. Latypov
Senior Scientist, Microbiologist, Institute of Microbiology	G. Djumaniyazova

Senior Scientist, Forestry Specialist, Scientific Production Association of Ornamental Plant Industry and Forestry (SPAOPIF)	Z. Novitskyi
Researcher, Forestry Specialist, SPAOPIF	M. Sabirov

3.5.2 Non-governmental organization "Agribusiness and Entrepreneurship"

Chairman of the LLC Agribusiness and Entrepreneurship, Academician in economic sciences	R. Khusanov
Specialist of the LLC Agribusiness and Entrepreneurship, Doctor of economic sciences	I. Kholmirzaev
Specialist of the LLC Agribusiness and Entrepreneurship, Doctor of economic sciences	A. Mukhtarov
Specialist of the LLC Agribusiness and Entrepreneurship, Doctor of economic sciences	M. Kosimov
Specialist of the LLC Agribusiness and Entrepreneurship	U. Khudoyberdiev
Technical computer assistance	Saburova

3.6 ICARDA research team

ICARDA Tashkent office, Project Coordinator (2009)	K. Kienzler
ICARDA Tashkent office, Project Coordinator (2007-2008)	R. Gupta
ICARDA Tashkent office, Head of the Regional Office	C. Martius
ICARDA Tashkent office, Project Assistant	D. Tursunova
ICARDA Tashkent office, Technical Assistant	T. Yuldashev
ICARDA Tashkent office, Economic Research Assistant	A. Mirzabaev
ICARDA Tashkent office, GIS Database Assistant	O. Tsay
ICARDA headquarters, Head of the Integrated Land and Water Management Program	T. Oweis
ICARDA headquarters, Head of GIS unit	E. De Pauw

4 Kazakhstan: Report on SLMR activities

The full report is presented in the Final Report - Part II.

5 Kyrgyzstan: Report on SLMR activities

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6 Tajikistan: Report on SLMR activities

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9 Common technical program: Activity 8. Developing new methodologies using the Greenseeker

9.1 Calibration and use of optical crop-canopy sensor (Greenseeker) for measuring crop development, comparing crop management practices and efficient nitrogen management

9.1.1 Introduction

10. The plants need sufficient nitrogen to grow and produce good quality food. Conventional nitrogen fertilization practices apply a single rate over areas of tens to hundreds of hectares before the crop is planted and during midseason in 3 splits. Recommended nitrogen rate in Uzbekistan for cereal crops ~180-220 kg ha^{-1}, while that in Egypt ~125-180 kg ha^{-1} and in the United States = 33 kg N ha^{-1} for every 1 ton of wheat –the amount of NO_3-N in the surface (0-15 cm) soil profile (Johnson et al. 1997). Farmers in Uzbekistan still apply nitrogen, but less than by 20-30% recommended by research institutions (FAO 2003) and nitrogen application is not field specific.

11. Only 33% of the total nitrogen applied for cereal production in the world is actually removed in the grain (Raun and Johnson 1999, Kienzler forthcoming), much less than that generally reported (Hardy and Havelka 1975). In 1999, the unaccounted 67% represented a $15.9 billion annual loss of N fertilizer (Raun and Johnson 1999). With the increasing costs of N fertilizer due to natural gas shortages, the unaccounted 67% is now estimated to be worth more than $20 billion USD annually (Raun et al. 2001), while 40-60% of nitrogen remain in the soil. Unaccounted nitrogen losses are 22-50% (Kienzler forthcoming, Bronson et al. 1991, Ibragimov 2007, Mahmood et al. 2001, Fritschi et al. 2004).

12. High fertilizer nitrogen use efficiency can be improved through field specific fertilizer nitrogen management using optical sensor (model: Greenseeker) which could be used to precisely measure the Normalized Difference Vegetative Indexes (NDVI) that takes care of both spatial and temporal variability in soil N supply.

13. The normalized difference vegetation index (NDVI) is an useful indicator indirectly obtaining information on crops such as photosynthetic efficiency (Aparicio et al., 2002), productivity potential, and potential yield (Peñuelas et al. 1994; Thenkabail et al. 2000; Ma et al., 2001 Raun et al. 2001; Báez-González et al. 2002). The agronomic vegetation index (NDVI) is also sensitive to leaf area index and green biomass (Peñuelas et al. 1994). Raun et al. (2001 and 2002) found a strong relationship between actual grain yield in winter wheat and the expected yield as determined from NDVI. The Greenseeker optical sensor has also been shown to be an important tool for efficient management of fertilizer nitrogen (N), analyzing spatial variability and factors limiting production (Govaerts et al. 2006, 2007).

14. Several researchers have suggested that grain yield can be estimated using spectral reflectance during different crop growth stages (Araus et al. 2001; Aparicio et al. 2002; Osborne et al., 2002; Babar et al. 2006). Using NDVI measurements during wheat growth, Raun et al. (2001, 2002) developed concepts of response indices to predict in-season yield potential of the crops. In turn these were used to develop a fertilizer N algorithm for assessing the fertilizer N requirements, which had a strong positive correlation with expected yields as well as with an achievable greenness of the leaves.

9.1.2 Objectives

15. The objectives of the present study were following:

- to calibrate the Greenseeker instrument using NDVI index and develop nitrogen calculator to determine nitrogen response on crop yield
- to estimate nitrogen requirements and predict crop yield on the base of nitrogen calculator even before the harvest of the crop.

9.1.3 Materials and Methods

9.1.3.1 Study site

16. During two wheat season (2007-2008 and 2008-2009) field experiments with application of different amount of nitrogen for the Greenseeker calibration have been conducted in experimental sites namely Almalybag, Daniyar, Faizabad/Horasan, Bugdaily and Akkavak located in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, respectively (Table 2, Table 3).

Table 2. Field plot activities for experimental sites where N calibration trials were established in 3 Central Asian countries (2007-2008)

	Kyrgyzstan	**Turkmenistan**	**Uzbekistan**
	Daniyar (rainfed)	Bugdaily (irrigated)	Akkavak (irrigated)
Coordinates	42°54.310′ N, 74°21.470′ E	37°48.982′ N, 58°42.459′ E	41°25.335′ N, 69°29.507′ E
Variety	Intensive	No data	Kroshka
Planting date	3-4.10.2007	8.11.2007	10.10.2007
Seeding rate kg ha^{-1}	200	No data	200
Mid-season fertilization dates	3-4.10.07 18.02.08	19.02.08 (incomplete data)	12.02.08; 24.03.08; 21.04.08;
Irrigation dates	No irrigation	19.02.08; 3.03.08; 01-02.04.08 (incomplete data)	11.10.07, 25.03.08, 22.04.08, 09.05.08, 12.05.08
Harvest date	5-6.07.08	No data	24-25.06.08

Table 3. Field plot activities for experimental sites where N calibration trials were established in 5 Central Asian countries (2008-2009)

Plot activity	Location							
	Kazakhstan	Kyrgyzstan	Tajikistan				Turkmenistan	Uzbekistan
	Almalybag (rainfed)	Daniyar (rainfed)	Faizabad (rainfed)	Faizabad (irrigated)	Horasan (rainfed)	Horasan (irrigated)	Bugdaily (irrigated)	Akkavak (irrigated)
Coordinates	43°13.790′ N, 76°42.070′ E	42°54.310′ N, 74°21.470′ E	38°35.017′ N, 69°22.753′ E	38°30.927′ N, 69°17.928′ E	38°04.022′ N, 68°42.008′ E	38°03.915′ N, 68°42.207′ E	37°48.982′ N, 58°42.459′ E	41°25.335′ N, 69°29.507′ E
Variety	Almaly	Intensive	Intensive		Navruz		Skifyanka	Moskvichka
Planting date	25.09.2008	28.10.2008	28.10.08	26.10.08	18.10.08	28.10.08	07.11.2008	24.09.2008
Seeding rate kg ha^{-1}	180	220	200	180	250	200	200	200
Mid-season fertilization dates (F1; F3 stages)	02.04.09 (F3 stage)	28.03.09	28.10.08; 30.03.09	26.10.08; 30.03.09	18.10.08 31.03.09	28.10.08; 31.03.09	02.02.08; 08.03.09	26.09.08; 11.02.09
Irrigation dates	No irrigation	No irrigation	No irrigation	No irrigation	No irrigation	No irrigation	08-09.11.08,05-06.12.08(incomplete data)	07.10.08, 9.10.08, 07.03.09, 4.06.09
Harvest date	20.08.09	28.06.09	28.06.09	14.07.09	02.07.09	25.06.09	14.06.09	06.07.09

17. During 2007-08 and 2008-09 wheat seasons, the treatments consisted of application of fertilizer N at 0, 50, 100, 150, 200 and 250 kg N ha^{-1} (irrigated zone) and at 0, 30, 60, 90, 120 and 150 kg N ha^{-1} (rainfed zone) applied in 2 equal split doses, one at planting and other at tillering stage (F3 stage) that occurs in early spring months (late February-late March).

18. Details of the experiments conducted in 2007-08 and 2008-09 such as planting date, seeding rate, fertilization, irrigation date, harvesting date and variety are given in Table 2 and Table 3. All field experiments were laid out in a completely randomized complete block design with three to four replications.

9.1.3.2 Treatments (Kazakhstan)

19. During the 2008-09 wheat season treatments (amount of nitrogen in kg N ha^{-1} of active component) were 0, 30, 60, 90, and 120 (N0, N30, N60, N90 and N120). The treatments were replicated thrice and no randomization was applied. Size of plots was 3 m x 3m.

9.1.3.3 Treatments (Kyrgyzstan)

20. Calibration of the Greenseeker has been done on treatments of nitrogen application from 0 to 150 kg ha^{-1} with 30 kg ha^{-1} N incremental step and from 0 to 90 kg ha^{-1} with 15 kg ha^{-1} N incremental step in 2007-2008 and 2008-2009, respectively. The treatments were replicated thrice. Observations were carried out over maize plantations in the Daniyar farmer holding in late April-early September 2008. Experiment has been laid out in accordance with six treatments of nitrogen application from 0 to 150 kg ha^{-1} with 30 kg N ha^{-1} incremental step and three replications. Nitrogen was applied in June 2008 at 4-6 leaves formation stage. Measurements with the sensor have been carried out after every 15 days. Area of each treatment was 15 m^2 (5 m× 3.0 m).

9.1.3.4 Treatments (Tajikistan)

21. During the 2008-09 wheat season treatments (amount of nitrogen in kg N ha^{-1} of active component) were 0, 30, 60, 90, 120, 150 (rainfed zone) and 0, 50, 100, 150, 200, 250 (irrigated zone). Size of the plots was 3.6 m × 7.0 m with 4 replications.

9.1.3.5 Treatments (Turkmenistan)

22. During the 2007-2008 and 2008-09 wheat seasons treatments (amount of nitrogen in kg N ha^{-1} of active component) were 0, 50, 100, 150, 200, 250 (irrigated zone). Size of the plots was 3.6 m x 7.0 m with 4 replications.

9.1.3.6 Treatments (Uzbekistan)

23. During the 2007-2008 and 2008-09 wheat seasons treatments (amount of nitrogen in kg N ha^{-1} of active component) were 0, 50, 100, 150, 200, 250 (irrigated zone). Size of the plots was 3.6 m x 7.0 m with 4 replications.

9.1.3.7 Commonly accepted methodology to calibrate Greenseeker

1. Lay out of the experiment. Apply fertilizer amount of N in graded doses on different dates.
2. Take NDVI observations at different dates after emergence (DAE). Note the emergence date correctly or else use date of planting/ sowing date.
3. Count the vegetation period from the emergence date or planting date, taking into account only the vegetation period with the growing degree days (GDD) > 0 .This implies that during the winter season days with GDD values <0 will not be counted.
4. Take NDVI observations at different dates after emergence (DAE). Note the emergence date correctly or else use date of planting/ sowing date.
5. Exclude the non-vegetation period (snow period) when GDD<0 or count the period as vegetation period when GDD>0 as per equation below:

   $GDD = (T_{min} + T_{max})/2 - 4.4 > 0$ [9.1]

   Where, Tmin, Tmax are minimum and maximum air temperature expressed in ^{o}C.

6. In-season estimated yield (INSEY) was calculated by dividing the NDVI data by the number of days from emergence date to sensing.

   $INSEY = NDVI_{i=0;n;\ D=0,n} / DAE$ [9.2]

   Where: DAE refers to days after emergence (DAE).

7. Collect crop yield data from all the N level plots and treatment replications
8. Plot all the INSEY at different dates against averaged crop yield data for different N levels on a graph describing yield as function of INSEY
9. Establish equation describing Yield as function of the INSEY
10. Calculation of response index (RI) of NDVI (RI_{NDVI}) and of yield to N fertilizer doses (RI yield) using following equations:

$$RI_{NDVI\ N=50;\ 100;\ 150;\ 200;\ 250} = (NDVI_{N=50;\ 100;150;200;250;\ F4(F6)\ stage}/NDVI_{N=0;\ at\ F4(F6)\ stage}) \quad [9.3]$$

$$RI\ yield = (Yield_{N=50;\ 100;150;200;250} / Yield_{N=0}) \quad [9.4]$$

11. Establish equation describing RI yield as function of the RI_{NDVI}

9.1.3.8 Commonly accepted methodology to validate Greenseeker, i.e. prediction of crop yields and nitrogen requirements on the base of NDVI data

1. Sense the N Rich Strip (NRS) or plot where N is maximum and there is no N deficiency
2. Sense a strip parallel to the NRS (farmer practice or FP)

3. Determine how many days from planting to sensing (days, GDD>0)
4. Compute INSEY (NDVI/days from planting to sensing where GDD>0)
5. Predict potential yield (YP_0) with no added fertilizer N based on growing conditions up to the time of sensing, that can be achieved with no additional (topdress) N fertilization (units: Mg ha^{-1}). For this purpose equation for grain yield and in season estimates of grain yield (INSEY) - - YP0 =a*$(INSEY)^b$ or exponential function equation should be developed in calibration stage:

   YP_0= Function (INSEY) [9.5]

6. Determine response index NDVI (RINDVI)

   $RI_{NDVI} = NDVI_{NRS}/NDVI_{FP}$ [9.6]

   Where: RI NDVI = NDVI from plots receiving adequate but not excessive pre-plant N, divided by NDVI from plots where no pre-plant N was applied.

7. Determine response index yield (RI yield) as function of RI_{NDVI}

   RI yield = f (RI_{NDVI}) [9.7]

8. Predict potential grain yield with added N using following equation:

   $YP_N = (YP_0 \times$ RI yield) [9.8]

   Where: YPN = Predicted or potential yield that can be achieved with additional (topdress) N fertilization based on the in-season response index

9. Generating a fertilizer N rate recommendation
   a. Computing grain N Uptake at YP_0 and YP_N
   b. Computing nitrogen requirements

24. The predicted amount of N that will be removed in the grain at harvest is computed as follows:

N_{req}= (Grain N_f uptake × YP_N - Grain N_f uptake ×YP_0)/NUE [9.9]

Where: Grain Nf uptake= 0.0239 represents (0.0239 kg N uptake / kg grain or 2.39% N in the grain for winter wheat grown in Oklahoma. We used Grain Nf uptake =0.0211% for Central Asian conditions (Kienzler forthcoming);

25. NUE = Nitrogen use efficiency should be taken from literature or from equation developed during calibration stage:

NUE =f (Grain N_f uptake × YP_N – Grain N_f uptake ×YP_0)/N actual [9.10]

Where N actual =actual applied nitrogen rates (N0, N50, N100,…N250 kg ha^{-1})

26. In this study we estimated NUE using equation [1.10]. Generally, its values range from 0.15 up to 0.50.

27. In order to validate the N responses, N-rich strips and farmer practice strips have been established on 4 farmers fields at the Uzbek Cotton Growing Research Institute sites in Tashkent province, 2 farmers fields located in the Esanboy ota farm and Sherzod Samandar Birligi farm in the Jizzakh and Syrdarya provinces in Uzbekistan and 3 farmer fields in Daniyar farm in Kyrgyzstan. Area of N-rich strip was 25 m^2. These farmers were allowed to practice their traditional N management practice in winter wheat as usual. NDVI measurements were taken at F5-F6 stage of wheat in N-rich strip and conventionally N fertilized plots. Using the N calculator developed at experimental site, the farmers were advised to apply N to meet in-season crop demands for nitrogen.

9.1.4 Results and discussions

9.1.4.1 Data availability from 5 CAC countries to calibrate and validate nitrogen fertilization calculator

28. First, it should be highlighted that despite several Greenseeker trainings and active consultations related to experimental design and data collection provided by ICARDA- SLMR Tashkent staff to all NARS partners and several reminders and requests, due to some reasons there were some shortcomings in operation and use of Greenseeker and collection of necessary NDVI, crop yield and meteorological data by some national institutions involved in Greenseeker experiment during 2007-2009. Table 4 indicates overall status of data collection in 5 CAC countries until 1st October 2009. Further results provided in the following paragraphs of this report were built on the base of available data.

Table 4. Availability of NDVI, crop yield data and meteorological data to develop nitrogen calculator

Country	NDVI data		Grain yield data		Daily meteorological data (Tmax and Tmin)	
	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009
Kazakhstan	No data	All data	No data	All data	No data	All data
Kyrgyzstan	All data	All data	Mean data[x]	All data	Incomplete data	All data
Tajikistan	No data	All data	No data	All data	No data	No data
Turkmenistan	All data	All data	All data	All data	No data	No data
Uzbekistan	All data	All data	All data	All data	All data	All data

[x] *Mean NDVI, crop yield and meteorological data are not sufficient to develop reliable nitrogen calculator*

9.1.4.2 NDVI data measurements over winter wheat crop in Kazakhstan (2008-2009)

29. The research site is located in foothill zone of Zaili Alatau in the Karasai district of Almaty region. NDVI data from April to June 2009 are presented Figure 2.

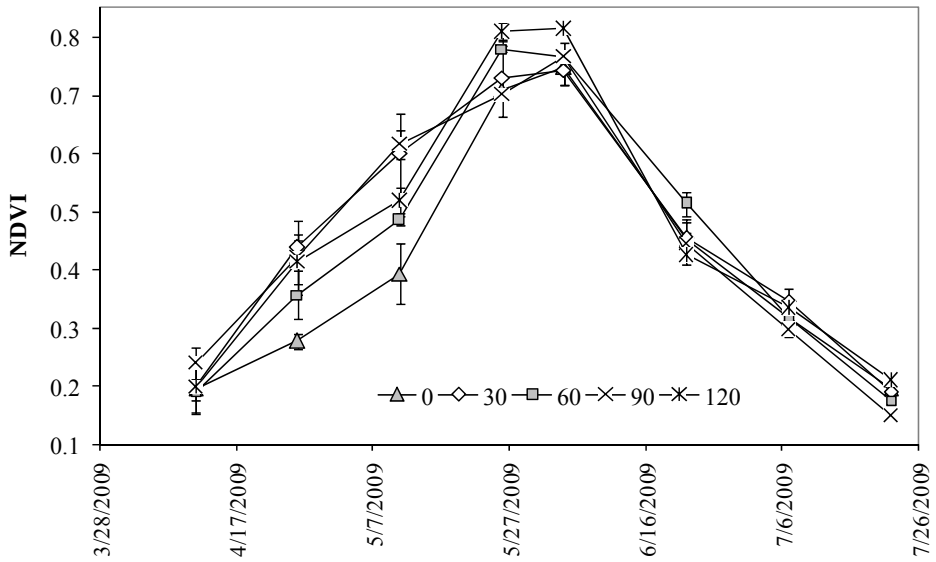


Figure 2. NDVI data measurements of winter wheat, N=0-90 kg ha^{-1}, April-June 2008

30. As one see from above figure, NDVI dynamics had a sustainable increasing trend under N60 and N120 treatments, while that much fluctuated under other treatments. NDVI were maximum on 26 May 2009, and started to decrease from 4 June 2009 which possibly associated with plant maturity stage. INSEY – crop yield relationship built on the base of NDVI measurements taken in mid April 2009 (F5 stage) for winter wheat sown in fall 2008 and harvested in summer 2009 are presented in Figure 3. Correlation between crop yield and INSEY was negative at F5 stage. There was response of wheat yield to nitrogen fertilization rate, i.e. increase of yields due to nitrogen application under nitrogen rates of 30 and 60 kg ha^{-1}. Maximum crop yield was observed under nitrogen application treatment N60, while minimum was under N90. Yields of wheat under nitrogen rates ranged from 90 to 120 kg ha^{-1} were even less than that under control. It seems that other factors might affected NDVI, i.e. mismanagement of trials, establishment of trials in the systematic way (without randomization), heterogeneity in initial nitrogen level caused by different nitrogen rate applied for the fore crop sown before winter wheat at this field. The reduction in crop yield under N90 and N120 treatments might be explained by "overfeeding" with nitrogen. As it known, plant vegetative mass is highly developing under over fertilization. In our case, straw weight has increased while grain yield has reduced i.e. photosynthetic efficiency coefficient has decreased, i.e. more photosynthetic energy was spent for creation of the vegetative biomass (straw) rather than for grain yield formation.

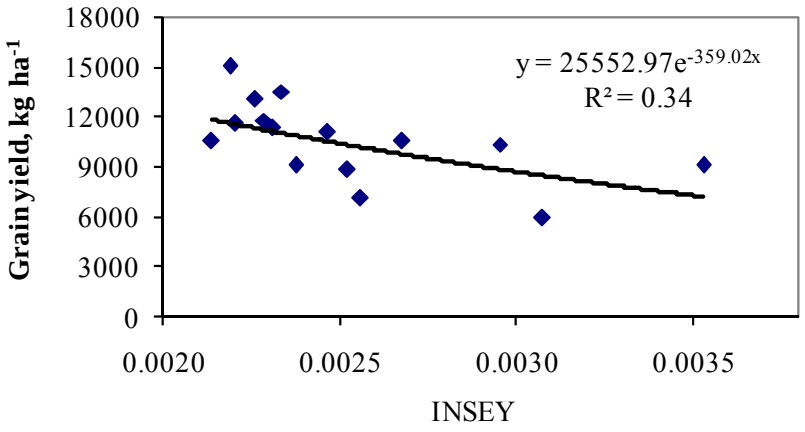


Figure 3. INSEY – crop yield relationship of winter wheat at Almalybag, 2009

31. It is early to draw any conclusions about optimum nitrogen application rates and there were not significant differences between nitrogen applied treatments (N0-N120) (Figure 4).

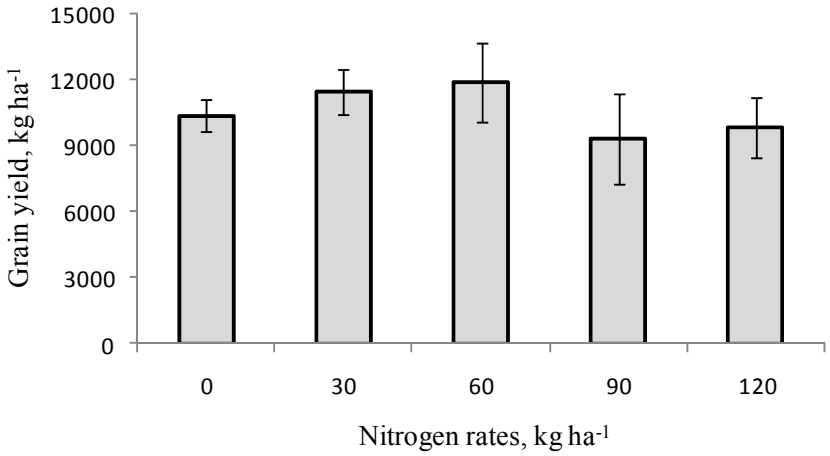


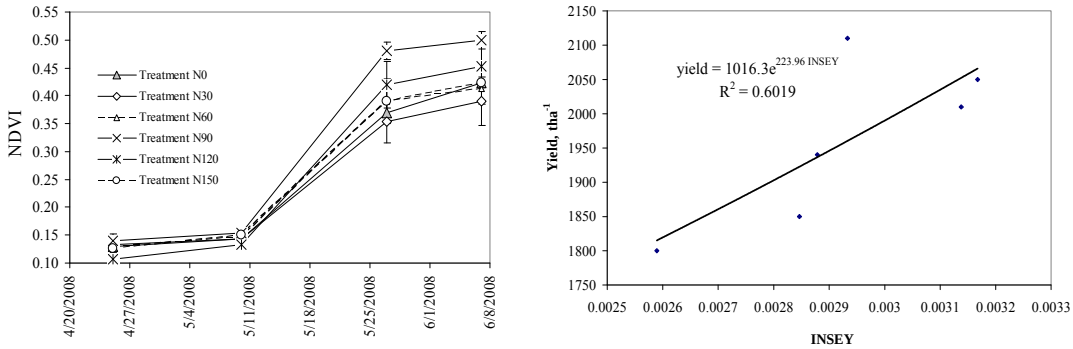
Figure 4. Winter wheat yields, N=0-90 kg ha^{-1}, Daniyar farm, 2007-08, 2008-09

32. In order to get more reliable nitrogen calculator and find optimal nitrogen application rates, it would be much valuable to continue calibration experiments with the same nitrogen rates tested in 2007-08.

9.1.4.3 NDVI data measurements over winter wheat crop in Kyrgyzstan (2007-2008)

33. NDVI had increased trend after applying fertilizer in one month at N90 and N120 treatments (Figure 5). Increases in NDVI in late May (flowering stage) were not significantly higher under N0-N60 and N150 treatments over initial level. Preliminary results indicated that

optimal rate of nitrogen fertilizer for the winter wheat ranged from 90 to 120 kg ha^{-1} in Chu Valley. INSEY-crop yield relationship (Figure 5) built on the base of average NDVI and crop yield data has relatively good coefficient determination (R^2=0.60). In spite of good correlation between INSEY and yield there were only few (6) measurements of harvested grain yields collected in the experimental site, which is not sufficient to prove strong relation between 2 parameters. NDVI and crop yields data to be collected from each replication and each furrow to get better results. Low correlation between RIndvi and RI yields proves above comments.



(a) (b)

Figure 5. Dynamics of NDVI (a) and INSEY – crop yield relationship (b) of winter wheat at Daniyar, April-June 2008

9.1.4.4 NDVI data measurements over maize crop in Kyrgyzstan (2008)

34. Maize NDVI values and INSEY – crop yield relationship for maize are presented in Figure 6. NDVI data measured at the phase of 10-12 leaves were used for calibration of Greenseeker. Correlation between crop yield and NDVI is positive (Figure 6). The calculator was developed in order to assess the required doses of Nitrogen fertilizers to be applied (Table 5)

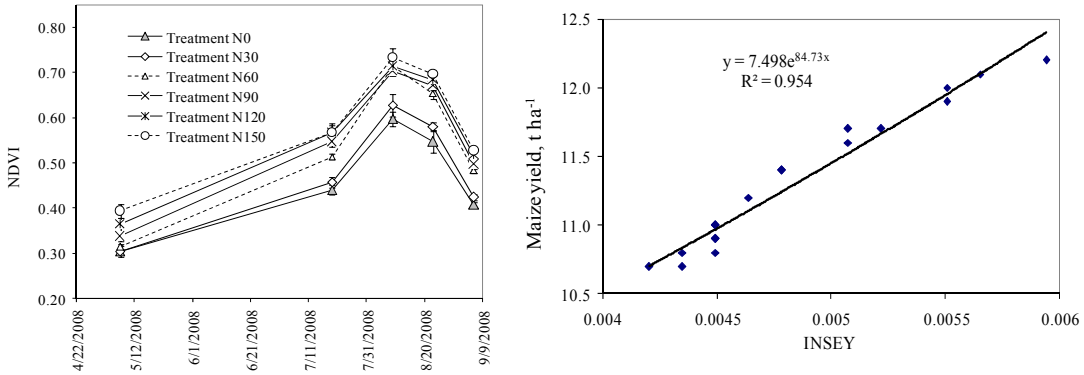


Figure 6. NDVI data measurements and INSEY –Crop yield relationship for maize, N=0-150 kg ha^{-1}, Daniyar, 2008

Table 5. Nitrogen prediction calculator developed for maize crop in crop season 2008 at Daniyar farm

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12
	Enter Plot NDVI	Enter number of days from planting where GDD>0	Compute INSEY	Compute YPo	Determine Rindvi	Riyield	Compute YPn	YPmax determined by agronomist (YPn cannot exceed YPmax)	Determine Grain N uptake at YPo	Determine Grain N uptake at YPn		Determine fertilizer N requirement
	NDVI Rich Strip =	0.41	INSEY = NDVI/ Days, GDD>0	YPo=7.4987*exp(84.733*INSEY)	RI=NDVI (Nitrogen Rich Strip)/NDVI (farmer check)	RIyield=0,3841*RIndvi+0,6301	YPn=YPo * RI	YPn(cap) <= 5 t ha^{-1}	GNUP_YPo = YPo in t ha^{-1} * 0.00432	GNUP_YPn = YPn in t ha^{-1} * 0.00432%		FNR = (GNUP_YPn - GNUP_YPo)/ NUE
	NDVI	GDD	INSEY	YPo_i t ha^{-}	RI ndvi	RI yield	YPn, t ha^{-1}	YPn(cap), t ha^{-1}	GNUP_YPo	GNUP_YPn	N needed	FNR, Nha-1
1	0.31	69	0.00449	10.97	1.32	1.14	12.49	12.49	0.04740	0.05395	0.00655	0.025
2	0.28	69	0.00406	10.58	1.46	1.19	12.61	12.61	0.04569	0.05448	0.00880	0.034
3	0.3	69	0.00435	10.84	1.37	1.16	12.52	12.52	0.04682	0.05408	0.00726	0.028
4	0.34	69	0.00493	11.38	1.21	1.09	12.45	12.45	0.04918	0.05377	0.00459	0.018
5	0.36	69	0.00522	11.67	1.14	1.07	12.46	12.46	0.05040	0.05381	0.00340	0.013
											Average N	0.023

9.1.4.5 NDVI data measurements over winter wheat crop planted in fall 2008 in Kyrgyzstan

35. NDVI data is presented in Figure 7. As it can be seen from the graph, maximum NDVI was observed at treatments N90, N60 and minimum NDVI at treatments N0, N30 in mid May 2009 (flowering stage). INSEY–crop yield relationship for winter wheat sown in 2008 and harvested in 2009 demonstrated high correlation (R^2=0.90) and presented in Figure 8.

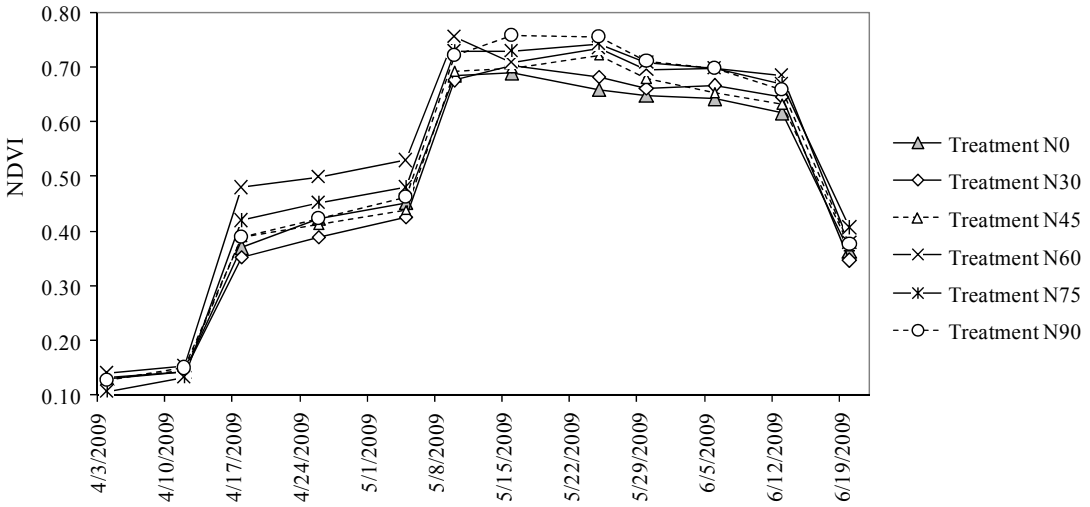


Figure 7. NDVI data measurements of winter wheat, N=0-90 kg ha^{-1}, 2009

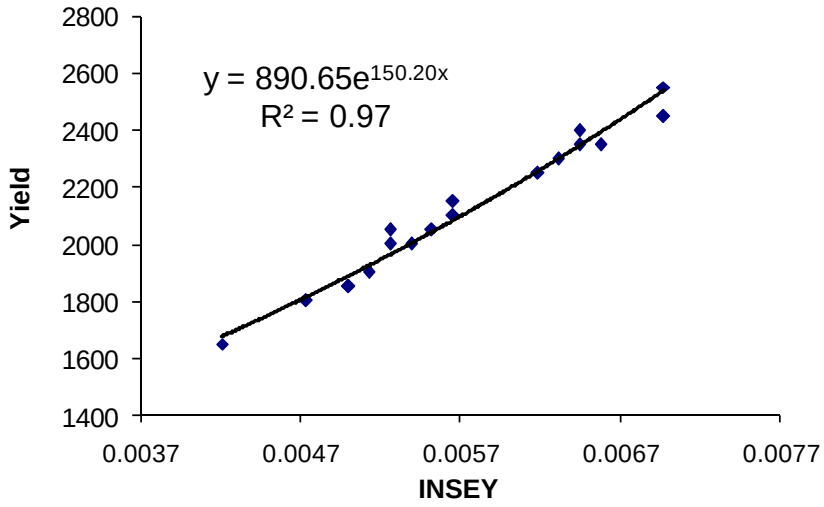


Figure 8. INSEY –Crop yield relationship for winter wheat, N=0-90 kg ha^{-1}, Daniyar, 2009

9.1.4.6 Validation of nitrogen calculator in Kyrgyzstan farmer plots.

36. Using the N calculator (Table 6) developed at experimental site in 2007-2008, the farmers were advised to apply N to meet in-season crop demands for nitrogen at 3 farmers'

fields at Daniyar farm. NDVI measurements were taken at F6 stage of wheat in N-rich strip and conventionally N fertilized plots in all above sites in early May 2009.

37. The results of winter wheat yields predicted at 177-197 days after emergence in Kyrgyzstan are presented in Table 6. Root mean square error (RMSE) for all sites between predicted and actual winter wheat yield with no added nitrogen fertilizer was 1.66 t ha^{-1} and that with added fertilizer was 1.95 t ha^{-1}. There was high difference between predicted and actual yield in all farms. Under using INSEY-crop yield relation and RIyield- RIndvi relationships from 2008-2009, RMSE significantly improved (RMSE=0.60-0.67 t ha^{-1}) (Table 7- Table 9).

Table 6. Prediction of winter wheat yield in Kyrgyzstan SLMR sites, using yield -INSEY relationship at 177-197 days after emergence; Y = 1016.3×Exp^(223.96×INSEY)

Farmer (farm)	N rate, kg ha-1, applied at boo-ting stage (F6) according to calculator	Grain yield, potential yield (YP_0) with no added fertilizer N, t ha^{-1}		Grain yield, potential yield (YP_N) with added fertilizer N, t ha^{-1}		NUE
		Predicted	Actual	Predicted	Actual	
1	51.7	4.33	2.04	4.77	2.04	0.20
2	16.9	2.98	2.28	3.12	2.28	0.20
3	18.7	4.00	2.40	4.20	2.40	0.20
	RMSE (1-3)		1.66		1.95	

Table 7. Prediction of winter wheat yield in Kyrgyzstan SLMR sites, using yield -INSEY relationship at 177-197 days after emergence; Y = 890.65×Exp^(150.20×INSEY)

Farmer (farm)	N rate, kg ha-1, to be applied at boo-ting stage (F6) according to calculator	Grain yield, potential yield (YP_0) with no added fertilizer N, t ha^{-1}		Grain yield, potential yield (YP_N) with added fertilizer N, t ha^{-1}		NUE
		Predicted	Actual	Predicted	Actual	
1	33.4	2.31	2.04	2.59	2.04	0.20
2	6.0	2.38	2.28	2.44	2.28	0.20
3	2.0	3.40	2.40	3.42	2.40	0.20
	RMSE (1-3)		0.60		0.67	

Table 8. Nitrogen prediction calculator developed for winter wheat crop sown at 1 farmer plot in crop season 2009 at Daniyar farm using equations INSEY-YIELD, RI yield –RIndvi developed using calibration data from wheat experiment in 2007-08

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12
	Enter Plot NDVI	Enter number of days from planting where GDD>0	Compute INSEY	Compute YPo	Determine Rindvi	Riyield	Compute YPn	YPmax determined by agronomist (YPn cannot exceed YPmax)	Determine Grain N uptake at YPo	Determine Grain N uptake at YPn	N yield, kg ha-1	Detemine fertilizer N requirement
			= NDVI/ Days, GDD>0	YPo= 1016.3* exp(223.96* INSEY)	RI=NDVI (Nitrogen Rich Strip)/NDVI (farmer check)	Riyield(=Y) = 0.4405 Rindvi(=X) + 0.5928	YPn=YPo * RI	YPn(cap)<= 5000 kg ha-1	GNUP_YPo = YPo in kg ha-1 * 0.0239	GNUP_YPn = YPn in kg ha-1 * 0.0239%		FNR = (GNUP_YPn - GNUP_YPo) /0.5043
	NDVI	GDD	INSEY	YPo, kg ha-1	RI ndvi	RI yield	YPn, kg ha-1	YPn(cap), kg ha-1	GNUP_YPo	GNUP_YPn	N yield, kg ha-1	FNR, kgNha-1
1	0.46	73	0.0063	4167.9	1.1	1.1	4577.1	4577.1	99.6	109.4	9.8	48.9
2	0.5	73	0.00685	4712.1	1.1	1.1	4984.2	4984.2	112.6	119.1	6.5	32.5
3	0.43	73	0.00589	3801.5	1.2	1.1	4308.7	4308.7	90.9	103.0	12.1	60.6
4	0.4	73	0.00548	3467.2	1.3	1.2	4070.4	4070.4	82.9	97.3	14.4	72.1
5	0.46	73	0.0063	4167.9	1.1	1.1	4577.1	4577.1	99.6	109.4	9.8	48.9
6	0.52	73	0.00712	5010.3	1.0	1.0	5210.0	5000.0	119.7	119.5	-0.2	-1.2
				4221.2			4621.2					
	NDVI Rich Strip =	0.528									*Average N, kg ha-1*	43.6
	NUE	20%										

Table 9. Nitrogen prediction calculator developed for winter wheat crop sown at 1 farmer plot in crop season 2009 at Daniyar farm using equations INSEY-YIELD, RI yield –RI ndvi developed using calibration data from wheat experiment in 2008-09

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12
	Enter Plot NDVI	Enter number of days from planting where GDD>0	Compute INSEY	Compute YPo	Determine Rindvi	Riyield	Compute YPn	YPmax determined by agronomist (YPn cannot exceed YPmax)	Determine Grain N uptake at YPo	Determine Grain N uptake at YPn	N yield, kg ha-1	Determine fertilizer N requirement
			= NDVI/ Days, GDD>0	YPo= 890.65* exp(150.20* INSEY)	RI=NDVI (Nitrogen Rich Strip)/NDVI (farmer check)	Riyield(=Y) = 0.896 Rindvi(=X) + 0.095	YPn=YPo * RI	YPn(cap)<= 5000 kg ha-1	GNUP_YPo = YPo in kg ha-1 * 0.0239	GNUP_YPn = YPn in kg ha-1 * 0.0239%		FNR = (GNUP_YPn - GNUP_YPo)/0.5043
	NDVI	GDD	INSEY	YPo, kg ha-1	RI ndvi	RI yield	YPn, kg ha-1	YPn(cap), kg ha-1	GNUP_YPo	GNUP_YPn	N yield, kg ha-1	FNR, kgNha-1
1	0.46	73	0.0063	2294.8	1.1	1.1	2579.6	2579.6	54.8	61.7	6.8	34.0
2	0.5	73	0.00685	2491.7	1.1	1.0	2595.8	2595.8	59.6	62.0	2.5	12.4
3	0.43	73	0.00589	2157.5	1.2	1.2	2580.1	2580.1	51.6	61.7	10.1	50.5
4	0.4	73	0.00548	2028.3	1.3	1.3	2593.1	2593.1	48.5	62.0	13.5	67.5
5	0.46	73	0.0063	2294.8	1.1	1.1	2579.6	2579.6	54.8	61.7	6.8	34.0
6	0.52	73	0.00712	2596.4	1.0	1.0	2610.3	2610.3	62.1	62.4	0.3	1.7
				2310.6			2589.8					
	NDVI Rich Strip =	0.528									*Average N, kg ha-1*	33.4
	NUE	20%										

38. Preliminary results indicated that optimal rate of nitrogen fertilizer for the winter wheat for the Chu Valley is between 60-75 kg ha^{-1}, where as farmers generally apply a much higher dose. But at the same time, least significant difference of means (5% level) estimated on the base of winter wheat yield data obtained in 2009 was found to be 375.7 kg ha^{-1} and there were not significant differences between nitrogen applied treatments (N0-N90) (Figure 9).

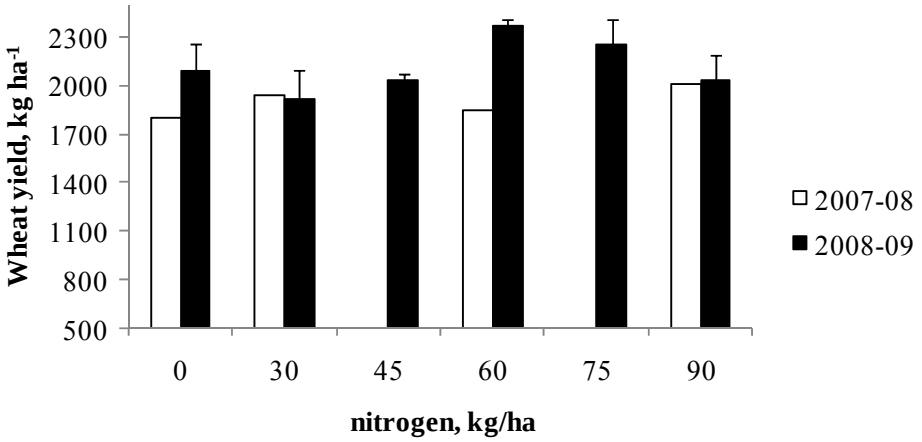
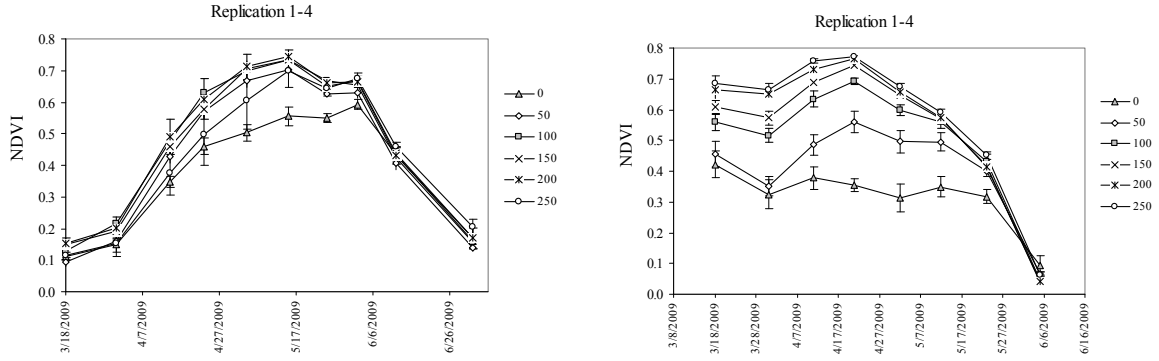


Figure 9. Winter wheat yields, N=0-90 kg ha^{-1}, Daniyar farm, 2007-08, 2008-09

39. In order to get more reliable nitrogen calculator and find optimal nitrogen application rates, it would be much valuable to continue calibration experiments with following nitrogen rates: 0, 30, 50, 60, 70, 80

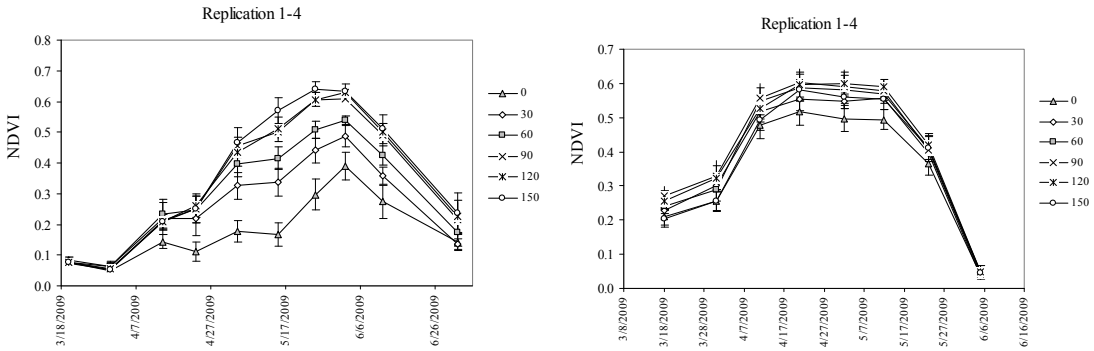
9.1.4.7 NDVI data measurements over winter wheat crop planted in fall 2008 in Tajikistan

40. Experiment for Greenseeker measurements has been laid out on four sites with different soil-climatic conditions in the irrigated and rainfed areas in accordance with six treatments and four replications mentioned in 1.1.1.4. NDVI dynamics during crop season, INSEY-crop yield relationship are presented in Figure 10 to Figure 11 and Figure 12 to Figure 15, respectively.



(a) (b)

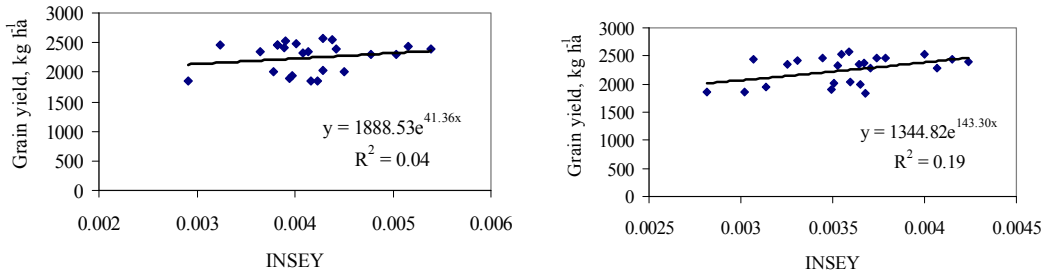
Figure 10. NDVI measurements of irrigated winter wheat in Faizabad (a) and Horasan (b)



(a) (b)

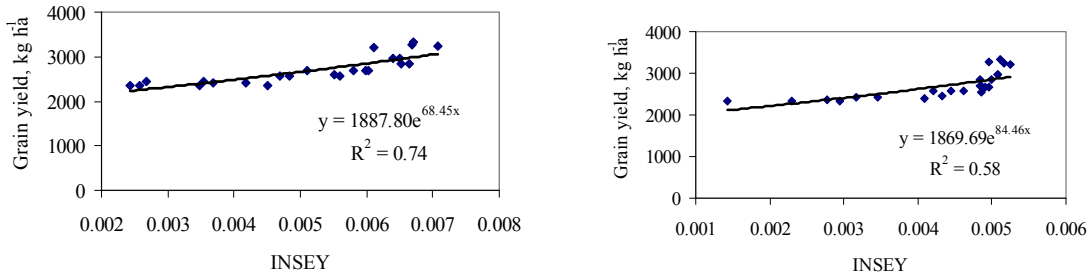
Figure 11. NDVI measurements of rainfed winter wheat in Faizabad (a) and Horasan (b)

41. As it could be seen from above figures higher-fertilized plots had higher NDVI and INSEY values than the lower-fertilized plots. The effect becomes more pronounced during F8-F10 stages in April-May (flag leaf visible – boot stage).



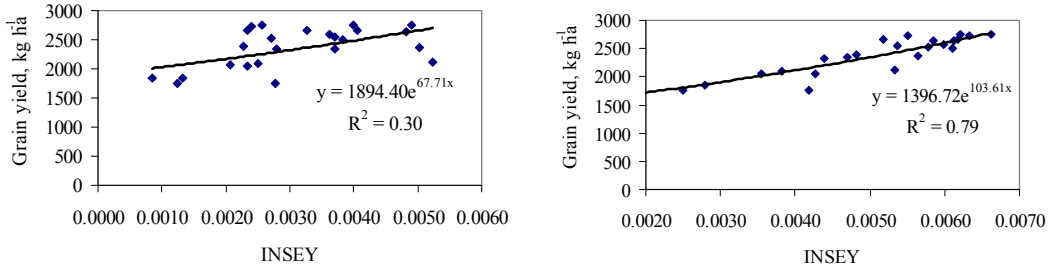
(a) (b)

Figure 12. INSEY –Crop yield relationship for winter wheat, Horasan rainfed, F4/F5 (a); F10.1 (b)



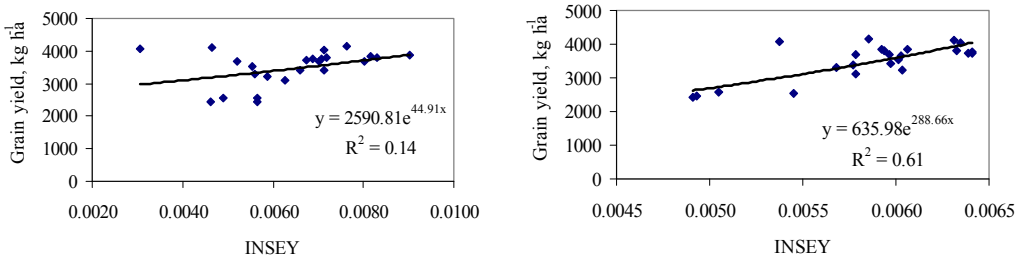
(a) (b)

Figure 13. INSEY –Crop yield relationship for winter wheat, Horasan irrigated, F4/F5 (a); F10.1 (b)



(a) (b)

Figure 14. INSEY –Crop yield relationship for winter wheat, Faizabad rainfed, F4/F5 (a); F10.1 (b)



(a) (b)

Figure 15. INSEY –Crop yield relationship for winter wheat, Faizabad irrigated, F4/F5 (a); F10.1 (b)

42. Correlation between NDVI (INSEY) winter wheat and its grain yield had increasing trend from F3 (tillers formed) until F10.1 stage (awn visible, heads emerging through slit of flag leaf sheath) followed by reduction after F10.5.1 (flowering) stage with maximum values observed at F10.1 stage (r = 0.690 ± 0.135), while that measured at F4/F5 stage (beginning of erect growth/leaf sheaths strongly erect) was relatively low (r = 0.360 ± 0.100) in 3 experimental sites (Horasan rainfed, Faizabad rainfed and Faizabad irrigated zone) out of 4 sites (Figure 16).

43. The correlation between NDVI winter wheat at its grain yield was found to be maximum (r = 0.840) at F4/F5 stage at Horasan irrigated zone.

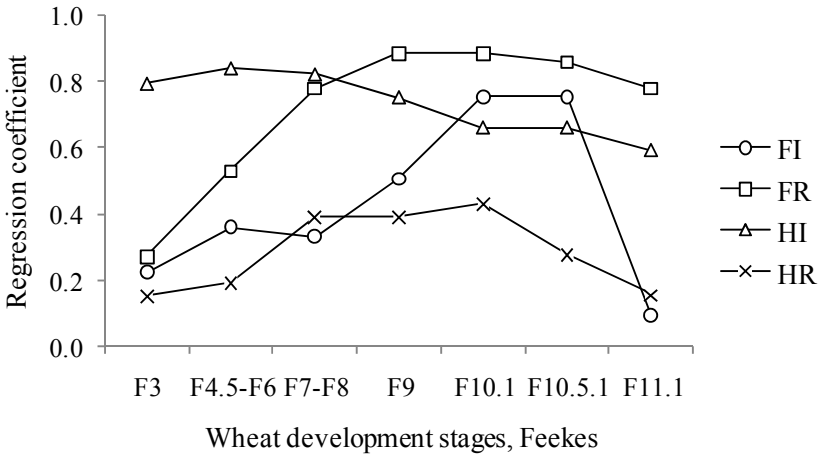


Figure 16. Effect of wheat development stage on regression coefficient between INSEY and crop yield at Faizabad irrigated (FI), Faizabad rainfed (FR), Horasan irrigated (HI) and Horasan rainfed (HR) zones in Tajikistan

44. In general, the yields of winter wheat tended to increase with the increase of nitrogen rate both at rainfed and irrigated sites in Tajikistan in 2008-2009 (Table 10).

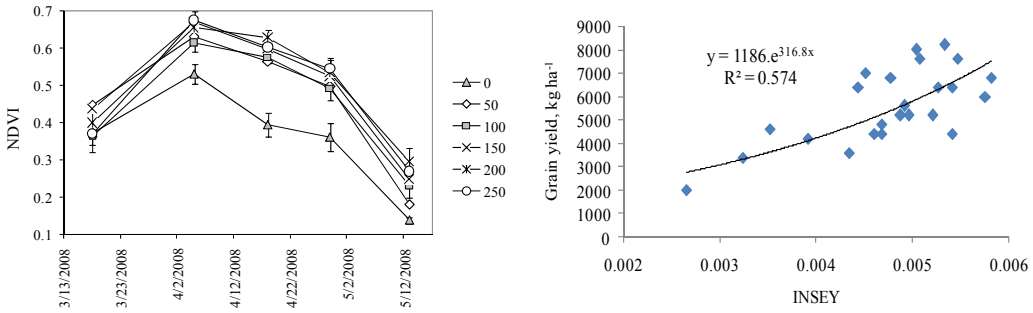
Table 10. Winter wheat yield (kg ha^{-1}) as affected by nitrogen application rates in Tajikistan experimental sites in 2008-2009

Nitrogen rate, kg ha^{-1}	Faizabad experimental sites		Horasan experimental sites	
	rainfed	irrigated	rainfed	irrigated
0	1800 a[x x]	2500 a	1875 a	2342 a
50 (30)[x]	2080 b	3310 b	1985 b	2422 a
100 (60)	2358 c	3640 c	2315 c	2575 b
150 (90)	2535 d	3660 c	2385 cd	2688 c
200 (120)	2652 e	3782 c	2458 de	3902 d
250 (150)	2742 f	4098 d	2522 e	3272 e
LSD at $p = 0.05$	46	159	58	54

[x] *Figures in bracket indicate nitrogen rate applied in rainfed zone*
[x x] *Means followed by the same letter in a column do not differ significantly at P≤0.05.*

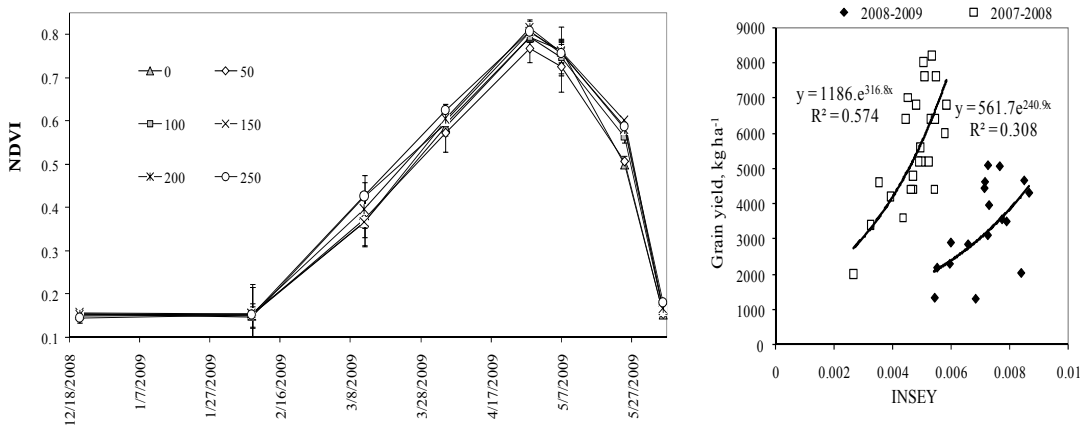
9.1.4.8 NDVI data measurements over winter wheat crop planted in fall 2007 in Turkmenistan

45. Experiment has been laid out to calibrate Greenseeker instrument for estimation of nitrogen to be applied for winter wheat yield in 2008 in accordance with six treatments and three replications mentioned in 1.1.3.5. NDVI dynamics during crop season, INSEY-crop yield relationship is presented in Figure 17 to Figure 18.



(a) (b)

Figure 17. NDVI (a) and INSEY –Crop yield relationship (b) for winter wheat, N=0-250 kg ha-1, 2007-2008



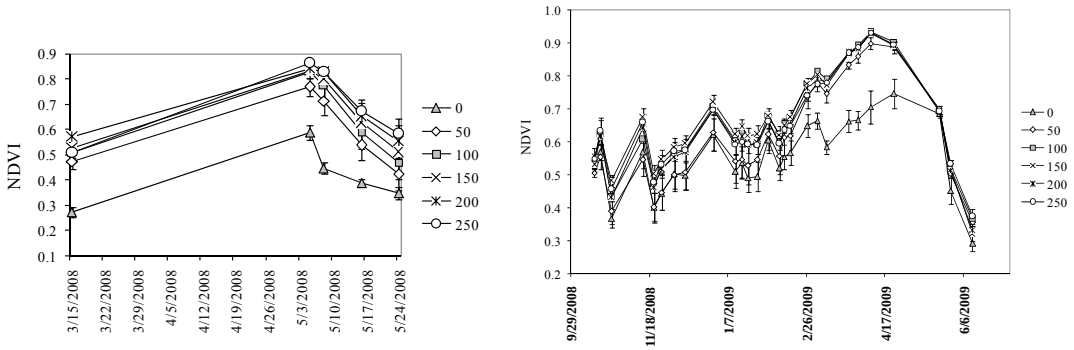
(a) (b)

Figure 18. NDVI dynamics during 2008-2009 (a) and INSEY –Crop yield relationship (b)for winter wheat, Bugdaily, 2007-2008&2008-2009, F5/F6 stage

46. Data collected from the calibration experiments in 2007-2008 and 2008-2009 were not much reliable, especially in 2008-2009 which could be explained by late sowing of winter wheat in fall 2008 (07 November 2008). In spite of good correlation found between INSEY and yield in 2007-2008 (r^2=0.574) at F5-F6 stage, the correlation for INSEY and yield was relatively weak (r^2=0.304) in 2007-2008. NDVI and crop yields data to be collected from each replication and each furrow to get better results. Final decision for selecting farmers' fields in order to make validation of first –second year calculator could be drawn only after checking of the row data.

9.1.4.9 NDVI dynamics during crop season in Uzbekistan in 2007-2009

47. Typical effects of nitrogen levels to NDVI readings of winter wheat presented in Figure 19 and INSEY-crop yield relationship for both years in Figure 20 to Figure 21.



(a) (b)

Figure 19. NDVI data measurements of winter wheat, N=0-250 kg ha^{-1}, 2007-2008 (a) and 2008-2009 (b)

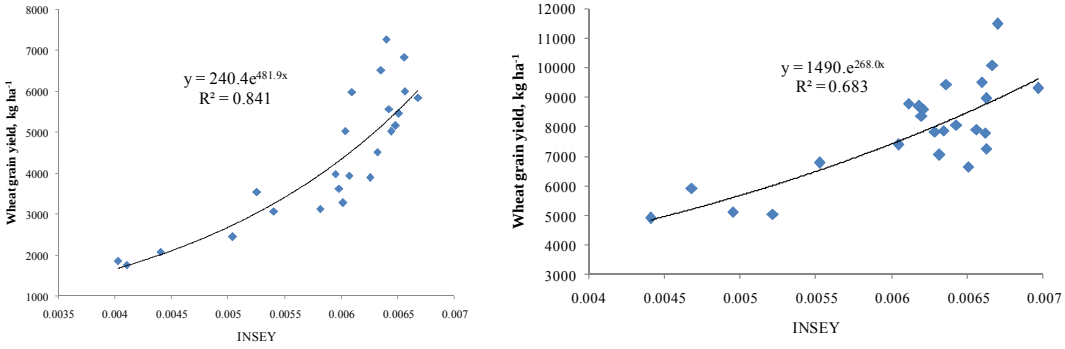
48. In general, the yields of winter wheat tended to increase with the increase of nitrogen rate at irrigated sites in Turkmenistan and Uzbekistan in 2007-2008 and 2008-2009 (Table 11).

Table 11. Winter wheat yield (kg ha^{-1}) as affected by nitrogen application rates in Turkmenistan and Uzbekistan experimental sites in 2007-2009

Nitrogen rate, kg ha^{-1}	Bugdaily site		Akkavak site	
	2007-2008	2008-2009	2007-2008	2008-2009
0	3550 c	1445 a	2035 a	5253 a
50	4700 bc	2230 b	4281 b	7556 b
100	5200 bc	2980 c	4308 b	8008 b
150	6050 ab	3710 d	4735 b	8332 b
200	7650 a	4410 e	5528 b	8434 b
250	6400 ab	4890 f	5574 b	9679 c
LSD at p = 0.05	1230	285	1466	781

[x] *Means followed by the same letter in a column do not differ significantly at P≤0.05*

49. The determination coefficient between grain yield and INSEY was 0.841 at F5/F6 winter wheat development stage in 2007-2008, and that was 0.683 in 2008-2009 in Akkavak (Figure 20). The relationship between measured grain yield and INSEY for Akkavak (r2=0.53) for both years (2007-2008 and 2008-2009) is illustrated in Figure 21.



(a) (b)

Figure 20. INSEY –Crop yield relationship for winter wheat, Akkavak, 2007-2008 (a) and 2008-2009 (b)

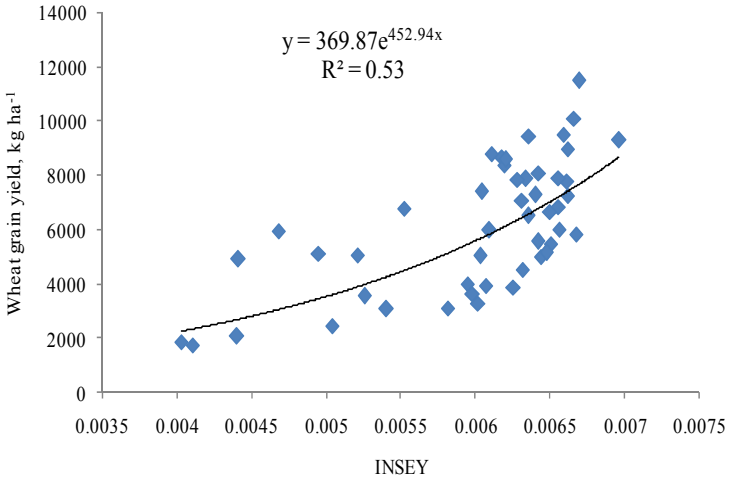


Figure 21. INSEY –Crop yield relationship for winter wheat, Akkavak, 2007-2009

Table 12. Nitrogen calculator developed for winter wheat crop in crop season 2008-2009, Akkavak farm, Uzbekistan

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12	STEP 13
	Enter Plot NDVI	Enter number of days from planting where GDD>0	Compute INSEY	Compute YPo	Determine Rindvi	Riyield	Compute YPn	YPmax determined by agronomist (YPn cannot exceed YPmax)	Determine Grain N uptake at YPo	Determine Grain N uptake at YPn	N yield, kg ha-1	NUE=0,006 N yield + 0,125,	Determine fertilizer N requirement
			= NDVI/ Days, GDD>0	YPo= 205.24*exp (448.09*INSEY)	RI=NDVI (Nitrogen Rich Strip)/NDVI (farmer check)	Riyield(=Y) = 3.59 Rindvi(=X) - 2.38	YPn=YPo * RI	YPn(cap)<= 7000 kg ha-1	GNUP_YPo = YPo in kg ha-1 * 0.0216	GNUP_YPn = YPn in kg ha-1 * 0.0239%		NUE (N yield / N rate), kg/kg	FNR = (GNUP_YPn - GNUP_YPo)/0.5043
	NDVI	GDD	INSEY	YPo, kg ha-1	RI ndvi	RI yield	YPn, kg ha-1	YPn(cap), kg ha-1	GNUP_YPo. Kg ha-1	GNUP_Ypn, Kg ha-1	N yield, kg ha-1	NUE=0,006 N yield + 0,125, kg/kg	FNR, kgNha-1
1	0.828	147	0.00564	2564.0	1.1	1.5	3815.1	3815.1	55.4	82.4	27.0	0.29	94.1
2	0.849	147	0.00578	2732.3	1.1	1.4	3805.9	3805.9	59.0	82.2	23.2	0.26	87.8
3	0.846	147	0.00575	2702.3	1.1	1.4	3807.8	3807.8	58.4	82.2	23.9	0.27	89.0
4	0.832	147	0.00566	2593.7	1.1	1.5	3813.7	3813.7	56.0	82.4	26.4	0.28	93.1
5	0.822	147	0.00559	2516.7	1.1	1.5	3817.0	3817.0	54.4	82.4	28.1	0.29	95.7
6	0.814	147	0.00554	2454.3	1.1	1.6	3819.1	3819.1	53.0	82.5	29.5	0.30	97.7
7	0.778	147	0.00529	2196.7	1.1	1.7	3822.7	3822.7	47.4	82.6	35.1	0.34	104.6
8	0.817	147	0.00556	2479.4	1.1	1.5	3818.3	3818.3	53.6	82.5	28.9	0.30	96.9
				2529.9			3815.0						
												0.29	94.9
	NDVI Rich Strip	0.893										Ammonium Nitrate, kg ha-1	284.0

9.1.4.10 Prediction of winter wheat yields during crop season in Uzbekistan

50. Using the N calculator (Table 12) developed at experimental site in 2007-2008, the farmers were advised to apply N to meet in-season crop demands for nitrogen at 4 farmers' fields at Uzbek Cotton Growing Research Institute sites in Tashkent province, 2 farmers' fields in Esanboy ota farm and Sherzod Samandar Birligi farm in Jizzakh and Syrdarya provinces in Uzbekistan. NDVI measurements were taken at F5-F6 stage of wheat in N-rich strip and conventionally N fertilized plots in all above sites in March-April 2009.

51. The results demonstrate that winter wheat yields can be predicted at 122-147 days after emergence in Uzbekistan (Table 13). Root mean square error (RMSE) for all sites between predicted and actual winter wheat yield with no added nitrogen fertilizer was 1.35 t ha^{-1} and that with added fertilizer was 1.57 t ha^{-1}. There was high difference between predicted and actual yield in farm 3 due to low plant stand. Under removing the yield data from this farm, RMSE significantly improved (RMSE=0.11-0.14 t ha^{-1}).

Table 13. Prediction of winter wheat yield in Uzbekistan SLMR sites, using yield -INSEY relationship at 122-147 days after emergence; Y = 205.24×Exp^(448.09×INSEY)

Farmer (farm)	N rate, kg ha-1, applied at boo-ting stage (F5-F6) according to calculator	Grain yield, potential yield (YP_0) with no added fertilizer N, t ha^{-1}		Grain yield, potential yield (YP_N) with added fertilizer N, t ha^{-1}		NUE
		Predicted	Actual	Predicted	Actual	
1 (Akkavak)*	95	2.53	3.20	3.81	3.57	0.29
2 (Akkavak)	89	4.60	3.99	5.73	5.60	0.30
3 (Akkavak)	47	6.32	3.28	6.70	3.11	0.17
4 (Akkavak)	86	4.45	3.88	5.48	4.52	0.26
5 (Esanboy ota)**	63	3.11	3.83	3.83	4.68	0.22
6 (Sherzod Samandar birligi) ***	93	2.84	2.72	4.06	3.65	0.28
	RMSE (1-6)		1.35		1.57	
	RMSE (1,2,4-6)		0.11		0.14	

**Uzbek Cotton Growing Research Institute (UCGRI) sites in Tashkent province*
***Branch of UCGRI experimental farm in Jizzakh province*
****Central Asian Scientific Research Institute experimental farm in the Syrdarya province*

9.1.4.11 Estimated yield vs. grain yield (all irrigated sites)

52. The relationship between measured grain yield and INSEY for all irrigated sites (Akkavak, Faizabad, Horasan, Bugdaily) for both years (2007-2008 and 2008-2009) is illustrated in Figure 22. Exponential models for entire data set resulted in relatively low coefficient correlation (r=0.53). Plant stands were poor following planting in Bugdaily site in fall 2008 and growing conditions were not ideal before sensing. In Faizabad irrigated site excessive rain delayed harvest to 14 July 2009 and consequently reduced grain yields because

of lodging and shattering. When data were removed for the two sites where grain yield was strongly influenced by abnormal conditions, the relationship between measured grain yield and INSEY (r=0.64) improved (Figure 23).

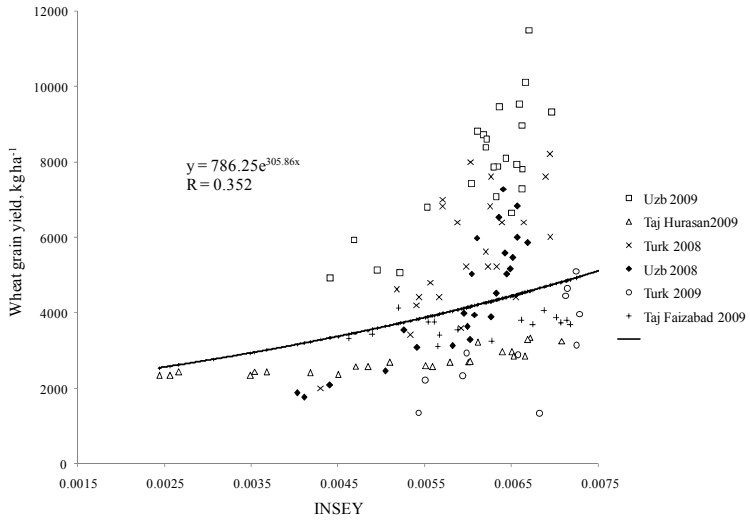


Figure 22. Winter wheat yield as function of INSEY at 134&121 day after emergence (DAE) (Akkavak, Uzbekistan, 2008&2009, respectively), 100 DAE (Horasan, Tajikistan, 2009), 105DAE (Bugdaily, Turkmenistan, 2008), 83DAE (Bugdaily, Turkmenistan, 2009), 67 DAE (Faizabad, Tajikistan, 2009)

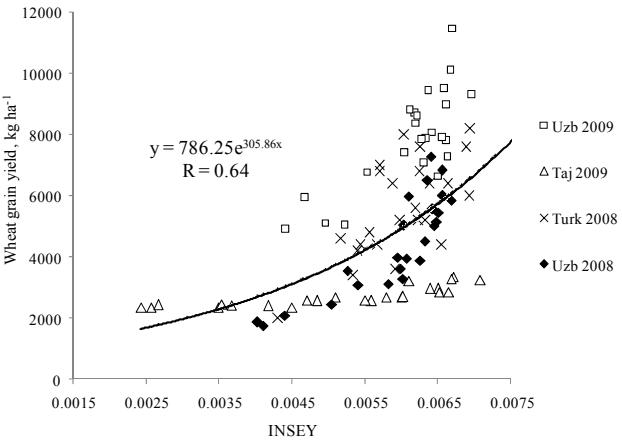


Figure 23. Winter wheat yield as function of INSEY at 134&121 day after emergence (DAE) (Uzbekistan, Akkavak, Tashkent province, 2008&2009, respectively), 100 DAE (Horasan, Tajikistan, 2009), 105DAE (Bugdaily, Turkmenistan, 2008).

9.1.5 Conclusions

53. The determination coefficient (r^2) between grain yield and INSEY ranged from 0.57 to 0.84 for irrigated experimental sites in Akkavak, Bugdaily and Horasan at F5/F6 winter wheat development stage in 2007-2009, and that ranged from 0.61 to 0.89 in irrigated and rainfed Faizabad at F10.1 (heading stage) in 2008-2009. It is also observed that in addition to nitrogen levels, there are several other factors that contribute to the crop yields such as timeliness and quality of farm operations, climatic conditions, quality of inputs, soil organic content, etc. In this regard, training of farmers on the proper sustainable land management agronomic practices as well as creating more opportunities for timely and easier access to credit to finance farm operations is crucial.

54. Results of NDVI measurements and grain yields allowed developing INSEY-crop yield relationship for winter wheat in irrigated conditions of Uzbekistan, Tajikistan and Turkmenistan at F5/F6 stage. A good relationship between grain yield and INSEY at F5/F6 stage was observed (r^2=0.64) when combining 3 locations (Akkavak, Bugdaily and Horasan) across 1-2 year period during 2007-2009.

55. Our estimates of potential grain yield using nitrogen optimization calculator developed on the base 1 winter wheat season (2007-2008) for irrigated wheat in Uzbekistan showed relatively higher accuracy and there were higher differences in actual and predicted grain yield at one site out of six sites due to lodging.

56. Potential grain yield estimated using nitrogen optimization calculator developed on the base 1 winter wheat season (2007-2008) for rainfed wheat in Kyrgyzstan showed relatively lower accuracy and there were higher differences in actual and predicted grain yield at all three sites. At the same time, potential grain yield predicted using INSEY-yield relationship developed on the base of 2008-09 data showed relatively higher accuracy. In order to get more reliable nitrogen calculator and find optimal nitrogen application rates, it would be much valuable to continue calibration experiments with following nitrogen rates: 0, 30, 50, 60, 70, 80.

57. These studies are to be continued in more locations in Central Asia with recommendation the same farming operations in all sites and data are to be shared in order to get reliable nitrogen prediction calculator. The same experiment for calibration with different rates of nitrogen at the SLMR sites are to be continued in 2009-2010 and efforts will be devoted for developing a unified and more robust N response curve for all the sites. The trial should be repeated next winter season for a more stable INSEY- yield relationship.

9.2 Developing a methodology for screening of improved winter wheat, triticale, barley and chickpea germplasm- for vigor, cold, drought and salinity conditions and weed competitiveness - Efforts towards crop diversification

9.2.1 Introduction

58. Extended experiences during the Soviet Union era showed that grazing winter season cereals was well recognized in particular owing to the good regeneration capacity of the varieties used. Yield penalties hardly occurred provided that the N removed due to cutting is replenished immediately after cutting. There is lack of information related to potential of winter wheat, triticale and barley for dual purpose, i.e. to get green fodder and grain+straw fodder. Dual purpose cereal and legumes can form important component of the strategy for doubling the productivity of the crop- livestock in Central Asia, and for rehabilitation of the degraded lands that directly influence the income generation potential and livelihood of poor rural communities and framers.

9.2.2 Objectives

59. The objectives of the present study were

- to estimate dual purpose potential of winter wheat, triticale, barley
- to screen chickpea germplasm for competitiveness to weeds, biomass and yield

9.2.3 Materials and Methods

60. Fifteen winter wheat entries, collected from the CIMMYT-ICARDA Integrated Wheat Program in Turkey, were evaluated for dual purpose (green fodder, grain + straws) in Tashkent Agrarian University experimental site. The crop cultivars were planted in a randomized complete block design on 20th of September, 2008 and 10th of October 2008. The plot size was 2.8 m^2 (1.4×2.0=2.8 m^2) for each cultivar. Total number of subplots was 90. The NDVI was measured at weekly intervals after emergence. Half of the area planted in September was cut on 12th November 2008 and half of the area planted in October was cut on 10th March 2009, for biomass determination as a proxy for livestock feed. The growth and development of winter wheat cultivars was next monitored in both the cut and uncut plots to compare their development.

61. In a second trial, elite cultivars of winter wheat, barley and triticale from Uzbekistan were compared for their ability to provide green biomass with CIMMYT-ICARDA winter wheat accessions for dual purpose. All the crops were planted in four replications in 30.8 m^2 sized plots within raised bed-furrow systems. The NDVI was monitored and related with green

biomass (fodder), sixty three (63) days after planting on 12th November 2008 and one hundred fifty one (151) days after planting on 10th March 2009.

62. Thirty-six (36) improved lines of chickpea were evaluated in a 70cm raised bed-furrow system for their yield performance, vigor (competitiveness to weeds) and ability to tolerate terminal drought usually prevailing late in the summer Tashkent Agrarian University experimental site. The cultivars were sown in plots according to a randomized complete block design on 5 March 2008 in a non-saline soil (EC=10-13 ms m^{-1}), replicated twice amounting to a total number of 72 plots. Each accession was planted in 2.1 m2 (0.7×3.0=2.1 m^2). Total number of subplots was 36×2=72. Following germination, NDVI measurements were taken every week using the Greenseeker optical sensor till crop maturity.

63. Six cultivars of chickpea (FLIP 01-50C, FLIP 03-63C, FLIP 04-18C, FLIP 04-31C, FLIP 04-35C, Uzbekistansky 32), which had been identified in July 2008 for early vigor and high yield potential, were sown in plots according to a randomized complete block design in 3 replications (2 furrows in each replication) amounting to a total number of 36 plots on November 14, 2008 to study their performance during the cold winter season of 2008-09. Each accession was planted in 5x1.4=7.0 m^2. NDVI measurements were taken after emergence every week using the Greenseeker optical sensor till crop maturity.

9.2.4 Results and discussions

9.2.4.1 Assessment of dual purpose potential of local cereal crops

64. The green biomass (fodder) production of the elite Uzbekistan cultivars of winter wheat, barley and triticale was monitored 63 days after planting showed the typical plant (NDVI) growth curves /dynamics (Table 14, Figure 24). In November cut the maximum fresh biomass was obtained in barley (11.68 t ha^{-1}), followed by triticale (7.16 t ha^{-1}) and winter wheat (5.5 t ha^{-1}). In March the maximum fresh biomass was obtained in triticale (13.01 t ha^{-1}), followed by winter wheat (11.85 t ha^{-1}) and barley (4.40 t ha^{-1}).

Table 14. Fresh biomass (green fodder) yields of winter wheat, triticale and barley cut in November 2008 and March 2009

Crop	Cultivar	Average green fodder biomass in November, t ha^{-1}	Average green fodder biomass in March, t ha^{-1}
Winter wheat	Kroshka	5.49	11.85
Triticale	Pragserebristyi	7.16	13.01
Barley	Bolgali	11.68	4.40

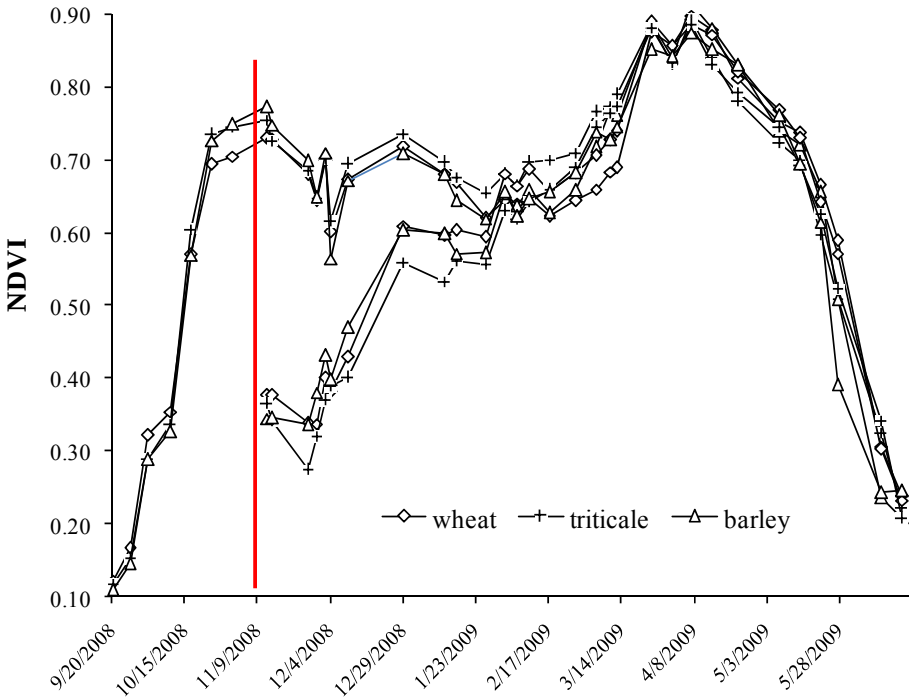
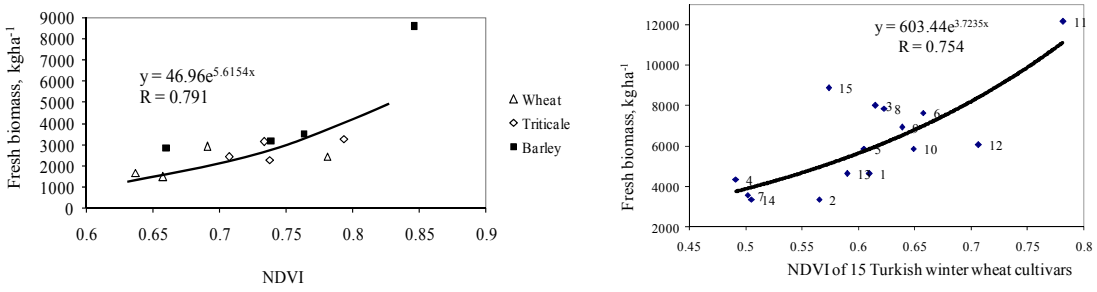


Figure 24. Growth dynamics of cereal crops (winter wheat, triticale and barley) planted in September

9.2.4.2 Relationship between NDVI and green biomass yields

65. The correlation coefficient between the green biomass and NDVI at 44 DAE of triticale, barley and winter wheat crops is high (r= 0.791), whilst r=0.754 between biomass and NDVI at 34 DAE of 15 CIMMYT-ICARDA winter wheat cultivars (Figure 25).



(a) (b)

Figure 25. Relationships between Green biomass yields and NDVI of cereal crops (barley, triticale and winter wheat), 63 days after emergence (a) and of 15 winter wheat accessions, 53 days after emergence (b) (number indicate the accession of winter wheat cultivar).

9.2.4.3 Effect of cutting time of the dual purpose local cereal cultivars on crop yields

66. As indicated in Table 15 and Figure 26, cutting in March substantially reduced the grain yields (by 73-87%) of all local cereal crops (wheat, triticale and barley) in comparison with cutting in November (34-39%). However, green biomass of winter wheat and triticale was almost two times higher when they were cut in March in comparison with cut in November. It might be explained by a little late cutting on 10th of March when winter wheat was at Feekes 6 development stage. It indicates that there are several cutting options could be tested to find optimum time of cutting of dual purpose crops with targeting on both high biomass and crop yields.

Table 15. Grain yields of dual purpose winter wheat, triticale and barley

Crop, cultivar	September planting		October planting	
	No cut	Cut in November	No cut	Cut in March
Wheat	6.52	3.98 (-39)	6.80	1.86 (-73)
Triticale	8.99	5.99 (-34)	9.40	1.50 (-84)
Barley	4.41	2.67 (-39)	4.76	0.63 (-87)

Figures in parenthesis indicate percentage decrease of yields over control (no cut)

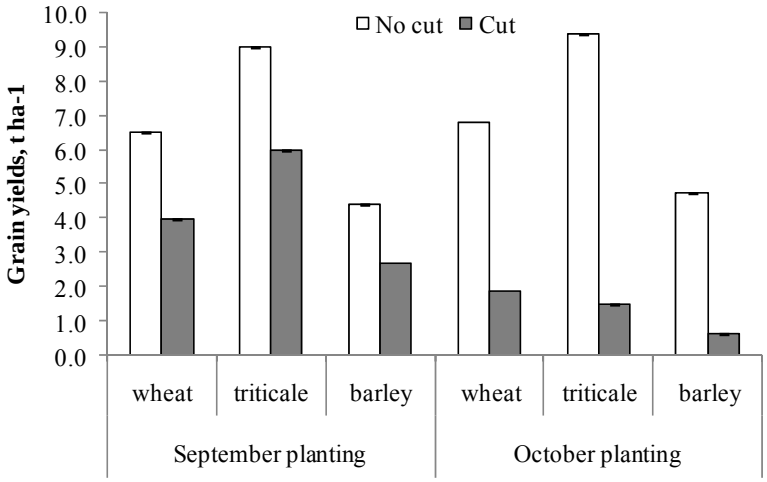


Figure 26. Effect of different time of cutting of local dual purpose cereal crop on crop yield

67. Using the NDVI measurements, cultivars were categorized into (i) crop vigor at early and mid-season growth rates, (ii) maturity group – early and late and (iii) yield potential. Results of the trials are given in Table 16. Cut of winter wheat in November and March did not affected on in-season vigor of local triticale and barley cultivars in mid-late season. Local barley even produced dry biomass higher by 26% in comparison with uncut, while dry biomass of local triticale cut in November was almost same with that uncut and cut of winter wheat in November reduced dry biomass by 13% over control (no cut). Cutting in March substantially reduced the dry biomass (by 46-68%) of all local cereal crops in comparison with uncut.

Table 16. Crop characterization and dry biomass of local winter wheat, triticale and barley cultivars

Crop, cultivar	In-season vigor			Dry biomass, t ha^{-1}	
	Early (F1-F3)	Mid-late (F4-F7)	Maturity (F10-F11)	No cut	Cut in November/ March[x]
September planting					
Wheat	S (M)	S (M)	L (L)	7.40	6.41 (-13) [xx]
Triticale	M (S)	F (F)	E (M)	10.78	10.93 (+1)
Barley	F (F)	M (M)	M (E)	5.08	6.38 (+26)
October planting					
Wheat	M	M (S)	E (M)	7.88	4.27 (-46)
Triticale	F	F (F)	L (L)	12.21	5.07 (-58)
Barley	S	S (M)	M (E)	5.51	1.77 (-68)

[x]*Dry biomass in this column representl total sum of dry biomasses during cut in Nov (March) and harvest (June 2009)*

[xx]*Figures in parenthesis indicate percentage decrease (-) or increase (+) of dry biomass over control (no cut)*

9.2.4.4 Assessment of dual purpose potential of 15 winter wheat accessions

68. Fresh biomass of selected CIMMYT-ICARDA winter wheat cultivars cut in November 2008 ranged between 3.36 to 12.14 t ha^{-1} with its maximum observed under Presto (Table 17). Cut in March 2009 produced fresh biomass in the range of 10.95- 23.36 t ha^{-1} with its maximum observed under Karma and BDMT06SK. The slowest growing cultivars for the purpose of green fodder were Mikham and Suzen (~ 3 t ha^{-1}) in November cut and Konya2002 and Bagci (~11 t ha^{-1}) in March cut.

69. The findings indicate the potential of using some selected CIMMYT-ICARDA winter wheat cultivars (Presto, Karma and BDMT06SK) not only for grain production but also for green fodder as to improve livestock feed during period of a general feed scarcity.

70. The NDVI indices indicated the wide variations in early growth vigor of the winter wheat cultivars which is a proxy for successfully competing with weeds. This variability in early growth vigor can be utilized in development of dual purpose wheat to ease fodder situation during winter season in Central Asia.

Table 17. Fresh biomass and grain yields of 15 winter wheat cultivars at Tashkent Agrarian University site

Cultivar No	Variety	Fresh biomass in November, t ha^{-1}	Fresh biomass in March , t ha^{-1}
1	Kutluk	4.64	14.29
2	Suzen	3.36	12.82
3	Izgi	8.00	18.57
4	Atay	4.36	15.36
5	Yildiz	5.86	14.70
6	Karahan99	7.64	13.21
7	Bagci	3.57	11.07
8	Konya2002	7.86	10.95
9	Ahmetaga	6.93	15.32
10	Karma	5.86	23.27
11	Presto	12.14	12.14
12	Tatlicak97	6.07	12.14
13	Melez2001	4.64	14.96
14	Mikham2002	3.36	16.43
15	BDMT06SK	8.86	23.36

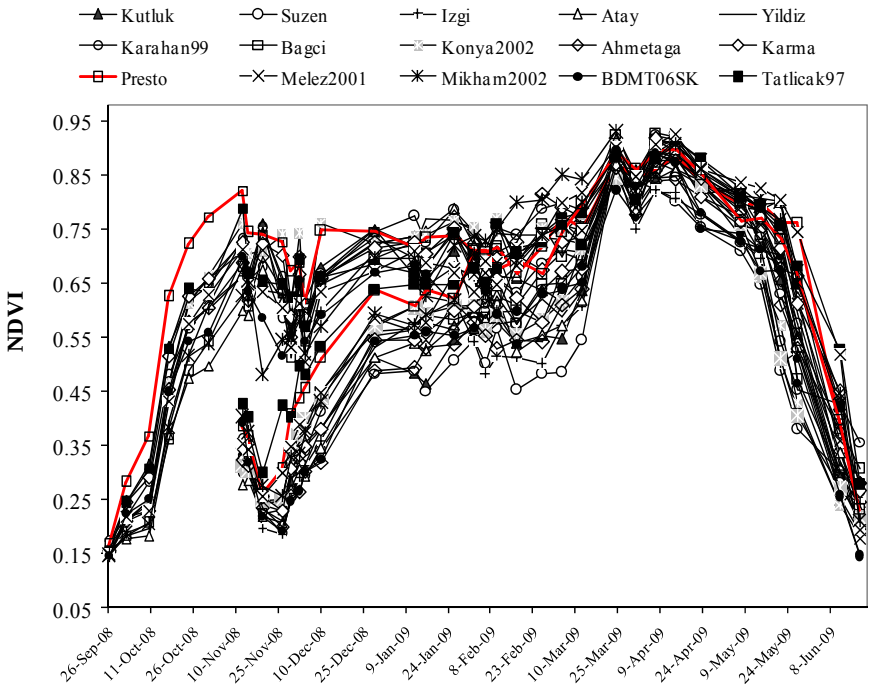


Figure 27. Dynamics of NDVI of winter wheat cultivars at TAU site, Uzbekistan

9.2.4.5 Effect of cutting of the dual purpose 15 CIMMYT-ICARDA cultivars on crop yields

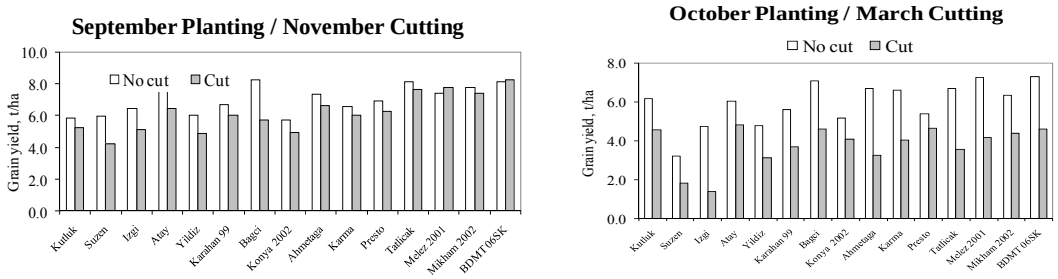
71. Using the NDVI measurements, cultivars were categorized into: (i) crop vigor at early and mid-season growth rates; (ii) maturity group – early and late; and (iii) yield potential. Results of the trials are given in Table 18. Cut of winter wheat in November did not affect in-season vigor of BDMT06SK, Tatlijak, Melez2001, Mikham2002 and Presto cultivars in mid-late season (F4-F7). These cultivars also produced a 10-28% higher dry biomass in comparison with uncut and without significantly yield losses (Table 18). The yields of Melez2001 and BDMT06SK under November cut was even a 2-5% higher in comparison with uncut. Cut in March did not affect in-season vigor of 12 wheat cultivars in mid-late season and even increased dry biomass of 9 cultivars by 15-33% over controls (uncut) (Table 18). In comparison with November cutting when crop yield reduction was only 4-30%, cutting in March reduced grain yields of all cultivars by 20-70% (Figure 29). Based on field results, four high yielding cultivars (Atay, Konya 2002, Presto and BDMT06SK) were identified as the most appropriate for dual purpose in October planting. Dry biomass of these cultivars was by 20-33% higher and grain yields were by 14-37% lower under cut (Table 18).

Table 18. Crop characterization and dry biomass (t ha^{-1}) of 15 CIMMYT-ICARDA winter wheat cultivars

Crop, cultivar	In-season vigor			Dry biomass		Grain yields of wheat,	
	Early (F1-F3)	Mid-late (F4-F7)	Maturity (F10-F11)	No cut	Cut in November / March[x]	No cut	Cut in November / March[x]
September planting							
Kutluk	F (M)	S (S)	M (M)	6.74	7.39 (+10) [xx]	5.86	5.24 (-11)
Suzen	M (S)	S (S)	E (E)	6.99	6.45 (-8)	5.98	4.22 (-29)
Izgi	M (S)	S (S)	E (E)	7.44	8.08 (+9)	6.42	5.10 (-21)
Atay	S (S)	M (S)	M (M)	9.15	8.80 (-4)	8.02	6.46 (-19)
Yildiz	S (M)	M (M)	E (M)	7.14	7.61 (+7)	6.05	4.87 (-20)
Karahan99	M (M)	F (M)	E (L)	7.84	8.53 (+9)	6.67	6.02 (-10)
Bagci	S (M)	M (M)	M (M)	9.48	8.26 (-13)	8.24	5.75 (-30)
Konya2002	M (M)	M (M)	E (E)	6.97	7.85 (+13)	5.73	4.93 (-14)
Ahmetaga	M (S)	F (M)	M (M)	8.64	8.08 (-7)	7.32	6.65 (-9)
Karma	F (M)	M (M)	M (M)	7.97	8.40 (+5)	6.59	6.01 (-9)
Presto	F (F)	M (F)	M (M)	8.34	9.29 (+11)	6.95	6.29 (-9)
Tatlicak97	M (F)	M (F)	M (L)	9.60	10.97 (+14)	8.14	7.65 (-6)
Melez2001	M (F)	M (F)	M (E)	8.69	10.53 (+21)	7.43	7.78 (+5)
Mikham2002	S (F)	F (F)	L (L)	8.98	9.91 (+10)	7.78	7.43 (-4)
BDMT06SK	M (M)	M (F)	E (E)	9.26	11.85 (+28)	8.11	8.25 (+2)
October planting							
Kutluk	F	F (M)	E (M)	7.10	8.14 (+15)	6.17	4.58 (-26)
Suzen	S	S (M)	E (M)	5.16	4.93 (-4)	3.22	1.83 (-43)
Izgi	M	M (S)	E (E)	5.63	5.58 (-1)	4.72	1.41 (-70)
Atay	S	S (S)	L (M)	6.71	8.88 (+32)	6.03	4.81 (-20)
Yildiz	M	S (S)	M (M)	5.74	6.74 (+17)	4.78	3.13 (-35)
Karahan99	M	S (M)	E (E)	6.67	8.17 (+22)	5.63	3.71 (-34)
Bagci	S	S (M)	M (M)	8.08	8.07 (-0.1)	7.09	4.62 (-35)
Konya2002	S	S (M)	E (E)	6.14	7.38 (+20)	5.18	4.08 (-21)
Ahmetaga	M	M (M)	E (E)	7.73	7.37 (-5)	6.70	3.24 (-52)
Karma	F	F (M)	M (M)	7.72	9.14 (+18)	6.63	4.04 (-39)
Presto	F	F (F)	M (M)	6.19	8.06 (+30)	5.38	4.64 (-14)
Tatlicak97	M	M (F)	L (M)	7.30	7.16 (-2)	6.70	3.58 (-47)
Melez2001	M	F (F)	L (L)	7.98	7.26 (-9)	7.25	4.16 (-43)
Mikham2002	S	F (F)	L (M)	7.10	8.35 (+18)	6.33	4.40 (-31)
BDMT06SK	F	M (M)	E (E)	8.08	10.73 (+33)	7.31	4.62 (-37)

[x] *Dry biomass in this column representl total sum of dry biomasses during cut in Nov (March) and harvest (June 2009)*

[xx] *Figures in parenthesis indicate percentage decrease (-) or increase (+) of dry biomass over control (no cut)*



(a) (b)

Figure 28. Effect of cutting of the dual purpose 15 CIMMYT-ICARDA winter wheat cultivars planted in September (a) and October on crop yields (b)

9.2.4.6 Evaluation of the Chickpea germplasm

72. During chickpea crop growing season (April-June 2008) NDVI dynamics of chickpea accessions, measured in a weekly base, demonstrated a wide range indicating strong differences in early growth vigor. Using the NDVI measurements, 36 cultivars were categorized into: (i) maturity group – early and late; (ii) crop vigor at early and mid-season growth rates and (iii) the yield potential monitored at crop maturity stage. Based on the field results on growth vigor, five high yield cultivars (yield > 3 t ha^{-1}) were identified (Table 19, Figure 29). The two chickpea cultivars (FLIP 03-63C, and FLIP 04-31C) belonged to early maturity group and the other three (3) were from the late maturity group (FLIP 01-50C, FLIP 04-18C and FLIP 04-35C).

Table 19. Crop characterization of 5 high yielding chickpea cultivars at Tashkent Agrarian University site (July 2008)

SNo.	Entry name	In-season vigor		Maturity group	Crop yield, t ha^{-1}
		Early	Mid		
6	FLIP 01-50C	M	F	L	3.35
13	FLIP 03-63C	M	F	E	3.30
26	FLIP 04-18C	M	F	L	3.00
27	FLIP 04-31C	S	F	E	3.46
30	FLIP 04-35C	M	M	L	3.19
Note = F-Fast, M-Moderate, S-Slow Maturity Group = (E-Early, L- Late)					

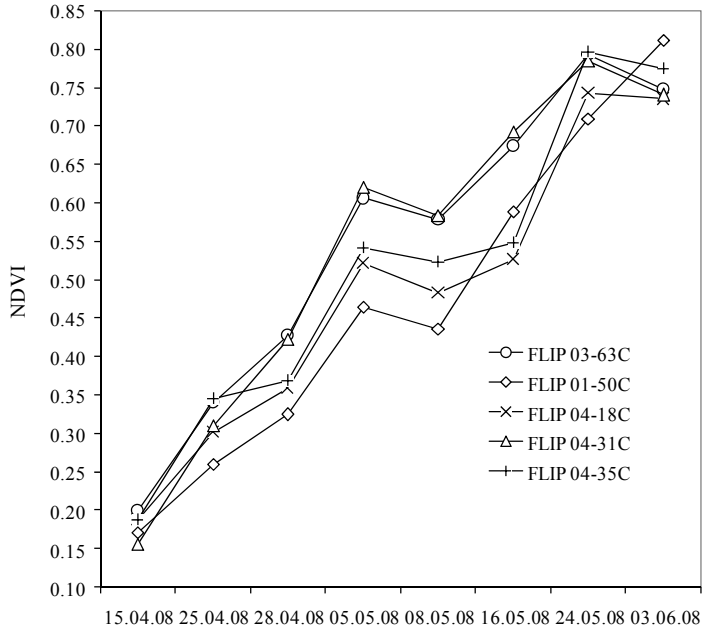


Figure 29. Typical NDVI measurements for specified chickpea accessions on different dates (2008)

73. Wide variations in NDVI indices were observed in mid-late and crop maturity stage so similar categorization was done in 5 high yielding varieties identified in July 2008 together with local (Uzbekistanskyi 32) variety. Results of crop categorization presented in Table 20. In 2009, the maximum chickpea yield (1.50 t ha^{-1}) was recorded in FLIP 04-35C variety, followed by Uzbekistanskyi32 (1.50 t ha^{-1}), FLIP 04-31C (1.28 t ha^{-1}), FLIP 04-18C (1.25 t ha^{-1}), FLIP 03-63C (1.01 t ha^{-1}) and FLIP 01-50C (0.58 t ha^{-1}) (Table 20, Figure 31). In the previous year (2008), the chickpea yield tend was in the order: FLIP 04-31C (3.46 t ha^{-1}) > FLIP 01-50C (3.35 t ha^{-1}) > FLIP 03-63C (3.30 t ha^{-1}) ≈ FLIP 04-35C (3.19 t ha^{-1}) > FLIP 04-18C (3.00 t ha^{-1}) > control = Uzbekistanskyi32 (2.26 t ha^{-1}).

Table 20. Crop characterization of 6 high yielding chickpea cultivars at Tashkent Agrarian University site (July 2009)

SNo.	Entry name	In-season vigor		Maturity group	Grain yield*, t ha^{-1}
		Early	Mid		
1	FLIP 01-50C	S	S	E	0.576±0.287
2	FLIP 03-63C	M	S	E	1.015±0.228
3	FLIP 04-18C	M	F	E	1.245±0.122
4	FLIP 04-31C	M	M	L	1.277±0.144
5	FLIP 04-35C	F	F	L	1.500±0.118
6	Uzbekistanskyi32	M	M	L	1.367±0.210
Note = F-Fast, M-Moderate, S-Slow Maturity Group = (E-Early, L- Late)					

**LSD=0.84 t ha^{-1} ± indicate standard error of mean*

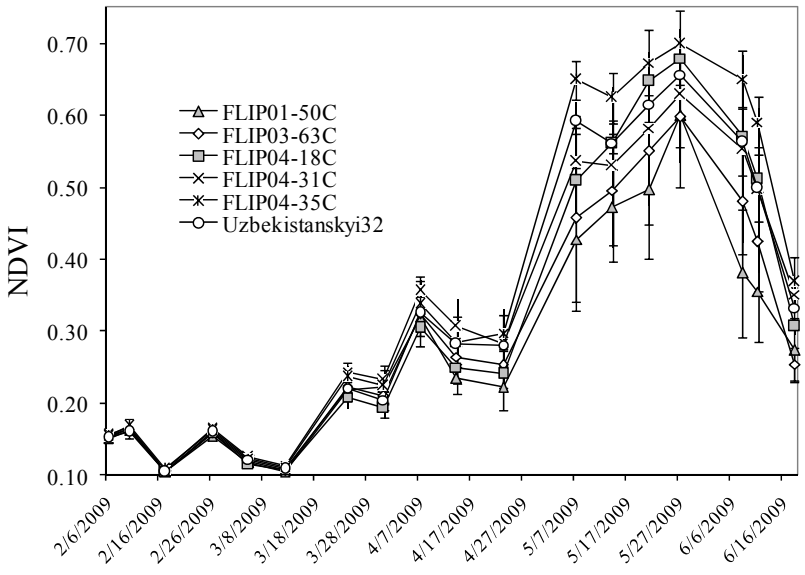


Figure 30. Typical NDVI measurements for specified chickpea accessions on different dates (2009)

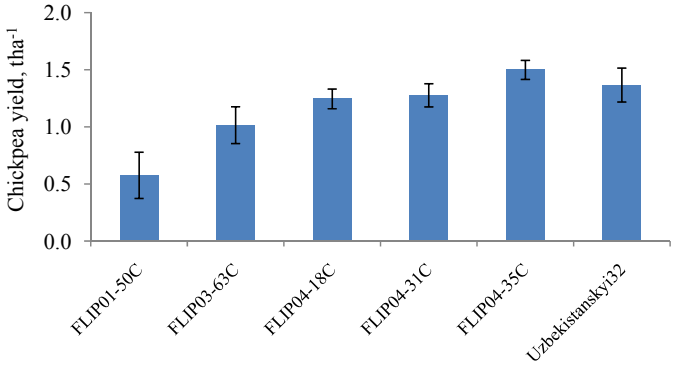


Figure 31. Effect of chickpea accessions on chickpea crop yield (2009)

74. Based on 2 chickpea crop season data we can make preliminary conclusion that FLIP 04-35C and Uzbekistanskyi32 are most suitable for fall planting whereas FLIP 04-31C and FLIP 01-50C are useful for spring season.

9.2.5 Conclusions

75. The findings indicate the potential of using Uzbek wheat, barley and triticale crops only for green fodder production but not for dual purposes since they produced highest fresh biomass (11.68-13.01 t ha^{-1}) during November and March cut while grain yields was less by 34-39% under November cut and less by 73-87% under March cut. There is need to repeat experiment with early cutting of wheat cultivars in spring season in order to reduce biomass losses.

76. High correlation (r=0.79) was found between NDVI at 44 days after emergence of local winter wheat, triticale and barley, whilst r=0.754 between biomass and NDVI at 34 days after emergence of 15 CIMMYT-ICARDA winter wheat cultivars. It gives possibility to identify optimum cutting time in relation to the fresh biomass during crop growing season.

77. The findings indicate the potential of using some selected CIMMYT-ICARDA winter wheat cultivars (Presto, Karma and BDMT06SK) not only for grain production but also for green fodder as to improve livestock feed during period of a general feed scarcity. Particularly, Presto is most suitable for September planting and November cutting whilst Karma and BDMT06SK for October planting and March cutting.

78. In comparison with November cutting when crop yield reduction was only 4-30%, cutting in March reduced grain yields of all cultivars by 20-70%. In view of dual purpose BDMT06SK, Tatlijak, Melez2001, Mikham2002 and Presto cultivars are most suitable cultivars for September planting since they produced a 10-28% higher dry biomass in comparison with uncut and yield losses were ≤ 9%. The grain yields of Melez2001 and BDMT06SK under November cut was even a 2-5% higher in comparison with uncut. Based on field results, four high yielding cultivars (Atay, Konya 2002, Presto and BDMT06SK) were identified as the most appropriate for dual purpose in October planting.

79. Based on 2 chickpea crop season data we can make preliminary conclusion that FLIP 04-35C and Uzbekistanskyi32 are most suitable for fall planting whereas FLIP 04-31C and FLIP 01-50C are useful for spring season. Results of earlier ICARDA screening trials had shown that productivity of the chickpea, planted in winter season is almost double of the spring season crop. But in our case yields of chickpea planted in November 2008 were almost two times lower of the spring season crop. Therefore there is need to repeat the same trial in fall-winter 2009 for cold and water stress tolerance to draw concrete recommendations.

10 Socio-economic analysis of policy, livelihoods and SLM options and their effect on land degradation

10.1 Review of literature on drivers of land degradation and their systemic interactions (Khusanov et al.)

Due to the length of the document, the full report is presented in the Final Report - Part III.

10.2 Livelihoods analysis at the benchmark sites: Survey results

10.2.1 Research questions

80. The basic hypothesis for this study is that land degradation may lead to increased vulnerability of farmers' livelihoods in Central Asia. However, farmers also have various coping strategies that affect their livelihood outcomes in a manner that reduces the vulnerability caused by land degradation. Therefore, the study's objective is to analyze the relationship between land degradation and rural livelihoods and to identify the coping strategies, both agronomic and socioeconomic, which farmers are adopting to reduce the negative impact of land degradation on their livelihoods.

81. The following research questions are posed:

- How land degradation impacts the livelihoods of farmers in the target areas?
- What coping strategies farmers are adopting and can adopt against land degradation? How successful are they? How and who can facilitate the success of these coping strategies?
- What actions and alternative policy and institutional options should be adopted to improve the livelihoods of farmers in the areas affected by land degradation and to ensure the sustainability of the resource base?

82. In total 299 Central Asian farmers were interviewed, i.e. around 30 at each research site. The detailed methodology of the survey was described in the first annual SLMR report 2008.

10.2.2 Results of the survey

10.2.2.1 Household assets

83. The absolute majority of farming households in the benchmark sites in each country are headed by males (Figure 32), with the average family size ranging between 5.6 persons in Kazakhstan to 3.7 persons in Turkmenistan (Figure 33). The average age of household heads is between 43-50 years (Table 21)

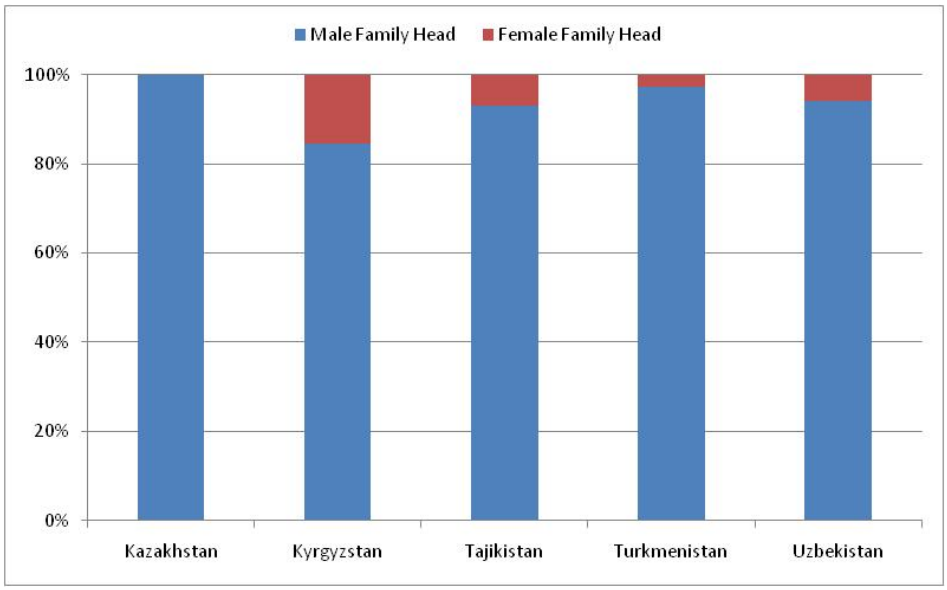


Figure 32. Gender of farming household heads

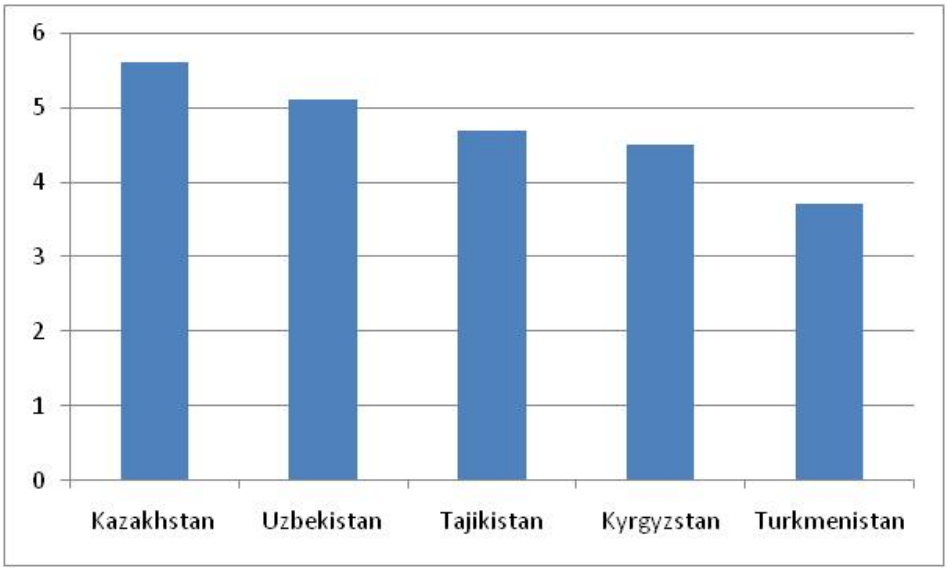


Figure 33. Average family size among the surveyed respondents in each country

Table 21. The average age of the surveyed farming household heads in the benchmark sites

Country	Average Age of Household Head	Standard Deviation
Kyrgyzstan	50	12.91
Kazakhstan	49	11.88
Tajikistan	49	11.89
Uzbekistan	46	10.27
Turkmenistan	43	10.43

84. The average age of all family members was between 30-37 years, but with age distribution differences in each country (Figure 34). In all the benchmark sites the share of males in the population was higher that the share of females (Table 22).

85. In terms of their marital status, 95.3% were married and living with their spouses, and 1.3% divorced, 2.3% widowed, and 1% never married, as a whole for all the countries.

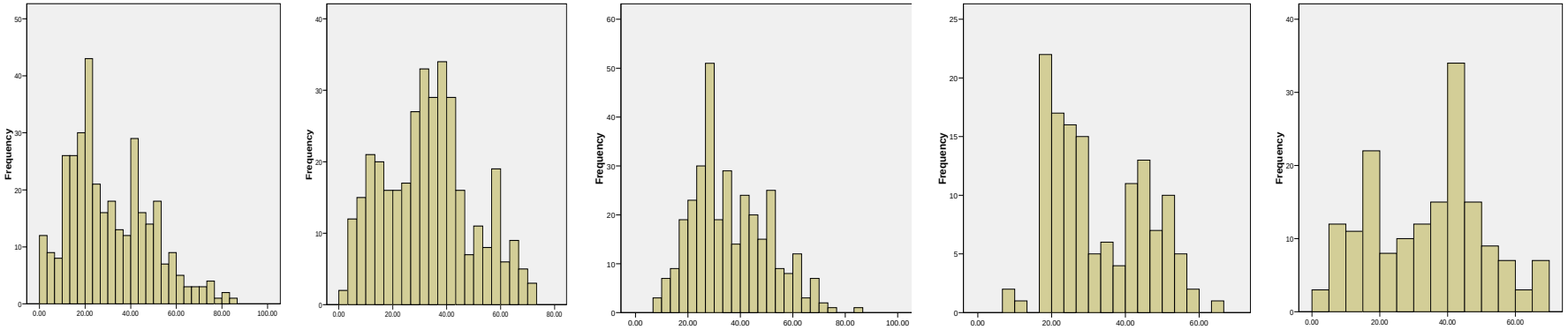


Figure 34. Age distribution of family members in the surveyed farming households in each country

Table 22. Share of males and females

Countries	Males	Females
Tajikistan	60%	40%
Uzbekistan	59%	41%
Kazakhstan	54%	46%
Turkmenistan	54%	46%
Kyrgyzstan	51%	49%

86. In all the countries, except Kyrgyzstan, farming was the main occupation of the majority of the household members, though with different proportions in each country (Table 23).

Table 23. Major employment sources of the surveyed households

Major employment categories	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Farming	54%	41%	88%	97%	56%
Public sector	12%	7%	6%	2%	4%
Non-farm private sector	14%	11%	2%	1%	20%
Other	21%	41%	5%	1%	20%

87. In terms of educational background, almost all of the surveyed farm heads have at least completed the school, while quite a large number of them have also university (bachelor) degree or some technical training (Table 24).

Table 24. The highest education level completed by the farming household head

Education type	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
School	13%	46%	60%	95%	35%
University - Bachelor degree	44%	16%	19%	0%	24%
University - Masters degree	0%	16%	7%	0%	6%
Technical training	43%	22%	14%	5%	35%

88. Of the total number of surveyed farmers in each country, 92% of farmers in Turkmenistan, 57% in Kazakhstan and 49% in Uzbekistan had previous jobs related to agriculture while in Tajikistan and Kyrgyzstan only 31% and 27%, respectively, had a previous professional experience directly in farming (Figure 35).

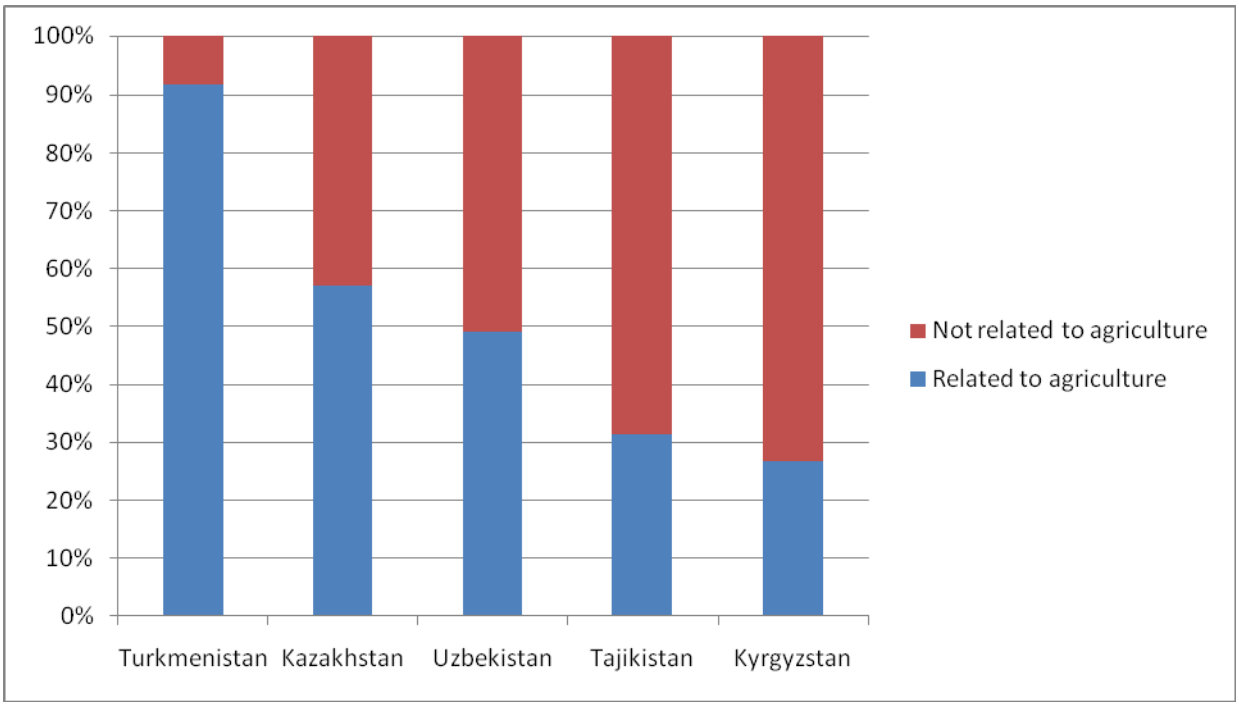


Figure 35. Professional experience before becoming farmer

10.2.2.2 Land Assets

89. All of the surveyed farming households were engaged in agricultural production during the last two seasons (i.e. 2006-2007 and 2007-2008). Farm sizes differed significantly between the countries and also between the two sites within each country (Table 25). The number of plots in each farming household were observed to be higher in the sites in Kazakhstan and Kyrgyzstan, and lower in the sites in Uzbekistan and Tajikistan (Figure 36).

Table 25. Farm sizes

Country	Site	Minimum	Maximum	Mean	St. Deviation
Kazakhstan	Shieli	4.0	1,267.0	116.4	221.2
	Abylai	25.0	3,950.0	632.4	801.1
Kyrgyzstan	Daniyar	0.1	120.0	11.0	21.4
	Kenenbay	0.3	24.9	3.7	6.1
Tajikistan	Faizabad	0.2	16.5	3.4	4.0
	Vaksh	1.0	27.0	4.3	4.8
Turkmenistan	Bugdayli	2.0	47.0	13.9	10.1
Uzbekistan	Syrdarya	10.0	57.8	26.8	13.7
	Kyzylkum	0.0	2.5	0.2	0.6

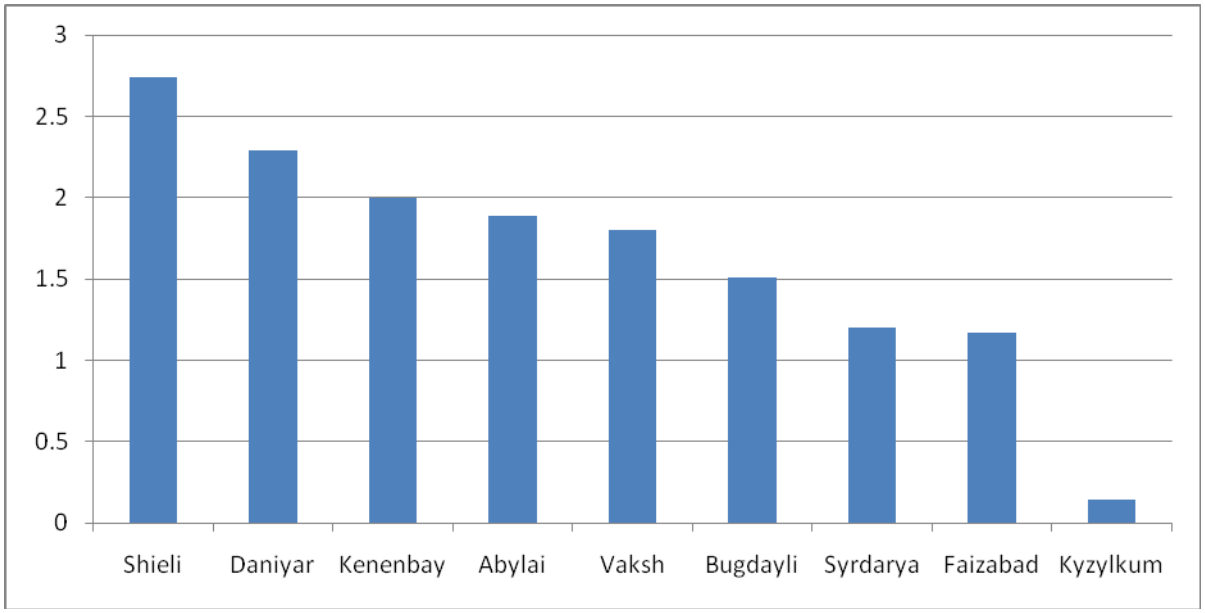


Figure 36. Average number of plots

90. During the winter season of 2007-2008, mainly annual crops were planted in all the sites, except in Abylai site in Kazakhstan, which is a pasture area, while in summer season 2008, perennial crops were also planted, mainly in Shieli site in Kazakhstan, while in others, only annual crops were mainly cropped in the summer season as well. The decision about the management of the plots is usually made by the farming household head.

Table 26. The share of irrigated and rainfed areas in the total number of plots and in the total area

Sites	**Of the total number of plots**		**Of the total area of plots (ha)**	
	Irrigated	Rainfed	Irrigated	Rainfed
Shieli	98%	2%	3,676	398
Daniyar	90%	10%	273	101
Kenenbay	61%	40%	128	33
Abylai	13%	87%	39	17,668*
Vaksh	100%	0%	151	0
Faizabad	46%	54%	16	103
Bugdayli	100%	0%	516	0
Syrdarya	100%	0%	803	0
Kyzylkum	100%	0%	5	0
Total			5,606	18,303

**pasture*

Table 27. Irrigation water sources

Sites	Area irrigated by (ha):		
	Well	Canal	Other
Shieli	0	3676	0
Daniyar	22	246	5
Kenenbay	0	126	2
Abylai	0	5	34
Vaksh	0	122	29
Faizabad	1	15	0
Bugdayli	0	516	0
Syrdarya	18	785	0
Kyzylkum	5	0	0
Total	46	5491	70

91. All the plots in the sites in Uzbekistan and Turkmenistan, as well as the Vakhsh site in Tajikistan are 100% irrigated, while in other sites the rainfed areas are quite important (Table 26). The irrigated areas are irrigated almost exclusively by the water taken from the irrigation canals (Table 27).

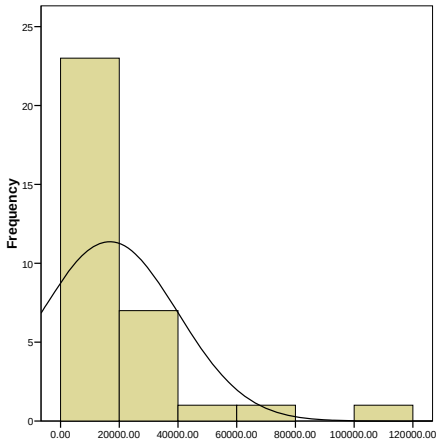
92. In terms of land tenure, almost all the surveyed farmers in Uzbekistan, Kazakhstan and Turkmenistan rented their lands from the respective Governments for specific time periods, while in Tajikistan, the land, in most of the cases, was rented from the Government without specific time period, i.e. for unlimited time, and only in a few cases for a specific time period. In Kyrgyzstan, absolute majority of the land was privately owned, with a few cases when it was rented from other farmers owning the land, or rented from the Government for specific time period. In all the countries, most or the entire household got their plots after the dismantlement of kolkhozes and sovkhozes. At the same time, quite an important share of households in Kyrgyzstan obtained some or all of the plots they own now by purchasing. In Kazakhstan and Kyrgyzstan, the farmers are able to use their land as collateral to obtain credits from financial institutions, while in Turkmenistan, Uzbekistan and Tajikistan they cannot. Farmers in all the countries, crop their lands themselves, with only a few cases of renting out or sharecropping, mainly in Kyrgyzstan and Kazakhstan. In Bugdayli site in Turkmenistan, the annual payment for leasing the land from the Government was 2,000 manats per ha (0.14 USD), in Vakhsh site in Tajikistan - 212 somoni per ha (~ 50 USD), in Kyrgyzstan renting in from the private owners and the Government, ranged from 600 somha-1 to 7,000 somha-1 som depending on the area (~ 15 – 175 USD); in Kazakhstan, both sites, from 30 to 250 tenge per ha (~ 0.3-1.8 USD) for renting in from the Government.

10.2.2.3 Income sources

93. The total income of the surveyed households in each benchmark site came from both agricultural and non-agricultural sources (Table 28). Although in some cases (especially Shieli and Daniyar), mean annual incomes are quite high, the analysis of the distribution of the income among the surveyed farmers shows that there are quite big inequalities (Figure 37)

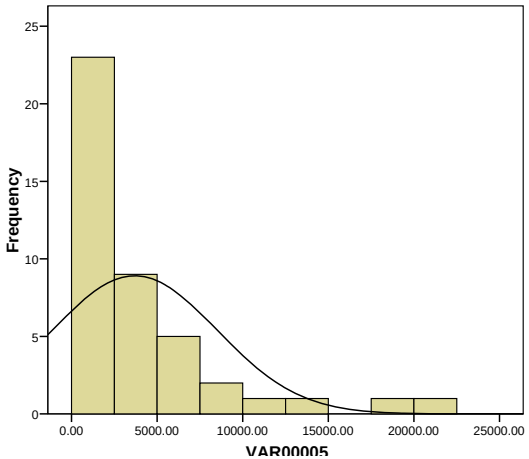
Table 28. Total income of surveyed households

Sites	Total annual income (USD)	
	Mean	St. Deviation
Shieli	42,733	145,966
Daniyar	16,709	23,164
Abylai	9,407	6,610
Kenenbay	3,689	4,814
Faizabad	9,266	7,021
Vaksh	5,415	6,277
Syrdarya	5,430	1,763
Bugdayli	3,137	2,084
Kyzylkum	707	359



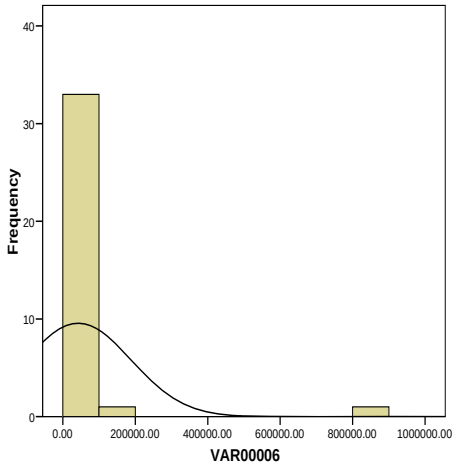
USD

Daniyar



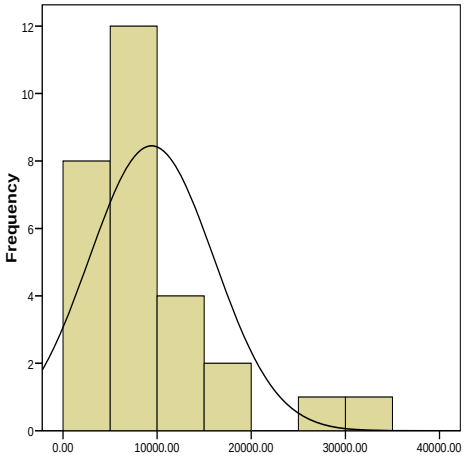
USD

Kenenbay



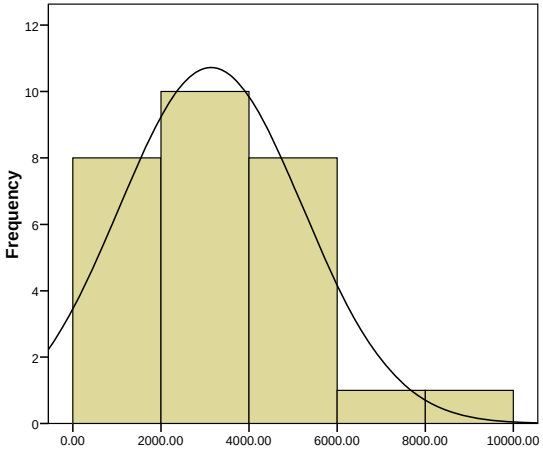
USD

Shieli



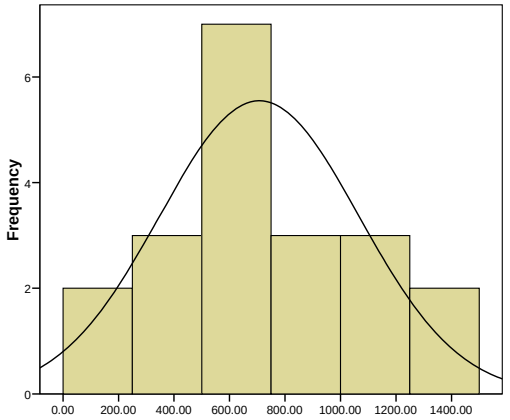
USD

Abylay



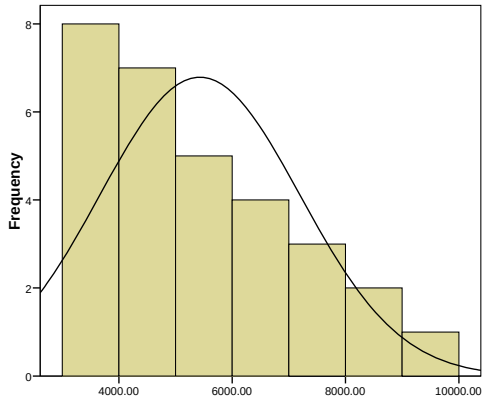
USD

Bugdaily



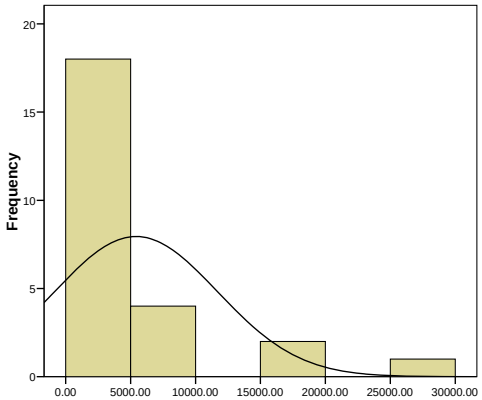
USD

Kyzylkum



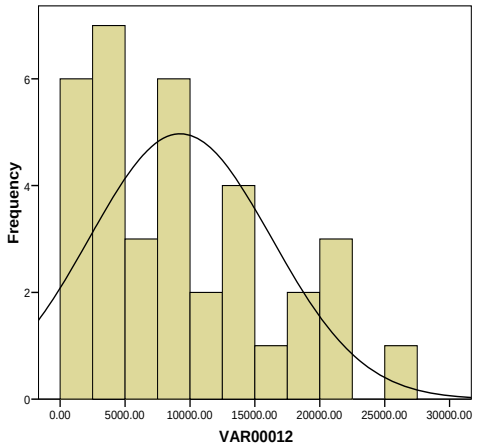
USD

Syrdarya



USD

Vakhsh



USD

Faizabad

Figure 37. Figure 11. Income distribution for the different research sites

94. The main source of income for all the sites, except Kyzylkum and Faizabad sites, were from agriculture (Table 29).

Table 29. Sources of income

Sites	Agricultural income	Off-farm income	Remittances from abroad	Total
Daniyar	72%	20%	8%	100%
Kenenbay	57%	43%	0%	100%
Shieli	96%	4%	0%	100%
Abylai	80%	20%	0%	100%
Faizabad	40%	39%	21%	99%
Vaksh	72%	23%	4%	99%
Bugdayli	87%	13%	0%	100%
Syrdarya	87%	12%	1%	100%
Kyzylkum	7%	93%	0%	100%

10.2.2.4 Livestock assets

95. Livestock represents an important source of livelihood assets in all of the surveyed sites. Main types of livestock owned by the households are cows, sheep, goats, camels and chicken (Table 31). The value of the livestock owned by the households is given in Table 32, while the average values of the livestock assets per households in each site are given in Table 30.

Table 30. Average values of the livestock assets per households

Sites	Average livestock assets per household, USD
Daniyar	2,751
Kenenbay	7,613
Shieli	5,731
Abylai	92,319
Bugdayli	1,612
Kyzylkum	2,674
Syrdarya	2,273
Vaksh	1,164
Faizabad	1,213

Table 31. The number of livestock

Sites	Cows	Bulls	Breeding Bulls	Horses	Donkeys	Sheep	Goats	Chicken	Ducks	Other Poultry	Camels
Daniyar	96	18		10	5	407	103	386	163	44	
Kenenbay	102	15		12	1	517		102		6	
Shieli	165	33		60		508	25	17			
Abylai	282	76		970		13,041	5				165
Bugdayli	113	32				327	257	489			3
Kyzylkum	30			13	3	298	237	70			39
Syrdarya	52	23		6	2	204	123	423	10		
Vaksh	63	22	12		5	79	3	145			
Faizabad	83	18		1		144	178	217	10	23	

Table 32. The total value of livestock assets by type of livestock (at the beginning of 2008)

Sites	Cows	Bulls	Breeding Bulls	Horses	Donkeys	Sheep	Goats	Chicken	Ducks	Other Poultry	Camels
Daniyar	42,474	4,842		8,579	274	30,018	4,995	1,390	511	468	
Kenenbay	76,026	7,447		12,763	53	230,553		458		39	
Shieli	78,840	14,352		58,720		47,328	1,248	96			
Abylai	134,400	34,720		932,880		1,244,800	280				237,840
Bugdayli	59,571	22				15	16	2			1
Kyzylkum	5,693			6,286	171	14,893	8,546	589			22,643
Syrdarya	27,607	11,478		4,450	143	15,514	6,736	2,204	50		
Vaksh	29,111	4,819	1,167		167	5,091	11	363			
Faizabad	23,333	3,653		417		6,386	5,580	2,883	42	161	

Table 33. Net difference in livestock dynamics at the end of 2008 as compared to the beginning of 2008

Indicators	Cows	Bulls	Breeding Bulls	Horses	Donkeys	Sheep	Goats	Chicken	Ducks	Other Poultry	Camels
Daniyar	1	-7	0	-15	-8	-98	-18	153	17	122	0
Kenenbay	3	-32	0	4	0	-1	0	-15	0	-3	0
Shieli	57	-9	0	2	0	203	10	0	0	0	0
Abylai	154	-21	0	173	0	5,656	0	0	0	0	20
Bugdayli	1	-3	0	0	32	22	-133	-209	0	0	-1
Kyzylkum	5	0	0	0	1	115	107	-1	0	0	2
Syrdarya	-22	-19	0	-3	-2	-119	-49	-298	-12	0	0
Vakhsh	-12	-1	0	0	16	-24	3	-44	0	0	0
Faizabad	9	-4	0	0	2	-17	-32	-67	12	4	6

96. The amount of funds the households have spent on feed varies greatly among the sites (Table 34). Both own production and procurement of feed from the market is important in Daniyar and Kenenbay sites. In Shieli and Abylai sites, farmers produce most of the animal feed themselves, or especially in case of Abylai site, fodder comes from the pasture. In Kyzylkum and Bugdayli sites, pastures were also indicated to be an important source of fodder. If some own production exists in Bugdayli site, in addition to procurement in the market and animal grazing in the pastures, in Kyzylkum and Syrdarya sites, there is virtually no own production of fodders was reported, fodder being bought from the market or coming from the pastures. In Vakhsh site in Tajikistan, both own production and market procurement are equally important sources of feed, while in Faizabad site in Tajikistan, farmers mainly procure the fodder from the market.

Table 34. Average feed expenditures compared with average livestock assets per household

Sites	Average livestock assets per household, USD	Average livestock feed spending per household, USD
Daniyar	2,751	1,178
Kenenbay	7,613	784
Shieli	5,731	37
Abylai	92,319	157
Bugdayli	1,612	32
Kyzylkum	2,674	748
Syrdarya	2,273	593
Vaksh	1,164	347
Faizabad	1,213	303

97. Households in most of the sites also sell animal products. In Daniyar and Kenebay sites, households sold mainly milk and meat, while in Shieli, Kenebay and Kyzylkum sites, households have not reported selling any animal by-products, except in three households (cow milk, mutton, sheep and goat skin). In Bugdayli site, cow milk was the major product sold, while in Syrdarya site meat was the major product sold. If in Vaksh site households sold mainly cow milk, in Faizabad site the products sold were, sheep and goat meat, and cow milk. Out of the nine sites, only in Daniyar, Kenenbay, Syrdarya, and Faizabad sites, selling animal by-products was a considerable livelihood activity (Figure 38), while in other sites, the households do not sell the animal by-products, or it is a quite a marginal activity.

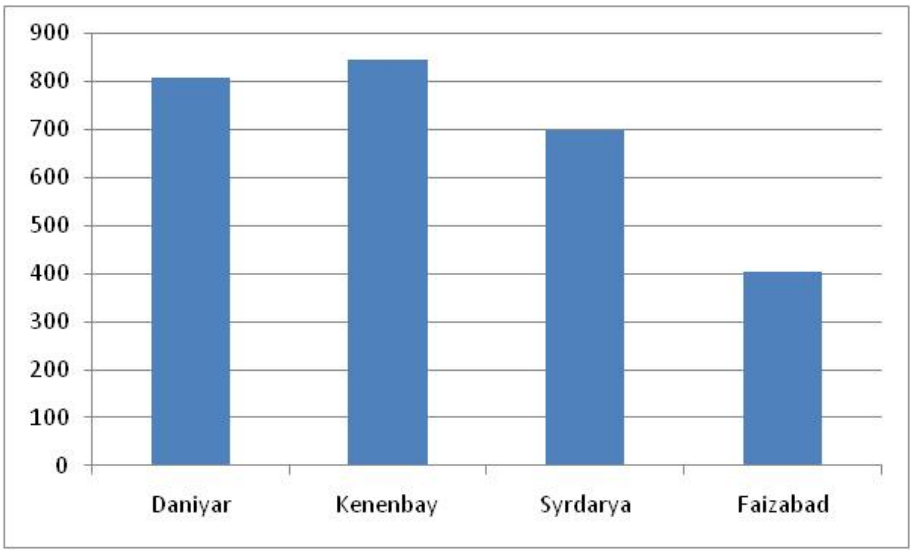


**Figure 38. Average value of animal by products sold per household, in USD **

10.2.2.5 Machinery assets

98. Machinery ownership is, overall, quite low. In Daniyar, Kenenbay, Kyzylkum, Bugdayli, Faizabad and Vakhsh sites, most of the farmers, except a very few, do not own any machinery. For example, in Daniyar and Kenenbay sites only three respondent farmers in each site own some machinery, similarly in Bugdayli, Vakhsh and Kyzylkum sites only two respondent farmers in each site. Machinery ownership was relatively higher in Shieli, Abylai, and Syrdarya sites (Table 35)

Table 35. Individual machinery ownership in selected sites

Machinery items	Shieli	Abylai	Syrdarya
Large tractor	39	50	3
Small tractor	0	0	19
Planter	7	6	24
Plow or harrower	27	29	24
Combine machine	11	1	0
Harvester	9	20	0
Leveler	4	0	6
Total machinery value per household, USD	10,433	13,093	5,940

99. Joint machinery ownership together with other households was reported only by respondents in Daniyar, Kyzylkum, Syrdarya and Faizabad sites. Among these sites, only in Syrdarya site joint machinery ownership is significant (Table 36), while in others this concerns only a very few households and the number of machinery owned jointly is quite low.

Table 36. Machinery items owned jointly with other farmers by the respondents at Syrdarya site

Machinery items	Syrdarya
Large tractor	18
Small tractor	11
Planter	6
Plow or harrower	4
Combine machine	12
Harvester	19
Leveler	20

100. Surveyed farmers in Shieli and Abylai sites do not rent out their machinery, probably because since other farmers also have their own machinery there is no demand for this. Renting out is actively practiced by the farmers in Syrdarya site and by those owning machinery in Faizabad site, earning in total as a group, 31,500 USD and 19,320 USD, respectively. The surveyed farmers in Syrdarya and Faizabad sites also spend a significant amount of funds on machinery repairs and maintenance, 17,175 USD and 8,550 USD, which points at the obsoleteness of the machinery assets they own.

101. Households in most of the sites also spent significant amounts of funds for renting in the machinery (Table 37).

Table 37. Machinery repair and maintenance expenditures

Sites	Payments for renting in machinery, USD
Daniyar	26,391
Kenenbay	23,804
Shieli	96,082
Abylai	0
Bugdayli	0
Kyzylkum	168
Syrdarya	16,044
Vaksh	19,574
Faizabad	13,888

10.2.2.6 Land degradation

102. Bigger share of the farmers in the benchmark sites have indicated that their yields are declining because of land degradation, except in Bugdayli, Abylai and Kyzylkum sites (Figure 39).

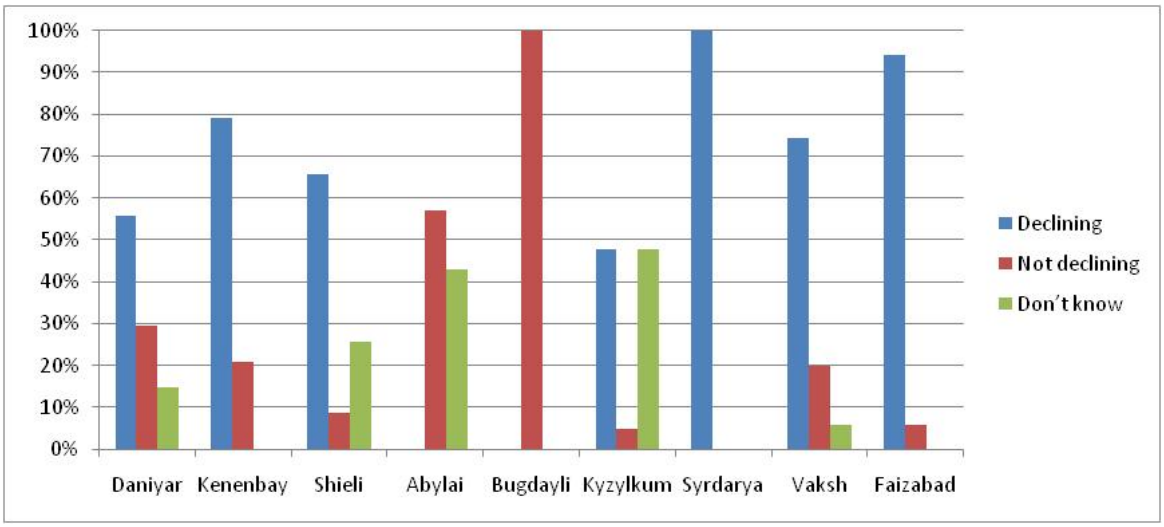


Figure 39. Perceived impact of land degradation on yields

103. Only in Bugdayli site, all of the farmers indicated that their yields are not declining, and in Abylai site 57% indicated that the yields are declining while the remaining said they don't know. In Kyzylkum site, the share of those who said yields to be declining and those who don't know was 48% each, while the remaining 4% said the yields are not declining. The following reasons were indicated for yield declines (Table 38). In this questions the respondents were given the option to choose among the options suitable for their circumstances such as 1) use more input to produce the same yield, corresponding to soil fertility decline or shallow soils, 2) lower yields in some years = late planting, 3) crop does not respond until fertilizers are applied in higher doses = nutrient fixation problems, 4) poor crop vigor and stunted growth = nutrient imbalances and salinity. Analyzing the indications of the farmers on the land degradation in their fields, major land degradation types in each site were identified (Table 39).

Table 38. Reasons for yield decline

Sites	Soil fertility decline or shallow soils	Late planting	Nutrient fixation problems	Nutrient imbalances and salinity	I do not know
Daniyar	33%	33%	33%	13%	7%
Kenenbay	4%	49%	6%	41%	0%
Shieli	13%	52%	8%	25%	2%
Abylai	-	-	-	-	-
Bugdayli	-	-	-	-	-
Kyzylkum	0%	37%	0%	32%	32%
Syrdarya	0%	100%	0%	0%	0%
Vaksh	24%	43%	12%	18%	4%
Faizabad	31%	30%	10%	30%	0%

Table 39. Major land degradation types in each site

Sites	Water erosion	Sodicity	Compaction, chemical deterioration	Soil moisture storage and chemical degradation	Poor quality of irrigation water/ use of drainage water	Poor soil fertility and salinity	High water table	Stoniness
Daniyar	3%	15%	21%	13%	8%	18%	18%	5%
Kenenbay	13%	2%	5%	0%	9%	31%	22%	18%
Shieli	15%	27%	14%	1%	34%	2%	5%	0%
Abylai	-	-	-	-	-	-	-	-
Bugdayli	-	-	-	-	-	-	-	-
Kyzylkum	0%	0%	0%	0%	19%	33%	48%	0%
Syrdarya	0%	0%	0%	0%	1%	0%	0%	0%
Vaksh	13%	17%	13%	15%	16%	11%	9%	6%
Faizabad	20%	4%	10%	12%	8%	15%	16%	16%

104. The farmers were also asked to indicate if they had problems with soil salinity in their fields. From the farmers responses it appeared that salinity is not a major problem in Abylai, Bugdayli, Kenenbay and Daniyar sites, while it is an important problem in the remaining five sites (Figure 40)

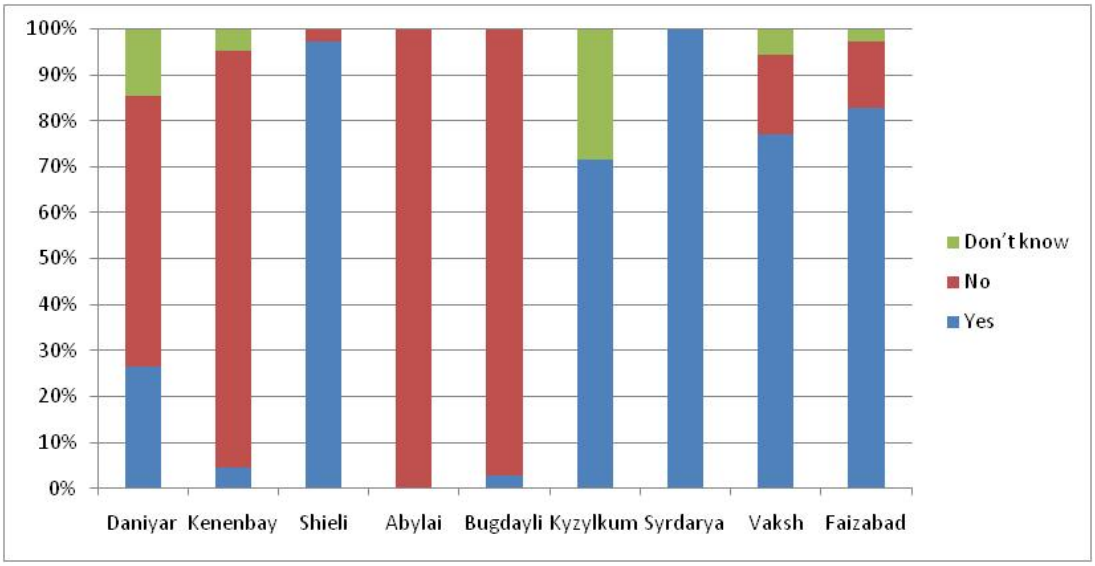


Figure 40. Soil salinity in the benchmark sites

105. The farmers were then asked why they think their lands are saline and given the options to choose from. Their responses were then analyzed as shown in Figure 41. The analysis showed that there maybe problems other then salinity that farmers understand as salinity effect.

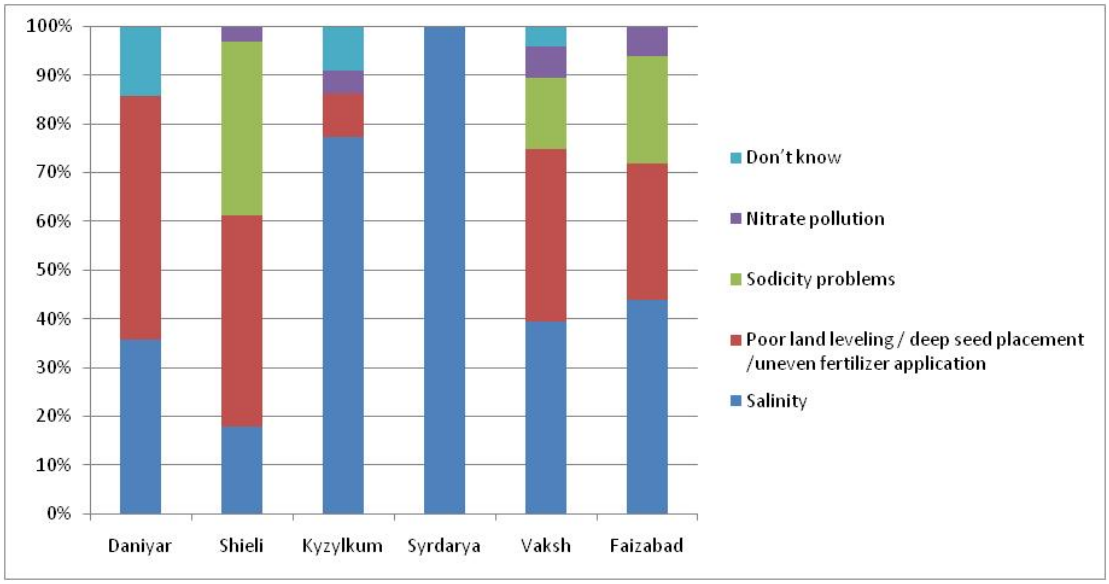


Figure 41. The farmers' misconceptions on salinity and possible other land degradation problems in the sites

106. The farmers were also asked about degradation problems in the rangelands. Among the surveyed farmers the private rangeland ownership is observed widely only in Abylai,

Kazakhstan (all respondents have private rangelands) and in Faizabad, Tajikistan (16 respondents have private rangelands). In other sites in Tajikistan, Kyrgyzstan and Kazakhstan, the private rangeland ownership is rare. In Uzbekistan and Turkmenistan, the farmers do not have rangelands in private property. The quality of rangelands were evaluated by farmers as follows, Figure 42:

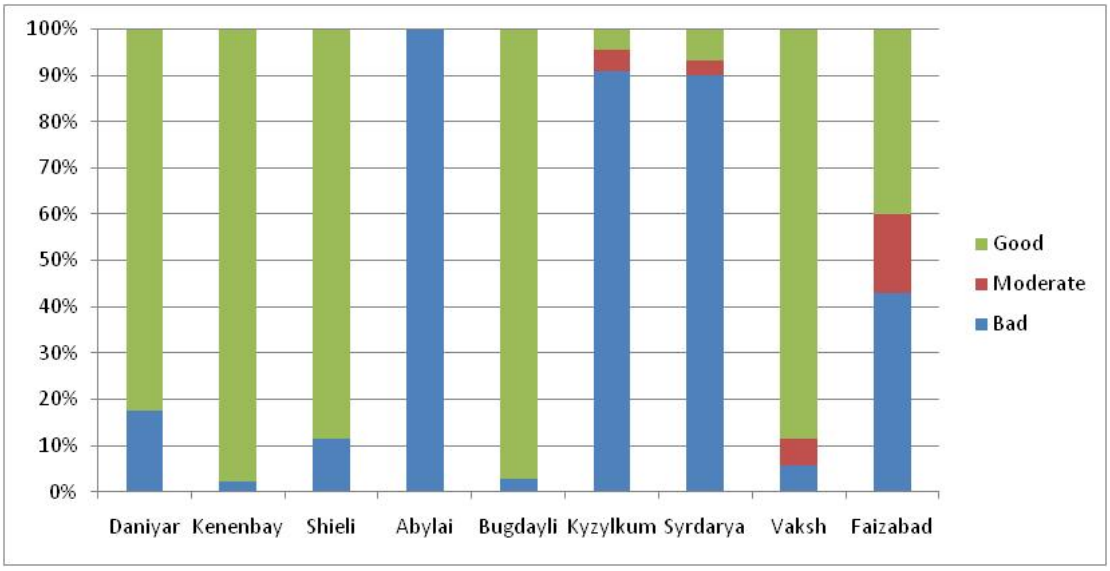


Figure 42. Rangeland quality

107. The farmers in all the sites, except Bugdayli site, indicated that most of their croplands are degraded to different degrees (Figure 43, for rangeland conditions of the Abylai site cf. Figure 42).

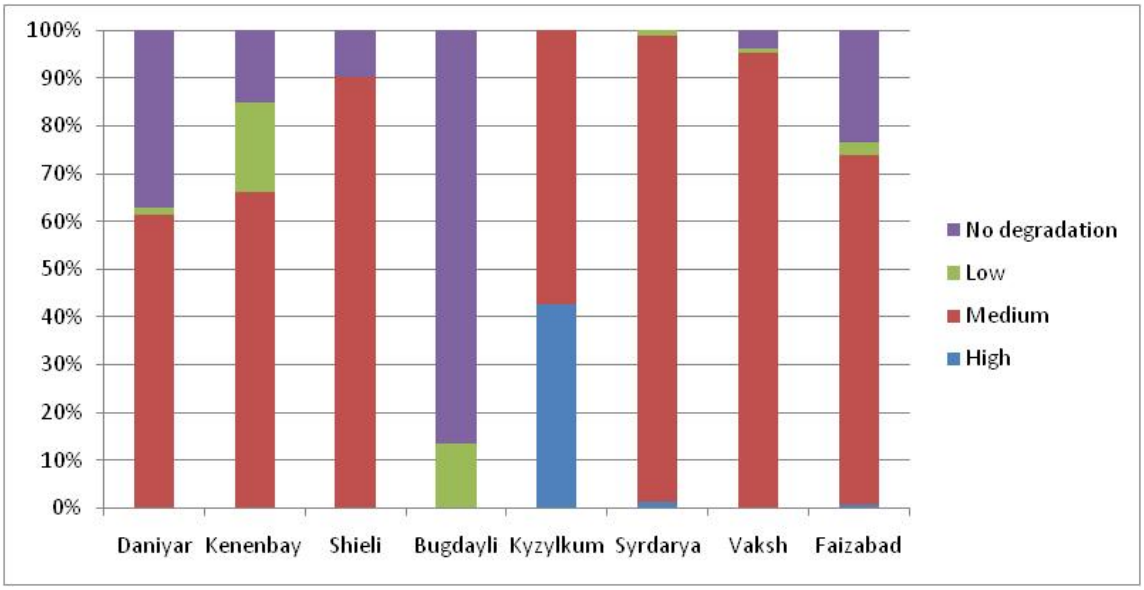


Figure 43. The farmers' perceptions on land degradation in their fields

108. The majority of the farmers also indicated that the quality of leveling in their plots was less than good, and some cases, in fact, very poor (Figure 44)

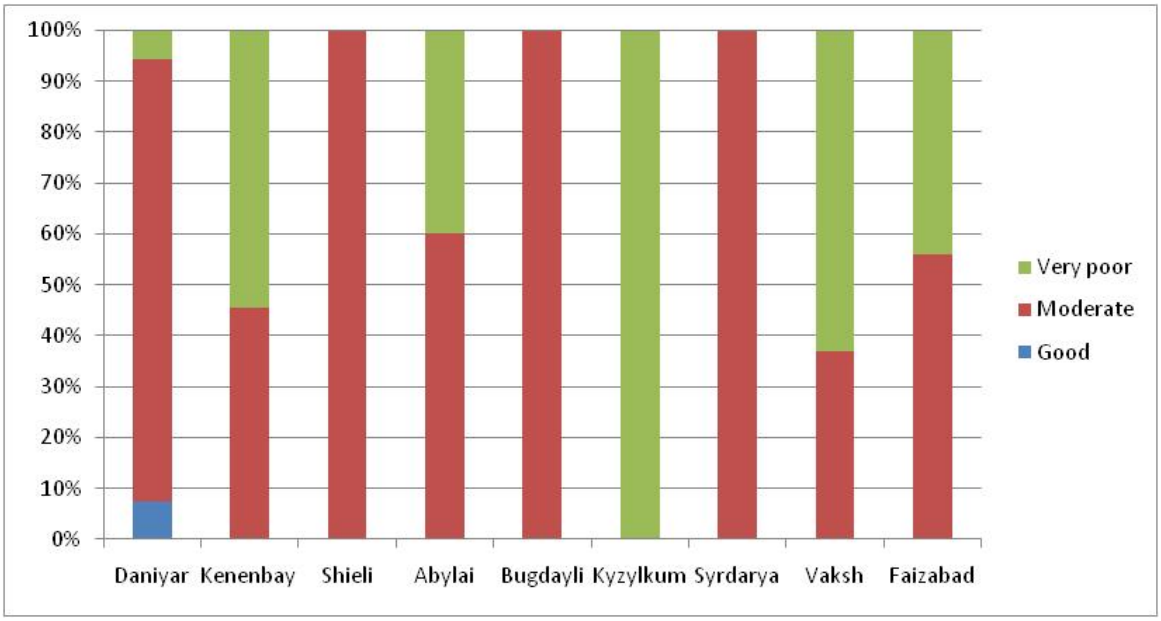


Figure 44. The quality of land leveling

109. Farmers in Uzbekistan (Syrdarya site) and Tajikistan (both sites) have reported that their cropping areas decreased as a result of land degradation in 2008 as compared to 2007, on average by 2.88 ha in the Syrdarya site, or when looked at the absolute values almost 11% of their total land holdings, on avarega by 0.2 ha in Vakhs site (similarly, 4.4% of the total land holdings), and on average by 0.1 ha in Faizabad site (3.1% of the total land holdings). The farmers in the other sites, with few exceptions in Daniyar site in Kyrgyzstan, have not reported decreases in cropping area due to land degradation between 2007 and 2008.

110. Land degradation was also not reported to cause crop yield decreases in the sites in Kazakhstan, Turkmenistan, and in Kyzylkum site in Uzbekistan (Abylai and Kyzylkum sites are specialized in livestock production), while in the sites in Kyrgyzstan, Tajikistan and Syrdarya site in Uzbekistan, many of the farmers reported the land degradation caused some crop declines in their farms (Table 40).

Table 40. Declines in crtop yields due to land degradation

Crops/Sites	Daniyar	Kenenbay	Syrdarya	Vaksh	Faizabad
Wheat	0.38	0.88	0.40	0.18	0.19
Cotton	-	-	0.30	0.18	-
Maize	0.85	-	-	0.13	0.11
Barley	0.24	1.02	-	-	-

111. When asked how their living standards have change this year as compare to the previous years, majority of the farmers have reported that there was no change, however, the life standards were reported to have deteriorated by the majority of the farmers in Faizabad and Kenenbay sites (Figure 45).

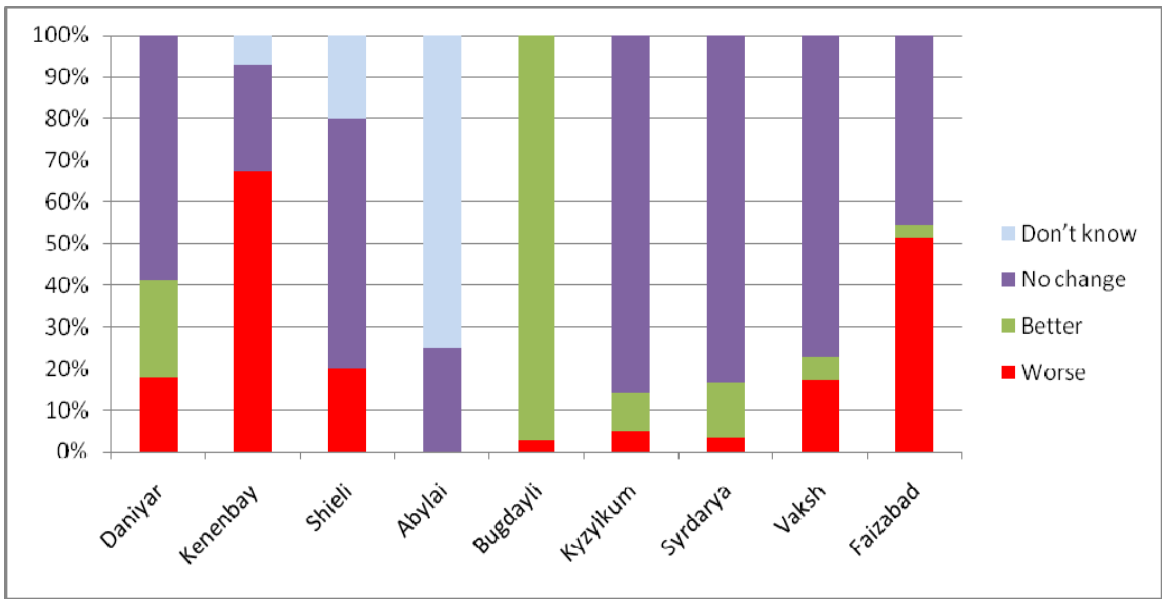


Figure 45. Change in livelihoods in 2008 as compared to 2007

112. If in Kenebay site, the major reasons for deterioration of life standards were indicated to be lower hartvests, high input prices and unemployment, in the Faizabad site, the major reasons for lower life standards were indicated to be lower soil fertility, higher input prices, and water shortages.

113. In response to land degradation, considerable or all of the farmers in some of the sites such as Syrdarya and Kenebay have changed their livelihood strategies, while in other sites the majortiy of the farmers did not (or could not) change their livelihoods strategies (Figure 46). The main coping strategies for farmers in Kenenbay and Syrdarya sites were strating new non-farm activities (66% and 60%, respectively), and/or planting of new crops better adapted to land cnditions (29% and 40%, respectively).

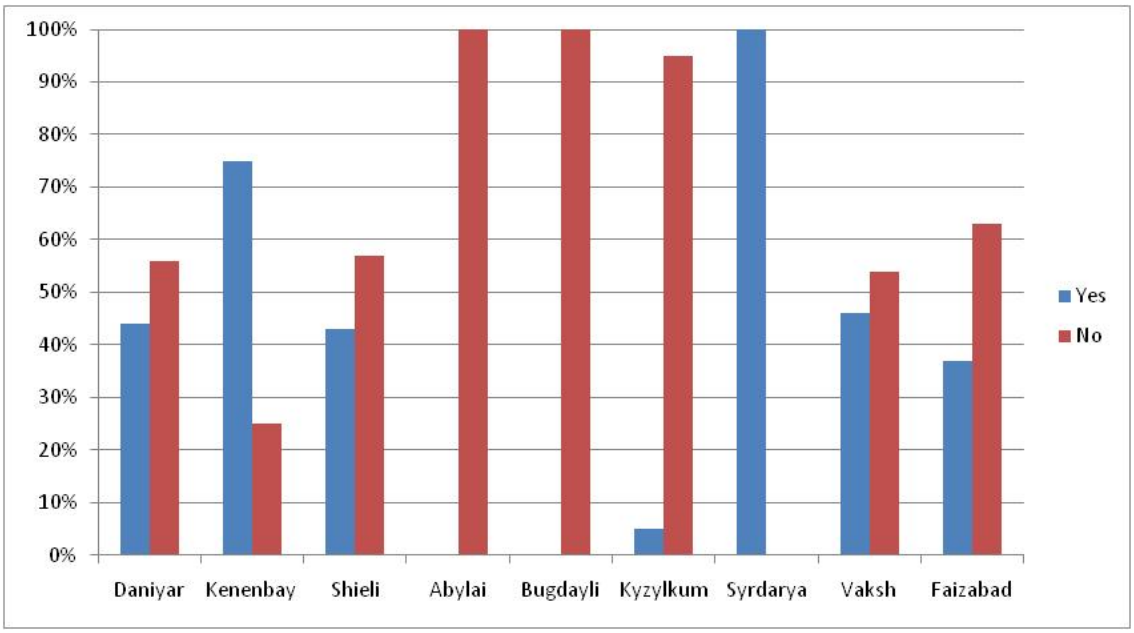


Figure 46. Change in livelihoods strategies as response to land degradation

10.2.2.7 Land management practices

114. The analysis of the survey responses showed that in spite of awareness of land degradation problems in their fields, majority of the farmers do not use good practices for land degradation management. It was found that only farmers in Bugdayli and Syrdarya sites usually use such land and crop management practices as land leveling, leaching, application of chemical and organic fertilizers, interrow cultivation, etc (Table 41). In other sites, these practices are used by very few farmers. The knowledge of farmers about crop management practices, as perceived by themselves, is also quite different from one site to another (Table 42). The farmers in Bugdayli, Syrdarya, Kyzylkum and Daniyar sites indicated that low labor requirements were the most important criteria for adoption of a new technology for them, while farmers in Kenebay site – the yield benefits are the most important criterion, for farmers in Faizabad and Vaksh – easiness and simplicity. For farmers in Shieli site – efficiency in controlling the land degradation is the most important element for adopting a new technology. Interestingly, although low initial investments were an important criterion for a new technology, it was not the most important criterion in none of the sites (Figure 47)

Table 41. Percentage of respondents using the indicated land and crop management practices in each site

Management practices/Sites		Daniyar	Kenenbay	Shieli	Abylai	Bugdayli	Kyzylkum	Syrdarya	Vaksh	Faizabad
Leaching	WS 07-08	6%	0	0	0	0	0	100%	0	0
	SS 08	6%	0	0	0	0	0	93%	3%	0
Cleaning drainage	WS 07-09	9%	0	3%	0	5%	0	0	6%	0
	SS 09	15%	0	29%	0	16%	0	0	3%	3%
Crop rotation	WS 07-09	15%	0	0	0	0	0	0	9%	0
	SS 09	35%	2%	3%	0	0%	0	3%	6%	0
Land leveling	WS 07-09	24%	0	0	0	78%	0	100%	6%	3%
	SS 09	32%	0%	23%	0	76%	0	93%	3%	3%
Interrow cultivation	WS 07-09	3%	0	0	0	68%	0	100%	0	0
	SS 09	15%	2%	0	0	0	0	93%	0	0
Integrated pest management	WS 07-09	3%	0	0	0	0	0	100%	0	0
	SS 09	6%	0%	0	0	76%	0	90%	3%	3%
Chemical fertilizer application	WS 07-08	15%	0	0	0	78%	0	100%	3%	3%
	SS 08	35%	5%	7%	0	72%	0	93%	0%	0
Manure application	WS 07-08	21%	0	0	0	11%	0	100%	0	0
	SS 08	26%	0	0	0	69%	0	93%	6%	6%

Table 42. Farmers' perceptions about their knowledge of land and crop management practices

Sites and indicators	Leaching	Land leveling	Fertilizer application	Water saving technologies	Crop rotations with legumes	Inter-row planting	IPM	Use of organic fertilizers	Orchards and forestry
Daniyar									
Unaware	68%	32%	33%	76%	58%	70%	82%	50%	79%
Somewhat aware	26%	24%	20%	12%	18%	24%	15%	15%	15%
Aware	6%	44%	47%	12%	24%	6%	3%	35%	6%
Kenenbay									
Unaware	86%	76%	18%	84%	76%	86%	86%	18%	76%
Somewhat aware	7%	5%	12%	9%	12%	2%	5%	49%	5%
Aware	7%	19%	70%	7%	12%	12%	9%	33%	19%
Shieli									
Unaware	0%	0%	0%	2%	5%	5%	5%	2%	5%
Somewhat aware	91%	91%	91%	89%	86%	86%	86%	89%	86%
Aware	9%	9%	9%	9%	9%	9%	9%	9%	9%
Kaptagay									
Unaware	3%	0%	0%	0%	0%	0%	0%	0%	0%
Somewhat aware	97%	100%	100%	100%	100%	100%	100%	100%	100%
Aware	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bugdaily									
Unaware	0%	0%	0%	0%	0%	0%	0%	0%	0%
Somewhat aware	0%	0%	0%	100%	0%	0%	0%	0%	95%
Aware	100%	100%	100%	0%	100%	100%	100%	100%	5%
Kyzylkum									
Unaware	100%	100%	100%	100%	95%	100%	100%	100%	100%

Somewhat aware	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aware	0%	0%	0%	0%	5%	0%	0%	0%	0%
Syrdarya									
Unaware	27%	27%	27%	27%	100%	27%	53%	27%	100%
Somewhat aware	73%	73%	73%	73%	0%	73%	47%	73%	0%
Aware	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vakhsh									
Unaware	0%	0%	0%	40%	3%	28%	48%	3%	23%
Somewhat aware	3%	3%	11%	14%	40%	43%	29%	17%	37%
Aware	97%	97%	89%	46%	57%	29%	23%	80%	40%
Faizabad									
Unaware	12%	11%	17%	57%	6%	28%	57%	3%	11%
Somewhat aware	0%	6%	3%	20%	54%	23%	9%	31%	23%
Aware	88%	83%	80%	23%	40%	49%	34%	66%	66%

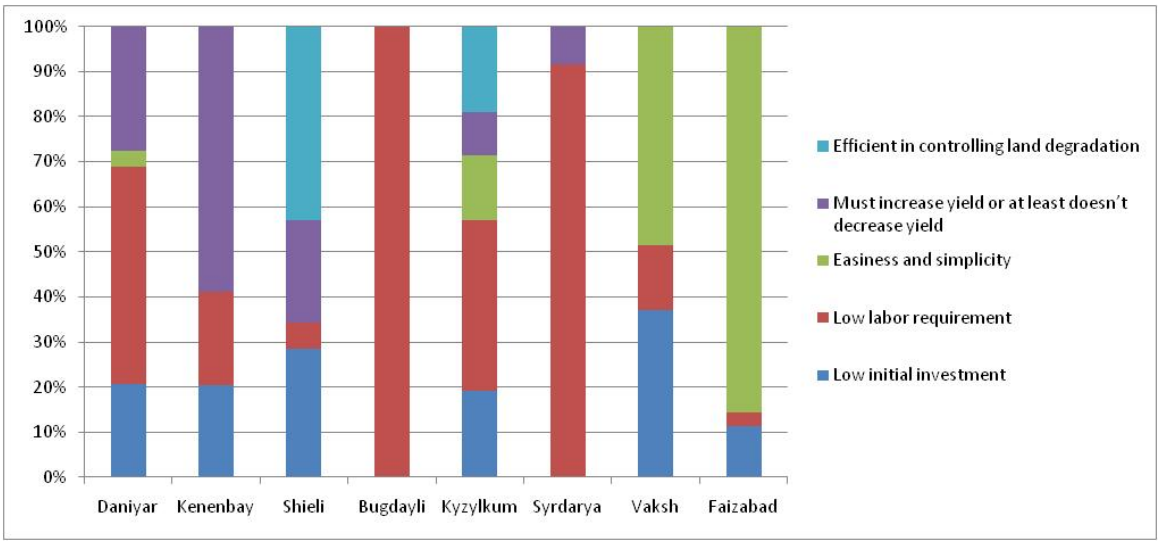


Figure 47. The most important criterion for adoption of a new technology

Note: Abylai site is omitted because very low number of responses was given for this question

10.2.2.8 Cropping activities

115. The number of crops cultivated by the farmers during the winter season 2007-2008 was not very great. In fact, farmers in Kyzylkum and Kenebay sites did not grow winter crops at all, while in other sites, the major crops grown were winter wheat, maize and barley (Figure 48).

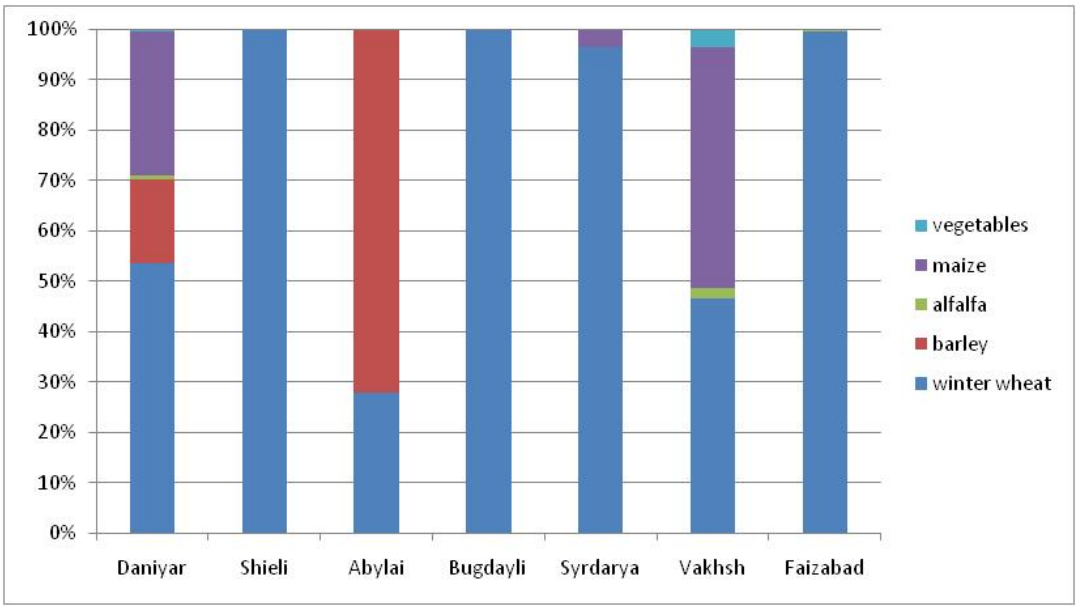


Figure 48. Composition of crops grown in winter season 2007-2008 (by area)

116. Although the number of crops grown increased during the summer season, especially in Daniyar, Kenenbay, and Shieli sites, however, in all other sites except these three sites the cropping was dominated by one crop (Figure 49).

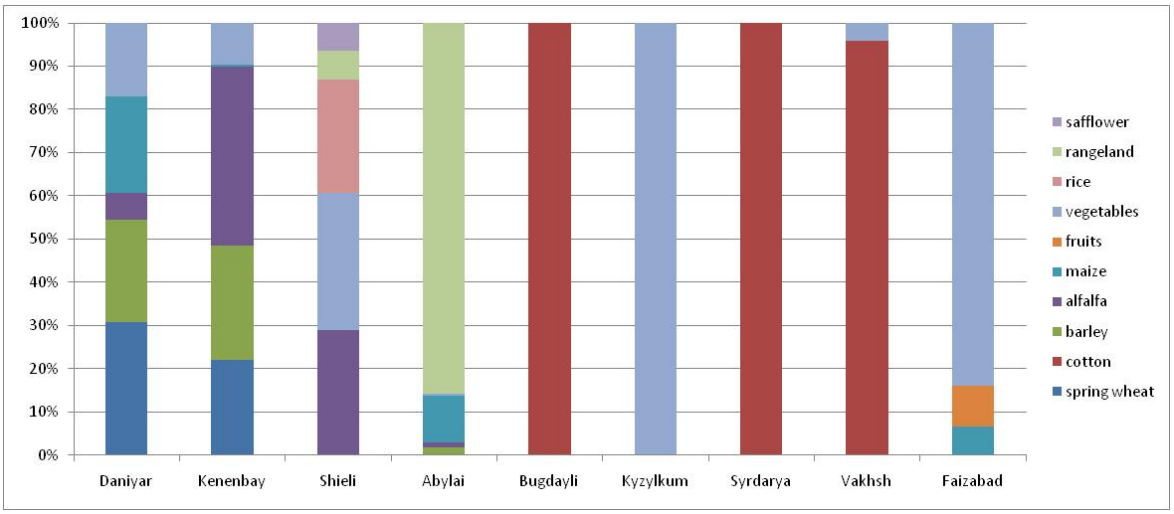


Figure 49. Composition of crops grown in winter season 2007-2008 (by area)

Note: vegetables here also include potato, melons and watermelons

10.2.2.9 Collective action

117. The participation of farmers in institutions of collective action is, overall, quite small. Only the farmers in Syrdarya site were all members of both the Water Users' Association (WUA) and of Farmers association (Figure 50). None of the farmers in Kyzylkum and Bugdayli sites indicated that they are members of either WUA or Farmers Association.

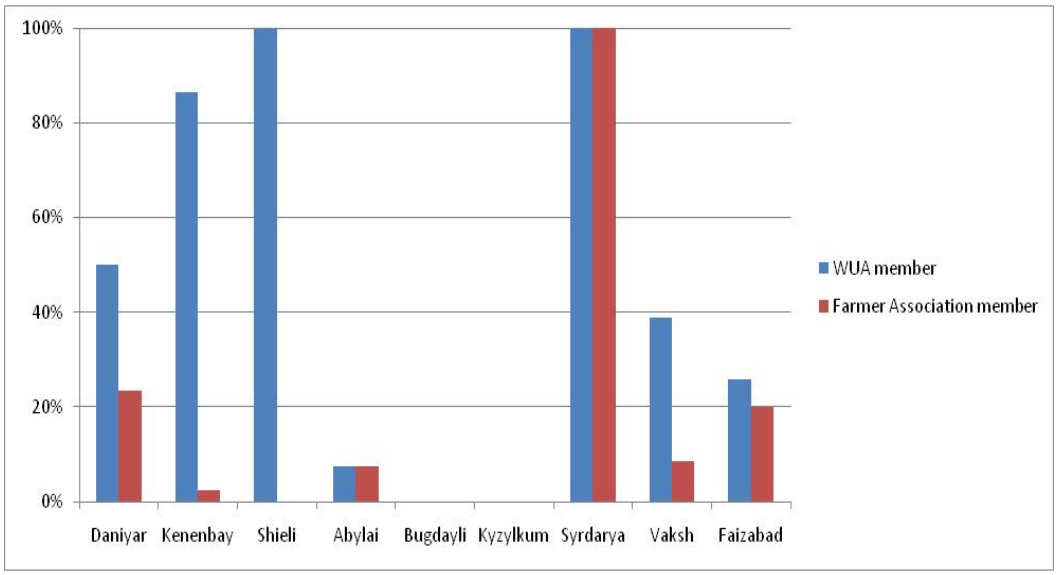


Figure 50. Participation in WUAs and Farmer Associations

118. All of the farmers in Syrdarya site indicated that the performance of the WUAs and Farmer Associations is satisfactory, while the evaluation of the performance of these two institutions was not so clear-cut in the other sites where they existed (Table 43)

Table 43. Evaluation of the performance of WUAs and Farmers associations by surveyed farmers

Sites	WUA performance			Farmer Association performance		
	Satisfactory	Not satisfactory	Don't know	Satisfactory	Not satisfactory	Don't know
Daniyar	24%	27%	48%	21%	12%	67%
Kenenbay	17%	73%	10%	5%	7%	88%
Shieli	0%	100%	0%	0%	3%	97%
Abylai	0%	7%	93%	0%	0%	100%
Syrdarya	100%	0%	0%	100%	0%	0%
Vaksh	36%	27%	36%	0%	16%	84%
Faizabad	0%	40%	60%	17%	37%	46%

119. Majority of farmers in Daniyar, Kenenbay, Faizabad and Syrdarya sites are willing to contribute to collective action by farmers against land degradation, either by cash or by in-kind contribution, while in Shieli and Abylai sites, majority didn't express the desire to contribute to collective action (Figure 51)

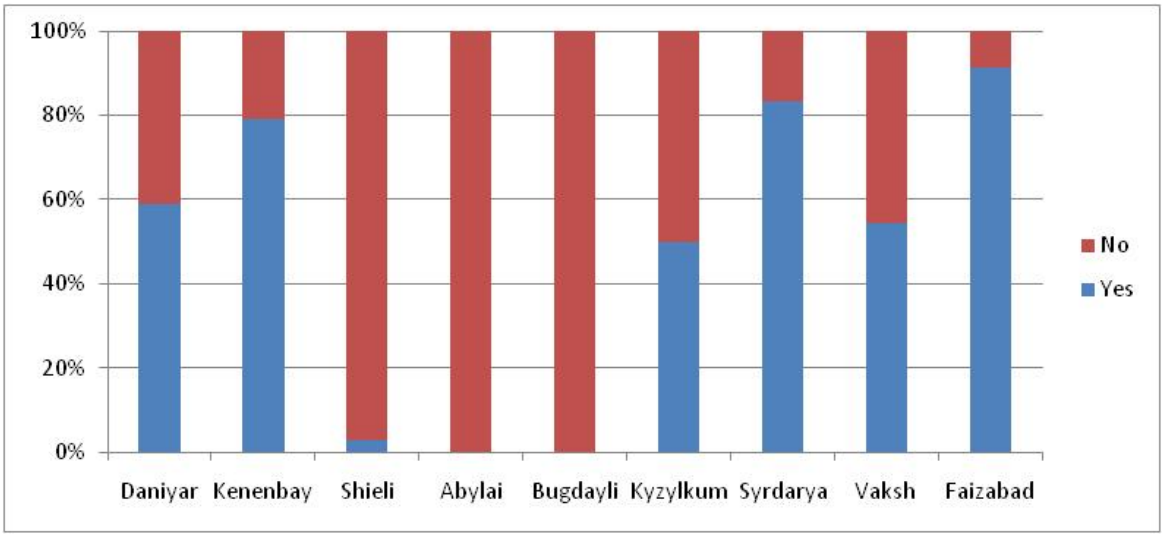


Figure 51. Willingness to contribute to collective action against land degradation

10.2.3 Conclusions and Recommendations

120. Almost twenty years have passed since the independence of the Central Asia countries and the beginning of market- oriented reforms in the region. Although there are still many similarities one can probably find, at the first glance, among the agricultural sectors in these countries, however, the livelihoods survey conducted within this project has also clearly

demonstrated the differences and diversity of socioeconomic and institutional factors that now affect the farming systems in the region as well as the status and dynamics of land degradation.

121. Among the household characteristics, one similarity among the benchmark sites is in dominance of males as farm heads. Although this fact is easily explained by cultural traditions in the region, it may also may lead to judgment error of equating it with male dominance in the agricultural work per se, which is, in fact, now, for most of the farming operations, is mainly done by women in the irrigated systems in the region. Having said this, it is also necessary to understand that decisions on farming operations are still made mainly by male household heads. This situation requires a fine analytical work for devising targeted extension and technology dissemination activities, but also for developing new agricultural technologies. The technology dissemination also should take into account that many of the farmers are relatively new to farming and previously had other professions.

122. While although the perceptions of farmers in different sites are different on the level of land degradation and its dynamics, most of the farmers surveyed have indicated that land degradation is increasing in their plots, leading to yield declines and consequently lower incomes. However, it was found that in spite of awareness of land degradation problems in their fields, majority of the farmers do not use good practices for land degradation management, such as mulching, reduced tillage, etc. The knowledge of farmers about these crop management practices is also uneven. Lower labor requirement and increased crop yields were cited as the key requirement for adopting new technologies by the surveyed farmers. Interestingly, although low initial investments were an important criterion for a new technology, it was not the most important criterion in none of the sites.

123. Technological advancement in agriculture leads to more efficiency in production, which usually translates into less labor requirements. From the other side, land degradation also "releases" labor from agriculture either because of less land available or because the available but degraded land cannot provide with sufficient crop yields and incomes to the growing farming population. Although the technologies successfully dealing with land degradation can help keep the employment in the agricultural sector in the short-run, in the long-term the need for labor transfers from agriculture to other sectors would probably prevail. As we have seen from the survey results, non-farm activities represented an important source of employment in some of the areas, while in some others they were insignificant. There is a need for further detailed studies to identify whether it is because of more/less severe land degradation or because of the (non)-availability of other employment opportunities, but what is clear, the issues of agricultural development and land degradation should always be looked at from an economy-wide perspective, not least since, for example, factors causing land degradation could be originating from other sectors of the economy. For our purposes here we would like to underline the need for enabling policies that facilitate and promote non-farm activities in the

rural areas, both as a coping strategy against land degradation - alternative source of income- which can also be used, for example, to adopt and implement measures against land degradation.

124. It is now widely acknowledged that farmers are usually not profit-maximizers but risk-minimizers. Although widely acknowledged, this thinking has not yet led to dramatic shifts in agricultural technology development where profit/yield maximization purposes still prevail. However, the growing climate variability in the region will increasingly put forward demands for agricultural technologies that perform in stable manner under various adverse conditions. In this regard, crop diversification is one of the highly effective measures to cope with various weather, yield and output price fluctuations. Not least importantly, diversified cropping systems also contribute tremendously to sustainable land management. The survey results showed that there is significant field for development in the region in terms of crop diversification. Those farmers practicing diversified cropping systems were able to better cope with land degradation challenges. Of course, in some other cases, the Governments have been able to minimize risks by subsidy programs in short and medium terms, but in view of competing demands for scarce budgetary resources, promoting crop diversification instead of subsidizing mono-cropping seems to be a more optimal strategy in the long-run.

125. Livestock production is also an important income diversification strategy, but not less importantly it is also a flexibly investment mechanism that provides the farmers in the irrigated areas of the region with reliably source of capital for on-farm operations and investments, including in SLM. In addition, livestock ownership is important source of farming household' capacity to resist and be resilient against external shocks, such as droughts or crop failures. However, one of the key problems across the region is the fodder availability for livestock, especially during harsh winter periods when there is little natural vegetation. Therefore, there is a need for increased fodder production (through crop diversification in the irrigated areas and increasing the productivity of vegetation in rangelands) and more efficient livestock production strategies.

126. Our survey results have not indicated to a strong link between land tenure and the level of land degradation in the specific sites. However, one important point that we would like to underscore is the need for farmers to be able to access to credit facilities, and this not only in terms of currently existing public or private-funded pre-financing of cropping operations, but also in terms of access to long-term, preferably below market rate credit opportunities for investing into efficient and sustainable agricultural technologies and farm infrastructure that enable sustainable land management. Subsidized credits for SLM make even more sense in those areas where land is public property and there are various State crop quota arrangements.

127. Machinery ownership or/and easy access to affordable machinery rental services is an important aspect for timely and quality farm operations. In this regard, the survey pointed out to important deficiencies in the region in terms of the very low machinery assets of farmers. There

is a need for policies that encourage the further dissemination of leasing opportunities for farmers for the procurement of new machinery at affordable prices.

128. The participation of farmers in institutions of collective action is, overall, quite small. Majority of farmers in irrigated sites where the farm sizes are smaller are willing to contribute to collective action by farmers themselves against land degradation, either by cash or by in-kind contribution, while in rangeland areas and irrigated sites with bigger land areas, most of the farmers didn't express the desire to contribute to collective action.

11 Summary of analyses and achievements by research topic

129. In the Central Asian countries, sustainable livelihoods for the population are rooted in agriculture which contributes from 6 to 45 % of GDP and employs up to 50% of the population. A priority was thus to increase agricultural productivity and focus on all pathways out of poverty and improved income generation. In the following chapter, some representative aspects of the research project results and achievements are presented which have not yet been discussed in this report *Part I*. The full report for each country is given in *Part II* of the final SLMR report.

11.1 Climate, land use and land degradation

130. Ecologically, the region of Central Asia is very heterogeneous. The climate is extremely continental with very cold temperatures in winter and very hot temperatures in summer (Figure 52): The mean annual temperature in February can reach around -20°C in the North of Kazakhstan and up to +5°C in the South of Turkmenistan. In July, the regions in northern Kazakhstan warm up to around 15°C, while in the South of Central Asia, the temperatures can reach on average 35°C.

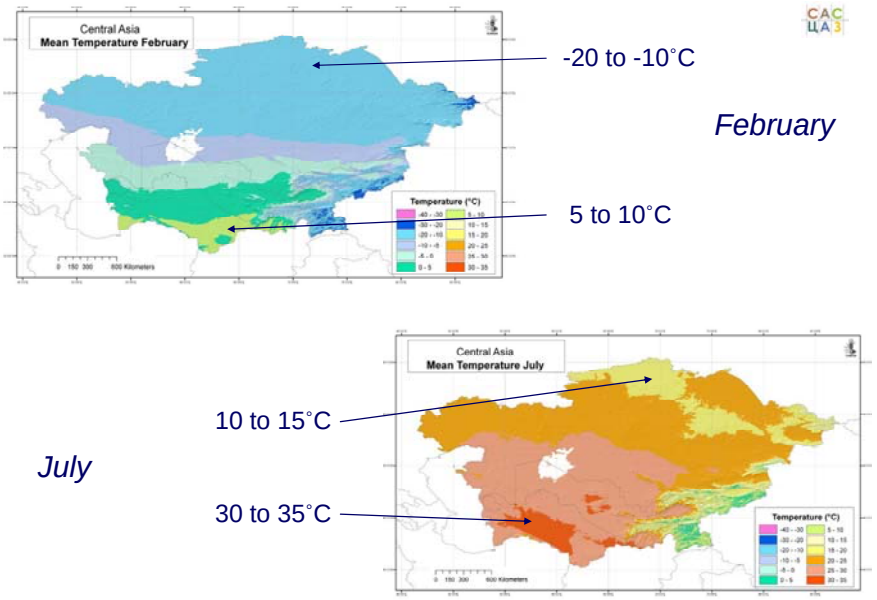


Figure 52. Mean annual temperature in Central Asia in February and July. Source: de Pauw 2008

131. Furthermore, the Central Asian region is coined by low amounts of precipitation and a very variably distribution of the annual rainfall in general (Figure 53). The annual precipitation fluctuates from around 300-400 mm in northern Kazakshtan to only 100 mm in large parts of Turkmenistan, Uzbekistan and the South of Kazakhstan. The mountain regions of the Pamir and Tien-Shan on the other hand receive far more (800-1000 mm on average). Accordingly, the

plant growth period is very much governed by the water availability. While in the North the growth period is between 210-240 days, in the South (Uzbekistan, Turkmenistan, parts of Tajikistan and Kazakhstan) the growth period is highly water-limited. Without additional irrigation, the growth period would be only 30-60 days.

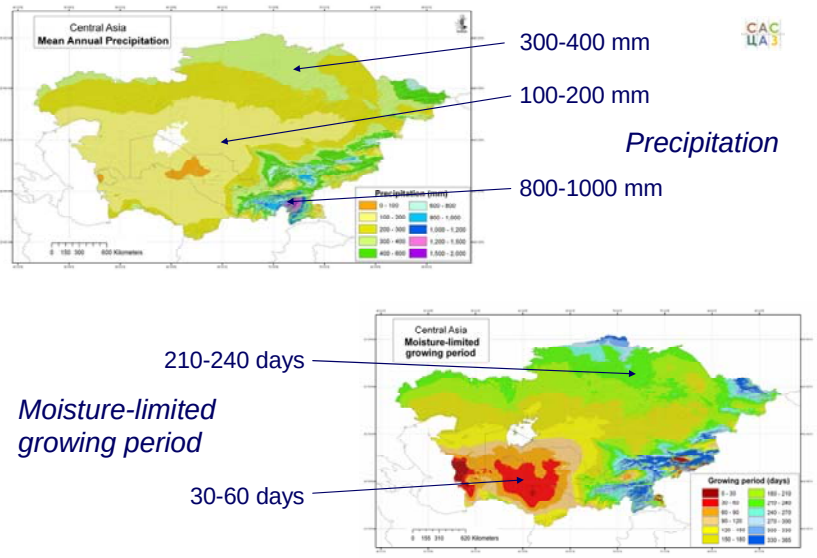


Figure 53. Mean annual precipitation and moisture limited growing period in Central Asia. Source: de Pauw 2008

132. The land use in Central Asia corresponds to the above-described climatic setting. Agro-ecologically, the Central Asian region can be grouped into four main zones: the irrigated areas, the rainfed areas (mainly in northern Kazakhstan and in the mountain regions of Kyrgyzstan and Tajikistan), rangeland and pastures, and small-scale agriculture in the mountain regions (see also Figure 54 and Figure 55) (de Pauw 2007). The large share of the irrigated agricultural land is irrigated with water from the rivers Syr Darya and Amu Darya (10 million ha); in Turkmenistan the entire agricultural area is being irrigated, in Uzbekistan, Kyrgyzstan and Tajikistan, the area comprises around 75% (Bucknall et al 2003).

Figure 54. Four main agro-ecological zones in Central Asia: irrigated areas (top left), rainfed areas (top right), rangeland and pastures (bottom left) and mountain areas (bottom right). Photos: ICARDA

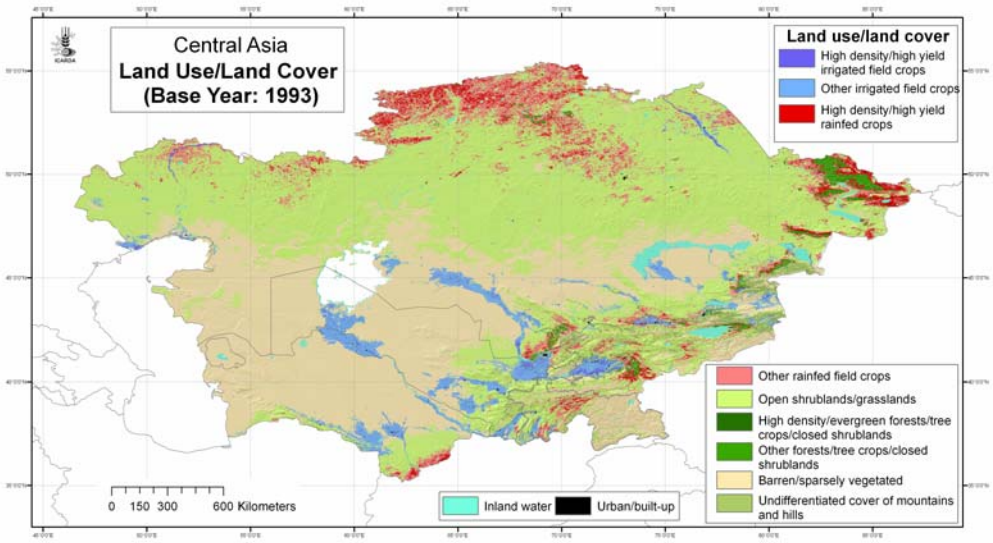


Figure 55. Land use in Central Asia. Source: de Pauw 2008

133. Overall, the total land area of Central Asia comprises approximately 400 million ha, of which more than half are rangelands and pastures (260 million ha), and only around 8 % (30 nillionen ha) are used for intensive agriculture (rainfed and irrigated together). This relatively small agricultural area yet feeds the around 61 millionen inhabitants of Central Asia, of which around 60% live in the rural areas. The pressure on the agricultural areas steadily increases due to the current population growth of around 2.1% (in Kazakhstan the population growth rate has already decreased slightly).

134. In Central Asia agriculture can be strongly differentiated between the North and the South. The large agri-businesses which are highly automized and technologized, can be foumd mostly in northern Kazakstan (Figure 56). The size of such businesses can go up to 600'000 ha as the farm Tayanshy-Astyk in the province Yasnaya, which is equivalent to the area of three former Soviet kolkhozes. Already in the South of Kazakhstan, the structure of the farms and enterprises changes. Agricultural production is more small-scale and comparatively less mechanized as in the North (Figure 57). Here, the farms are smaller in size and use different equipmemt as in the North, have less liquidity and a different income structure and situation. In some parts of Uzbekistan, Turkmenistan and Tajikistan, fertilizer is still being applied manually (e.g. to wheat, rice and vegetables), and on the subsistence-type smallholdings ("dekhqan" farms), hand-harvesting is common.

Figure 56. Large-scale agriculture in northern Kazakhstan. Photos: ICARDA (K. Kienzler)

Figure 57. Small-scale agriculture in southern Central Asia. Photos: ICARDA (K. Kienzler)

135. Central Asia is thus a very large and (ecologically) diverse region. The region offers a diverse agriculture and land use with high growth potential. The climatic conditions encourage the growth of a wide range of fruits and vegetables and other agricultural products (e.g. water melons, pomegranate, grapes, figs, silk, cotton, etc.), which clearly gives the region a comparative advantage.

136. The natural resources of the Central Asian region are degrading already since decades as a result of the strong emphasis of the Soviet system on production targets rather than production efficiency. Soil salinity, low soil fertility, soil erosion and waterlogging (and shallow groundwater tables) are some of the main aftereffects of land degradation in Central Asia. Affected are more than 232 million ha, of which alone the area of saline soils (36 million ha) is equivalent to the entire German Federal Republic. Between 40-60% of the irrigated area are affected by salinization and waterlogging (FAO 2006, Qadir et al. 2007), and in Turkmenistan even up to 96% of the irrigated area are subject to salinity (Bucknall et al. 2003), which in turn severly threatens agricultural production.

137. GIS analyses of the spatial distribution of the different forms of degradation (Figure 58) show that overall, hardly any area in Central Asia is not affected in one way or other by land degradation.

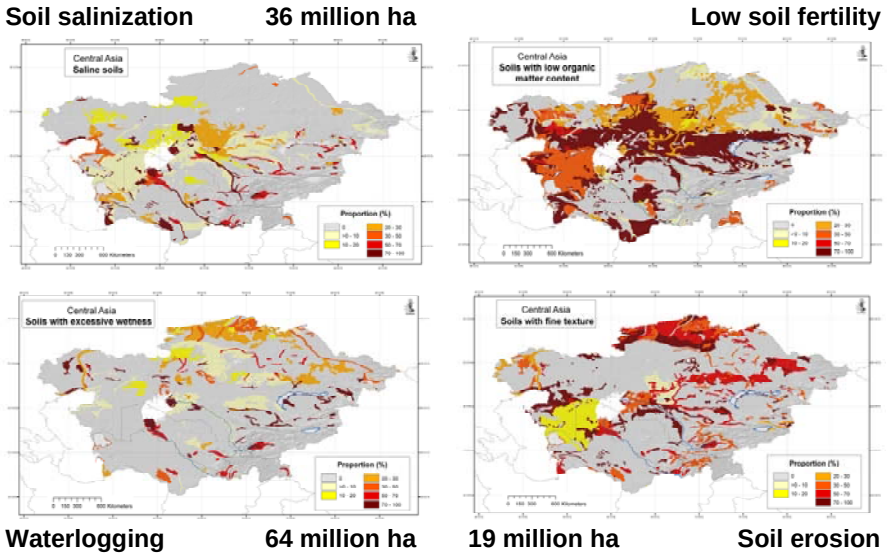


Figure 58. Forms of land degradation and their spatial distribution in Central Asia. Source: de Pauw 2008

11.2Agricultural production systems

11.2.1Laser-assisted land leveling

138. Proper land leveling is a prerequisite for irrigated agriculture and salinity control. Laser leveling is not new in the Central Asian region, but after the break-up of the Soviet Union, land leveling using laser technology is not practiced, and moreover, the equipment is not available

for farmers to use with their tractors. Therefore, five laser-leveling units have been bought in the frame of the SLMR project, and have been passed to the National Coordinators of each of the participating countries (Figure 59).

Figure 59. Laser-assisted land leveling in Kyrgyzstan

139. In combination with locally-made scraper buckets, the laser-leveling units encouraged water savings of up to 35% or 50-60mm per irrigation, and during leaching even more water could be saved (as measured in Khorezm in the ZEF/UNESCO project) (Figure 60). Also the germination of the crops was improved due to the homogenous soil moisture distribution. After land leveling, the productivity of wheat enhanced from 13.5% up to 40.7 % in Uzbekistan. Most important for the farmers was the fact that this equipment could be used with the local small tractors (e.g. TTZ-80-10, MTZ, etc.). For ICARDA scientists, this equipment was used as pre-requisite for the raised-bed planter (see section below).

Figure 60. Leaching of salts prior to planting; the fields have been land-leveled using the laser-leveling unit (Uzbekistan)

140. As this equipment is rather expensive, farmers not participating in the SLMR project were reluctant to buy the unit themselves. Instead, the project tried to encourage the idea of shared use or leasing of such equipment, as land leveling would only be necessary every 3-5 years once the field would be properly leveled.

141. As it is a little sophisticated in its use, the farm managers and scientists were intensively trained in the field by ICARDA scientists. In future, the dissemination of such technologies has to be combined with good training and explanations, as to avoid the removal of fertile top soil as result of inappropriate use (Figure 61).

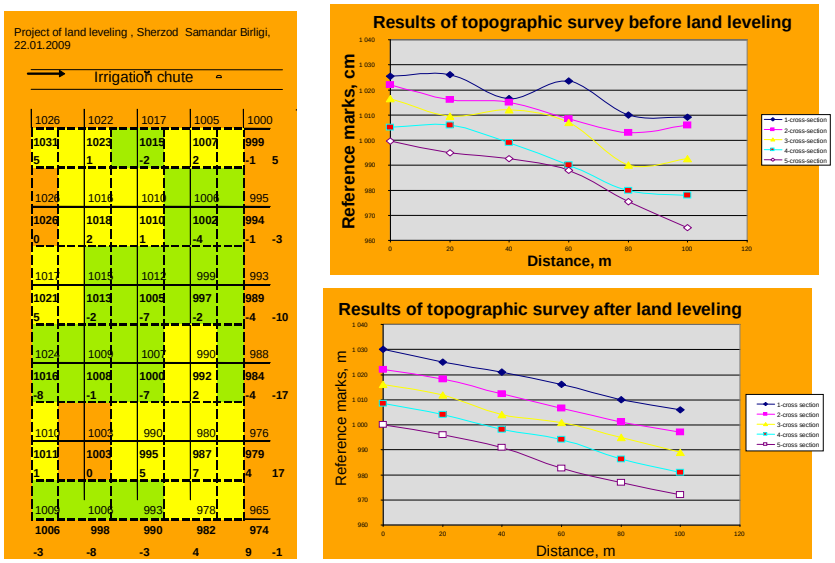


Figure 61. Results of topographic survey prior to land leveling (top) and after the leveling (bottom) using the laser leveling unit (Uzbekistan)

11.2.2 Raised-bed planting

142. In the irrigated production systems of Central Asia, crops are grown on raised beds while the furrows are irrigated. Shaping of the furrows usually follows seeding and fertilization, requiring additional mechanized action in the field.

143. The five *Dashmesh* raised-bed seeding units imported from India in the frame of the SLMR project have the advantage that they can simultaneously seed, fertilize and shape the furrows (Figure 62). Distributed to all 5 participating countries, the raised-bed planters were used for several research activities including seed management, crop diversification and zero-tillage (conservation agriculture).

Figure 62. Raised-bed seeding using the imported Indian *Dashmesh* seeder in Turkmenistan

144. With the laser leveler in combination with the raised-bed seeder, the SLMR project hit the nerve of the researchers and farmers and raised high interest. Raised-bed seeding improved seed germination for rice and winter wheat and thus almost halved the seeding rate necessary (Figure 63), but also other crops such as maize. Enhanced germination rates thus lead to yield increases up to 22%.

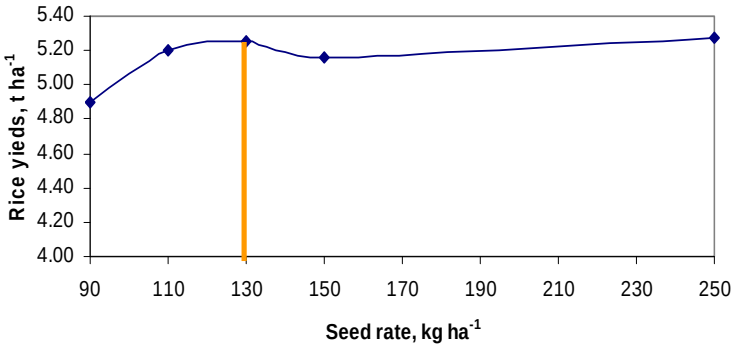


Figure 63. Effect of seeding rate on rice yield in Kazakhstan

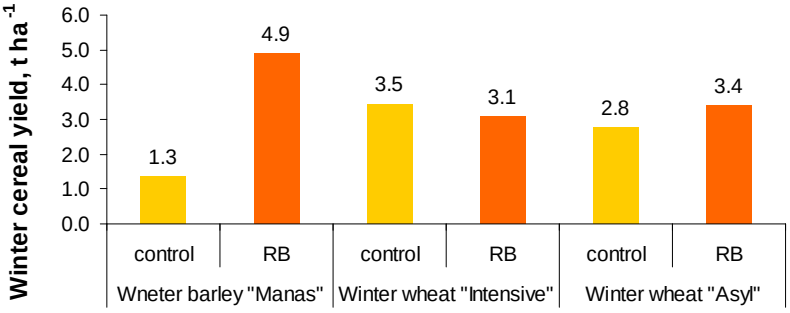


Figure 64. Effect of tillage system (control = farmers' practice; RB = raised-bed planting with imported Indian Dashmesh seeder) on winter cereal yield (Kyrgyzstan)

145. The most important benefit and most convincing for the NARS scientists and farmers was the cost reduction due to the reduction of mechanized activities from 11 to 5. Turkmenistan

reported reduced production costs of winter wheat of nearly 23%, and Uzbekistan of around 12%. Consequently, the net profit could be doubled (Table 44).

Table 44. Effect of planting technology (control = farmers' practice; RB = raised-bed planting with imported Indian Dashmesh seeder) on winter wheat yield and net profit (Uzbekistan)

Parameters	Control	RB
Yield, t ha^{-1}	6.0	6.4 (+7%)
Net profit, USD ha^{-1}	71.6	156.6 (+219%)

146. Farmers have frequently voiced criticism about the imported planter as being too heavy to use with local MTZ/TTZ-80 tractors, which the smaller farmers own. Instead, it is necessary to rent out heavier tractors. Furthermore, they complained about the weak furrow openers which do not withstand the Central Asian soils very well, and the plastic pipes for fertilizer and seeds which get very stiff and inelastic for late-fall or early-spring seeding. To overcome the purely technical constraints the ICARDA team encouraged the involved farmers to adapt the equipment with the help of technicians and mechanics. In Kazakhstan, the rice research station has consequently adapted the planter to the local conditions on their own initiative (Figure 65).

Figure 65. Adapted local seeder to include features of the imported Indian Dashmesh raised-bed seeder (Kazakhstan)

147. The spread of this planter is further constrained by the fact that they are not locally produced, and its import is rather expensive for the farmers in Central Asia. Although the national policies of the Central Asian countries stress the importance of agriculture, the need for suitable planters to be made accessible to farmers is underestimated, even though these tools are important for successful adoption of conservation agriculture.

148. So workshops for local production would need to be encouraged in order to further promote this equipment. Moreover, the provision of key services such as land leveling and (no-till/raised bed) planting may provide employment opportunities to the rural population and in small-scale manufacturing and transport related sectors

149. Where the seeder is available, all Central Asian scientists expressed their willingness to continue working with it. In Kazakhstan, scientists have the support from the local governor (hokim) for requesting governmental grants from the government for the multiplication of the planter which they have already successfully copied and adapted to local conditions (see above). In Kyrgyzstan, a farmers day is planned where workshop owners and farmers will be brought together to exchange options for the multiplication without waiting for governmental support.

11.2.3 Cropping system diversification

150. With collapse of former Soviet Union, seed systems for all crops except cotton and wheat have become virtually non-available. Diversifying the current cotton-wheat rotations by including legumes and fodder crops can prove helpful in reducing fodder shortages, increase soil fertility and improve the farmer's food security. For ICARDA staff most important was that by using the raised-bed planter the cropping systems could be diversified, and direct seeding was possible (as a condition for conservation agriculture). Of particular interest for ICARDA was to increase the share of drought-tolerant food legumes in the rotation, i.e. mung beans and chickpea, fodder crops, i.e. triticale and barley, and other improved varieties.

151. The use of the raised-bed planter allowed for diversifying the cropping geometry. Changes in planting geometry opened new opportunities for diversification of the common cotton-wheat cropping systems in Central Asia and hence helped increase income and improve livelihoods.

152. Intercropping of cotton with legumes, maize with legumes, or sainfoin with barley proved highly profitable for farmers (Figure 66). In Tajikistan, inter-cultivation of beans and red beets with summer maize on 60 cm raised beds significantly improved the total system productivity. Also in case of Uzbekistan, intercropping maize or cotton with mung bean doubled the net profit without significantly affecting the yields (Table 45). The improved mung bean varieties (e.g. variety *Marjon*) obtained from ICARDA's sister center ARVDC (World Vegetable Center) outperformed the local variety by almost half a ton (Figure 67).

Figure 66. Maize intercropped with mung beans (left) and cotton intercropped with mung bean (right) (Uzbekistan)

Table 45. Effect of intercropping on yield and net profit (Uzbekistan)

Crop establishment geometry	Crop yield, t ha^{-1}		Net profit, USD ha^{-1}
	Maize	*Mung bean*	
Maize, control*	3.5	-	701
Maize + mung bean, in pair rows, RB	3.9 (+12%)	1.3	1499 (+214%)
	Cotton	*Mung bean*	
Cotton, control	5.4		767.9
Cotton + mung bean, in pair rows, RB	4.8 (-11%)	1.4	1546.76 (+201%)

**Control = farmers' practice, single row on beds; RB = raised-bed planter, intercropping in pair rows*

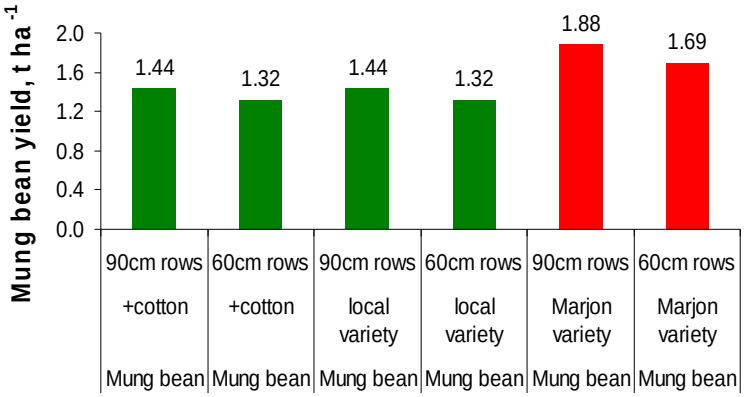


Figure 67. Yield of mung beans under different cropping systems as well as for different varieties (Uzbekistan)

153. In Uzbekistan, scientists and farmers continue to use the introduced rotation also after the project end: cotton – barley – maize/mung bean on raised-beds; treatments include control, direct seeding and residue retention.

154. Also, different chickpea varieties were tested (see section Greenseeker research report, Part I). While mung bean can be planted as a summer crop, chickpea fits into the Central Asian rotation as alternative winter crop (Figure 68). Experiments in Uzbekistan have shown that 1.5 t chickpea yield can be achieved.

Figure 68. Chickpea growing in Uzbekistan

155. However, the total production of food legumes in Central Asia is low, i.e. chickpea is only grown in Kazakhstan and Uzbekistan (FAOSTAT 2009), and mung beans are grown only in Uzbekistan, in the North of Turkmenistan, and in southern Kyrgyzstan. Also the export of pulses is generally low, although Kazakhstan increased its export from 0 to 15'000 t within one year due to the sudden demand increase. However, the farmers complained that there was no infrastructure for export assisting producers to sell such crops.

156. Furthermore, the consumption of chickpea and mung bean greatly varies from region to region (historical), e.g. in Tashkent and Samarkand, people eat chickpea in their traditional dish "plov" and in Tashkent they also eat chickpea as "Mahara soup". In the regions Khorezm, Ferghana, Kashkadariya, people prefer mung bean. In Kazakhstan's North, people don't consume chickpea, while in the South, they do. In Kyrgyzstan, particularly in the Ferghana valley close to Uzbekistan, in those regions where people from southern Kyrgyzstan migrated to, and where a Turkish community lives, dishes with mung bean/chickpea are prepared. Also in northern Turkmenistan bordering Uzbekistan and where the Turkish influence is large, people eat mung bean. In Tajikistan, both crops are known and consumed.

157. Seeds of other alternative crops such as triticale were passed to the Central Asian partners, and improved varieties of cereals were tested. In Kazakhstan, the production costs for planting winter triticale in comparison to winter wheat were lower, while at the same time winter triticale biomass yields (5.6 t) exceeded those of winter wheat (4.8 t) due to the greater

number of triticale tillers (50) in comparison with wheat (39). Moreover, as soon as the seed multiplication holding will be established, the Kazakh farmer will launch the seed production for selling triticale elite seed not triticale straw for fodder due to the higher price (50 Kazakh Tenge against 30 Tenge if sold as a fodder). Furthermore, around 3.5 t of green biomass for fodder can be obtained if the crop will be cut in spring ("dual-purpose", see also the Greenseeker research report, Part I).

158. Nevertheless, crop diversification using food legumes and fodder crops is not as easy to achieve, as the personal preferences and regional eating habits strongly regulate the production (except north Kazakhstan, where they produce for export if there is a market), and export facilities are still not sufficiently developed. Furthermore, also the governmental regulations have to be taken into account when introducing new crops and different cropping schemes.

11.2.4 Residue retention

159. In all 5 countries, the crop stubbles, essential for conservation tillage, are often burned in lack of tractors for plowing, or, more commonly, residues are removed from the field as livestock feed. However, retaining plant material on the soil surface has many benefits such as increasing soil organic matter content and water infiltration, cutting back unproductive losses of soil moisture through evaporation thus reducing secondary salinization, facilitating nutrient recycling, and protecting the soil against erosion.

160. Planting into standing stubbles, however, require special machinery, i.e. direct seeders such as the raised-bed planter (Figure 69). Experiments of directly seeding cotton or maize into cereals residues have shown to produce similar or even higher yields as the control treatments in Kyrgyzstan and Uzbekistan (Figure 70).

161. Factors constraining residue retention as well as direct seeding are the fact that mulching and plant residues on the soil are part of a new paradigm for farmers and scientists, not necessarily only in Central Asia. Currently some of the Central Asian countries still have tillage regulations that limit the possibility of farmers to leave residues on the field. Due to the competition with livestock feed, the availability of residues in the field is not seldomly limiting this part of conservation agriculture practice. Also, the machinery needed to plant into the often rather bristly stubbles such as double-disc direct planters are neither locally produced nor are the farmers capable of importing them themselves. Direct investments and medium-credits (> $10'000 USD) the purchase of such equipments could raise farmers' interest in this practice, as the spreading of such equipment depends on the initial acquisition costs, availability of credits and leasing facilities.

Figure 69. Plant residues kept in the field protect the soil against erosion, increase the organic matter content, enhance the water-infiltration capacity of the soil and reduce the process of secondary salinization. Photo: ICARDA (K. Kienzler)

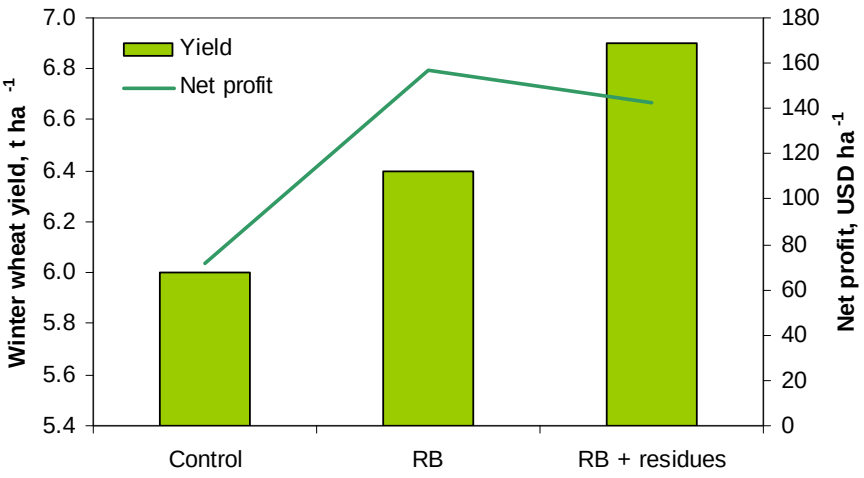


Figure 70. Winter wheat yield depending on the tillage system (control = farmers' practice including plowing; RB = raised-bed seeding; RB + residues = seeding into standing stubble/plant residue with minimal movement of the soil) (Uzbekistan)

11.3 Erosion control in mountain production systems

11.3.1 Residue management

162. Soil water erosion is widespread on sloping lands, particularly in the mountains of Kyrgyzstan, Tajikistan and Turkmenistan. Also, wind erosion is an increasing problem in those areas where the soil structure promotes saltation and suspension of soil particles. Soil surface plant residue applications are know to significantly reduce erosion.

163. Research experiments showed that in the mountainous regions of Kyrgyzstan and Tajikistan erosion could be reduced and soil moisture content in the topsoil increased when applying mulch. Especially residues from grapevines (Figure 71, Figure 72) allowed more soil moisture accumulation and storage than hay mulch, and 18-21% more moisture than the plowed control.

Figure 71. Grapevine branches are kept on the terraces in Tajikistan as residues to protect the soil from erosion and increase the soil moisture content. Photo: ICARDA (K. Kienzler)

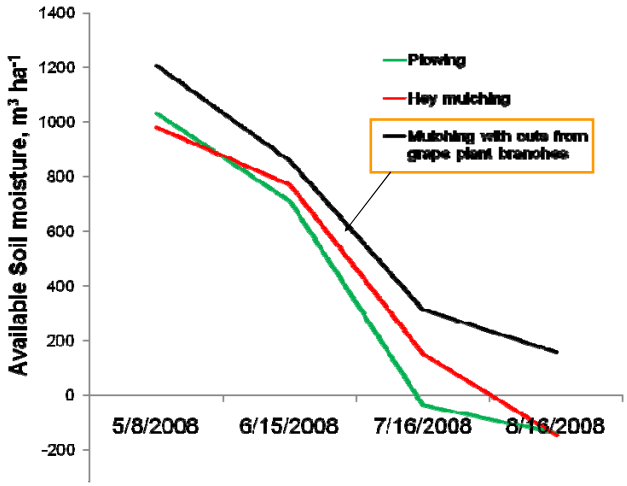


Figure 72. Effect of retaining different types of plant residue on available soil moisture (Tajikistan)

164. Additional effects were achieved with changes in the terrace design: Inward-sloping terraces with mulch helped catch melting snow better, reduce soil loss from water erosion, and thus significantly improved grape production.

11.3.1.1 Afforestation

165. Reforestation and afforestation of eroded areas and those lands prone to erosion is an important measure to combat land degradation. In Tajikistan, different tree species were grown in tree nurseries (Figure 73) and then presented to threatened regions, where local authorities together with the SLMR partners planted several hundreds of tree saplings on bare mountain land. Also, demonstration sites were established in Tajikistan to show interested authorities the potential of reforested areas (Figure 73).

166. The Tajik group (as all other SLMR partners) was very active to disseminate the results in several conferences, e.g. on June 30, 2009, the Tajikistan partners organized a conference on "Methods of combating the soil erosion" where around 60 representatives from agricultural and land and water management organizations, farmers and local administration participated. The conference was also broadcasted on the Tajik TV news program "Ahbor".

Figure 73. Tree nursery (left) and afforestation campaign (right) in the mountains of Tajikistan. Photos: ICARDA

167. In Turkmenistan, soil erosion on sloping lands around Ashgabat ("Green-Belt Project") could successfully be reduced by maximizing the surface cover with extra-short duration pigeon pea varieties planted around small tree saplings (Figure 74). Also planting a mix of varieties of suitable tree saplings as shelter belts around the large agricultural fields showed first effects in reducing wind erosion and reducing the threat on crops, and thus found high support in the farming population (Figure 75).

Figure 74. Erosion-threatened trees planted in the "Green-belt project" protected with short-duration pigeon pea (Turkmenistan)

Figure 75. Tree saplings planted around large agricultural fields as shelter belts protect the soil from wind erosion (Turkmenistan). Photos: ICARDA (left), NSEC-Turkmenistan booklet (right)

11.4 Water use, irrigation and salinity control

168. In the irrigated areas of Central Asia, salinization and waterlogging are major problems due to either the lack of drainage systems or poor maintenance of existing drainage systems and rising water tables. Opportunities exist for improving water use, irrigation practices and control salinity, if appropriate soil salinity is regularly monitored and suitable on-farm irrigation and drainage practices are employed to maximize the productivity of water. In the course of the

SLMR project, different technologies and approaches were used to increase the water use efficiency and water productivity including laser-assisted land leveling (see section above), irrigation using portable plastic chutes, and different water sources for irrigation and leaching. Also, salinity mapping systems were established using different methods (EM-38 equipment, hand-held salinity meter, manual soil sampling).

11.4.1 Plastic-chute assisted irrigation

169. Several sets of portable plastic chutes with regulated holes at the bottom produced in Uzbekistan (PPL-50, SANIIRI) were given to the NARS partners in Uzbekistan and Kyrgyzstan (Figure 76). In Kyrgyzstan, controlled irrigation in sloping lands using the plastic chutes saved water, improved in-field water application and minimized irrigation-induced soil erosion. In Uzbekistan, the chutes were used in the rangelands for irrigating small fodder fields in proximity of artesian wells (Figure 76). Owing to the chutes, the irrigation efficiency was increased and the farmer was able to successfully plant fodder and cucurbit crops (see also section Rangelands below).

Figure 76. Plastic-chute assisted irrigation in Kyrgyzstan (left) and Uzbekistan (right)

170. Nevertheless, researchers and farmers also voiced criticism. One of the weaknesses of the plastic chutes was the partly not-matching joints between the different chutes leading to leakages and inefficiencies in irrigation water application. This needs to be checked and improved with the further production of the chutes. Also the costs are quite high for smaller farmers. However, in Kyrgyzstan, one farmer has already copied the principle by using halves of water bottles stuck into each other thus forming a cheap version of the bigger plastic chutes. Generally, the plastic chutes present a suitable option for in-field irrigation of smaller fields as they help to control irrigation and thus reduce water flow velocity and over-application of water.

11.4.2 Use of different water sources and amounts for leaching salts from the soil

171. Using different sources of water for leaching salts from the saline soils will reduce the pressure on the fresh water resources in Central Asia. Therefore, in the SLMR project frame,

several crops were leached with water of different salinity levels (fresh water from main canals, saline water from drainages), and in different combinations.

172. As research results in Kyrgyzstan from the previous year had confirmed the possibility of using saline drainage water with an EC 1-3 dS m^{-1} to meet crop water demands in later growth stages with out sacrificing yields, irrigation applications in 2009 were carried out using water directly from the reservoir, which was not of high salinity.

173. Research in Uzbekistan looked at water and crop productivity for different leaching treatments under controlled conditions using field-installed lysimeters and in field conditions (Figure 77). Irrigating the lysimeters with drainage water (EC of 5-7 mS cm^{-1}) followed by fresh water saved fresh canal water and improved the leaching efficiency and winter wheat yields. Although leaching of salts from moderately saline soils was more effective for higher water applications (400 mm instead of 200 mm), the higher soil salinity after lower leaching intensity (even down to 100 mm) did not affect the winter wheat yield (around 5.8 t ha^{-1} irrespective of leaching amount). Yet, the water productivity for halving leaching amounts from 400 to 200 mm was higher. Also *post*-sowing soil leaching at the rate of 150 mm following sowing of winter wheat with the raised-bed planter showed successful results.

Figure 77. Lysimeter experiment with controlled conditions (front) and farmer-researcher managed field experiments (back) in Uzbekistan

174. The corresponding field experiments showed leaching efficiency for all winter wheat and cotton treatments that had been laser-leveled. Furthermore, the conjunctive use of drainage and irrigation water allowed reducing the fresh water use to 150 mm when using 70 mm saline drainage water for leaching of winter wheat. For cotton production in 2009, the most effective salt-leaching treatment was postponing the leaching schedule from mid-winter time to the last days of February and early March.

175. Conjunctive use of drainage and fresh water thus showed to increase water productivity by 15-25% in Kyrgyzstan, Turkmenistan and Uzbekistan. Nevertheless, it is necessary to

continue monitoring the soil processes during several more vegetation seasons to confirm the results, as the long-term effects on the soil and crop performance are not yet known.

11.5 Rangeland productivity and biodiversity increase

176. Due to the increased demand for food and feed and increasing livestock numbers, many rangeland areas in Central Asia are poorly managed resulting in feed deficits, soil erosion, loss of plant biodiversity, and expanding desert margins. The SLMR project addressed these aspects in the Kyzlkum desert of Uzbekistan, and in the piedmont areas of southern Kazakhstan.

177. In Kazakhstan, perannial phyto-ameliorative plants such were selected to improve the productivity of the natural rangelands. Favorable conditions of the year 2009 resulted in a better survival rate of the young plants and their active growth and development. The results of the two-year experiment showed that within the piedmont areas more resistant were Vaida Buasie (*Sameriaria boissieriana*), Izen (*Kochia*), Teresken (*Kraschenninnikovia*) and Chogon (*Halothamnus*), while in the sandy areas Vaida Buasie (*Sameriaria boissieriana*), Zhitnyak (*Agropyron*), Teresken (*Kraschenninnikovia*), Chogon (*Halothamnus*), Juzgun (*Calligonum*) and Saksaul (*Haloxylon*) showed highest resistance to unfavorable conditions of the rangelands (Figure 78). These plant species are thus highly suitable for diversifying the rangeland plant population and increase the pasture quality for the livestock herds.

Figure 78. Monitoring survival rates and growth of perannial phyto-ameliorative plants such as *Haloxylon aphyllum* (Saxaul) in the rangelands of southern Kazakhstan

178. At the selected experimental SLMR site in the Kyzlkum desert (saline soils), Uzbekistan, perspective salt-tolerant high-productive fodder crops including different varieties of alfalfa,

cereals (Figure 79), halophytes including licorice, and fruit trees were grown for high forage and protein units per hectare[2] and as alternative income sources to livestock production.

179. The dry biomass yield of barley (5.0 t ha^{-1}) and rye (4.8 t ha^{-1}) showed that these fodder crops have good potential to grow under these conditions. With applications of manure, it was yet possible to harvest around 50.0-80.0 t green biomass of maize, sorghum and millet. The legume crop alfalfa when cut five times during the season yielded up to 15 t of hay. Highest dry biomass yield gave Sudan grass (19.0 t ha^{-1}), which can even be cut twice during the season. Highest (potential) grain yield was harvested from the triticale plots (2.6 t ha^{-1}); however, the large share of the yield of the crops was eaten by birds. Thus, in the Kyzylkum conditions at small scale irrigation agriculture, cereals can be cultivated mainly for hay production for livestock. Particularly the cultivation of maize, sorghum, millet and alfalfa provides high nutritious, vitamin fodder and substantially improve the availability of fodder in the Kyzylkum desert.

Figure 79. Cereals (left) and fodder legume (alfalfa, right) production in the Kyzlkum desert, Uzbekistan

180. Licorice (*Glycyrrhiza glabra*) which is well-eaten by cattle yielded 24.0 t of green biomass, but it can serve as an additional income source when selling the rootstock as industrial raw material. Furthermore, the possibility of growing watermelons, melons and pumpkins fertilized with livestock manure from the local herds was assessed as alternative income source. The Uzbek farmer achieved very high yields of good quality (tasty) for all those crops, i.e. 32.0 t ha^{-1} watermelons, 30.0 t ha^{-1} melon, and 20.0 t ha^{-1} pumpkins (Figure 80). Due to the high demand of watermelons the farmer sold his products at a price of 500 soum per kg (0.3 USD per kg) and made substantial profit. Thus, growing this type of fruits additionally to his regular livestock production increased his income and improved the livelihood of his family.

[2] At this site, ICARDA's sister center ICBA (International Center for Biosaline Agriculture) is already long-term engaged in growing and multiplying halophytes and salt-tolerant fodder crops. Thus, in collaboration with ICBA, some of the experiments were continued in the frame of the SLMR project.

181. Presently, the area of irrigated land in this region is increasing. Local smallholders have already begun also to cultivate alfalfa, sorghum, maize, watermelon, melon and cucurbit. In shirkat farm "Madaniyat" areas with alfalfa crops in 2009 were reached to 2 ha, areas of watermelons to 5.0 ha.

Figure 80. Melons are an alternative income source for the Kyzlkum farmer (Uzbekistan)

182. Overall, the rangeland experiments showed high potential for combating biodiversity loss, while increasing fodder availability and encouraging different sources of income generation for the livestock farmers in the region. Nevertheless, more effective rangeland management is needed including seasonal grazing regulations in accordance with the highest productivity and fodder value of the pastureland vegetation, and adequate pastureland rotation systems. Besides the ecological problems there are particularly the social problems that need further attention in order to maintain livelihoods in rural areas where wellbeing of the families and rural communities heavily depend on livestock systems.

11.6Socio-economic analyses

183. Some of the key findings of the socio-economic literature review are that land degradation has been progressing rapidly over the last two decades, leading to lower crop yields and negative impacts on rural livelihoods. The reasons for land degradation are complex and numerous: biophysical, socioeconomic, institutional and policy related. Often they re-enforce each other. Agricultural policies have often exacerbated land degradation (e.g., shift from large-scale to small-size farms, insecure tenure, dirigisme, etc.). Central Asian countries face similar land degradation problems, but their socioeconomic, institutional and policy contexts are becoming increasingly divergent.

184. One of the biggest challenges for the development of the agricultural sector is yet the lacking connection to markets and the missing regional cooperation, poor transportation networks and limited trade with agro-products. The engagement of the Central Asian countries in fostering food security in their own countries has led to decreasing efficiencies in the value

chain in comparison to a free market situation, and forced import substitution rather than regional specialization. Land degradation and expected/occurring climate change impacts are highly interlinked.

185. Farmers are very concerned about land degradation and are keen on remedies, when possible with low labor requirements, simple and cheap. The survey (see section above) has shown that farmers are – depending on how much they are affected by land degradation – open for new approaches. The region is rich in human capital but lacks experts with specific land management skills. The physical asset base is low. So livestock production has become the most important coping strategy for smallholders and farmers.

186. On farm level, the economic analyses showed that conservation agricultural practices increase farming profitability (25-60 USD ha^{-1} of fuel savings), contribute to sustainable land management (e.g. water use efficiency, soil fertility), and these practices are competitive with conventional technologies in terms of yields. The constraints for conservation agricultural practices are lack of suitable machinery, alternative uses of crop residues (hay) as fodder, high herbicide costs, strict regulations on farming practices in some of the Central Asian countries, and the difficulty to achieve the paradigm shift (e.g., no tillage) with farmers, researchers and politicians.

187. A thorough literature review on different socio-economic aspects related to land degradation is provided in *Part III*.

11.7GIS-based similarity mapping

188. In order to potentially outscale the developed technologies of the SLMR project to similar environments, the research sites were characterized by using GIS and agro-ecological characterization activities (see de Pauw 2008). The analyses showed that most of the experimental sites have only little similarity with other areas in the Central Asian region, while the Kyzlkum rangeland site is similar to and thus representative for a very large area of the pastures and rangelands of Uzbekistan, Turkmenistan and southern Kazakhstan (Figure 81). This is largely owing to the fact that the rangelands make up the largest share of land in Central Asia.

189. Using the GIS-based similarity analyses environments similar to the SLMR project sites could be identified where the developed technologies could be outscaled. Overall, the similarity mapping was found to be a highly useful tool in pre-determining potential experimental sites and their representativeness for particular agroecological conditions or production systems. The methodology can thus not only be used to identify regions to which the results can be extrapolated to, but also to reflect on the representativeness of the selected sites and critically reconsider some of the research locations.

190. Additional data at the level of the field research sites is needed such as climatic data, but also at the level of Central Asia, i.e. a regional soil map. As long as data on climate, landform and land use/land cover for a particular site/region is insufficient, also the similarity analysis has its limitations.

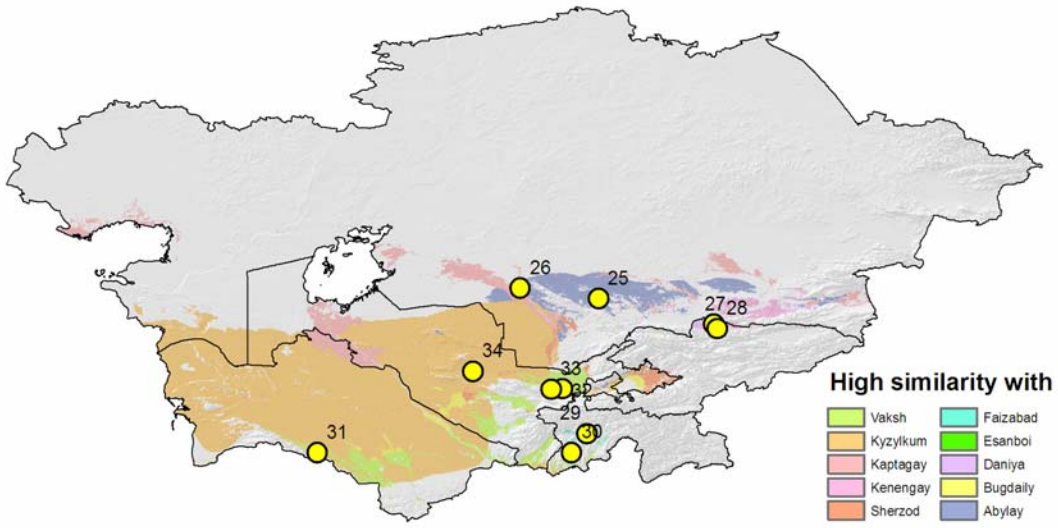


Figure 81. High similarity (index > 0.5) with different SLMR research sites. Source: de Pauw 2008

11.8 Final SLMR workshop and the "Research Prospectus"

191. From August 04-05, 2009, the Center for Agricultural Research in the Dry Areas (ICARDA) organized an international workshop to discuss the results of the Sustainable Land Management Research (SLMR) Project in the Poytakhkt Hotel in Tashkent.

192. The participants includes around thirty scientists from the five Central Asian countries Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, Heads of the Central Asian Countries' Initiative for Land Management (CACILM) National Secretariats, UNCCD Focal points, Heads of the National Agricultural Research Systems (NARS) of the five countries and national coordinators of the SLMR project, the Head of the Multi-Country Secretariat of CACILM, and ICARDA staff from Headquarter in Aleppo, Syria, and from the regional office for Central Asia and the Caucasus in Tashkent.

193. At the meeting, the participants actively discussed the results and gave recommendations for improving agricultural production, while increasing sustainable land management and improving rural livelihoods in Central Asia. They exchanged ideas and planned the next phase of CACILM that, depending on the funding, will focus on climate change adaptation and mitigation strategies for the region.

194. English and Russian versions of the minutes of the meeting were shared with all participants and donors.

195. The SLMR project document "Research Prospectus: A Vision for Sustainable Land Management Research in Central Asia" was printed in English and Russian (Figure 82) and distributed to all the participants of the 3rd Steering Committee Meeting in Dushanbe, 2009. An updated reprint was made available to the participants of the final SLMR workshop, and was uploaded to the ICARDA-CAC website: www.icarda.org/cac/slmr.asp.

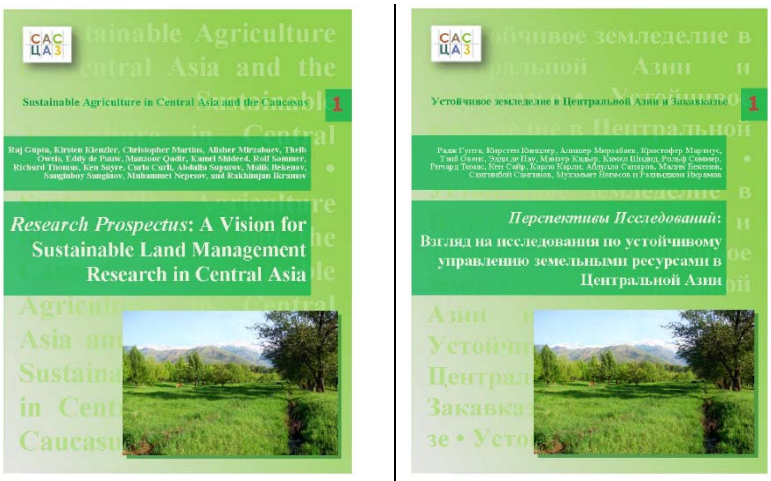


Figure 82. The "Research Prospectus" in English and Russian, ISSN 0254-8318

12 Potential and challenges

196. The above-given summary of the different research achievements demonstrates that the SLMR project addressed a vast range of problems when implementing its diverse research portfolio. In the course of the project phase, the cooperation and interaction with the NARS partners, farmers and other institutions was intensive and enthusiastic, and all sides showed readiness to engage in such a challenging project.

197. Although the impact of the SLMR activities is difficult to measure at this stage right after the project end, a preliminary impact assessment showed that some technologies were favored by the NARS and farmers, e.g. the laser leveler and raised-bed planter. Both have the potential to spread if the multiplication will be supported (e.g. in Kazakhstan and Kyrgyzstan, actions in this direction are already taking place). Other activities such as the increase of biodiversity of the rangelands were of less interest to the farmers at this stage, but highly important for the scientists. The project still lacks alternative policy and institutional options to support adoption of sustainable land management practices developed, as the NARS partners have not fully established strategies for facilitating refinement and adoption of sustainable land management practices.

198. Aside from the varying interest of the different stakeholders in the sustainable land management practices, the SLMR project observed several major constraints for a widespread dissemination and use of conservation agricultural practices in Central Asia. It has become clear that the often desired "one-size-fits-all" product of sustainable land management for entire Central Asia does not exist and pursuing such an approach is bound to fail in the region for many reasons including the different political settings, i.e. liberalized and state-regulated economies, and various extents of governmental support to new agricultural approaches in the five countries. As long as production targets are set by the government, as in the 'southern' countries Turkmenistan and Uzbekistan (and Tajikistan), the diversification of the crop rotations and modification of tillage systems will inevitably need the support from the highest administration, and changes in the farm management are likely to be slow or to be implemented stepwise. Farmers producing in the 'northern' countries like Kazakhstan and Kyrgyzstan, on the other hand, feel little interference from the state and are open for new approaches. Yet, as all farmers elsewhere in the world, changes in the production systems have to guarantee immediate profit, and sustainability of the practice is only of secondary importance.

199. Often overlooked is also the need but lack of appropriate machinery for sustainable land management. Seeders for untilled soils and for raised-bed planting are not yet commercially produced in the region, nor have the farmers sufficient capital to purchase such machinery. Given the present high uncertainty of marketing commodities, the general undercapitalization in rural areas, the long distances to the urban centers with potential buyers, the restrictions in input supply, the farming population obviously is not in a position to eagerly experiment with new

technologies. The import or even the development of machinery suitable for implementing sustainable land management practices in the irrigated production systems is therefore essential.

200. Applied agricultural and environmental research organizations stand on very weak legs in comparison to the international research branches due to lack of funds and outdated research facilities and materials. Strengthening the national research institutions as well as training young scientists is thus essential for the further development and adoption of suitable technologies which are sustainable and cost-effective and can generate (additional) income.

201. Overall, the adaptation of sustainable land management practices to the local conditions has to be considered an innovation process by itself with the aim of modifying conventional crop production technologies to the respective agricultural system while providing a platform for diversification and sustainable intensification. This requires not only a shift in research paradigms but also in agricultural thinking towards the development of cost-effective technologies and use of agricultural machinery that are best suited for small farm households, and resource-conserving practices which combat degradation. This furthermore demands the support of extension-type structures for awareness creation among all stakeholders and specific trainings, requires improving links between farmers and markets, and strengthen service organizations necessary for the successful implementation of modern land management practices with benefits for people and nature alike.

13 Conclusions and outlook

202. The Central Asian countries have a large and promising agricultural and environmental potential. The majority of the population in these countries directly or indirectly derives their livelihoods from agriculture. Irrigated areas, where most of the farming populations reside, are of major importance in securing national food supply and the livelihood of the people. Now in view of the economic and demographic pressures, there is an urgent need to enhance the agricultural production in the countries and restore degraded land to sustain those systems vis-à-vis quality of the natural resource base and increase the social well-being of the population.

203. The Sustainable Land Management Research (SLMR) project addressed major on-farm land and water management constraints at 12 benchmark sites with the aim to find sustainable innovations on land and water use which are economically feasible and socio-culturally acceptable while protecting the environment.

204. Results have abundantly demonstrated that adoption of improved technologies of land and water management could enhance productivity, resulting in higher rural incomes and household food security, and contribute to the conservation of natural resources and the sustainability of agricultural production in the region.

205. Although the project has successfully developed some options for sustainable land management in Central Asia, many issues remain to be addressed. Some of the issues are tightly interwoven with the problems of transition, including policies that are hindering the adoption of more appropriate technologies, especially those of crop diversification and conservation tillage, lack of extension-type structures, poor institutional capacities and lack of rural credit.

206. Other issues differ depending on the agroecological zones (irrigated, rainfed, mountains, and rangelands) and the natural resource base (e.g. soil, water). Water availability continues to be a critical issue for most of the Central Asian countries because of generally dry climate and frequent drought reoccurrence, especially in view of the predicted impact of climate change.

207. Based on the consultations with NARS and participants at the final SLMR workshop, therefore a number of issues have been prioritized for the next phase of the SLMR project:

1. Climate change (mitigation and) adaptation will be the overarching concept, with the "Research Prospectus" serving as extended concept note.

2. Research strategies and activities need to be focused and prioritized to meet the challenges of climate change, and the number of benchmark sites should be reduced. More attention should be given to the development and support of "Centers of Excellency", i.e. specialized think-tanks and integrated research "hubs" where several research questions can be addressed by trans-disciplinary teams, to reduce the need for duplification.

3. There is an urgent need to continue developing science-based concepts for efficient water-wise technologies and salinity management, conservation agriculture practices as well as for drought-resistant and salt-tolerant crops, adjusted grazing and feeding management for increasing range-livestock productivity, and other alternative coping strategies to diversify the income-generating opportunities and increase the resilience of the rural households in Central Asian in changing climatic conditions.

4. Promotion of the newly-introduced practices and machinery prototypes, and conservation agricultural as a strategic platform for sustainable land management needs to be followed up.

5. Selected private-sector agencies and advisory services must to be involved and closely integrated in the research concept (i.e. public-private partnerships) to advance the spill-over effect.

6. The inter-institutional coordination of the NARS partners needs more strengthening and support, i.e. transboundary exchange of expertise on sustainable land management (agronomists, farmers, scientists, technicians etc.) to reduce the scientific isolation.

7. A formal mechanism with NARS has to be developed to attract young scientists and link research better to universities in order to overcome the aging of the research branch and increase the capacity of research and preparedness to handle the new challenges under a changing climate (pests, diseases, stresses, scarcities, etc.).

8. Further in-depth socio-economic, institutional and policy research are needed to translate the sustainable land management options developed into broader policy and institutional recommendations which will enhance technological and institutional change.

9. The farmers' dependence on the weak extension system needs to be reduced by improving the mechanisms for institutional and technical support, and encouraging more extension institutions and multi-stakeholder consultations.

10. The overall aim is to further strengthen the capability and skills of farmers and local stakeholders (e.g. institutions and organizations) in developing locally adapted sustainable, diversified and cost-effective land and water management strategies, and increase their confidence to cope with the effects of climate change.

14 Acknowledgements

The Sustainable Land Management Research project was carried out within the framework of the CACILM. The funding from GEF and the support of the MSEC in Bishkek and the ADB is gratefully acknowledged.

I would like to take this opportunity to express my deep gratitude to all who have contributed to this research project. The successful realization of this project was only possible owing to the encouragement and support of all the research partners and their assistants in the Central Asian countries, the ICARDA staff, as well as the NSEC staff who made invaluable contributions to and comments on our work and reports.

Highest thanks are also given to the project assistants to the SLMR Project, ICARDA-CAC, Tashkent, Ms. Dilafruz Tursunova and Mr. Tulkun Yuldashev, for their endless support and their excellent services during the project time. Together with Ms. Dilyara Gumarovna, they have managed to translate and edit the tremendous amount of final Russian research reports of all the research partners, which have fed into this final report.

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16 Appendix I

16.1 Financial status and expenditure statement 2007-2009

Both tables will be provided as soon as the budget is closed by the Finance Department at ICARDA headquarters.

Table 46. Project financial status for the period June 2007 - October 2009

Table 47. Expenditure statement by component (US $) from July 2007 -December 2007

NARS / ICARDA (GIS & SEP Research)	SLMR Component-I	SLMR Component				Total Expnditure (USD)
	[4]Developing a program of SLM Options including projec planning workshop	National Research Activities	[1]Procureme nt of equipments	[1]Training and workshop [2]Dissemina tions	[3]Coord. Monitoring & Travel	
Kazakhstan						
Kyrgyzstan						
Tajikistan						
Turkmenistan						
Uzbekistan						
ICARDA-SLMR Coord. Unit						
ICARDA- GIS						
ICARDA/ SEPR /NGO						
Total						

[1] Training & workshop and procurement costs handled by ICARDA on behalf of the national partners

[2] Dissemination costs are directly spent by the NARs on stakeholder involvement and up scaling technologies

[3] Coordination and monitoring costs include connectivity, and office expenses etc.

[4]Refers to costs incurred in Inception planning meeting on NARS participants.

17 Appendix II

17.1 Overall program schedules of the research activities of the SLMR-ICARDA country components

Table 48. Time schedule of SLMR project activities 2007-2009

Activities	2007		2008				2009		Status
	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr3	Qtr4	
Output 1. CA countries through the application of integrated systems analysis will have greater understanding of the policy, institutional, environmental drivers of land degradation, and will develop a comprehensive research									
1.1 Coordination and monitoring of regional and national research activities in all the five countries through the establishment of multi-disciplinary teams of national and international scientists									
1.2 Common methodology and research approaches for data collection, factor analysis and system modeling developed for the diagnostic activities									
1.3 Orientation workshop for national scientists and enumerators organized									
1.4 Analyses of driving forces, causes, impacts of land degradation in CA countries through participatory diagnosis and integrated system analysis									
1.5 Ex-ante bio-economic modeling combined with extensive stakeholder consultation									
1.6 Mechanisms for local participation in SLM activities researched and established									
Output 2. Research prospectus for SLM research and donor-support for the duration of the CMPF Support Project developed including development pathways, research hypotheses and links with NPFs									
2.1 Integrative research hypotheses formulized by CA countries and research findings for identification of major factors determining comparative advantages of development pathways synthesized									
2.2. Existing development pathways identified using cross-country analysis and incorporated into NPFs									
2.3 Development pathways that are strongly associated with land management options (mainly resource conservation practices) identified									
2.4 Major development domains using GIS tools and potential benchmark sites identified in each CA country									
2.5 Ex-ante analysis of potential trade-offs between competing interests and the implications for different options									

2.6 A draft research prospectus developed based on the results of activities 2.1 – 2.6. through multi-stakeholder workshops									
2.7 National scientists trained through on-the-job and specialized courses									
2.8 Simple tools for local assessment and monitoring of land degradation developed									
Output 3. Research projects initiated in benchmark sites in all five countries of Central Asia and options tested with the land users									
3.1 Benchmark sites identified for each of the development pathways having strong association with land management aspects and using cross-country approach									
3.2 Digital database of benchmark site using GIS tools for monitoring and further outscaling developed and available to CA countries									
3.3 Alternative livelihood and land management options selected and tested that provide quick and effective evidence of their benefits in a community-based participatory approach involving young scientist									
3.4 Community arrangements for managing common pool and land resources and potential institutional options identified									To be discussed with communities
3.5 The impact of different alternative land management options on livelihood and environment monitored									
3.6 Alternative SLM options demonstrated to broad audience of stakeholders									
3.7 Ex-post analysis of trade-offs between competing interests and the implications for each development pathway									
3.8 Alternative policy and institutional options to support adoption of SLM practices developed through combining policy analysis with field results									
3.9 Young national scientists trained through on-site and specialized training									
Output 4. National development programs establish strategies for facilitating refinement and adoption of SLM practices									
4.1 Extension/advisory services established under each national coordination council									To be discussed with council
4.2 Mechanisms for upscaling and outscaling of SLM strategies and practices identified and analyzed across the CA countries									
4.3 Outscaling mechanisms assessed and tested through participatory action research and ex ante assessments									

4.4 Mechanisms of wider community involvement, public awareness and advocacy campaign such as Farmers' Fairs, Field Days, Farmers' Schools etc. tested in the CA countries									

Table 49. Time schedule of research activities in Kazakhstan 2007-2009

Kazakhstan	Qr3	Qr4	Qr1	Qr2	Qr3	Qr4	Qr1	Qr2	Indicators	Outcomes
1. Evaluate current status of land degradation on the irrigated areas of "Kaptagay" LLC, Kazakhstan	X	X	X	X					Annual reports Bench mark database on land degradation Reports on C stocks and potential for C sequestration Direct-seeding of dry rice (DSR) New cultivars for rice yield improvement Methodology for assessment of agronomic and crop management interventions on growth and land quality Technologies for rehabilitation of saline soils	Farmers start practicing DSR and afforestation technologies in the neighboring areas to improve quality of natural resources Institutions use the methodologies of comparative evaluation of SLM interventions
2. Assessment of current soil organic carbon status and potential for carbon sequestration in the irrigated areas of "Kaptagay" LLC, Kazakhstan	X	X	X	X						
3. Study the effect of irrigation schedules on rice yield, irrigation water saving and soil salinity				X	X	X				
4. Study the effect of different border dimensions on salt-water balances in rice for saving irrigation water and decreasing salt buildup				X	X	X	X	X		
5. Evaluate the performance of new rice cultivars developed in Kazakhstan and the Russian Federation				X	X	X	X	X		
6. Calibration and use of the Greenseeker for measuring crop development, comparing crop management practices and efficient nitrogen management				X	X	X	X	X		
7. Evaluate the performance of different trees, shrubs, grasses and fodder crops in sub-mountain plains, sand areas in the Abylay area	X	X	X	X	X	X	X	X		
8. Dissemination of results and developing mechanisms for upscaling and outscaling of the SLMR options			X	X	X	X	X	X		

Table 50. Time schedule of research activities in Kyrgyzstan 2007-2009

Kyrgyzstan	Qr3	Qr4	Qr1	Qr2	Qr3	Qr4	Qr1	Qr2	Indicators	Outcomes
1. Evaluation of performance of new cultivars (wheat, barley) suited for different tillage systems for improved water productivity in shallow groundwater table conditions	X	X	X	X	X	X	X	X	Reports Improved cultivars and seed availability	Institutions use the methodologies of comparative evaluation of SLM interventions
2. Study the effect of different herbicide molecules (pre- and post-emergence) on weed dynamics and water productivity for increased farm incomes	X	X	X	X	X	X	X	X	Technologies on use of multi-quality waters	Farmer start custom services and SMEs initiate agribusinesses
3. Study the effect of controlled irrigation methods for improving crop-water productivity, and reduce irrigation-induced soil erosion		X	X	X	X	X	X	X	Methodology for assessment of the agronomic and crop management interventions on growth and land quality	Farmers use improved seeds
4. Effect of conjunctive use of fresh and drainage water on crop yields and soil salinity build-up		X	X	X	X	X	X	X		
5. Evaluate the impact of laser-assisted land leveling on water savings, salinity and crop yields in irrigated agro-ecologies				X	X	X	X	X		
6. Calibration and use of the Greenseeker for measuring crop development, comparing crop management practices and efficient nitrogen management			X	X	X	X	X	X		
7. Dissemination of results and developing mechanisms for upscaling and outscaling of the SLMR options			X	X	X	X	X	X		

Table 51. Time schedule of research activities in Tajikistan 2007-2009

Tajikistan	Qr3	Qr4	Qr1	Qr2	Qr3	Qr4	Qr1	Qr2	Indicators	Outcomes
1. Effect of strip cropping on runoff and soil erosion on sloping land under in agri-horti production system	X	X	X	X	X	X	X	X	Annual Reports Technologies for crop production in sloping lands Technologies for soil-moisture conservation for terrace agriculture, gully plugs, and tree-crop combinations in agri-horti production systems Methodology for assessment of the agronomic and crop management interventions on growth and land quality New cultivars for rice yield improvement Methodology for assessing the agronomic management interventions on growth and land quality Technologies for rehabilitation of the saline soils	Neighboring farmers practice the different technologies developed in the project to improve the quality of natural resources Institutions use the methodologies of comparative evaluation of SLM interventions
2. Study the impact of tillage, terrace configurations, snow catching for soil moisture conservation on yield of cereal crops and grapes and soil erosion on slopes		X	X	X	X	X	X	X		
3. Rationale use of degraded sloping land for enhancing productivity in low and high rainfall regions		X	X	X	X	X	X	X		
4. Evaluate the efficiency of mechanical and vegetative measures in controlling gully erosion for rehabilitation of degraded sloping lands	X		X	X	X	X	X	X		
5. Calibration and use of the Greenseeker for measuring crop development, comparing crop management practices and efficient nitrogen management		X	X	X	X	X	X	X		
6. Promoting communities-based nurseries for afforesting sloping lands	X		X	X	X	X	X	X		
7. Dissemination of results and developing mechanisms for upscaling and outscaling of the SLMR options		X	X	X	X	X	X	X		
8. Evaluate the performance of wheat, barley, rapeseed, cotton and halophytes grown on saline soils in Vakhsh		X	X	X	X	X	X	X		
9. Study the impact of land-leveling and agronomic interventions on soil salinity and moisture distribution and crop performance using the EM probe and the Greenseeker				X	X	X	X	X		

Table 52. Time schedule of research activities in Turkmenistan 2007-2009

Turkmenistan	Qr3	Qr4	Qr1	Qr2	Qr3	Qr4	Qr1	Qr2	Indicators	Outcomes
1. Assessment of yield losses due to late planting in cotton-wheat cropping systems		X	X	X	X	X			Reports on yield losses due to salinity and salt tolerance ratings	Neighboring farmers practice the different technologies developed in the project to improve quality of natural resources Institutions use the methodologies of comparative evaluation of SLM interventions Farmer begin custom services and SMEs initiate agribusinesses
2. Assessment of yield losses due to salinity; determine salt tolerance of cotton and wheat under prevailing climatic conditions				X	X	X			Surface cover and RTCs for SLM developed	
3. Farmer participatory trials for validation, fine-tuning and development of new RCTs				X	X	X	X	X		
4. Develop permanent raised-bed planting systems for cotton – wheat rotations				X	X	X	X		Methodology for assessment of agronomic management interventions on growth and land quality developed	
5. Maintaining favorable salt balances in raised-bed systems for cotton-wheat rotations				X	X	X	X			
6. Potential of pigeonpea in developing surface cover to control soil erosion in sloping lands			X	X	X	X	X	X	Other reports	
7. Calibration and use of the Greenseeker for measuring crop development, comparing crop management practices and efficient nitrogen management				X	X	X	X	X		
8. Evaluate the impact of laser-assisted land leveling on water savings, salinity and yields in irrigated agro-ecologies			X	X	X	X	X	X		
9. Dissemination of results and developing mechanisms for upscaling and outscaling of the SLMR options				X	X	X	X	X		

Table 53. Time schedule of research activities in Uzbekistan 2007-2009

Uzbekistan	Qr3	Qr4	Qr1	Qr2	Qr3	Qr4	Qr1	Qr2	Indicators	Outcomes
1. Assessment of soil leaching requirements in irrigated areas to enhance water productivity and reduce drainage volumes (Lysimeter and field experiment)		X	X	X	X	X	X		Reports Technologies on salinity management Afforestation technologies for diversification of saline environments Seed availability for diversification crops	Neighboring farmers practice the different technologies developed in the project to improve quality of natural resources Farmer begin custom service laser-leveling services and SMEs initiate agrobusinesses Farmers use improved crop seeds Institutions use the methodologies for comparative evaluations of SLM interventions
2. Maintaining favorable soil-salinity balances in permanent raised-bed irrigated cotton-wheat systems		X	X	X	X	X	X			
3) Assessment of both native and non-native tree and grass species for their biomass productivity, salt tolerance and bio-drainage ability to rehabilitate the degraded rangelands in arid agro-ecologies		X	X	X	X	X	X			
4. Evaluation of diversified, salinity-resistant crops for enhancing biomass production for livestock in degraded rangelands			X	X	X	X	X			
5. Calibration and use of the Greenseeker for measuring crop development, comparing crop management practices and efficient nitrogen management				X	X	X	X			
6. Study the impact of laser-assisted land leveling on water saving, salt leaching, and crop performance in irrigated agro-ecologies using the EM probe and Greenseeker			X	X	X	X	X			
7. Dissemination of results and developing mechanisms for upscaling and outscaling of the SLMR options		X	X	X	X	X	X			

18 Appendix III

18.1 Meetings, workshops and trainings conducted and attended in 2007-2009

Table 54. Overview of Farmers' Field Days, trainings, conferences, workshops and other events during the SLMR project phase 2007-2009

Farmers' Field Days				
Location	**Date**	**Topic**	**Organizers**	**No. participants**
Tajikistan	5-6 Apr.08	Mulching, anti-erosion, water saving technologies in foothill zone	Tajik SSRI	38
Kushmanata, Uzbekistan	28. Jul. 08	Laser leveling, raised beds, lysimeters, leaching trails, portable irrigation chutes, salinity measurement devices	SANIIRI, ICARDA	40
Esanboy ota, Jizzakh, Uzbekistan	29. Jul. 08	Laser leveling, raised beds planting	SANIIRI, UCRI, ICARDA	70
Kaptagay, Kyzylorda, Kazakhstan	02. Aug. 08	Raised bed, direct seeded dry (DSD) rice technology, new rice germplasm, water savings technologies, weed management	ICARDA, Kazakh SASRI, Kazakhstan National Agrarian University, Kazakh Rice RI	60
Abylay, Kaptagay, Kazakhstan	23. Aug. 08	Raised bed/zero till Indian planter, water conservation technologies, NDVI measurements using Greenseeker and etc	Kazakh SASRI, Kazakh Rice RI and ICARDA	50
Kyzylkum, Uzbekistan	02. Sep. 08	Halophytes, trees and fodder crops production, use of saline artesian water for crops irrigation using plastic chutes	URIKSBDE, SANIIRI, ICARDA, ICBA	38
Kushmanata, Uzbekistan	13-14. Oct. 08	Laser leveling, raised beds, zero-till, portable irrigation chutes, salinity measurement devices	SANIIRI, ICARDA	35
Kushmanata, Uzbekistan	07. Mar. 09	Laser leveling, raised beds, lysimeters, leaching trails, portable irrigation chutes, salinity measurement devices	SANIIRI, ICARDA	30
Kushmanata, Uzbekistan	10. May 09	Laser leveling, plastic chute irrigation	SANIIRI, ICARDA	20
Daniyar, Kyrgyzstan	10-11. July 08	raised bed planting, laser land leveling	Kyrgyz Ministry of Agriculture and Water Industry	10

Kaptagay, Kazakhstan	15-16. July 2009	Farmers' Field Day on integrated rice production systems (raised-bed planter, mulching, improved varieties, seeding density)	Kazakh Rice RI, Kazak SASRI	(2 ICARDA staff)
Trainings				
Location	**Date**	**Topic**	**Organizers**	**Number of Participants**
Aleppo, Syria	17-29. Nov. 07	GIS training	ICARDA HQ	3
Tashkent, Uzbekistan	03-07. Feb. 08	Greenseeker	ZEF, ICARDA	26 (2 ICARDA staff and 17 NARS partners working in the SLMR project)
Tashkent, Uzbekistan	24-27. Apr. 08	Laser leveler	ICARDA	10 farmers and technicians
Esanboy ota, Jizakh, Uzbekistan	8-9. July 08	Laser leveling, raised beds planter, zero till drill	SANIIRI, UCRI, ICARDA	10
Esanboy ota, Jizakh, Kushman ata, Uzbekistan	23. July 08	Laser leveling, raised beds planter, zero till drill	SANIIRI, UCRI, ICARDA	10
Urgench, Uzbekistan	6-13. Aug. 08	Greenseeker	ZEF, ICARDA, CIMMYT	20 (2 ICARDA staff)
Tashkent, Uzbekistan	05-08. Sep. 08	Greenseeker	ICARDA	8
Syrdarya, Uzbekistan	12-13. Dec. 08	Greenseeker	ICARDA	3
Tashkent, Uzbekistan	15-24. Dec. 07	Training on use of EM-38 Soil conductivity meter	ICARDA	3
Uzbekistan, Kazakhstan		DRS technology	ICARDA	12
Dushanbe, Tajikistan	16-20. Mar. 09	Greenseeker	ICARDA	10 (Tajik Soil RI)
Conferences, workshops related to SLMR (or where SLMR work was presented)				
Location	**Date**	**Topic**	**Organizers**	**Number of Participants**
Tashkent, Uzbekistan	8-9. Feb. 08	Workshop on Research Prospectus for SLMR activities under CACILM	ICARDA	38
Kibray district, Uzbekistan	5-6. Dec. 08	RTCs	UCRI, ICARDA, IWMI	25 (3 ICARDA staff)
Tashkent, Uzbekistan	4-14. Oct. 08	Inception Workshop of the SLM Information System Multi-country Component of CACILM	CACILM, ADB, FAO	30 (2 ICARDA staff)
Urgench, Uzbekistan	27-30. Mar. 09	Crop modeling using APSIM and CropSyst	ZEF	15 (2 ICARDA

				staff)
Dashaguz, Turkmenistan	7-9. July 08	Workshop on laser land leveling	Turkmen NIDFF	20
Dashouz, Turkmenistan	7-9. Aug. 08	International exhibition "Turkmen agro 2008"	Turkmen NIDFF	
Dushanbe, Tajikistan	3-4 Apr. 09	3rd CACILM Steering Committee Meeting	ADB / MSEC	2 ICARDA staff
Shymkent, Kazakshtan	16-17 Apr. 09	XIIth International Agrarian Conference "Agricultural Science for Agricultural Production of the Republic of Kazakhstan, Siberia and Mongolia"	Ministry of Agriculture of Kazakhstan, KazAgInnovatsiya, SWSRPCA	2 ICARDA staff
Astana, Kazakhstan	8-10 July 09	Conference on "No-till with soil cover and crop rotation: A basis for policy support to conservation agriculture for sustainable production intensification"	Ministry of Agriculture of Kazakhstan, CIMMYT, FAO, Washington State University and others	2 ICARDA staff
Tashkent, Uzbekistan	4-5. Aug. 09	Final SLMR Workshop	ICARDA-CAC	30 (including NARS and ICARDA staff)
Tashkent, Uzbekistan	9-10. Sept. 09	Final seminar on "Information systems for sustainable land management" (SLM-IS)	NSEC Uzbekistan	1 ICARDA staff
Tbilisi, Georgia	12-16. Sept. 09	12th Meeting of the Steering Committee of the CGIAR Program and ICARDA-CAC Regional Program Planning Meeting	ICARDA-CAC	15 ICARDA staff
Tashkent, Uzbekistan	28-29. Sept. 09	Training workshop on "Challenges of sustainable water use in arid and semi-arid regions (under conditions of climate change)"	ZEF, ICARDA-CAC	40 (3 ICARDA staff)
Aleppo, Syria	20-22. Oct. 09	2nd ICARDA Science Week	ICARDA	40
Other events				
Location	**Date**	**Event**	**Organizers**	**Number of Participants**
Turkmenistan	05. June 08	TV program Altyn Asyr	Turkmen NIDFF	Dr. Nepesov interviewed on SLMR technologies

Kyrgyzstan	10-11. July 08	The field days were covered by 3 TV channels and several news papers	Kyrgyz Ministry of Agriculture and Water Industry	10
Turkmenistan	12. June 08	TV program Altyn Asyr	Turkmen NIDFF	Dr. Nepesov interviewed on SLMR technologies
Kaptagay, Kyzylorda, Kazakhstan	02. Aug. 08	TV and print media	Kazakhstan SASRI, Kazakhstan National Agrarian University, Kazakh Rice RI	Local governors ("akim") and other interviewed after field visits
Turkmenistan	08. Aug. 08	TV program Altyn Asyr	NIDFF	Dr. Nepesov interviewed on SLMR technologies
Kaptagay, Kyzylorda, Kazakhstan	25-26. Aug. 08	Radio / TV interviews on the Farmers' Field Days and DSR technology	Kazakhstan SASRI	Dr. Gupta, K. Bakiryly, Kh. Djamantikov (Kazakh scientific research institute), Dr. Otarov from Almaty
Kyzylkum, Uzbekistan	02. Sep. 08	Halophytes, trees and fodder crops production, use of saline artesian water for crops irrigation using plastic chutes	URIKSBDE, SANIIRI, ICARDA, ICBA	Field day was covered by newspaper "Pravda Vostoka"
Kaptagay, Kyzylorda, Kazakhstan	03. Sep. 08	Newspaper report - Syr boiy No. 183 (17501) dated September 3, 2008 – "Is the new method of rise cultivation capable of increasing rice productivity"	Kazakh Rice RI	Director of the Kazakh Scientific RI of Rice Growing
Kaptagay, Kyzylorda, Kazakhstan	14. Sep. 08	Interview by the national TV channel "Khabar"	Kazakh Rice RI	Dr. Karlikhanov interviewed on SLMR technologies
Faizabad, Khorasan, Tajikistan	28. Feb. 09	National TV (1st channel)	Tajik SSRI	15
Obikyik, Tajikistan	18. Mar. 09	National TV (program "Ahbor")	Tajik SSRI	20
Tashkent, Uzbekistan	27. Aug. 09	Newspaper "Novi vek" No. 34 (27.08.-02.09.09) "For the sake of the land"	Free lancer journalist	Report about SLMR activities in Uzbekistan