KIER DISCUSSION PAPER SERIES

KYOTO INSTITUTE
OF
ECONOMIC RESEARCH

http://www.kier.kyoto-u.ac.jp/index.html

Discussion Paper No. 648

"Extent of Salt Affected Land in Central Asia: Biosaline Agriculture and Utilization of the Salt-affected Resources"

Kristina Toderich, Tsuneo Tsukatani, Ismail Shoaib, Igor Massino,
Margarita Wilhelm, Surat Yusupov, Tajiddin Kuliev & Serdar Ruziev

March 2008

KYOTO UNIVERSITY

KYOTO, JAPAN

Discussion Paper No. 648

Extent of Salt Affected Land in Central Asia: Biosaline Agriculture and Utilization of the Salt-affected Resources

Kristina Toderich[1], Tsuneo Tsukatani[2], Ismail Shoaib[3], Igor Massino[4], Margarita Wilhelm[5], Surat Yusupov[6], Tajiddin Kuliev[7] & Serdar Ruziev[8]

March 2008

Kyoto Institute of Economic Research
Kyoto University

The current status and trends of salinization in Central Asia are discussed with waterlogging of marginal land/plant and water resources problems. The discussion here includes strategies for development of integrated biosaline crop-livestock based system on food-feed crops and forage legumes for better livelihood of poor farmers. Transfer of technologies and/or methodology of ICBA in planting of both perennial and annual valuable halophytes are a new approach that should be tested in Central Asia. Yield data of new varieties of sorghum and pearl millet ICBA/ICRISAT germplasm indicates considerable adaptability of introduced genetic material to saline soil conditions.

This research was supported by ICBA Funds and a Grant in Aid for Scientific Research, Japan Ministry of Education and Culture, 2006 (Monbusho International Scientific Joint Research Program, No. 15252002), represented by Professor Tsuneo Tsukatani

1 International Center for Biosaline Agriculture (ICBA), Central Asia & Caucasus sub-office, Tashkent, Uzbekistan. Email: ktoderich@cgiar.org;

2 Professor Emeritus, Kyoto University: tsuka@kinet-tv.ne.jp (His position is from April 2008.);

3 International Center for Biosaline Agriculture (ICBA HQ), Dubai, UAE: Email: s.ismail@biosaline.org.ae;

4 Scientific Production Center for Maize Production, Tashkent region, Uzbekistan;

5 Uzbek Research Institute of Karakul Sheep Breeding and Desert Ecology Research, Samarkand , Uzbekistan: ecokar@rol.uz;

6 Institute of Agriculture and Agroecology in Pre-Aralie, Kyzyl-Orda, Kazakhstan: pniiaesx@rambler.ru;

7 Department of Botany, Gulistan State University, Gulistan Uzbekistan: kuliev@mail.ru;

8 Ministry of Agriculture of the Republic of Turkmenistan, Ashgabat, Turkmenistan: Email: rozyews@online.tm

1

Extent of Salt Affected Land in Central Asia: Biosaline Agriculture and Utilization of the Salt-affected Resources

by

Kristina Toderich, Tsuneo Tsukatani, Ismail Shoaib, Igor Massino, Margarita Wilhelm, Surat Yusupov, Tajiddin Kuliev & Serdar Ruziev

Abstract

The current status and trends of salinization are discussed with waterlogging of marginal land/plant and water resources problems including strategies for development of integrated biosaline crop-livestock agriculture based system on food-feed crops and forage legumes for better livelihood of poor farmers in Central Asian (Uzbekistan, Kazakhstan, Turkmenistan and Tajikistan).

Transfer of technologies and/or methodology of ICBA (International Centre for Biosaline Agriculture) in planting of both perennial and annual valuable halophytes (based on around the world dataset from similar sites and conditions) are a new approach that should be tested in Central Asia. Afforestation, as an option to mitigate land degradation, requires a judicious evaluation and selection of multipurpose tree species (MPTS) to make use of marginal unproductive/salt-affected lands and lower the elevated groundwater table (GWT) via biodrainage. The leading among 21 screened native and introduced tree and shrubs species with regards to survival rate, growth characteristics and adaptability to high saline natural environment proved to be *Haloxylon apphyllum*, *Salsola paletzkiana*, *S. richteri* at the saline sandy deserts, followed by atriplex undulate, Hippophae ramnoides, *E. angustifolia*, *Acacia ampliceps*, *U. pumila*, *P. euphratica* and *P. nigra var. pyramidalis, Robinia pseudoacacia*, *M. alba*, *Morus nigra* on clay loamy hyromorphic soils, whereas fruit species such as *Cynadon oblonga*, *Armeniaca vulgare, Prunus armeniaca* and species of *genera Malus*, though desirable from the farmer's financial viewpoint, showed low bio drainage potential.

Planting herbaceous fodder crops within the inter-spaces of fodder salt tolerant trees and shrubs on intensive agro-forestry plantations could solve the animal feeding problem in the degraded (both by overgrazing and salinity) desert and semidesert marginal areas. Yield data of new varieties of sorghum and pearl millet ICBA/ICRISAT germplasm collected at the conclusion of the 2006-2007 growing seasons indicates considerable adaptability of introduced genetic material to saline soil conditions, when compared to local material. Sorghum and pearl millet crop residues utilization could be an option for bio fuel production in the region.

2

Introduction

The desert/semidesert plains/lowlands of Central Asian countries (Uzbekistan, Kazakhstan, Turkmenistan, Kyrgyzstan and Tajikistan) for many centuries have experienced the influence of mankind, and its natural vegetation cover was altered to a greater or lesser degree. These countries rely heavily on irrigated agriculture, whose contribution to the national economy comprised 34% of the GNP, 70% of the foreign currency income, and 55% of employment (Uzgipromeliovodhoz, 2003). Summer-vegetation, silvi-viticulture and all horticulture crops in the Aral Sea Basin countries require supplemental irrigation to ensure better yield. Uzbekistan is the main water consumer among the five countries, annually using over 50 km^3 of water for agriculture, domestic and industrial purposes, which is about a half of the entire basin water budget (Djalalov et al., 2005). Together with Turkmenistan, Uzbekistan consumes 83% of the water resources generated in the Aral Sea Basin although the two countries "produce" less than 13% of this water. Between 1960 and 1999, the irrigated area only in Uzbekistan expanded from about 4.5 to almost 7.9 million ha, and this area was mainly allocated to the monoculture of cotton as a main cash crop (UNEP, 2000). A negative side effect of this impressive expansion induced land salinization and desertification (UNEP & Glavgidromet, 1999). A recent global assessment of land degradation showed that about 41% of the presently cultivated lands have been irreversibly degraded (FAO, 2000). Soil conditions heightening the risk of land degradation in the whole Central Asian region include salinity, sodicity, hydromorphy, soil shallowness, and risk of erosion (FAO, 2000). Among these, soil salinity and sodicity are the most severe affecting 53% of the countries arable lands. For instance, the annual losses in Uzbekistan due to land degradation through salinization have been estimated as USD 31 million, while withdrawal of highly salinized lands out of agricultural production has cost USD 12 million (World Bank, 2002).

Most irrigated lands in the Aral Sea Basin are subject to salinity due to the sharply continental arid climate (aridity coefficient: $Ka < 0.12–0.3$, Chembarisov et al., 1989). Under such arid climate conditions an additional source of soil salinization comes from quick soluble salts in Central Asian river water. Use of surface flow of rivers for irrigation increases salt accumulation in soils and underlying deposits (Shirokova & Morozov 2006). In addition about 24% of the land suffers from light to severe chemical and physical soil degradation caused by agricultural activities, mainly use of chemical fertilizers. About 13% of total lands in Central Asia have been severely degraded mainly during the past 40 years "with no possible reclamation at a farm level" (FAO, 2000). The risk of soil salinization is further aggravated due to the rising water table, as a result of high irrigation water application in the fields and the poorly managed drainage channel system. It is estimated that all water users, domestic and agricultural alike, suffer from poor management of the water sector. A key problem in maximizing water benefits for all countries is the structure of the agricultural sector itself. The rapid expansion of irrigated agriculture in Central Asia has greatly reduced the flow of the two major rivers (Syrdarya and Amudarya) that naturally flowed in the Aral Sea. In addition, the dry bottom of the Aral Sea has become one of the major sources of active wind erosion, which affects about 56% of the irrigated area both in Uzbekistan, Kazakhstan and Turkmenistan (mostly in the Dashauz region) imposing risk for land degradation. It has been estimated that during strong dust storms as much as 1.5–6.5 tons/ha of dust containing 260–1,000 kg/ha of toxic salts is carried out from the former Aral Sea bed onto adjacent lands (UNEP and Glavgidromet, 1999).

Areas in the lower reaches of the Zarafshan, Vakhsh, Amudarya and Syrdarya rivers are particularly threatened by secondary soil salinization with its entire irrigated land suffering from salinity (Uzgipromeliovodhoz, 2003). Extensive use of traditional furrow irrigation leads to soil erosion, salinization and waterlogging, thus greatly reduces not only the sustainability of agriculture, but also the long term security of rural community. Waterlogging and salinization are major problems affecting all cotton and wheat growing regions of Central Asia. As results, huge amount of productive irrigated lands are turning to degraded marginal lands which are then abandoned by farmers. The predominant reasons for their development are poor irrigation water management and inadequate drainage, rising groundwater tables and associated mobilization of primary salts within the soil profile. Bucknell et al. 2003 report that approximately 600,000 ha of irrigated cropland in Central Asia has become derelict over the last decade due to water logging and salinization. It is estimated that approximately 20,000 hectares of irrigated land in Uzbekistan is lost to salinity and invariably abandoned every year. Saline areas are generally found in poorer areas of the region with per capita incomes 30% lower than average national indicators and unemployment levels 40% higher.

Soil salinity and waterlogging are a heavy burden for resources poor farmers, who are located in such land-degraded zones. Awareness of the farmers about soil/water conservation and management of marginal lands is also very poor. Measurement of water applied to the crop and irrigation scheduling for reclamation of salt prone marginal lands is still based on conventional approaches. This is further aggravated by the fact that there is absolutely no data available on basic requirements of water management in crops viz., moisture extraction pattern, water requirements of different crops, impact of water deficits (quantitatively), at different crop growth periods. Poor rural communities and farmers, especially in desert remote areas loss their own interest to be involved in the agriculture development and majority are migrating to the cities or even to other countries for searching alternative jobs. Due to lacking of funds their families and children in the created situation cannot get good education and health assistance. Additionally the reclamation of salt-affected marginal lands has received relatively little international donor and research attention (Small and Bunce, 2003).

There is also a mismanagement and interaction between Ministry of Agriculture and Water Management, local communities and authorities. Lacking of sufficient financial resources do not allow them to initiate and conduct a large-scale rehabilitation of salt prone lands, maintaining and reconstruction of drainage collector system, land planning and its rational use among stallholders and agropastoralists. Additionally, difficulties occurred in the land leaching due to the scarcity of surface water resources for irrigation that crucially occurred in the middle stream of Amudarya, Zarafshan, Kafirnigan, Sherabad, Vakhsh and Syrdarya Rivers Basin.

The main objectives

- to conduct a contemporary assessment of the effects of salinity in major crop and livestock production systems, survey of the status of saline irrigated areas and their prospects for rehabilitation, design of technology packages for optimum utilization of marginal saline land and water resources in Central Asia;

- to provide a selection of salt tolerant crops, assessment and development of innovative practices in managing or rehabilitating salt affected lands that includes the use of marginal lands and irrigation waters;
- to determine the most suitable tree and shrubs species for afforestation on marginal lands, based on their morpho-physiological characteristics, salinity tolerance and the socio-economic criteria such as fuel wood and fodder;
- to evaluate indigenous and non-conventional halophytes and domesticate them into production system through farmer's participatory programs.

1. Salt affected soils, irrigation system and their impact on crop production

The relief of the whole Central Asia is mostly flat with insignificant slopes located mostly in the upper stream countries. The intensive development of cropping agriculture which started after 1970s as a result of extensive construction of irrigation system has superseded natural vegetation. Huge territories of virgin open rangelands in the Central Asian River Valleys and foothills areas have been completely converted into farming irrigated lands. Upper stream countries (Kyrgyzstan, Tajikistan), being situated in the highland areas in the region receives good rainfall, but looses most of its water due to run-off, resulting in water deficiency during growing seasons. In the lower stream countries (Turkmenistan, Uzbekistan and Kazakhstan) soil salinity is a big problem in some of the locations of agricultural irrigated lands due to groundwater, resulting from excess irrigation during cultivation of cotton and other crops, high evaporation during hot summer and/or poor drainage. Salinity induced soil in the Aral Sea Basin, where the negative environmental consequences are considered to be some of the largest caused by humanity in recent times, has increased steadily over the last few decades.

According to official data from the Ministry of Agriculture and Water Management of Uzbekistan for autumn 2004 (MAWR, 2004), on 34% of the irrigated lands in Khorezm the groundwater table varied from 0 to 1 m below the surface and on 59% it ranged between 1 and 1.5 m depth. Under these conditions, 55% of the irrigated lands were classified as slightly saline (2-4 dS/m), 33% as medium saline (4-8 dS/m) and 12% as highly saline (8-16 dS/m). The percentage of saline soils in 2004 is significantly increased compared to the situation in 1990, when the share of slightly, medium and highly saline lands was 50%, 33% and 10%, respectively. In 2000, a year of notable water shortage, the percentage of medium and highly saline soil increased significantly, whereas slightly saline soils decreased to 45%. From last decades the rapid changes in area affected by secondary salinization occurred in Karakalpakistan, Khorezm and Syrdarya regions (Mirza chul steppe in Uzbekistan), northern Turkmenistan (Dashauz Province), Kyzyl-Orda region in Kazakhstan, Fergana Valley and Asht massive along Syrdarya river both from Tajik and Uzbek transboundary areas; Kashkadarya, Chardjew and Bukhara oasis along Amudarya river. Currently areas suitable for agricultural development in Central Asian River Basins are continuously decreased (Table 1).

Table 1 Distribution of arable agricultural lands and their salinity level (Data summarized at 2004)

Total Area, Mln. ha	Non-saline	Slight	Moderate	Severely
FAO SMU *including:*	32,666.76	8,929.8	3,755.29	8,822.59
Uzbekistan				
Syrdarya region	86.59	144.62	105.81	76.63
Kashkadarya region	2,086.79	566.642	146.556	59.73
Khorezm region	102.0	197.4	194.9	100.7
Karakalpakstan	75.4	175.7	141.3	168.2
Turkmenistan				
Northern region (including Dashauz province)	162.1	335.4	281. 7	195.0
Kazakhstan				
Kyzyl-Orda region	29.1	105.8	117.3	32.9

Table 2 Underground water, mineralization and salinity in Tajikistan (data of 2003)

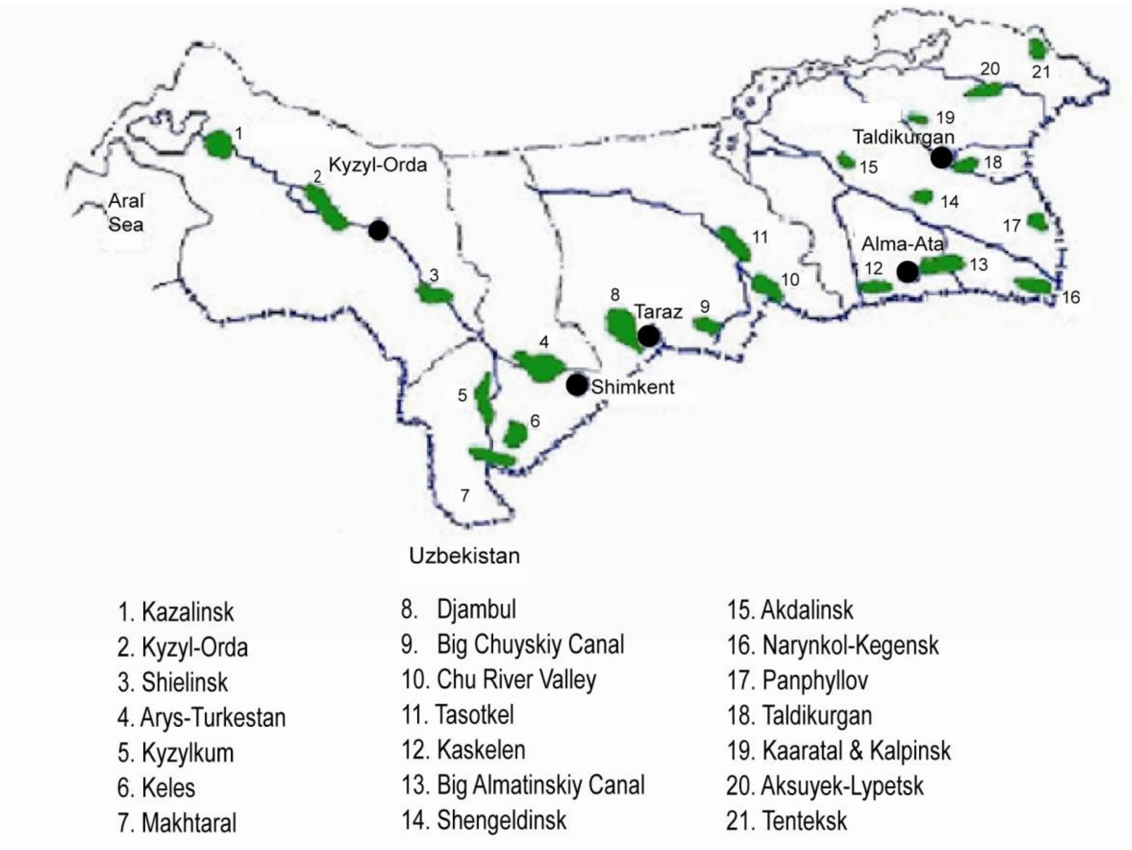
Name of the region	Irrigated area (th.ha)	Among them the level of underground water (th.ha)				Level of mineralization and areas of irrigated lands (th.ha)			Degree of salinity and areas of irrigated lands (th.ha)			
		≤ 1 m	1-2 m	2-3 m	≥ 3 m	≤ 1g/l	1-3 g/l	≥3 g/l	no saline	weak	medium	high
Kulyab	79.7	1.0	21.0	10.2	47.5	49.2	27.3	3.3	68.5	10.3	6.2	2.8
Kyurgan Tyube	241.7	7.1	42.3	25.1	167.2	32.6	178.8	30.3	197.7	26.5	14.9	2.6
Sugda	259.3	1.6	25.4	28.8	203.6	240.0	1.6	17.8	201.3	36.7	12.6	9.8
Gissar	100.1	0.3	2.7	39.2	57.9	99.3	0.7	0.1	99.1	0.9	0.0	0.0
Total	680.9	10.0	91.4	103.3	476.2	421.0	208.3	51.5	494.6	74.4	33.7	15.2

According to statistics for last five years only in the Syrdarya province the lands affected by salinization, especially human caused were increased from 87 to 95%. Among them more than 80% are heavy saline. All these lands being partly used as low productive gradually are out from the irrigated agricultural use and abandoned by farmers. In the Mirza chul steppe the area of arable lands for the last 10 years has reduced from 805,000 ha in 1991 to 531,000 ha in 2006.

The similar tendency of extension of salt-affected lands was described in the agricultural irrigated zones in Tajikistan, where high salinity level enrich with water-soluble salts throughout the profile at a depth of 0.5-2.0 m (Vasilchikova, 1982, Toderich et al., 2006). As seen from table 2 the most severe salinization and waterlogging processes are taking place in the Kulyab (Vakhsh and the middle stream of Amudarya Rivers Basin) and Sugd (Syrdarya river Basin) regions, where about 29.0% are affected by salinity.

Fluctuations of saline lands in the region are mostly determined by the content of total soluble salts in the top soil layers (0-100 cm). Among 21 agriculture zones suitable for winter wheat, cotton and rice cultivation in the southern part of Kazakhstan compared with the whole country territories the most salt affected lands can be distributed as following Kyzyl-Orda > Alma-Ata > Djambul > South Kazakhstan Provinces (Fig.1 and Table 3).

Figure 1 Distribution of irrigated lands in southern part of the Republic Kazakhstan



As long as the extension of land salinization in Kyzyl-Orda region continue to aggravate, the health and livelihoods of the population already suffering from salinization, waterlogging and oil-industrial contamination are threatened further. Appropriate measures to help to the rural population to mitigate and manage the widespread land degradation are urgently needed.

Table 3 Irrigated lands and salinization in southern Kazakhstan (Data, 2005)

Administrative regions	Total Irrigated lands, th.ha	Total non-saline, th.ha/%	Total saline lands, th.ha/%	Among them th.ha/%		
				Low salinity	Medium salinity	High salinity
Almata	648.6	252.9 39.2	395.7 61.0	198.5 30.6	158.2 24.2	39 6.0
Djambul	243.8	150.7 61.8	93.1 38.2	66.8 27.5	17.3 7.0	9 3.7
Kyzyl-Orda	287.1	2.9 1.5	284.2 98.5	125.8 43.8	79.4 27.2	79 27.5
Southern Kazakhstan	500.4	333.3 66.7	167.1 33.3	102.6 20.5	48.5 9.6	16 3.2
Total	1679.9	739.8 44.0	940.1 56.0	493.7 29.5	303.4 18.0	143 8.5

Focusing on countrywide soil chemistry of surveyed salt-affected areas with shallow water table we found out that the predominant salinity type is chloride-sulphate, while sulphate-chloride type is also described. Ground water salinity varies from to 2.0-8.2 g/l. Sodium and magnesium are the dominating cations. It was also found that the organic matter in these soils ranges from 0.7 to 1.5 g/1, while the cation exchange capacity varies between 5-10 cmol (+) kg/1. Total nitrogen (N) and phosphorus (P) contents in salt affected soils are low, usually ranging between 0.07-0.15% and 0.10-0.18%, respectively. Available potassium (K) content is classified as low or moderate (Fayzullaev, 1980). Consequently, the natural fertility of the saline soils, especially in the of main Central Asian rivers deltas is characterized as rather low, and cultivation of most agricultural crops requires high inputs of chemical fertilizers or applying of costly leaching practice. This strategy, however, increases the risk of re-salinization in the root zone and leaching process has to be repeated every cropping season in order to avoid build-up of high salt concentration. In this respect the appropriate practices for salinity control should be selected based on the quantification of water and salt movement in the soil, crops response and adaptation to water and salinity stress and how environmental conditions and management influence these interactions. In this regard, efficiently water use for irrigation couple with introduction of modern bio-remediation technologies as mentioned by Feere and Stockle (1996) can help to integrate all interactions and define the best management for crop production under saline environments.

Summarizing the existing information and based on the geological and hydrological characteristics, we have concluded that all Central Asian countries demonstrate the most characteristic features of natural continental (not marine/coastal) salinization, sodication and alkalinization. Since the most important direct source of soil salinization is the shallow groundwater level below the lowland surface, there is a chance of irrigation-related salinization in two dominant situations: when the abundant use of river waters causes waterlogging and rise of saline groundwater (salinization from below the surface); and when typically saline tubewell-waters are used for irrigation (salinization from above) as it is a case in Kyzylkum (Uzbekistan) and Karakum (Turkmenistan) deserts.

2. Irrigation and drainage network system impact

Extensive irrigation network and complementary drainage water collectors were mostly constructed in the 1960s (Katz, 1976). Water from main Central Asian Rivers is channeled to agricultural fields by gravity through a hierarchically arranged irrigation network including main, inter-farm, and on-farm canals. Compared to the whole Aral Sea Basin, only in Khorezm region, which makes only 3% of the total area, has a comparatively very dense network (Table 4). Yet, only 11% of these canals are lined (Vodproject, 1999), greatly reducing the amount of water that ultimately reaches agricultural fields. Mostly surface irrigation is practiced that includes 64% furrow, 31% strip and 5% basin irrigation (Abdullaev, 2002).

The drainage system is mainly open horizontal. Drainage water is conveyed via hierarchically constructed collectors from the irrigated fields into numerous artificial small lakes and salt prone depressions (Karakata, Mingbulak, Ayakagitma, Beshbulak, Kukayaz, Mulali etc.) outside of the irrigated area.

Table 4 Irrigation and drainage network in Aral Sea Basin and Khorezm

Irrigated area	Aral Sea Basin	Khorezm	%
Canal length, km main and inter-farm irrigation	28,000	1,895	7
On-farm irrigation	168,000	14,338	9
Total	196,000	16,233	16
main and inter-farm drainage	30,000	1,305	4
On-farm drainage	107,000	6,374	6
Total	137,000	7,679	10

Source: 1:25000 GIS maps (ZEF/UNESCO GIS lab Urgench, after A. Khamzina, 2006).

The impact of blocked drains is generally strongest in light and shallow soil layers with good filtration properties and decreases as the soil texture becomes heavier. An important ameliorative aspect of the all plains and river deltas of Aral Sea Basin is that the soils there are fine-grained silty sands located at different depth. Sandy soils with shallow groundwater tables are free from salts more quickly during leaching periods and salt restoration is going very slow (Jabbarov et al. 1977, Gintzburger et al. 2003). Additionally, in sandy soils decreasing of water table level may completely inhibit the salt accumulation process in the upper layers. Furthermore, the under-laying sandy layers facilitate groundwater flow-out at natural degree of drainage and help to wash out the salts. Consequently, the blocking of irrigation canals and drains is considered to be a feasible activity for slightly saline soils with shallow sandy soil layers (Yusupov et al., 1979).

Due to the gradual increase in salinization of soils and rising of water table, the majority of lands in the cropping farms in all surveyed countries have been gradually turned into marginal lands and removed from cultivation of traditional agricultural crops. Data on salinity of soils and surface water from various sources (open canal, drinking water and collector-drainage water) indicates a significant increase in the salinity levels. A direct correlation exists between the water table levels and the spread of salinization over different country's irrigated lands. Today the major problem in the northern Tajikistan, Fergana Valley, Mirzachul (formerly Golodnaya) steppe and partially northern Turkmenistan areas seems to be the inefficiency of drainage channels, excess volume of irrigation water, resulting in rising groundwater level. As a result of high solar radiation and evaporation rates, the salts are brought on the upper surface of soil and resulting in low yields of crops. The drainage channels that were built during Soviet Union era have been last maintained some 15-20 years. As a result, most of these channels are choked and there is an imbalance between the inflow and outflow of water in these channels. In most of the farms, the farmer's are forced to use the drainage water (4,000-5,000 ppm, 6-7 dS/m) when irrigation water is not available. In spite of the presence of extensive drainage network on 310,000 ha, 36% of the drained area (104,000 ha) has groundwater at 2 m depth from ground surface. As a result, salt accumulation naturally occurs in the soil and causes to rise at the surface, consequently leading to decreased plant growth and yields. Estimates of cotton losses due to salinization, accounts to 100,000 t/yr. Since this is the cash crop in the region, efforts are made to control the salinization process, which continues each year. Fluctuations of the GWT (groundwater table) in the Aral Sea Basin areas are mostly driven by irrigation and leaching activities (Ibrakhimov et al., 2004, Rakhmatullaev, 2004). Typically, GWTs may rise up to 1.2-1.4 m during the growing period, March to August, and fall in October down to about 1.8 m. Despite the shallow levels of the GWT in the Syrdarya and Amudarya River Deltas, GW use for irrigation is limited due to the high energy expenses required for pumping in conditions of extremely slow lateral subsurface water movement (Katz, 1976, Rakhmatullaev, 2004). Another important reason restricting the utilization of GW is its salinity level, mostly inappropriate for crops establishment.

During 1988-2001, the land area of Priaralie with GW levels shallower than 2.0 m averaged 84%, while areas with elevated GW salinity of 3-10 g/l averaged about 10% of the total irrigated area (MAWR, 2001). Such conditions require continuous operation of a well functioning artificial drainage system (Mukhammadiev, 1982). However, given the shallow GWTs and increasing land salinization in Aral Sea Basin countries , as well as Hungry steppe, Fergana Valley including Asht massive in the northern Tajikistan it can be concluded that the current draining and carrying function of the irrigation and drainage network is unsatisfactory (Toderich et al, 2005, Ibrakhimov, 2005).

Most of the abandoned irrigated lands have irrigation and drainage infrastructure, although often it is in a derelict state. The government is scheduling to return on an annual basis 10,000-15,000 ha of abandoned land back into production through reconstruction/rehabilitation of irrigation and drainage infrastructure. This approach requires huge investments from the government budget and therefore, the speed of rehabilitation of abandoned lands through government funds is slow and a long-term process.

Since maintenance of drainage system is costly, time consuming and requires annual recurring costs, alternate strategies needs to be identified for localized management, i.e. on-farm management.

3. Crops-Livestock farming system under saline environments

Many of Central Asian plain regions, like Khorezm, Bukhara and Fergana Valley are considered as one of the most ancient agricultural areas in the world (Altman, 1947). Currently existing farming systems include three main types: state farms, private farms and *dekhan* farms or household plots (Vlek et al., 2001). In Khorezm region only (Uzbekistan) by 2005, on-going post-Soviet reforms have resulted in the establishment of 13,839 private farms cropping about 188,329 ha or an average of 13.6 ha per farm and 247,840 *dekhan* farms cropping about 48,912 ha or an average of 0.2 ha per farm (Khorezm hokimiat, 2005). Irrigation water within the region is centrally distributed to the farms according to the area irrigated and crops grown. Agriculture is predominantly oriented towards cotton, wheat and rice cultivation. Among these, the cash crop cotton is the most common being planted on about half of the total arable land (Djalalov et al., 2005). Irrigated areas in whole five countries have been continuously expanding and by the year 2003 approximated 49% of the total area. Among them, about 42% is locally classified as having high potential for crop cultivation. Some 20-35% of the soils are classified as marginal, i.e., unsuitable for cropping (Abdullaev, 2002; Martius et al., 2004). However, limited water resources, soil salinity and poor soil fertility are still the major constraints to crop-livestock production in whole surveyed area. Today the farmers enface significant losses in soil fertility and as results in low cotton and grain (wheat and other gramineous crops) production. For example, the yield of cotton was decreased from 2.4 t/ha to 1.3 t/ha for last decades (for the period 1990-2005). The similar tendency was marked for the wheat production-as still order state major crop in all surveyed countries. Following independence, the large state farms inherited the problems already manifest in the high-input, energy intensive agricultural production methods of the Soviet system. Due to lack of financial resources, the former state-operated irrigation systems are deteriorated. Both the area harvested and yields have declined, with large areas of arable land, especially in Kazakhstan being left fallow.

The intensive development of irrigated agriculture and increase in cotton farming system between upper and downstream countries resulted in misbalance between water resources and land use. Water charges for 1 kg of raw cotton vary from 2.86 up to 4.04 m^3 of water used, which substantiate the huge quantity of water used throughout the entire units of irrigated system. It was also determined that for last 30–35 years, yield of cotton ranged within 2.77-3.28 t/ha, in spite that the crop capacity of cotton could be 3–4 times higher, if soil/water condition and thermal resources are favorable. Sharp decrease in cotton yield was observed from 1992 to 2003, when the average yield of raw cotton was reduced up to half. The main reason was related to poor functioning of irrigation infrastructure (pumping stations and drainage systems) and deterioration of soil fertility. Additionally, lack of water controlling instruments for flow rate; accumulation of erosion sediments in the drainage systems; inadequate water consumption according to the yield of crops; loss of surface water still remains a challenge in the region. The lack of competition in cotton financing and processing, and the absence of freedom of choice for farmers has resulted in steady decline of cotton farm productivity and profitability.

Most crops currently grown in all irrigated agricultural provinces of Central Asian countries are local and have been under cultivation for a long time. Most of the varieties grown lacks resistance against viral, fungal and bacterial diseases are not suitable for market demand (apart from local consumption), have a short shelf life, and lack shipment quality, appearance and size. The widespread use of self-produced seeds of open pollinated crops varieties remains a barrier to uniformity and reduces overall crop productivity. Post harvest technologies are poor developed or non-existent in the region. Double cropping has been a general trend in these semi-arid regions. Farmers usually cultivate wheat and barley in winter-spring and cotton, beet, melon and others crops in summer with irrigation. Wheat yields are also low at an average of 1.3 t/ha. The reduced productivity resulted in declining profitability of farms and increased poverty incidence, especially in rural areas. The quality of cotton seeds and other crops available to the farmer is generally of a low standard and as a result, the yields are lower than could be achieved if seed of higher performing varieties were more widely available.

Since both land and water are becoming more saline, biological approaches for reclaiming root zone area and also to sustain economic productivities are essential. Both local and introduced germplasm for initially lowering water table, followed by management practices to cultivate salt-tolerant forage and crops, and halophytes, can help to improve the livelihood of the local population in the target areas. Introduction of a range of deep rooted annuals and perennials forage species, legumes, chenopod and tree species can be used in a demonstration plot to monitor the changes in soil and water. This will assist with dryland salinity control and to provide productive options in whole Central Asian countries.

An additional good option for improving the livelihoods of the rural population in the patchily salt affected sandy deserts is to make of use the huge resources of underground slightly mineralized water. The artesian waters could be used for development of arid fodder production systems, in addition for recreation, vegetable production, and other purposes through management practices. The establishment of high productive livestock-feeding systems will ensure the safety of natural habitat and increase the income levels of the poor farmers. However, since the whole issue is using the saline artesian water for long-term sustainable production, care needs to be taken on management and environmental issues as well.

Livestock production is an integral part of livelihoods for rural poor communities under Central Asian saline environments. After independence, sale of livestock was the only source of income for the farmers, which resulted in huge reductions in the aggregate herd size. The sharp decrease of the livestock and poultry is observed. From 1991 until 2002, the total number of cattle (including cows) reduced by 76%, sheep and goats by 64%, and poultry by 95%. Earlier most part of the animals belonged to the public sector, i.e. in collective farms, state farms etc., but after 1991, a significant part of the cattle livestock are in households and in dekhan holdings. Parallel with reduction of livestock, a reduction in cattle-breeding production is observed also. Within the period of 1991-2002 production of meat in agricultural enterprises has reduced by 88%; milk by 84% and eggs by 98%. Dairy production has also been significantly affected. In 1991, the average annual milk production/cow was

2404 liters, which was reduced to only 1532 liters in 2002. This has been mainly related to the significant reduction of forages in the region.

In this respect, high-quality livestock feed is in short supply in the region due to limited access to high-quality grazing lands and increasing livestock and human populations. Recent research has shown that salt-tolerant food-feed crops and forage legumes could be used to increase resources for human and livestock consumption. However, efforts are needed to develop integrated biosaline crop-livestock agriculture based systems on food-feed crops and forage legumes for poor farmers using salt-affected soils and saline irrigation water (Toderich et al, 2006).

Thus, alternative agricultural production systems may assist in utilizing the marginal resources, provide economic returns, and environmental benefits to the farmers and agropastoralists in the remote arid areas. With proper screening and evaluation, non-conventional halophytes and salt tolerant crops can become an integral component in local crop-livestock feeding and farming production systems where water and/or soil salinity occurs.

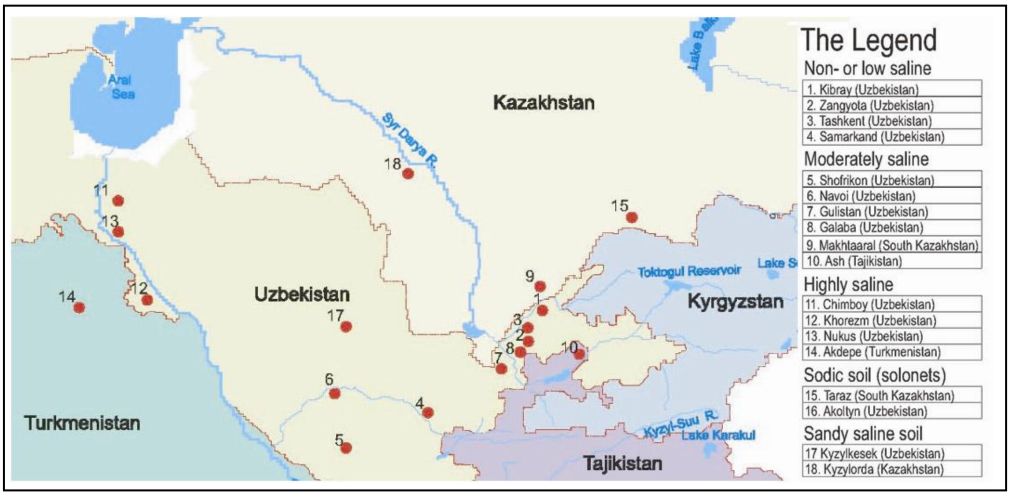
4. Biosaline system based on food-feed crops and forage legumes for farmers

A pilot study of ICBA (International Centre for Biosaline Agriculture) in collaboration with local institutions and farmers was conducted in 2005-2007 under arid/semiarid saline environments in Uzbekistan, Kazakhstan, Tajikistan and Turkmenistan. Various trials on biosaline agriculture production were established under different eco-agroclimatic zones in Central Asia that significantly differ in soil salinity level. Our experiments were conducted under the following soils environments:

- low or slightly (1.5-3.5 dS/m) saline serosems (Zangyota farm, Tashkent region) and salt-affected sandy desert lands (Kyzylkesek site, Navoi region) in Uzbekistan;
- Moderately saline (6-8 dS/m) that was the case at Galaba Farm, Syrdarya province (Uzbekistan) Asht massive, Sogd region (Tajikistan) and Makhtaral Experimental Plot (South Kazakhstan). Under these saline environments farmers continue to cultivate salt tolerant both traditional and non-traditional crops because of the reluctance for alternate crop options or policy implications;
- high saline (partially, sodic and heavy clay saline soils) at 8-12 dS/m at was described during the plant growth season at the Akdepe Experimental site, Dashauz province (Turkmenistan) and at the Experimental Station of Priaralie Research Institute of Agroecology and Agrochemistry, Kyzyl-Orda (Kazakhstan). Usually farmers obtain very low yields of the crops and sometimes there are complete crop failures depending upon the severity of the problem. The potential area and experimental trials for Biosaline Agriculture Development in Central Asia are shown in the Figure 2. .

The development of innovative approaches to managing salinity included native and introduced salt tolerant crop and forage species; the utilization of marginal quality waters to change and significantly improve cropping systems and the management of specific soil related constraints. The bioremediation of abandoned saline lands was one of a number of strategies that we employed to bring these lands back to their full production potential. This approach, however, should not be viewed as a substitute to technical interventions (i.e. improved water management, effective drainage infrastructure etc) but rather as a phase in the rehabilitation/reclamation of salt movement process and increasing of green biomass production.

Fig. 2 Benchmark sites for sorghum and pearl millet productivity



Source: Kristina Toderich & Oksana Tsoy, 2007 (unpublished data)

The main goal of this component is to evaluate crop and forage species for their ability to grow and produce economic yields on saline soils; and secondly, to evaluate a range of management options for the cultivation of forage species and tree/shrub plantation under salinity conditions with a specific focus on their role in bio-drainage.

In was expected that crop benefits by improvement in soils and micro-climatic conditions provided by the trees/shrubs; reduction in weed speed and potential evapo-transpiration, buffered temperatures, sand storms, increased organic matter in the soil given more stable structure, high permeability, better water budget, and quicker turnover of geobiogene.

Introduction of strips-alley cropping system suggested in this study represent an alternative for private farms in the livestock-based farming system, as well as a way to diversify feed resources under unfavorable saline environments. It also leads to the uniform distribution of good quality feed resources throughout the year and during difficult periods while preserving soils, water and phytogenetic resources. Another technique used in the salt affected sandy desert environments is to plant shrubs as windbreaks to spare the land for other crops and help protect the soils from wind erosion and sand encroachment. At present efforts are made to provide plants materials (seeds, seedlings, younger plants) to the farmers and train them on how to manage the improved salt prone marginal lands.

4.1. The potential and challenges of afforestation on saline marginal lands

The rapid expansion of irrigated agriculture in Central Asia has greatly reduced the natural desert, riparian and foothills forest that has also contributed to the advancing desertification process inclusive secondary salinization and waterlogging. Conventional solutions to combat waterlogging and salinity still are horizontal subsurface drainage systems consisting horizontal buried pipes and deep open drains. From 1960 to 1980, costly drainage systems were constructed for the irrigated lands in all Central Asian countries. Previous experience, however, had shown that these systems although having distinct advantages create several problems such as disposal of the drainage water, maintenance and high cost of drainage infrastructure and involvement under tree plantations highly productive lands (Abrol et al, 1988, Djalalov et al., 2005). Elsewhere, afforestation has proved to be effective in re-vegetating saline landscapes, providing valuable products to farmers from marginal degraded land, and make use of the otherwise unproductive land and lower the elevated groundwater table (GWT) via biodrainage (Heuperman et al., 2002; Marcar and Craw-Ford, 2004). However, to ensure effective and sustainable outcomes, afforestation of marginal lands must be preceded by a comprehensive evaluation of appropriate both native and introduced tree species.

An overview of the forest resources in Central Asia for the period 1983-2007 showed 4.0-5.0 times decrease, resulting mainly from agricultural expansion and continuous anthropogenic pressure, such as overgrazing, cutting and up-rooting for fuel wood, as well as secondary soil salinization impact (UNEP and Glavgidromet, 1999). In the past, large parts of the land under the desert saksaul (*Haloxylon* spp.) forest in the Bukhara region, the riparian *tugai* forests of Kazalinsk, Tigrovaya Balka, Muynak, Karakalpakistan and Fergana Valley were taken under agricultural use, decreasing the forest cover to more than 10.7% (Khanazarov & Kayumov, 1993, Turdieva et. all, 2007). In addition, 85% of woody desert vegetation is represented by small trees at 4 m in height (FAO, 2005, Gintzburger et al, 2003). In 1999, Uzbekistan prepared its National Action Program to combat land desertification in the country (UNEP and Glavgidromet, 1999). Program measures included land afforestation particularly on the saline dry bottom of the Aral Sea (Khanazarov and Novitsky, 1990), as well as on its periphery, to protect agricultural land from wind erosion and sand/salt deposition. Within irrigated areas, tree shelterbelts have been planted to protect the adjacent cropped fields. These measures have been guided by previous numerous studies throughout Uzbekistan and Turkmenistan (Botman, 1988; Kayumov, 1986; Nechaeva et al, 1978, Nechaeva , 1985, Kayimov, 1993, Kayumov et al., 1997, Gintzburger et al, 2003, Djanibekov, 2003, Kamilov et al., 2003), which noted the ameliorative effects of the shelterbelts such as yield increases on adjacent agricultural fields by 15-20%. In the meantime, afforestation of degraded land, abandoned from agricultural use, has not received much attention, although various studies in Uzbekistan have examined the salinity tolerance of various tree species and the use of saline water for forest production (Fimkin, 1972, Khamzina 2006). However, past species assessment studies have mostly used the limited conventional height/diameter measurements to evaluate tree performance (Fimkin, 1983; Makhno, 1962). In a few cases, tree aboveground dry matter production was measured (Khanazarov and Kayimov, 1993), and even less information has been collected on root biomass, structure, and dimension although these are key physiological parameters for the assessment of species suitability for afforestation (Heuperman et al.,2002, Khamsina,2006). Fast root growth and biomass development, characterizing by establishment on marginal land are important but not exhaustive features that suitable species must possess. Knowledge of survival rate, reproduction and physiological characteristics of salt tolerant species would facilitate the selection of appropriate trees for planting over the predominant shallow groundwater tables (GWT), which would enhance water discharge through biodrainage and, by this, mitigate the problem of waterlogging and salt accumulation at the root zone. However, available information on plantation by various species under the typical agro-climatic conditions in Aral Sea Basin are insufficient and needs to be supplemented to make better-informed farmers and policy makers on the selection of tree species for afforestation. In addition, using selection criteria measuring the ecological advantages of various species on marginal land, tree species were selected that provide direct benefits to farmers, such as producing wood for fuel and construction, landscaping purpose and/or fodder for livestock (Lamers, 1995; Rockwood et al., 2004). Although fuel wood consumption is significant in Central Asian countries (UNFCC, 2001), no comprehensive database on fuel wood characteristics has been established yet. The information on fodder quality of perennial vegetation in Central Asian region mostly covers rangeland species, while data on fodder tree species is sparse (Gintzburger et al., 2003). Therefore, there is an interest in complementing the conventional methods of tree-growth evaluation employed by foresters with appropriate assessment methods used in ecologically oriented studies that estimate relative growth rates and green biomass production under saline habitats (Poorter, 2002; Poorter and de Jong, 1999). Recent conditions of the salt affected environments in the desert and semidesert areas of Aral Sea Basin has lead decision makers and scientists to take urgent measures to rehabilitate, sustainable use and protect the marginal resources to enhance their productivity damaged by human activities (Gus Gintzburger et al, 2003 Khamzina, 2006,). However, few studies in Uzbekistan have addressed the suitability of indigenous and exotic tree and shrub species for rehabilitation and reclamation of degraded salt affected marginal habitats within irrigated areas.

The International Center for Biosaline Agriculture (ICBA) along with ICARDA and IWMI through has initiated studies of degraded lands, characterized by soil salinity, rising saline GWT and low soil fertility in Aral Sea Basin and developed strategies for their reclamation that promises the farmers a return from those areas of their land where crops are no longer profitable. It is hoped that the findings of this study will support efforts of afforestation of the degraded landscapes not only in the intervention region but also in other areas of Central Asia suffering from similar problems of soil salinization and sodification.

The Akdepe salt affected marginal farmer fields (Dashauz region (Turkmenistan), Kyzylkesek Experimental station of the Karakul Sheep Breeding Institute (Navoi region, Uzbekistan), as well as Kazalinsk demonstration plot site, Institute of Agriculture and Agroecology in Pre-Aralie (Kyzyl-Orda region, Kazakhstan) have been targeted in the current study as one of the areas in Central Asia most strongly affected by waterlogging and salinization. The sites were characterized by poor soil-nutrient stocks (humus < 1.0) and severe secondary soil salinization. Over the two growing seasons, the ground water table (GWT) averaged 2.5 m and 0.5 m below the soil surface at the loamy and the sandy site, respectively. The mean electrical conductivity of the groundwater was 3.3 and 4.9 dS/m for sandy saline desert (Kyzylkesek) and 5.8 – 16.5 dS/m for clay loamy deltaic soils (Kazalinsk and Akdepe) sites. Plantations were established on the degraded abandoned lands, which were levelled and leached from salts prior to the experiment to provide homogeneity of initial growing conditions. Following soil leaching, 500 of 0.5 and -year-old seedlings of 13 multipurpose tree and shrub species (50 seedlings per species) were planted at the sites, which measured 0.09-0.35 hectares. Seedlings of introduce halophytic species were produced at the Akdepe experimental station and at the nursery of the Plant Industry Institute, Uzbekistan, and were transplanted to the site under appropriate management in the fall period (.ICBA Guidelines, 2005, Toderich et al, 2006). Seedlings were planted between the ridge and bottom of the irrigation furrow at a spacing of 3.0 x3.0 m, half way from the furrow bottom. This large spacing between rows/plots was introduced to minimize possible competition of different tree species in the rhizosphere from horizontal extension of the root systems due to the high GWT. The prepared furrows were about 40 cm deep and 70 cm wide. Each plot consisted of two rows with 25-30 randomly planted trees. Biometric parameters and survival rates were determined per each site. It was found that the optimum target density should be around 900-1200 trees/ha.

Since the introduction and distribution of tree species for afforestation of degraded salt affected marginal lands in the Aral Sea Basin will be a huge effort a prior literature survey regarding selection of multipurpose deciduous tree and shrub species representatives of native and previously introduced drought and salt tolerant species were selected to conduct our experiments. Our purpose was achieved by creation of pastoral shelter, wind breaks and tree belts of *Haloxylon aphyllum* and other species: *Salsola Richteri, S. Paletzkiana, Elaeagnus angustifolia,* various species of genera *Tamarix, Halothamnus subaphylla, Ulmus densa* and cultivated fruit trees like *Morus nigra, M. alba, Prunus domestica*, Armeniaca *vulgare, Malus silvestris, M. domestica, Cynadon oblonga, various species of Populus, Robinia pseudoacacia, Salix babylonica, and two new introduced tree species: Acacia ampliceps and Tuja occidentalis* The comprehensive analyzing of multipurpose tree species (MPTS) suggested selection of tree species most appropriate from the perspective of high survival rates, quick initial growth, rapid establishment, ability of the root systems to adapt and cope with nutrient-poor and salt-stressed conditions and having high suitability for bio-draining. Suitable species we have also selected by their valuable source for fruits, foliage/fodder, and/or firewood to motivate farmer engagement in afforestation. Additional growth characteristics such as self-propagation by root suckers and high tolerance to salinity and frosts after tree establishment were also considered during our studies. As availability of irrigation water on marginal land is inadequate, the establishment and growth of tree species was field tested under deficit irrigation regime by using traditional furrows. The maximum seasonal amount of water applied (about 1,600 - 3,800 m ha depending of the tree species) was much lower than the quantity used by the dominating crops such as cotton (10,000 m ha), winter wheat (6,000 m ha) and rice (25,000 m ha) (MAU & AASU, 1996) which still can be grown on marginal lands.

The afforestation of saline marginal lands with the above selected species was initially dependant on irrigation before the trees can solely rely on the available groundwater resources. Based on the performance of the trees, it can be concluded that stand establishment was successful given the accessibility of the groundwater resources of an appropriate quality. The salinity level of the GWT (8.0 – 16.5 dS/m), though inappropriate for the common local agricultural crops, did not restrict growth of these tree species. Due to the sample soil moisture conditions provided by the groundwater and irrigation (although applied at deficit rates), the trees tolerated the strong soil salinity without inhibition in survival and growth rate.

Table 5 Performance indicators of native and introduced species of tree and shrubs

Parameters species	Growth rate (at first year)	Root establishment	Reproduction	Above ground DM production	Bio-drainage potential; feed and firewood value	Soil salinity level	Winter frost tolerance	Rate survival (%)
Haloxylon aphyllum	+	±	a,b,c	+	±	+	+	±
Tamarix hispida	±	+	invasive	±	±	+	+	+
T. rasimossimus	±	+	invasive	±		+	+	±
Salsola Richteri	+	+	a,b,c	±	±	±	±	±
S. plaetzkiana	+	+	a,b,c	±	±	±	±	±
Populus alba	±	±	a,b	±		+	±	+
P. nigra var.pyramidalis	±	±	a,b	±	+	±	+	-
P.euphratica	±	±	a,b	±	+		±	-
Salix babylonica	±	±	a,b,c	±	±	+	±	-
Hyppophae ramnoides	±	±	a,b,c	±	±	+	±	+
Ulmus densa	-	-	a,b	±	±	±	±	±
Elaeagnus angustifolia	+	+	a,b,c	+	+	+	±	+
Robinia pseudoacacia	-	+	a,b,c	+	+	-	+	±
Prunus armeniaca	-	-	a,b	-	-	-	-	±
Morus alba	+	±	a,b	+	-	±	±	+
Morus nigra	+	±	a,b	+	±	±	±	±
Malus domestica	±	±	a,b	±	±	-	-	±
Malus silvestris	±	-	a,b	±	±	±	+	±
Cynadon oblonga	±	±	a,b	±	±	±	±	+
Armeniaca vulgare	±	±	a,b,c	±	±	±	±	+
Thuja occidentalis	-	-	b	-	-	-	-	-
Acacia ampliceps	+	+	a,b	+	+	+	-	-
Atriplex undulata	+	+	a,b,c	+	+	+	+	+

+ =high potential; ± = medium potential; - = low potential

The leading tree species with regards to survival rate, growth characteristics and adaptability to high saline natural environment proved to be *Haloxylon apphyllum, Salsola paletzkiana, S. richteri* at the saline sandy site, followed by *E. angustifolia , U. pumila, P. euphratica* and *P. nigra var. pyramidalis, Robinia pseudoacacia, M. alba, Morus nigra* whereas fruit species such as *Cynadon oblonga, Armeniaca vulgare, Prunus armeniaca* and species of genera Malus, though desirable from the farmer's financial viewpoint, showed low bio drainage potential. The overall ranking of the trees, weighing all parameters concurrently (tab. 4), shows that species of genus Tamarix, Salix babylonica and partially Elaeagnus angustifolia have the highest potential for growing on both loamy and sandy soils, which represent the dominant soil textures in the region. Useful above-ground DM production for 2006-2007 seasons followed the sequence Acacia ampliceps > E. angustifolia > M.alba, M.nigra > U. densa > P.euphratica > Robinia pseudoacacia > Salix babylonica. These species combined fast growth with a moderate ability to develop leaf biomass rapidly, which is characterized by a feed quality sufficiently to be used during the off-season, when feed availability is limited.

Wild species Ulmus densa and species of genus Tamarix, maintaining high absolute values of above-ground biomass, were very tolerant to saline-alkali soil with a pH values of up to 8,5. In addition, it tolerates low soil moisture and low ambient humidity Although U. densa does not seems only partly suitable for the afforestation of degraded soils, since it is also known for its vulnerability and high mortality at an early age (Wang Shiji et al., 1996), which is confirmed by the findings in the present study.

The overall ranking of the trees, weighing all parameters concurrently (tab. 4), shows that species of genus Tamarix, Salix babylonica and partially Elaeagnus angustifolia have the highest potential for growing on both loamy and sandy soils, which represent the dominant soil textures in the region. As results, at marginal sites where a shallow, slightly-to-moderately saline GWT is available throughout the growing season *Elaeagnus angustifolia, Robinia pseudoacacia* and new introduced *Acacia ampliceps* showed the fastest growth and highest water use, indicating the greatest suitability for planting on saline low fertility land, which was very likely also due to its N fixation capability under saline conditions. Since the N-fixing these also have superior feed and firewood characteristics, they may provide added value, which makes them the most suitable candidates for biodrainage purposes. Preliminary outcomes of this preliminarily studies on salt affected soils in the floodplains and River deltas of Aral Sea Basin have also indicated that tree plantations with E. angustifolia, Ulmus densa, Populus, Morus species have potential for increasing the soil organic matter due to the relatively rapid leaf litter decomposition.

Morus nigra and *Cydonia oblonga* showed adequate DM production on degraded land, although demonstrating high biomass allocation towards the root fraction. Among tree species, Poplar (*Populus alba* and *P. euphratica*) showed maximum growth for all parameters studied followed by mulberry (Morus nigra). Populus diversifoilia which displayed high rates of leaf and wood production appeared to be the most sensitive to saline sandy soil type. Similarly, it had slow longitudinal root growth and low root DM production at sandy site while exhibiting superior below-ground development at the sandy loamy soils

Introduced coniferous species *Thuja occidentalis* was the only species that showed poor growth under furrow irrigation at the Dashauz province and at the second year died due to its high sensitivity to frosts.

The assessment of tree performance during the first three years on marginal land showed high growth rates, which were comparable to those reported for trees on irrigated agricultural land, despite the increase of the root-zone salinity from slight to strong .Chemical soil analysis conducted during the period 2005-2006 showed that the post-leaching soil salinity at both sites did not increase significantly but remained slightly saline.

The integration of sociological surveys and tree demonstration trials can assist in gaining farmers' willingness to integrate ecologically appropriate species that can provide direct benefits to degraded land where crops and majority of fruit trees are unproductive

Evaluation of survival rate, performance and productivity including biomass and seed production of non-conventional halophytes firstly introduced in Central Asian flora: *Acacia ampliceps* and *Atriplex nummularia*, *A. undulata* and *A. amnicola* showed its high potential for the reclamation of salt affected marginal lands. All species tolerated average root-zone salinity of 8-16,8 dS/m. Seedlings of *Acacia ampliceps* were obtained from by direct seed sowing in the field (February 2006) and through the establishment in plastic bags. The growth rate of *Acacia* was very fast at 12-18 cm per month at the rooting stage and 25-30 cm when the basal stems develop woody characters. Among *Atriplex* species, the highest seed germination (approximately 89%) under field condition was observed for *Atriplex undulata*, which showed a rapid growth rate and accumulation of biomass. The biomass produced in 1, 5 years was 5.6 kg /m^2 and was readily browsed by cattle and small ruminants. In addition plant height and plant diameter (D1) ratio of *Atriplex undulata*, in respect to different types of reproduction showed that plants grown through vegetative propagation results in better establishment (Fig.3). This method will be more convenient for farmers.

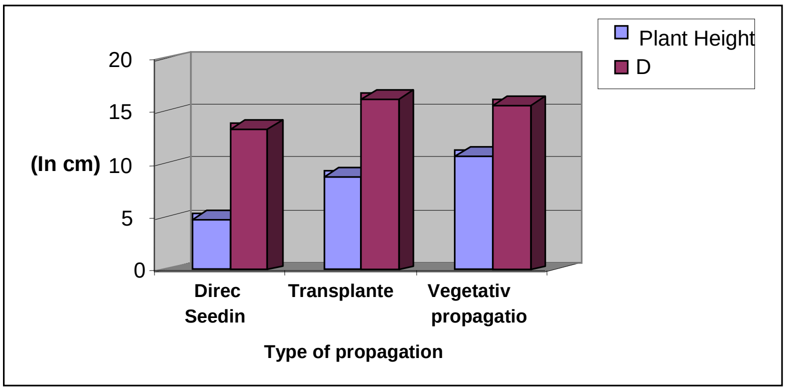


Figure 3 Plant growth of *Atriplex undulata* using different methods of propagation (Gulistan University experimental plot, September 2007)

Comparative studies of plant vigour and response to strong frosts that were marked at the end of 2006 and beginning of 2007 showed that *Atriplex undulata* performed very well, when compared with *A. nummularia, A. amnicola* and *Acacia ampliceps* grown under the similar saline environments over the same time (Table 6).

Earlier data collected in 2006, showed a low frost tolerance of *Acacia ampliceps* and two species of *Atriplex* (*A. nummularia and A. amnicola*). The maximum temperature at which the plants survived was at -12 ºC. However, *A. undulata* survived (95%) in the strong winter frost (20-25 ºC) and at the beginning of March showed good re-growth ability. We found out that *Atriplex undulata* seems to be the frost tolerant, most widely adapted and high yielding species under high saline environments. *Acacia ampliceps* and *A. nummularia* were also among the high yielding and fast-growing species that were tested, but with less frost tolerance.

Table 6 Plant performance of non-conventional halophytic trees and shrubs (from ICBA) (Galaba Farm compared with Akdepe site trials, 2006-2007)

Traits/Date of observation	Plant height (cm)		Average air temperatures		Plant vigor (%)	
	A*	B**	A	B	A	B
Acacia ampliceps						
16 August 2006	25.4	78.5	28	31.2	100	100
1 September 2006	39.5	96.7	22	20.7	100	100
1 October 2006	51.5	120	10.7	0 - +5;	100	100
1 November 2006	98.2	-	+5; -2-8;	-10	0	0
22 December 2006	-	-	-11.8	-14.9	0	0
January 2007	-	-	-14***	-17.5	0	0
Atriplex undulata						
August 2006	32.0	42.1	34.4	31.2	100	100
September 2006	56.6	63.6	26.3	20.7	100	100
1 October 2006	82.0	136.2	10.7	0 - +5;	94	100
1 November	91.6	136.2	+2; -6	-10	90	98
22 December 2006	no changes	no changes	-11.8	-14.9	90	90
January 2007	no changes	no changes	- 14.0;	- 15	86	90
February 2007	no changes	no changes	-3 ; -6	-7 -9	86	90
March 2007	re-growth	re-growth	-3.36 + 6	-5 + 2	86	90
Atriplex nummularia						
August 2006	38.1	31.1	28	31.2	100	100
1 September 2006	62.7	40.9	22	20.7	100	100
1 October 2006	71.0	68.4	10.7	0 - +5;	100	100
1 November 2006	72.8	68.4	+2; -6	-2 - 8	0	0
22 December 2006	died	died	-14.8***	-16.9***	0	0
Atriplex amnicola						
August 2006	28.3	33.9	28	31.2	100	
1 September 2006	48.6	54.7	22	20.7	100	100
1 October 2006	75.6	68.3	10.7	0 - +5;	100	100
1 November	89.9	71.0	+2; -6	-10	0	0
December 2006	died	died	-14.8***	-14.9	0	0

A*: Clay saline desert (Gulistan);
B** Akdepe site, February 2007;
*** A strong frost up to (-20 °C) has been noted once at Akdepe site, Turkmenistan.

4.2. Evaluation of local and introduced salt tolerant germplasm

4.2.1. Mixed cropping of cereals cultivated between strips of saltbushes (Atriplex)

Fabaceae species represent about 9.8% (Korovin, 1961, Granitov, 1964) of the overall flora of arid/semiarid zones of Uzbekistan. Preliminary field trials, exhibited their potential use in the rehabilitation of degraded arid and semiarid lands, as reported by experienced surveyors (Erejepov, 1978, Halilov, 1993, Kamalov, 1995, Mavlyanov, 1997, Ashurmetov et al., 1998, 2002, Toderich et al., 1998, Kushiev et al., 2006). Preliminary results show that this material is genetically rich with potential for drought and salt resistance. Despite a number of recent publications regarding to plant salt stress tolerance, the structural mechanisms of genetic control to drought/saline resistance are still poorly understood. Many native legumes Acacia, Astragalus, Alhagi, Glycyrrhyza, Melilotus, Cicer, Vicia, Lathyrus of Central Asian desert flora that may be sometimes rhysomatous, are remarkably drought/salt tolerant and capable of sustaining relatively heavy grazing (Ashurmetov et al., 2002). They grow well in association with other wild arid plant communities and often provide severe competition to perennial species both in natural and sowing pasture plant communities on saline soils and on disturbed mine contaminated sites. This material is still available, but many taxa are at the verge of disappearance due to grazing abuse and may become an irreversible loss of mankind biodiversity resources. Under the current cotton and wheat production system that dominates parts of Uzbekistan and Turkmenistan, small-scale farmers are not able to apply adequate levels of fertilizer due to their high costs. As a nitrogen-fixing salt tolerant legumes have been expected to enhance soil fertility. In addition, majority of above cited legumes are deep-rooted crops that extracts water from depth thereby decreasing elevated groundwater levels in the case of waterlogged soils. In this regards our present studies includes evaluation of annual and perennial, mostly wild legumes such as *Mellilotus album, Mellilotus officinalis, Vicia angustifolia, Lathyrus sativus, Lotus corniculatus, Lens culinarius* along with of two local and ICBA's alfalfa (*Medicago sativa*) varieties both in clean and mixed sowing with Triticale and ICBA's barley (*Hordeum vulgare*) varieties. All mentioned species were establish by direct broadcasting seeding between wide –space forage shrubs hedgerows, i.e. between rows of Atriplex undulata. It was expected that this system could provide:

- the suitable and efficient water use: shrubs having a deep rooting system use moisture not available for annual crops;
- microclimate is changed reducing wind speed and soil erosion and moderating temperatures extreme;
- short-term vegetation of annual frost tolerant winter legumes and cereals will provide with additional high protein forages in early spring time; additionally being planted in dense standing biomass these crops significantly decrease the water table level and evapotranspiration that simultaneously decrease the salinization of upper soil profile;
- early-maturating legumes can be leave as green manure into the filed before starting of sowing period for cotton;

- the combination of energy-rich and protein-poor stubble of gramineous crops could be complemented by the energy-poor, but nitrogen rich shrubs.

Trial was conducted in an area of 0.25 ha at farmer's field in Galaba Farm under clay loamy saline desert environments at Syrdarya province with a combination of barley-alfalfa and triticale-alfalfa cropping systems between rows of Atriplex *undulata*

Preliminarily results on evaluation of inter-cropping fodder legume mixed with salt and frost tolerant barley and Triticale showed a positive effect in increasing fodder biomass per unit land area (Table 7).

Table 7 Salt tolerant crops under alley-cropping system

№	Treatments/Crops	Height of Plant	Date of Harvest (first cutting)	Fresh Biomass (g/m^2)	Fresh Biomass (t/ha)	Dry Biomass (t/ha)
1	Alfalfa Anand-2 (pure stand)	58.0	20.04 07	520	5.20	1.60
2	Alfalfa ICBA germplasm (pure stand)	55.3	20.04.07	400	4.00	1.20
3	Barley (pure stand)	66.2	20.04.07	1050	10.50	3.20
4	Alfalfa "Kyzylkumskaya" (pure stand)	76.0	20.04.07	720	7.20	2.10
5	Alfalfa + barley			1450	14.50	4.40
6	Triticale (pure stand)	94.0	20.04.07	1030	10.30	3.09
7	Alfalfa+ Triticale		20.04.07	1640	16.40	4.98

Fresh biomass of alfalfa (first seasonal cutting) in pure stand was 7.20 t/ha, while mixed sowing with Triticale increased to 16.40 t/ha. Experiments suggest that *A. undulata* mixed with various short–terms (*Vicia angustifoilia and Onobrychis chorsanica Bge*) and long term vegetation legumes like alfalfa, *Melilotus officinalis, and Lathyrus sativa* may be successfully integrated into a farming livestock feeding system. This will provide alternative winter-spring forage with efficient protein- energy balance. We have found that barley-Triticale-alfalfa yields were at 20% higher, in such alley-cropping system that in traditional barley-fallow system. Growing salt-tolerant high-yield alfalfa in combination with cereals, alternated by strips of *Atriplex undulata* could help farmers produce more high nutritional values forage (both fresh and as hay).

For each of the cereals an analysis was undertaken to determine whether there were significant difference in the yields of these cereals under the different alfalfa varieties (Fig. 4)

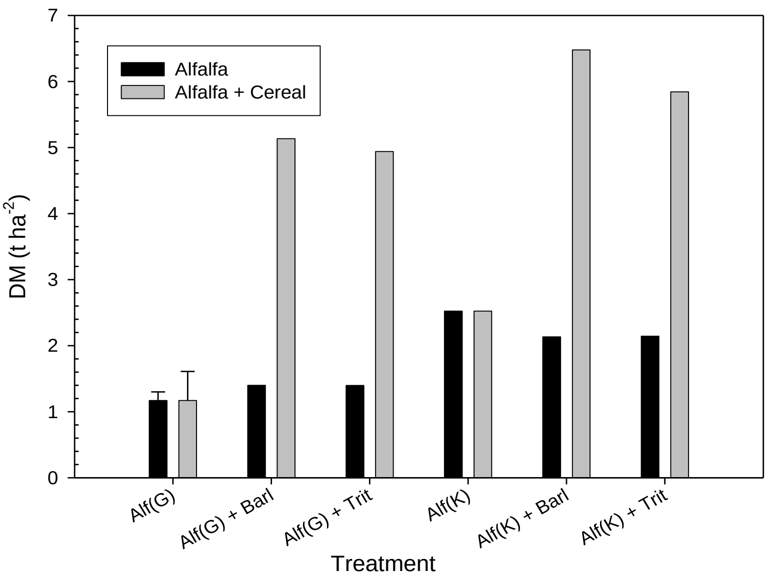


Figure 4 Differences in yields of alfalfa intercropped with early maturing cereals

No significant differences in yields for both barley and triticale were observed with respect to the variety of alfalfa, hence the yield increases associated with mixed cropping of barley and triticale with alfalfa is associated with the superior yield potential of local Kyzylkumskaya alfalfa variety. Thus, the data would suggest that there are significant advantages in growing mixed cereal/alfalfa with respect to biomass production.

4.2.2. Evaluation and selection of sorghum and pearl millet

Research introduction of sorghum in Central Asia dates back to the late 1940th. Sorghum bicolor as a C_4 crops, under the irrigated agricultural and rain fed zones of this region, is largely cultivated as fodder crop and as feed for human consumption by the rural poor, mostly in the remote desert and semidesert marginal areas (Alekseeva et al., 1959; Dzhabarov, 1961; Edenbayev, 1991; Massino, 1982, 2004, 2006, (Begdullayeva et al., 2007)). This gramineous crop grows on diverse soil types and in a variety of climatic conditions and is well adapted to extreme marginal salt/affected; waste/abandoned with shortage water resources environments. Previous investigations showed that sorghum as cereal alternatives grows well, where other crops generally fail completely. Despite of its highly economical value the area under its cultivation as a percentage of total cereals is relatively low, i.e. less than 3.8%. During mid 1990 there was a considerable decrease in sorghum area in Uzbekistan and Turkmenistan due to decline in its consumption. The cultivation of sorghum and pearl millet in the irrigated agricultural zones of all Central Asian countries was replaced by other crops like cotton, wheat, alfalfa and vegetables, while the area and production of sorghum has been renovated during the last decades. It appears that sorghum is again becoming popular due to its adaptability to harsh climatic semiarid conditions with poor soil fertility.

Dual-purpose crops (grain and fodder), where the crop-livestock (mixed) farming system widely practiced, is considered as one of the important livelihood strategies of rural communities and farmers. Dual-purpose sorghum under irrigated summer season is usually taken up as a second crop after early legumes or wheat. Under the condition of intensification of agriculture and, consequently, increasing of salinization there would be a huge demand for sorghum grain in future for animal feed because there is no sufficient production of maize to be used in animal nutrition. Introduction and development of early-maturing dwarf genotypes will fit in intercropping systems based on low canopy crops, like soybean and others legumes. Recently research is going on for selection of sweet sorghum and exploring opportunities for ethanol production from sweet sorghum (Massino, 2006). Early spring seed sowing of sorghum varieties on the saline/degraded desert soils (February-March) ensures high yields of fresh biomass due to using of winter-spring rainfall/precipitation (Toderich, unpublished data).

Trials for evaluation and first screening of 15 sorghums and 26 improved lines of pearl millet of ICBA/ICRISAT germplasm was evaluated using 15 agro-biological characters in order to identify the most salt/drought tolerant and high productive under different eco-agroecological zones of Central Asia, which significantly differ in soil salinity. Two years testing of pearl millet germplasm showed a high survival rate and fresh biomass accumulation for the IP 6112, IP 19612, ICMS 7704, IP 6110, IP 19586, ICMV 155 Brist, and HHVDBC Tall, MC 94 C_2, Daura Genepool, Sudan Pop III and Gurenian 4 improved lines/genotypes. Yields of fresh biomass at the end of plant vegetative period varied from 10.2 to 12.3 kg/m^2 with a plant density of 65-100 plant m^{-2}. Height of plants ranged 165-280 cm and number of basal tillers varied from 9-32, respectively. These accessions are characterized as early flowering and fast maturing. For example more than 75% inflorescences development and seed maturation of IP 19612, ICMS 7704 ICMV 155 Brist, Dauro Genopool, Sudan Pop III, ICMV 155 Brist, HHVDBC Tall had occurred by the end of July being sown in the middle of April. The length of panicle for majority of above-mentioned accessions varied from 18.9-39 cm. Under an irrigation regime with moderately saline water (EC 1.62-8.21 dS/m) with the averaged rate of water irrigation as 600m^3 the 10 top accessions of pearl millet were identified The highest seed production capacity was observed for Sudan Pop III (3.85 kg/m^2) and ICMS 7704 (3.38 kg/m^2).

Under farming saline environments of Central Asia the average values of green fodder production in the top-yielding sorghum varieties/lines changed from 87.0-97.3 t/ha with equivalent dry matter production levels ranging from 16.0-27.0 t/ha. Similarly, the top-yielding populations/lines of sorghum were identified that exhibited grain yield of local variety at 2.0-2.5 times. Preliminarily data revealed that plant productive longevity significantly varies among tested accessions and is positively correlated with the sum of effective temperatures. Sugar Graze, Speed Feed, Pioneer 858, and ICSV 745, SP 39105 sorghum varieties are considered to be the most early-maturation accessions. According to flowering patterns of sorghum introductions the following early-flowering genotypes were identified: IP 39105, Pioneer 858, ICSV 745, Speed Feed, Sugar Graze, Super Dan; and late-flowering samples: SP 39262, ICSV 745, ICSV 112. The high performing 8 accessions of sorghum with an average dry matter production of 13.3-27.3 tons/ha and seed yield of 0.50-2.6 tons/ha tested under different seasonal ranges of soil salinity could be also selected for further dissemination in Uzbekistan. The highest yield of fresh biomass varied between 7.0 kg/m^2 (Super Dan), 7.4 kg/m^2 (Speed Feed) up to 8.0 kg/m^2 (Sugar Graze) and 4.6 kg/m^2 (Pioneer 858), respectively. The majority of slow-growing and late-maturing accessions of sorghum, namely ICSV 112, ICSV 745, SP 39105, SP 712 are characterized by having a thick succulent stems and long and ramified panicles that made these varieties useful both for forage (silage) and grain production.

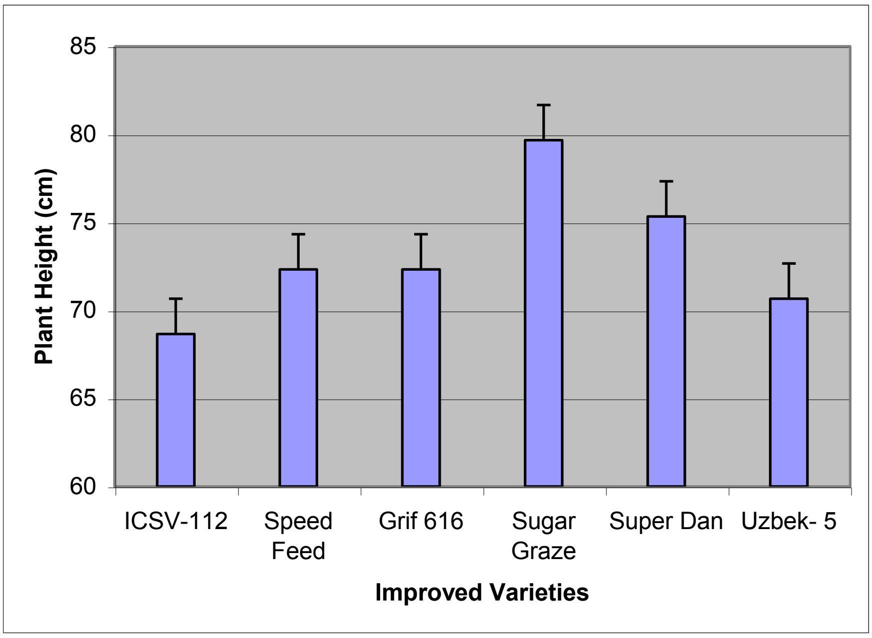


Figure 5 Average plant heights of top-yielding improved lines of sorghum (ICBA germplasm) compared with local standards at 65 days after sowing (July 2007).

Experimental data showed that the productivity of sorghum differs between the countries and regions within the country with varying rainfall, soil type and level of salinity (Fig. 6)

Evaluated sweet sorghum local breds and ICBA/ICRISAT improved lines reach full milky stage between 81-128 days under two seasonal irrigation with rate norm of 700-800 m^3 and a plant density of 60-82 thousand/ha. Stalk for sugar extraction can be harvested in 4-5 weeks before seed maturation. The highest yield of fresh biomass with produced about 68% of juice and almost 8.5 t/ha total sugar was marked for Uzbekistan-18 varieties, followed by Karakalpakistan (6.5 t/ha total sugar) with Orangevoe 160 (4.1 t/ha total sugar) as local varieties and Sugar Graze, ICSV 745, ICSV 112 among tested improved lines from ICBA that could successfully used for the ethanol production. The disadvantages of local varieties however are its continuous and late maturity. ISCV 112 and ISCV 745 varieties from ICBA sound more promising due to almost simultaneously maturity, despite of insignificantly lowest extractable juice and total sugar production compared with standard.

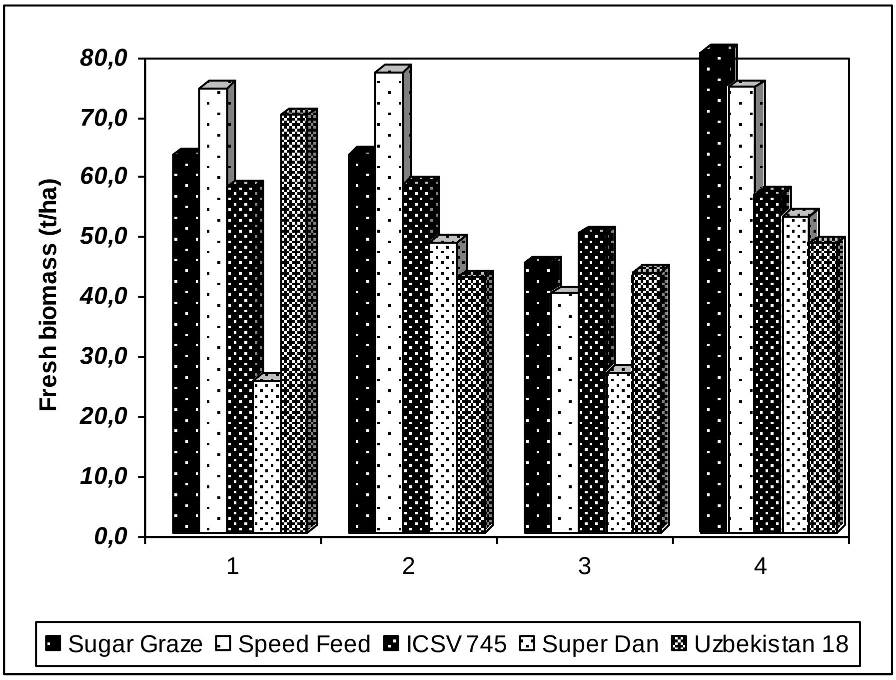
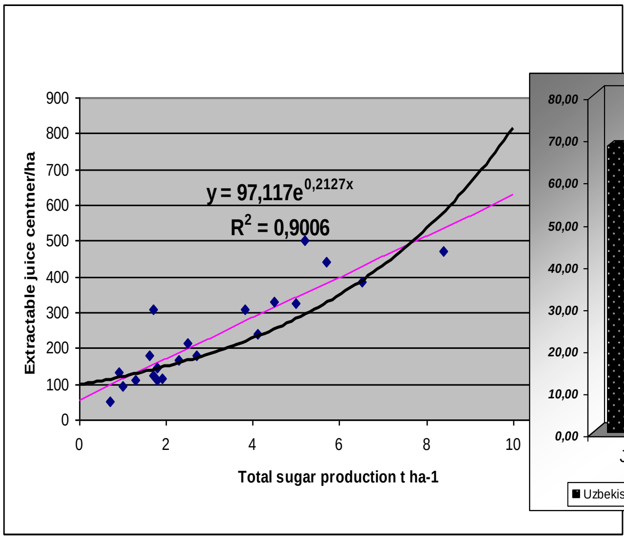


Figure 6 Fresh biomass of top-yielding varieties of sorghum

1. Tashkent region. slightly saline (Ec=1.5-3.5 dS/m)
2. Kazakhstan. medium (moderately) sodic alkaline soils (Ec=4.5–6.8 dS/m)
3. Kyzylkum. medium sandy saline (6.0–8.0 dS/m)
4. Turkmenistan. high saline clay loamy soils (8.0–12.0 dS/m)

Sorghum varieties Uzbekistan-18, Safar 3 and Karakalpakskiy bred at NARS (National Agriculture Research Stations) and selected ICBA/ICRISAT genotypes during 2006-2007 vegetation seasons have yielding ability of 39.9-70.3 t/ha with an average 65.1-77.7% extractable juice .Sugar juice content and total sugar calculated on hectare ranges between 5. 7-13.1% and 1.8-8.4 t/ha respectively (Figs. 7, 8).

As a sugar-bearing crop, Sorghum bicolor has well emerged under moderately saline soils in Uzbekistan. The research infrastructure, however, that would support a rapid scaling up of sugar-bearing varieties/improved lines of sorghum plantations in Central Asian countries is currently not in place. Achievable sugar content, stover and seed yields are still uncertain, and little is known about the incentive structures under which smallholder farmers would grow this plant for smaller/and larger companies, which would make investments in ethanol extraction.



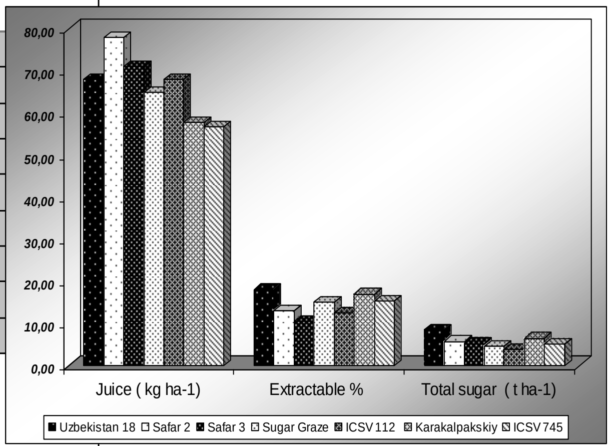


Fig.7 Extractable juice and total sugar production yields from local and introduced varieties of sweet sorghum

Fig.8 Relationship of total sugar with extractable juice production at 116 days after sowing sweet sorghum

Conclusions

An integrated Biosaline Agriculture program for sustainable and integrated use of marginal mineralized water and salt-affected soils for food-feed crops and forage legumes in order to improve food security, alleviate poverty and enhance ecosystem health in smallholder crop-livestock systems should be still developed for Central Asian countries. Such approaches could be achieved through improving productivity of crop-livestock systems per unit of saline water and/or salt-affected soil, enhancing the adoption of innovative strategies and bioremediation technologies, and income generation for resource-poor farmers whilst reversing salinity induced soil and water degradation, which finally will increase environmental goods and services.

In addition, evaluation, domestication and large scale utilization of native and introduced halophytic resources it would have a significant goal for salinity control, remediation and economic development of arid/saline lands. One of the most promising uses of halophytes will be the production and conservation of important seeds germplasm. The demand for seeds of salt-tolerant species has increased and a number of farmers have become interested to apply biosaline agriculture techniques as a feasible option for their marginalized farms. An innovative selection programs and development of suitable modern agro-technologies are needed to multiply seeds and/or salt tolerant plant material, establish them within natural plant communities and introduce them where they are suitable in different ecosystems. The outline of the general strategies for salt affected and degraded rangelands regeneration and management in new changing desert/semi-desert environments and socio-economic systems should still be developed and modeled.

Our findings from the screening of the 21 species offer a spectrum of options for afforesting degraded land. In order to implement afforestation of marginal patches of irrigated land in lower reaches of main Central Asian Rivers, the ideal multipurpose species should combine a number of features such as: high survival rate, quick growth, halophytic and xerophytic characteristics, and high utility value of firewood and/or foliage.

Salt tolerant trees and/or shrubs species, e.g., Populus euphratica, Salix babylonica, Elaeagnus angustifolia, Morus alba, M.nigra Ulmus densa, Robinia pseudoacacia, Cynadon oblonga, Armeniaca vulgare, Hippophae ramnoides nad acacia ampliceps (exceptional under arid continental with subtropical elements climate) established on good deep soils have good potential as part of the silvi-agropastoral production system. Fodder shrubs were associated with cereal farming system, including native rangelands halophytes alone, or mixed with various traditional salt tolerant fodder crops. As part of the desert land re-vegetation and/or rangeland improvement saltbushes Atriplex canescens, A. canescens A. undulata, A. nummularia and A. amnicola were recently introduced at the saline sandy desert zones of Kyzylkum. Our preliminarily results showed that the establishment of forest-like strips salt affected marginal lands, even with salt-tolerant species, requires irrigation during the initial stage of growth before sole reliance on available groundwater resources can become possible. Since the availability of irrigation water on marginal lands are limited there is a need for assessment of ground water budget distribution , as well as studying and adoption of water saving irrigation techniques, which has been applied for tree plantations in other arid regions of the world (Andreu et al., 1997; Levy et al., 1999).

The high productivity of *T. androssowii, T.hispida, Salix babylonica* and *E. angustifolia* makes them the most promising candidates for afforestation of degraded saline habitats with immediate economic benefits. However, Tamarix spp. and Elaeagnus angustifolia are often referred to as aggressive colonizers, since they tend to invade natural habitats and push out other species (Cleverly et al., 1997). Species of genus Tamarix, Salix babylonica and E. angustifolia showed high ability to self-propagate by vigorous sprouting, and thus intensive control is recommended (Tesky, 1992, Le Houerou, 2000, Toderich et al, 2006). Although these species have the capability to grow on saline soils, Tamarix plantations may not benefit the environment in the long run, since this halophytic shrub releases accumulated salts via salt glands and thus increases soil salinity (Forestry Compendium, 2000). Given these characteristics of Tamarix plantation does not seem to have great potential for the afforestation of salt-affected land, although further investigation is necessary.

E. angustifolia, Morus alba, M.nigra, Acacia ampliceps, Robinia pseudoacacia and *Ulmus densa* offer possibilities as supplementary feed to the low-quality roughages such as wheat stalks used throughout the off-season in all investigated areas. If, for example, livestock were fed with a mixture of this low-quality roughage and the leaves of superior fodder species, farmers would save a considerable amount of crop residues. The use of *E. angustifolia* leaves as feed is not common in the region, possibly due to a lack of knowledge about its high nutritious value, but low usage might also be related to the labor costs needed to defoliate the thorny twigs (Khamzina 2006). Although *M. alba* shows good fodder potential, in arid/semiarid areas of whole Central Asian region it plays a major role in sericulture, which leaves little room to expand its potential as a provider of fodder for ruminants. To determine the real feed /nutritional values of the examined trees, the feed intake and live weight increments of livestock should be studied in vivo.

Although, the cultivation of trees requires a waiting period, the use of multipurpose species, as investigated in this study, promises the farmers a return from those areas of their land where crops are no longer profitable. The expansion and commercialization of non-timber forest products has the potential to increase the cash income of rural Uzbek households. No data on the economy of non-timber forest products in Central Asian countries were available at the time of this study, and providing such data will be imperative for economic studies. Another aspect that remains unstudied is the degree to which this type of afforestation effort can contribute, on a larger spatial scale, to carbon sequestration. If carbon trading benefits can be added to the benefits from non-timber forest products, this would create a “win-win” situation from both an ecological and economic point of view (Gintzburger et al, 2005)

Summarizing experimental data we have concluded that the high irrigation water use efficiency of trees on marginal lands within the degraded landscapes of the Aral Sea region is potentially attractive for afforestation rather than for further cropping. However, more detailed information on the performance of these species - particularly on their adaptive biomass partitioning under conditions of irrigation water scarcity, soil salinity and low fertility - is needed before final recommendations about their suitability for afforestation of degraded land can be made. Therefore, follow-up research should quantify the further salt accumulation rate in response to the groundwater uptake, determine the influence of increasing salinity on growth and water use of older plantations and, if required, estimate leaching demands for maintaining plantation sustainability.

Diversification of cropping system under prevailing saline conditions could sustain agricultural productivity of salt affected areas and increase profits of farmers. The introduction of new species and varieties of forage crops, grasses, legumes and shrub species in sole or mixed farming system could potentially reduce waterlogging commonly observed on saline soils whilst contributing to restoration of degraded lands and better livelihoods of poor rural communities. With the release of plant material provided by ICBA in 2005 from quarantine, field trials were established and monitored in each of the target Central Asian countries. Forage crops being assessed in these studies include sorghums, pearl millets, and salt tolerant varieties of alfalfa, all of which are currently not grown extensively in the region. Yield data collected at the conclusion of the 2006-2007 growing seasons indicates considerable adaptability of introduced genetic material to saline soil conditions, when compared to local material

Planting herbaceous fodder crops within the inter-spaces of fodder salt tolerant trees and shrubs on intensive agro-forestry plantations could solve the animal feeding problem in the degraded (both by overgrazing and salinity) desert and semidesert marginal areas. In addition, wild halophytes species planted in widely spaced patterns allows for easy mechanical cultivation and harvesting of grass and cereals.

Pilot production studies are encouraging and indicate cost effectiveness of up-scaling of grain and sweet sorghum raw material for ethanol production in Central Asian region. Although sorghum production is still low and gives in less value comparative to rice, maize, the crop is drought/salt tolerant and has good adaptability to grow on marginal salt-affected lands. These traits give benefit and supplement fodder resources to the poor farmers in remote desert areas of Central Asia. Sweet sorghum varieties indicated in this paper are the most attractive for alternative uses of sorghum as bioethanol source. Future programs will bring new salt affected marginal lands into production of sorghum. However, state support, strong research and coordination between processing small/large companies, research institutions and farmers should be developed for sorghum breeding, adoption of relevant technologies available for the process of ethanol production in Central Asia.

References

Abdullaev U. V. 2002. Gateway to Land and Water Information: Uzbekistan national report. http://www.fao.org/ag/agl/swlwpnr/reports/y_nr/z_uz/uz.htm#irrigat.

Abrol I.P., Yadav S.P. and Massoud F.I. 1988. Salt-affected soils and their management. FAO Soil Bulletin 39, FAO, Rome, 143 pp.

Abdullaev U. 2003. Republic of Uzbekistan. Land degradation assessment in dry lands (LADA). State Design and Research Institute (Uzgip), Tashkent.

Alikulov Z.A. and Besbaeva B. 1990. Method of purification of xanthine dehydrogenase from dry wheat seeds and its activation by exogenous molybdate. USSR patent N 4704254/13. Approved 30. 07. 1990.

Alikulov Z.A., Savidov N., Sagi M., Lips H.S. 1995. Study of MoCo-containing proteins in barley and ryegrass. 4th Intern. Symp. on Inorg. Nitrogen Assimil. Darmstadt. (9-10).

Altman V. 1947. Ancient Khorezmian civilization in the light of the latest archeological discoveries. J. Am. Oriental Soc. 67(2), 81-85.

Andreu L., Hopmans J.W. and Schwankl L.J. 1997. Spatial and temporal distribution of soil water balance for a drip-irrigated almond tree. Agricult. Water Manage. 35: 123-146.

Aripov T.F., edit., 1999. Abstracts of Scientific Conference "Problems of contemporary microbiology and biotechnology", 27-29 October, Tashkent.

Ashurmetov O.A., Khasanov O. Kh., 1997. "Modern state of arid pastures, forecast and methods of their optimization". Bulletin of SCST. Proceedings of International seminar "The desert of Central Asia: protection and development". № 3-4, Tashkent.

Ashurmetov O.A., Kamalov Sh.K. , 1998. "Phytomelioration of the Aral Sea dried bottom and Amudarya delta". Arid Land Studies, 7S, Japan.

Ashurmetov O.A., Karshibaev Kh. K., 2002. Seed reproduction of legumes in arid zone of Uzbekistan, Tashkent "FAN", 203p.

Begdullayeva, T., K.M. Kienzler, E. Kan, N. Ibragimov, and J.P.A Lamers. 2007. Response of Sorghum bicolor varieties to soil salinity for feed and food production in Karakalpakistan, Uzbekistan. Irrig Drainage Syst, 21, [3-4], 237-250.

Botman E.K. 1988. Improvement of sustainability and effectiveness of protective plantations in rain-fed conditions in Uzbekistan. Summary of PhD thesis. Volgograd, 24 pp (in Russian).

Chembarisov, E.I. and Bakhritdinov, B.A. 1989. Hydro-chemistry of river and drainage waters of Central Asia. Tashkent, Ukituvchi, 132pp.

Djalalov A.A., Ishanov Kh.Kh. and Azimov U.A. 2005. Project proposal on strategic planning to fulfil the principles of integrated water resource management (National report, the Republic of Uzbekistan), 46 pp (in Russian).

Djanibekov N. 2003. Private farm survey. Uzbekistan (unpublished data).

Erejepov S. E., 1978. Flora of Karakalpakia, its economical characteristics, use and

conservation. Tashkent, 295 p.
FAO. 2000. Based on the work of Bot A.J., Nachtergaele F.O. and Young A. Land resource potential and constraints at regional and country levels. World Soil Resources Report, No 90, Rome, FAO, 114 pp.
FAO. 2005. Global Forest Resource Assessment, Uzbekistan Country Report by the Forestry Department.
Fayzullaev B.F. 1980. Water and solute regime of the soils developed on the various alluvial sediments of the Amudarya River (in the Khorezm Oasis). Tashkent, SANIIRI, 25 pp (in Russian).
Ferrer F. and C.O. Stockle, 1996. A model for assessing crop response and water management in saline conditions. Water report 8, Irrigation scheduling: from theory to practice. http://www.fao.org/ docrep/W4367E/w4367e0j.htm#Contents (posted 1996; verified 18 August, 2005).
Fimkin V.P. 1983. Recommendations on assortment of tree and shrub species for saltaffected soils in the Golodnaya Steppe. Tashkent, Uzbekistan, Middle-Asian Forestry Research Institute, Ministry of Agriculture of Uzbek SSR, pp 1-13 (in Russian).
Gintzburger G., Toderich K.N., Mardonov B.K. and Mahmudov M.M. 2003.Rangelands of the arid and semi-arid zones in Uzbekistan. V.Howe and CIRAD Editing and Publication Service, France, 426 pp.
Gus Gintzburger, H.N. Le Houerou and Kristina Toderich, 2005. The Steppe of Middle Asia: Post 1991 Agricultural and Rangeland Adjustment. Arid Land Research and Management, 19:1-2: pp. 19-43.
Granitov I.I., 1964. Vegetation cover of South-Western Kyzylkum. (Rastitelnyi pokrov yugo-zapadnikh Kyzylkumov) Tashkent: Nauka. Tom 1, 334 S.
Halilov H.R. & Toderich K.N., 1993. “Ecologic-biological studies of fodder species of genus Astragalus for their introduction under foothills conditions of Uzbekistan”. PhD thesis, Leningrad, 139 p.
Hedden P. 1993. Modern methods for the quantitative analysis of plant hormones. Ann.Rev.Plant Physiol. 44:107-129.
Heuperman A.F., Kapoor A.S. and Denecke H.W. 2002. Biodrainage - principles, experiences and applications. Knowledge Synthesis Report 6, International Programme for Technology and Research in Irrigation and Drainage (IPTRID), FAO, Rome, 79 pp.
Ibrakhimov M., Park S.J. and Vlek P.L.G. 2004. Development of groundwater salinity in a region of the lower Amu-Darya River, Khorezm, Uzbekistan. In: Ryan J., Vlek P.L.G. and Paroda R. (eds). Agriculture in Central Asia: Research for Development. Proceedings of a Symposium held at the American Society of Agronomy Annual Meetings at Indianapolis, Indiana, USA, ICARDA, Aleppo, Syria, pp 56-75.
Ibrakhimov M. 2005 Spatial and temporal dynamics of groundwater table and salinity in Khorezm (Aral Sea Basin), Uzbekistan. PhD thesis. Center for Development Research (ZEF), Universität Bonn, Bonn, 175 pp.
Ishizaki S.M., Silva J.A., Toma W.Y. 1991. Soil-plant relationships in pangola grass and intortum fertilized with molybdenum and copper. J. Plant Nutr. 14(3):295-313.
Jabbarov H.M., A.U. Usmanov, A.R. Yusupov and H.E. Yakubov. 1977. To establish the regularity of changes in soil during leaching and irrigation of crops with saline water and to develop the mathematical model for salt movement calculation (In Russian). pp. 1-148.

Johnson J.L., Hainline B.E., Rajagopalan K.V. 1980. Characterization of molybdenum cofactor of sulfite oxidase, xanthine oxidase and nitrate reductase. Identification of a pteridine as a structural component. J. Biol. Chem. 255, 1783-1786.

Kamalov Sh.K., 1995. "Working out of technology of clayey saline phytomelioration in the southern part of Aral sea". Second circular and registration announcement. Desert technology III an engineering foundation conference. Journal of Arid Land Studies, 5S, 311-315.

Kamilov B., Ibragimov N., Esanbekov Yu., Evvet S. and Heng L. 2003. Drip irrigated cotton: irrigation scheduling study by use of soil moisture neutron probe. Int. Water Irrig. 23, 38-41.

Katz D.M. 1976. The influence of irrigation on groundwater. Kolos, Moscow, 271 pp (in Russian).

Kayumov A.K. 1986. Regarding the increase of yields of cotton and grain crops protected by tree shelterbelts in the Middle Asia. In: Protective forest planting, Mehnat, Tashkent, pp 98-102 (in Russian).

Kayumov A.K. 1993. Biocenoses of forest-agrarian landscape of the irrigated lands. FAN, Tashkent, 132 pp (in Russian).

Kayumov A.K., Sultanov R.A., & Novitsky Z.B., 1997. The struggle against land degradation and desertification by means of afforestation and rational use of land. In the Bulletin of State Committee for Science and technology of the Republic of Uzbekistan. Proceedings of the International conference "The Desert of Central Asia: Protection and Development", Tashkent, No 3-4, 108-112.

Khamzina A. 2006. "The assesment of tree species and irrigation techniques for afforestation of degraded agricultural landscapes in Khorezm, Uzbekistan, Aral Sea Basin".Ecology and Development Series. Vol.:39. Cuviller Gottingen, Germany, 2006.

Khanazarov A.A. and Kayimov A.K. 1993. Forest resources of Uzbekistan. Tashkent, 63 pp (in Russian).

Khanazarov A.A. and Novitsky Z.B. 1990. Afforestation and the Aral Sea. Forestry 9, 35-37 (in Russian).

Khorezm hokimiat. 2005. Quantity of private and dekhkan farms in Khorezm.

Korovin, E.P. 1961. Vegetation of Middle Asia and Southern Kazakhstan. Uzbekistan Academy of Science Press, Tashkent (in Russian).

Koshiba T., Saito E., Ono N., Yamamoto N. Sato M. 1996. Purification and properties of flavin- and molybdenum containing aldehyde oxidase from coleoptiles of maize. Plant Physiol. 110, 781-789.

Lamers J.P.A. 1995. An assessment of wind erosion control techniques in Niger: Financial and economic analysis of windbreaks and millet crop residues. PhD thesis. Verlag Ulrich E. Grauer, Stuttgart, 208 pp.

Le Houerou H.N., 2000. Utilization of fodder shrubs and trees in the arid and semiarid zones of West Asia and North Africa." Arid Soils Research and Rehabilitation, 14(2), 2-34.

Levy Y., Columbus D., Sadan D. and Lifshitz, J. 1999. Trickle linear gradient for assessment of the salt tolerance of citrus rootstocks in the orchard. Irrig. Sci. 18: 181-184.

Leydecker M-T., Moureaux T., Kraepiel Y., Schnorr K., Caboche M.1995. Molybdenum cofactor mutants, specifically impaired in xanthine dehydrogenase activity and abcisic acid biosynthesis, simultaneous overexpress nitrate reductase. Plant

Physiology. 107, 1427-1431.
Makhno G. 1962. Elaboration of methods for forest management on salt-affected soils in Khorezm Region. Scientific report. Middle-Asian Forestry Research Institute. Tashkent, 213 pp (in Russian).
Martius Ch., Lamers J.P.A., Wehrheim P., Schoeller-Schletter A., Eshchanov R.,Tupitsa A., Khamzina A., Akramkhanov A. and Vlek P.L.G. 2004.Developing sustainable land and water management for the Aral Sea Basin through an interdisciplinary research. In: Seng V., Craswell E. and Fukai S.(eds) Water in agriculture, pp 45-60, ACIAR Proceedings No116, Canberra.
Mavlyanov Kh., 1995. Yantachniki Uzbekistana. Tashkent. " Mekhnat". 167 p.
Mavlyanov Kh., 1997. Ontogenesis of Alhagi species Gagneb. Uzbek Journal of Biology. N 2, 39-43.
MAWR (the Ministry of Agriculture and Water Resources) 2001. Hydrologic Amelioration Expedition. Database.
MAWR. 2004. Annual report of Amu-Darya Basin Hydrogeologic Melioration Expedition, Khorezm region. Ministry of Melioration and Water Resources (MAWR), Tashkent.
Mendel R.R. and Alikulov Z.A. 1983. Reversible immobilization of molybdenum cofactor on a gel matrix via sulfhydryl groups J.Chromatography. 267, 409-413.
MMTU (Mott MacDonald Ltd, Temelsu International Engineering Services Inc., and Uzgipromeloivodkhoz Institute of the Ministry of Agriculture and Water Resources). 1997. Drainage Project, Phase I: Data collection and review.
Mukhammadiev U.K. 1982. Water resource use. Tashkent: 113p. (in Russian).
Nechaeva N.T., Shamsutdinov Z.Sh, Muhamedova G.M, 1978. Improvement of Desert Rangelands of Middle Asia.Ilyum, Ashgabad, 64p.
Nechaeva N.T., (eds.), 1985. Improvement of Desert Ranges in Soviet Central Asia. Amsterdam, Harwood Academic Publisher, 327p.
Nikolaeva M.G., Razumova M.V., Galdkova V.M., 1985. "Reference book in germination of seeds dormancy". L., Nauka, 346 p.
Poorter H. 2002. Plant growth and carbon economy. Encyclopaedia of life sciences, pp 1-6. Macmillan Publishers Ltd, Nature publishing group.
Poorter H. and de Jong R. 1999. A comparison of specific leaf area, chemical composition and leaf construction costs of field plants from 15 habitats differing in productivity. New Phytol. 143, 163-176.
Poptsov A.V., 1976. "The biology of hard seeds in the plants". M, 302 p.
Rakhmatilloev R.R. 2004: The technology of programming of cotton yield under different means of irrigation in Tajikistan, Ministry of Melioration and Water Economy of the Republic of Tajikistan, Dushanbe, 93p.
Rockwood D.L., Naidu C.V., Carter D.R., Rahmani M., Spriggs T.A., Lin C., Alker G.R., Isebrands J.G. and Segrest S.A. 2004. Short-rotation woody crops and phytoremediation: Opportunities for agroforestry? Agrofor. Syst. 61, 51-63.
Sagi, M., Omarov, R. T. and Lips, S. H. 1998. The Mo-hydroxylases xanthine dehydrogenase and aldehyde oxidase in ryegrass as affected by nitrogen and salinity. Plant Sci. 135, 125-135.
Sagi, M. Fluhr, R. and S. H. Lips. 1999 Aledehyde oxidase and xanthine dehydrogenase in a flacca tomato mutant with deficient abscisic acid and wilty phenotype. Plant Physiol. 120, 571-578.
Sagi, M., Scazzocchio, C. and Fluhr, R. (2002). The absence of molybdenum cofactor

sulfuration is the primary cause of the flacca phenotype in tomato plants. Plant J. 31, 305-317.
Schubert K.R. and Boland M.J. 1990. The ureids. In: The biochemistry of plants. Eds. B.J.Miflin and P.J.Lea. 16, 197-282.
Shirokova Yu.I. and Morozov A.N. 2006. Salinity of Irrigated Lands of Uzbekistan: causes and present state. In the "Sabkha Ecosystems". (Eds.: M.Ajmal Khan, Benno Boer, German Stanislavovich Kust and Hans-Jorg Batrh). Vol.II: West and Central Asia. 249-259.
Small I. and Bunce N. 2003. The Aral Sea disaster and the disaster of international assistance. J. Int. Aff. 56(2), 59-73.
Toderich K.N. Idzikowska K., Halilov H.R., 1998. "Hardness of seeds and germination dynamics of Fabaceae arid species." Journ. Arid Land Studies, 7S, 167-172.
Toderich K., Tsukatani T., Abdusamatov M., Rakhmatullayev R., Latipov R. and Khujanazarov T. 2006. A farm in Kumsangir of Tajikistan: A Perspective of Water/Land Use along Pyandzh River. Kier Discussion Paper 619, Kyoto University, Japan, 58p.
Vasil'chikova S.I.1982: Gray-brown soils of Tajikistan, Dushanbe, Donish publisher, 315-316.
Ventom A.M., Deistung J., Bray R.C. 1988. The isolation of demolybdo xanthine oxidase from bovine milk. Biochem. J. 255, 949-956.
UNEP. 2000. State of environment of the Aral Sea Basin. Regional report of the Central Asian States' 2000. http://www.grida.no/aral/aralsea/english/water/water.htm
UNEP and Glavgidromet. 1999. National Action Programme to combat desertification in Republic of Uzbekistan. Tashkent, 117 pp.
Uzgipromeliovodhoz (State Design and Research Uzgipromeliovodkhoz Institute, Ministry of Agriculture and Water Resources, Republic of Uzbekistan). 2003. Land Degradation Assessment in drylands (LADA). Technical report, Uzbekistan, FAO, 43 pp.
Vlek, P.L.G., Martius, C., Wehrheim, P., Schoeller-Schletter, A., Lamers, J. (2003): Economic restructuring of land and water use in the Region Khorezm (Uzbekistan) (Project Proposal for Phase I). ZEF Work Papers for Sustainable Development in Central Asia, 1, 75 pp. http://www.khorezm.unibonn. de/downloads/WPs/ZEF-UZ-WP01_proposal.pdf.
Vodproject. 1999. Production association, the Ministry of Agriculture and Water Resource Management, Uzbekistan. Annual report.
Walker-Simmons M., Kudrna D. A., Warner R.L. 1989. Reduced accumulation of ABA during water stress in a molybdenum cofactor mutant of barley. Plant Physiol. 90:728-733.
World Bank for Reconstruction and Development. 2002. Global condition of environment. Tashkent.
Yusupov A.R., A.U. Usmanov and H.E. Yakubov. 1979. To establish the regularity of changes in soil during leaching and irrigation of crops with saline water and to develop the mathematical model for salt movement calculation (In Russian), pp.1-50.