Chapter 13
Uzbekistan: Rehabilitation of Desert Rangelands Affected by Salinity, to Improve Food Security, Combat Desertification and Maintain the Natural Resource Base

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Synopsis The chapter describes briefly the two key land degradation problems faced by Uzbekistan (i) widespread loss of rangeland productivity and stability, including loss of biodiversity and invasion by unpalatable and/or invasive species and (ii) problems associated with rising saline water tables and land abandonment.

Results of research on vegetation distribution along salinity gradients, and evaluation of some indicators of salt tolerance are reported. The outcome of the screening of many plant species, herbs, shrubs and trees and the development of agro-silvi pastoral systems as a means of rehabilitating degraded land and improving

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livelihoods is outlined. The development and adoption of Biosaline Agriculture practices as a way to restore productivity of salt affected desert lands is explained.

Key Points

- Rangeland vegetation of the arid and semi arid zones of Uzbekistan served as a crucial natural resource for livelihood development of the pastoral communities for many centuries and at the same time acts now as an "ecological tool" of protection against desertification. It is thus of great importance to preserve natural rangelands and to maintain their long term stability through application of consistent grazing management or using of improvement methods through cultivation of native drought and salt tolerant species.
- Facing the challenges of food security, Central Asian countries are keen to improve utilization of rangelands. Unfortunately, most governments in the region have limited financial resources, inconsistent legal instruments, and weak capacity to regulate and monitor sustainable use of rangelands. Thus, a more holistic approach to the ecosystem processes is needed in order to reduce the feed gap and mitigate rangeland degradation and desertification.
- Spatial and temporal changes of natural rangelands vegetation in the arid area affected by salinity need to be understood in order to initiate different revegetation strategies. Halophytes are an underutilized plant resource. They grow well in association with a variety of arid/semi-arid rangeland species and often provide severe competition to perennial species, both in natural and improved pastures.
- Where rangeland degradation has occurred there is need for rehabilitation measures to be applied. Incorporating fodder halophytes into the agro-silvi pastoral system or domestication of wild halophytes species represents low cost strategies for rehabilitation of desert degraded rangelands and abandoned farmer lands affected both by soil and water salinity.
- Introduction and adaptation of native drought tolerant fodder desert species and halophytes have the potential to provide a way to improve the livelihood of farmer's income at abandoned degraded marginal areas.
- A mixture of desert fodder species planted within the inter-spaces of salt-tolerant trees/shrubs plantations improves productivity of degraded rangelands affected by soil salinization. Application of such an approach solves the animal feed gaps in the lands degraded both by overgrazing and salinity, and leads to increased income for farmers. Agro-silvi-pastoral approaches for landscape planning and rehabilitation of saline soils represent a model of ecosystem function/services for agro-pastoral communities as adaptation measures to mitigate climate change impacts
- Dryland salinity and associated water quality are recognized to be among the most severe natural resource degradation problems in the marginal desert belt of Aral Sea Basin. Access to irrigation water in this region has drastically decreased in the last years, which caused additional obstacles to rangelands productivity and agricultural production. Replacement of deep-rooted, perennial

native vegetation with shallow-rooted, annual agricultural crops and halophytic pastures has resulted in increased recharge causing shallow saline water tables leading to dryland salinity and loss of plant diversity. This results in greater amounts of water entering a groundwater system, water table rise and the concentration of naturally occurring salts near the soil surface.

- The Integrated Biosaline Agriculture Program for sustainable use of marginal mineralized water and salt affected soils for food-feed crops and forage legumes assists in improving food security, alleviating poverty and enhancing ecosystem health in smallholder crop-livestock systems. Diversification of agro-ecosystems and development of new agricultural capacities could increase income source of rural poor and farmers which so far are often dependent on two major crops (e.g. cotton and wheat).

Keywords Halophytes • Biosaline agriculture • Saline soils • Poverty alleviation • Rural poor • Small-holder • Crop-livestock systems • Food security • Agro-silvi-pastoral systems • Revegetation strategies • Drought tolerant fodder • Xerophytes • Sand dunes • Salinity gradient • Geobotanical survey • Carbon isotope analysis • Spatial and temporal changes • Grazing impacts • Above and below ground biomass • Salt-tolerant species • Radial attenuation of stocking pressure • Piosphere • Aral sea

1 Introduction

The inland Irano-Touranian desert ecosystem (that encompasses Uzbekistan and its neighbors) is considered one of the most fragile under currently ongoing climate changes. It is characterized by reduced richness of species, especially trees and shrubs, and, thus, by low resistance to local extinctions. With an area of 447,000 km^2 (approximately the size of France), Uzbekistan stretches 1,425 km from west to east and 930 km from north to south (Fig. 13.1).

The physical environment of Uzbekistan is diverse, ranging from the flat, desert topography that comprises almost 80 % of the country's territory to mountain peaks in the east reaching about 4,500 m above sea level. The south-eastern portion of Uzbekistan is characterized by the foothills of the Tian Shan Mountains, which rise higher in neighboring Kyrgyzstan and Tajikistan and form a natural border between Central Asia and China. The vast Kyzyl Kum Desert, shared with southern Kazakhstan, dominates the northern lowland portion of Uzbekistan. The most fertile part of Uzbekistan, the Fergana Valley, is an area of about 21,440 km^2 directly east of the Kyzyl Kum and surrounded by mountain ranges to the north, south, and east. The western end of the valley is defined by the course of the Syrdariya river, which runs across the north-eastern sector of Uzbekistan from southern Kazakhstan into the Kyzyl Kum. Although the Fergana Valley receives just 100–300 mm of rainfall per year, only small patches of desert remain in the center and along ridges on the periphery of the valley. The remainder has been developed for irrigated cropland and horticulture.

Fig. 13.1 Bordering Turkmenistan to the southwest, Kazakhstan to the north, and Tajikistan and Kyrgyzstan to the south and east, Uzbekistan is not only one of the larger Central Asian states but also the only Central Asian state to border all of the other four former Soviet Republics. Uzbekistan also shares a short border with Afghanistan to the south

Water resources, which are unevenly distributed, are in short supply in most of Uzbekistan. The vast plains that occupy two-thirds of Uzbekistan's territory have little water, and there are few lakes. The two largest rivers feeding Uzbekistan are the Amu Darya and the Syrdariya, which originate in the mountains of Tajikistan and Kyrgyzstan, respectively. These rivers form the two main river basins of Central Asia; they are used primarily for irrigation, and several artificial canals have been built to expand the supply of arable land in the Fergana Valley, Mirzachuli steppe and Aral Sea Basin.

Around 255,000 km^2 or 57 % of the country are rangelands. They have traditionally been used as common grazing lands for livestock. About 78 % of the rangeland cover is desert and semidesert plains (Gintzburger et al. 2003). Most of the farming in Uzbekistan's desert rangeland regions is Karakul sheep husbandry, followed by goat, camel and horse husbandry. The total number of head is greater than ten million (Mahmudov 2006). More than 2.3 million people are entirely dependent on livestock production for food and economic security (Yusupov 2003). The natural *Artemisia*-ephemeral and ephemeroidal rangelands are the main grazing lands for sheep and goats, and have been throughout history. Ninety-five percent of their total diet comes directly from the grazing and the remaining is harvested by the farmers and local herders and used when no grazing is available. Anthropogenic impact, on top of abiotic disturbances, is thus a part of the disturbance regime this area has been exposed to through the ages. High localized anthropogenic impact often results in rapid land degradation and even desertification, hence altering the native vegetation cover of rangeland areas. The human footprint has increased with the ever-growing human population, as can be seen in the expansion of degraded rangelands in Uzbekistan.

Land degradation of desert and semidesert rangelands throughout the whole Central Asian region has reached an alarming level, calling for prompt action. It was estimated that out of more than 16.4 Mha, 73 % are affected by degradation (Nordblom et al. 1997). of various origins, including anthropogenic impact and climate fluctuation. The anthropogenic disturbances alone are estimated to affect 7.4 Mha (UNCCD 2006). Grazing induced rangeland degradation is common across large desert zones of Uzbekistan and causing major ecological transformations resulting in biodiversity loss and occurrence of nonequilibrial ecosystems (Gintzburger et al. 2003). Yusupov (2003) estimated that of all disturbances, overgrazing by livestock was the most serious, accounting ting for 44 % of the total degradation, followed by uprooting and cutting of vital shrubs for fuel (25 %). All other disturbances, including all abiotic disturbances such as drought and wind erosion, accounted for only one-third of the disturbances. The effect of grazing is often localized and is ubiquitous around watering points and settlements. Changes in vegetation cover and composition have led to the disappearance of many native fodder species. Gradual reduction in biomass, changes of, for example, species composition from palatable plants into unpalatable, increased trampling and soil compaction are frequently observed. At the present time the area of degraded desert rangelands continues to grow due to overgrazing. A typical impact covers a radius of 2–5 km around watering points, with the most intense degradation occurring closest to the wells. Grazing occurs throughout the year. The animals are kept half of the year in the mountains or other distant regions, but they are brought back to the settlements as winter approaches. It is during this winter grazing seasons that most of the degradation occurs, as grazing pressure is high due to low vegetative production.

According to Salmanov (1996), the area of rangeland occupied by exotic/unpalatable plant species is now 1.5 million hectares (Mha). The original vegetation was completely removed because of the heavy grazing pressure. Mostly of anthropogenic origin (Ashurmetov et al. 1998). The degradation process has become severe and needs urgent measures to avoid the loss of phytogenetic resources and botanic diversity of the rangelands.

An understanding of the degradation processes currently ongoing in Uzbekistan rangelands is limited as traditional research has mostly focused on optimizing livestock fodder production (e.g. Shamsutdinov 1975). Since livestock production in Uzbekistan in arid and semi-arid zones is based on rangeland vegetation, current studies have focused on improvement of low productive grazing lands and rehabilitation of degraded rangelands. Less interest has been given to the driving factors of land degradation and their interaction with other ecosystem components e.g. response of vegetation to organizational changes, institutional transition from former Soviet system, and grazing induced disturbances. In recent years, due to poor localized grazing management, rangeland degradation has increased. An understanding of the current trend of vegetation changes due to ecological and anthropogenic factors gives the potential of sustainable management of natural rangelands. Driving factors of grazing induced rangeland degradation and their interaction with other ecosystem components were not often studied in previous works. Such a multidisciplinary approach of vegetation assessment was applied in semi desert vegetation of Karnabchul (see Fig. 13.3) where grazing induced rangeland degradation is common as observed in other desert areas of Uzbekistan (Rajabov 2010).

The effect of grazing is often localized and is ubiquitous around watering points and settlements in Uzbekistan. The grazing pressure diminishes with distance from these foci and forms a gradual change in vegetative cover, species composition and soil properties. To study such systematic changes, grazing gradient method has been widely used to examine the plant responses to grazing in different ecological zones (e.g. Austin 1977; Andrew 1988; Li et al. 2008). Grazing gradient analysis provides the ideal method by which to detect plant traits to a certain range of grazing pressures (Andrew 1988).

Interdisciplinary research based on an ecological approach was applied to detect the fine scale degradation processes and to understand full scenarios of plant-soil-animal interactions in order to keep the rangeland ecosystems in balance. This approach is the focus of this chapter and is illustrated by our field work in Uzbekistan.

2 Description of the Study Sites

The studies on desert vegetation along a salinity gradient were conducted in Kanimekh district at the Research Station of the Uzbek Research Institute of Karakul Sheep Breeding and Desert Ecology (lat. 41° N and Long 60° E at an altitude of 113 m). This region has a typical inland arid climate with a hot, dry summers and cold winters: annual mean temperature is 11.4 °C, and annual mean precipitation is 120 mm, which falls in the growing season from May to September.

We have chosen Kyzylkesek site – an area located between two hot springs (vertical drainage flow) in Central Kyzylkum Desert in order to determine spatial changes of vegetation as from the xerophytes in sandy dunes towards typical halophytes in Karakata salt depression (Fig. 13.2). Each zone differs by its relief, total soluble salts, floristic composition and botanic diversity.

Additionally we have conducted field research to assess the spatial and temporal vegetation succession of Karnabchul (a typical sagebrush-annuals semidesert rangeland) as a function of piospheric effects in two different range sites (39°50′N and 65°55′E) shown in Fig. 13.3.

2.1 Methodology

2.1.1 Vegetation Surveys

Geobotanical descriptions were done using 2 m × 50 m transect (in semi shrub plant communities) and 5 m × 50 m transect (in shrub plant communities – *Haloxylon*

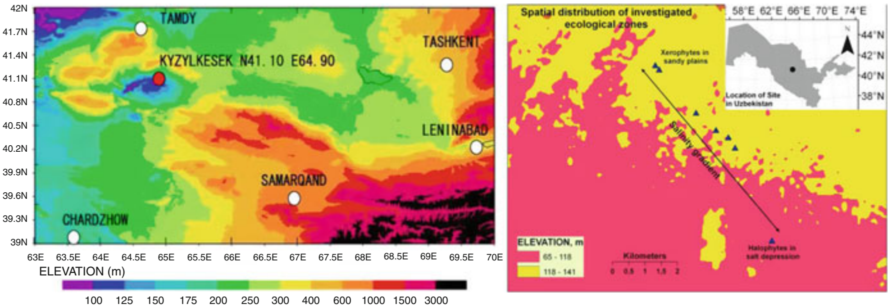

Fig. 13.2 (**a**, **b**) Topographical landscape map of target research area in Kyzylkum desert (Karakata saline depression) The *dot in the square* in the large scale map (*right*) indicates the location in relation to the whole region. The salinity gradient on micro relief level includes the area between two artesian thermal springs (shown as *triangles*). The plant community and soil was studied along this gradient (Source: Toderich et al. 2008)

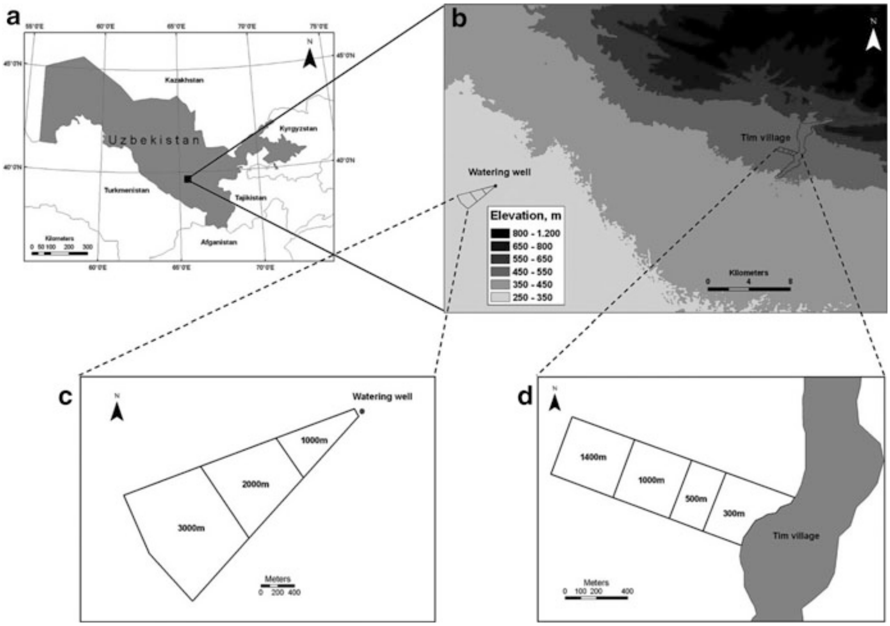

Fig. 13.3 Location of the study area in Karnabchul, Uzbekistan (**a**), digital elevation model (*DEM*) (**b**), schematic illustration of the measurement transects laid out perpendicular to the well (**c**), and village (**d**). DEM was obtained from Earth Remote Sensing Data Analysis Center (ERSDAC 2009; Rajabov 2011)

aphyllum Association), in three replications. Total numbers of shrubs of each species within the 100 and 250 m^2 were counted in three size classes (big, medium, small) based on plant height and diameter. For each size class and each species one representative plant was harvested and separated into woody, green and dead parts.

The total biomass for each subplot was determined by combining density data of each species present. Cover of individual shrub species was determined from a 50 m-line intercept along one edge of the 2 m × 50 m and 5 m × 50 m plot.

Aboveground biomass of investigated species was harvested at the end of October each year. Seasonal measurements of vegetation parameters (biomass, density, vegetative cover) along the apparent grazing gradient were conducted during 2005–2007. A conceptual framework of successive vegetation changes along the grazing gradient was developed by applying State and Transition (S&T) models. Vegetation data were analyzed by applying Non Metric Multidimensional Scaling (NMS) ordination. Seasonal dynamics of the Normalized Difference Vegetation Index (NDVI) derived from Landsat imagery were examined to detect the vegetation changes caused by grazing. The vegetation succession was demonstrated as a presence/absence of unpalatable/palatable species in plant composition as a function of piosphere effects.

2.1.2 Soil Sampling

Soil samples were collected from different depths (0–20; 21–40; 41–60; 61–90; 91–120 cm). Sodium (Na^+) ion concentration was analyzed by water extract from air-dry soil and plant samples (100 mg of sample) and detected on atomic adsorption spectrophotometer (Hitachi 2007, Japan). Salinity gradient was characterized by contents of Na^+ ions in the soil profiles. The regression analysis was applied to investigate correlation between remote sensing data, Na^+ ion content and EC values calculated from field data in order to predict soil salinity and vegetation changes.

Soil Salinity was also determined using an electromagnetic conductivity device (EM38) was standardized at reference temperature of 25 °C as EC increases at a rate of approximately 1.9 % (Rhoades et al. 1999). We used the formula provided in Sheets and Hendricks (1995), who fit the curve to a conversion table given in USDA (1954): $EC_{25} = EC_a * [0.4470 + 1.4034\varepsilon^{(T/26.815)}]$, where EC_{25} is standardized EC_a and T-soil temperature.

2.1.3 Carbon Isotope Analysis of Desert Vegetation

The distribution and abundance of desert plant communities were examined. Plant species were collected along a sequence of increasing ground-water depths in eight transects. Experimental data from Carbon and Oxygen isotopes were used to assess the responses of native plants to salinity and the effect of salinization on natural vegetation in Uzbek dryland ecosystems.

Carbon isotope composition ($d^{13}C$) of plant material is related to intrinsic water use efficiency in C_3 plants (Farquhar et al. 1989). The positive correlation was found between the salinity and the $d^{13}C$ of leaf organic matter both in salt-tolerant species and salt-sensitive species (Seemann and Critchley 1985). These reports indicate that salt stress may decrease the CO_2 concentration inside the leaf via the stomata closure and consequently increase the intrinsic water-use efficiency (Naoko et al. Unpublished data). There was, however, no report that presented the response of the $d^{13}C$ of leaf organic matter to the salinity

Carbon and oxygen isotope ratios were expressed by the following equation:

$$\delta^{13}C \text{ or } \delta^{18}O = \left(\frac{R_{sam} - R_{std}}{R_{std}}\right) \times 1000\ (‰)$$

where R_{sam} and R_{std} represent the $^{13}C/^{12}C$ or $^{18}O/^{16}O$ of the samples and standard, respectively. PDB and VSMOW were used for the standards for $d^{13}C$ and $d^{18}O$, respectively.

The photosynthetic organ samples (leaves and short pieces of stems in the case of aphyllous species) were oven-dried at 70 °C for 48 h and finely ground. The $d^{13}C$ in the organic samples was analyzed using a continuous flow system of an elemental analyzer and an isotope ratio mass spectrometer (Flash 2000 and Delta S, Thermo Fisher Scientific) at Field Science Education and Research Center, Kyoto University, Japan.

3 Results and Grazing Management Implications

3.1 Spatio-Temporal Changes of Vegetation of Semi-desert Rangelands Along a Grazing Gradient

The long term effect of grazing on semi-desert rangeland vegetation was studied in proximity of a typical watering well located 25 km south-east of Zirabulak Mountains in Karnabchul. Vegetation parameters (projective cover, density, green biomass of perennials and above-, below ground biomass of annuals) were collected in a radius of 3,000 m from the watering point.

Vegetation cover of study site is strongly affected by livestock grazing. Radial attenuation of stocking and grazing pressure from the watering point (the so-called piosphere effect, Lange 1969) resulted in changes in perennial and annual species composition. Radial symmetry of grazing pressure is resulted in rapid changes of vegetation community. The spatial variability that was observed shows gradients, and is derived from intense grazing around water sources at the well site. Grazing-driven changes in perennial and annual species composition in the closest areas and intermediate distances from the focal point were demonstrated as presence/absence of unpalatable/palatable species in plant composition.

The prevailing vegetation stratum of the study area is dominated by semi shrub (*Artemisia diffusa*) and perennial/annual herbaceous species (e.g. *Carex pachystylis*, *Poa bulbosa*, *Bromus tectorum*, *Alyssum desertorum*, *Trigonella noeana*). Existing physiognomy and floristic pattern of Karnabchul represents homogeneous type of vegetation which is commonly described as *Artemisia*-ephemeral rangelands

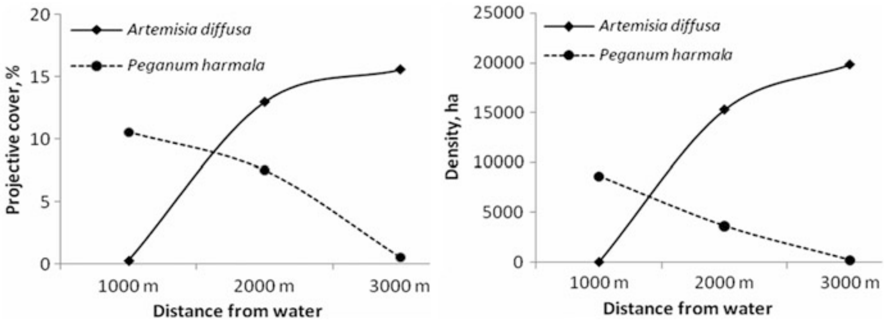

Fig. 13.4 Interrelation of typical fodder (*Artemisia diffusa*) and unpalatable species (*Peganum harmala*) along a grazing gradient from a fixed watering point in Karnabchul

(Gaevskaya 1971; Salmanov 1986). This type of rangelands is characterized by low forage productivity (0.15–0.36 t DM/ha^{-1}) with high interannual variations that is largely dependent on climatic conditions (Gaevskaya and Salmanov 1975). The vegetation of *Artemisia*-ephemeral rangelands is the main source of forage for livestock, and has been throughout history. Despite the low forage production of these rangelands, they provide 95 % of total diet of livestock. Anthropogenic impact is thus a part of the disturbance regime to which this area has been exposed since time immemorial.

Throughout the 40 years since the well was established, *A. diffusa* has been constantly overgrazed and trampled by livestock. Vegetation is usually absent around the well within the radius of 60–80 m. This zone is characterized by a highly compacted, flat surface with black or brown color as a result of intense trampling. At the next 1,000 m from the well invader plant *P. harmala* dominates. This plant is recognized as an indicator of overexploited-overgrazed rangelands and is not touched by livestock because of its toxicity, strong characteristic smell and high content of alkaloid in green leaves and seeds (Gintzburger et al. 2003). *P. harmala* thus dominates the first 1,000 m from the well (Fig. 13.4). A rise in the number of unpalatable plants in vegetation composition results in decreased qualitative values of the rangelands. Presence of *P. harmala* can be used as a sign of beginning of severe changes in vegetation structure under the intense grazing.

The shift towards dominance of unpalatable plants in vegetation composition has resulted in very low quality of grazing rangelands in term of fodder value of plants. As a function of increased distance away from the watering point, available grazing area for animals increases and stocking pressure on the this area decreases (Andrew and Lange 1986). This is reflected in the appearance of *A. diffusa* in the area of 2,000 m from the well (Fig. 13.4). Relatively high grazing pressure promotes *P. harmala* to remain in the vegetation cover consisting of 31 % of total vegetative cover and 18 % of the density in plant composition. In contrast, 56 % of the total perennial biomass of vegetation community in the distance of 2,000 m consists of *P. harmala*. Beyond 2,000 m, *A. diffusa* becomes more abundant and at a distance

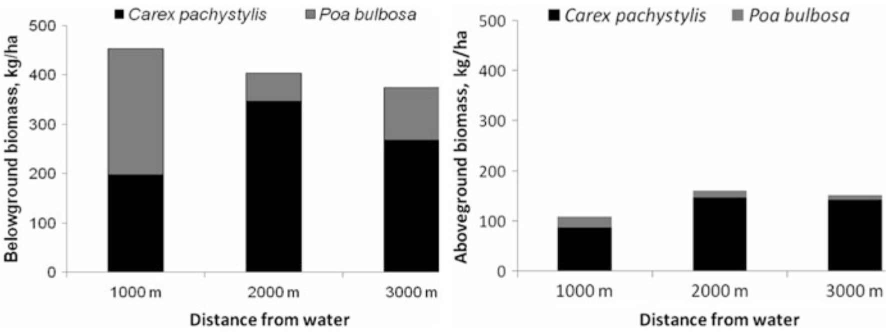

Fig. 13.5 Dynamics of below- and above-ground biomass of ephemeroids as a response to different grazing intensities

of 3,000 m it is dominant over *P. harmala*. Vegetation structure of ephemeral and ephemeroidal species is influenced by the heavy grazing. Competition existed between *P. bulbosa* and *C. pachystylis* under the heavy grazing pressure around the watering well. *P. bulbosa* had less aboveground biomass than *C. pachystylis* along all grazing gradients from the well (Fig. 13.5).

The greater abundance of *C. pachystylis* around the watering well is related to edaphic factor. Light sierozem soils near the watering well are a more suitable for *C. pachystylis*. As a piosphere response, the species had opposite directional changes along the grazing gradient – *C. pachystylis* increased with distance and *P. bulbosa* decreased with distance from the watering point (Fig. 13.5). However, despite of favorable soil condition for *C. pachystylis*, belowground biomass declined under the heavy grazing at the 1,000 m zone, where *P. bulbosa* dominates. An increase of ephemeroids under heavy grazing negatively affected persistence of *A. diffusa* and it was replaced by *P. harmala*.

The vegetation succession was demonstrated as a presence/absence of unpalatable/palatable species in plant composition as a function of piosphere effects. NMS analysis indicated the evident different processes of vegetation cover of two study sites due to distinct grazing regimes. NDVI analysis showed that Landsat imagery provides relevant information about vegetation changes along the grazing gradient in the Karnabchul semi-desert. Such results of multidisciplinary approach of vegetation assessment with combination of ecological models open the way in conception of realistic methods for sustainable rangeland management (Rajabov 2011).

Our studies confirm the identical trend of vegetation changes of previous studies along the grazing gradient. Grazing caused the appearance of intermediate herbaceous species in the vegetation composition of the village area. Increased grazing pressure shifted to the formation of another vegetation state with an abundance of intermediate plants. The density and other parameters of intermediate plants decreased as a function of distance away from the village. Trampling, however, has a more disturbing factor than grazing in the location closest to the watering well. In the last states of vegetation succession, some dominant ephemerals disappeared from the vegetation community because of high trampling by livestock animals, but not because of overgrazing. Besides trampling and grazing pressure, another important factor of vegetation change is over-supply of natural fertilizers and moisture (e.g. animal dung and urine) in topsoil around water wells due to high animal density and intensive utilization of water points. This, apparently, transforms soils around water sources into more mineralized conditions and consequently affects underground micro-flora and aboveground vegetation.

Increased grazing-driven disturbance has resulted in replacement of ephemeroids by undesired annuals. The radial symmetry of grazing pressure around the well has resulted in more rapid changes in vegetation structure than around the village where the grazing intensity is distributed around the elongated village area. Different edaphic factors played a key role in the formation of vegetation structure. Such vegetation changes of rangelands under the impact of grazing are distinctively described by integration of the S&T model. Piosphere analyses helped to identify states and transitions of vegetation communities and their shifts over time under grazing-induced disturbances. Application of such ecological concepts in range assessment helps to understand the driving factors of vegetation changes and to provide a framework for solution of degradation problems and sustainable management of natural resources.

3.2 Vegetation Changes Along a Salinity Gradient

Dryland salinity and associated water quality are recognized to be among most severe natural resource degradation problems in the marginal desert belt of Aral Sea Basin. The annual losses in Uzbekistan due to salinization have been estimated at US$ 31 million, while withdrawal of highly salt affected lands out of agricultural production costs an estimated US$ 12 million annually. Most of the irrigated lands in Aral Sea Basin are subjected to salinity due to sharp continental arid climate with aridity coefficient from 0.12 to 0.3. Initial sources of the accumulated salts in soil profiles are irrigation water. The risk of salinization is further increased due to the rising water table associated with poorly managed drainage systems.

Salt affected lands in desert areas of Uzbekistan demonstrate the most characteristic features of natural continental (not marine/coastal) salinization and alkalinization. Low organic matter (<1.0 %) and high accumulation of salts and poor water holding capacity render these soils unproductive. The predominant salinity type is sulfate-chloride. Sodium and magnesium are the dominating cations. Total nitrogen (N_2) and phosphorus (P) contents usually ranged between 0.7–5.5 and 10.0–18.26 mg/kg, respectively. Available potassium (K^+) content is classified as low or moderate. The dominant cation is Na^+ and the dominant anion is SO_4^{2-}.

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 sulfate -chloride type is also described. Ground water salinity varies from 2.0 to 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 and 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. Consequently, the natural fertility of the saline soils, especially in the of main 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, efficient water use for irrigation coupled with introduction of modern bio-remediation technologies can help to integrate all interactions and define the best management for crop production under saline environments.

Access to irrigation water in this region has drastically decreased in the last years, which caused additional obstacles to rangelands productivity and agricultural production (Lamers et al. 2005; Toderich et al. 2010). Replacement of deep-rooted, perennial native vegetation with shallow-rooted, annual agricultural crops and halophytic pastures has resulted in increased recharge causing shallow saline water tables leading to dryland salinity and loss of plant diversity. This results in greater amounts of water entering a groundwater system, water table rise and the concentration of naturally occurring salts near the soil surface. Slight changes in temperature or soil moisture and dissolved salts regime could therefore substantially alter the composition, distribution and abundance of species. Increased frequency of climatic extremes and changes in soil salinity induce changes in plant functional group composition with invasion of non-native annual plant, which significantly reduce productivity in arid ecosystems. Therefore, functioning of these arid systems depends to a high degree on plant diversity.

4 Role of Biosaline Agriculture Technologies to Improve the Productivity of the Degraded Rangelands

4.1 Floristic Composition of Vegetation of Salt Affected Lands, Mineral Content and Evaluation of Halophytic Germplasm

The inland Irano-Touranian desert ecosystem including plant communities is considered one of the most fragile under currently ongoing climate changes. It is characterized by reduced richness of species, especially trees and shrubs, and, thus, by low resistance to local extinctions (see Chap. 17).

The vegetation cover of sandy deserts has a complicated spatial structure, which forms as a result of initial heterogeneity of the micro- and mesorelief landscape due to processes of soil denudation, salt accumulation and changing moisture content along soil profiles. Numerous seasonal surveys done by us during 2005–2011 have identified more than 380 species of different groups of salt loving plants (wild halophytes representing 19 taxonomical families). The study areas show a high endemism in plants (about 3.4 % from total species). Most noticeable is the relative richness of the Chenopodiaceae with nearly 33 %, equivalent only with Australia's chenopods. It is also quite rich in Asteraceae (20 %), Poaceae (11 %); Fabaceae and Brassicaceae (about 11 %). Species belonging to Polygonaceae, Plumbaginaceae, Zygophyllaceae, Cyperaceae account for a smaller share (3–5 %), whereas, Eleagnaceae, Plantagainaceae and Frankeniaceae make up an even smaller part (<1.0 %) of rangelands halophytic pastures. Among cited plant resources there is a number of native and exotic halophytes both C_3 and C_4 plants suitable for reclamation of arid and semi-arid, salt/affected and waterlogging areas that have proven very useful in demonstration trials.

The distribution of halophytic vegetation is related to inter-specific and intra-specific plant species competition, grazing capacity and land management. Desert topographical features and salinity gradient are of primary importance in determining the contribution of species with different photosynthetic pathways or taxonomic relations in forming of core ecological plant community types or vegetation units. Relative abundance of different growth forms and different pathways vary with seasonality of precipitations; e.g. spring-summer rainfall favors the abundance of C4 pathways chenopods. Annual ephemerals (short-lived) and ephemeroids occur in spring-early summer in times of moisture availability both in open rangelands areas and/or beneath the canopy of perennial plants. Our observations show that as results of drought impact the prevalence of open areas on rangelands increases with aridity and many species become increasingly restricted to run-on or moisture accumulation places. In high saline areas (named solonchaks) there is virtually no plant cover or only limited number of salt loving (halophytes) can grow.

Based on this mapped vegetation pattern distribution (Fig. 13.6) and on ground data we found that there were only a few core species, which determine productivity of rangelands of the studied biotopes/niches. Assessing the grazing potential of degraded rangelands by mapping zonal halophytic vegetation allowed us to identify salt pioneer plant species for each studied zone in order to initiate the reclamation process of saline prone soils. Among frequently found species there were *Climacoptera lanata*, *Kochia scoparia*, *Atriplex nitens*, *Salsola rigida*, *Halothamnus subaphylla* (Chenopodiaceae), *Glyzhyrrhyza glabra* (*Fabaceae*) annual and perennial species, growing well both on salty crusts (solonchak-alkaline soils), on clay and gypsum deserts, on takyr and high saline sandy soils . Therefore, we consider these species as a model plant for calculation of rangeland productivity both on virgin area and under cultivation (agro-silvi pastoral model) by using supplement irrigation with low quality water and application of fertilizers (Toderich et al. 2008).

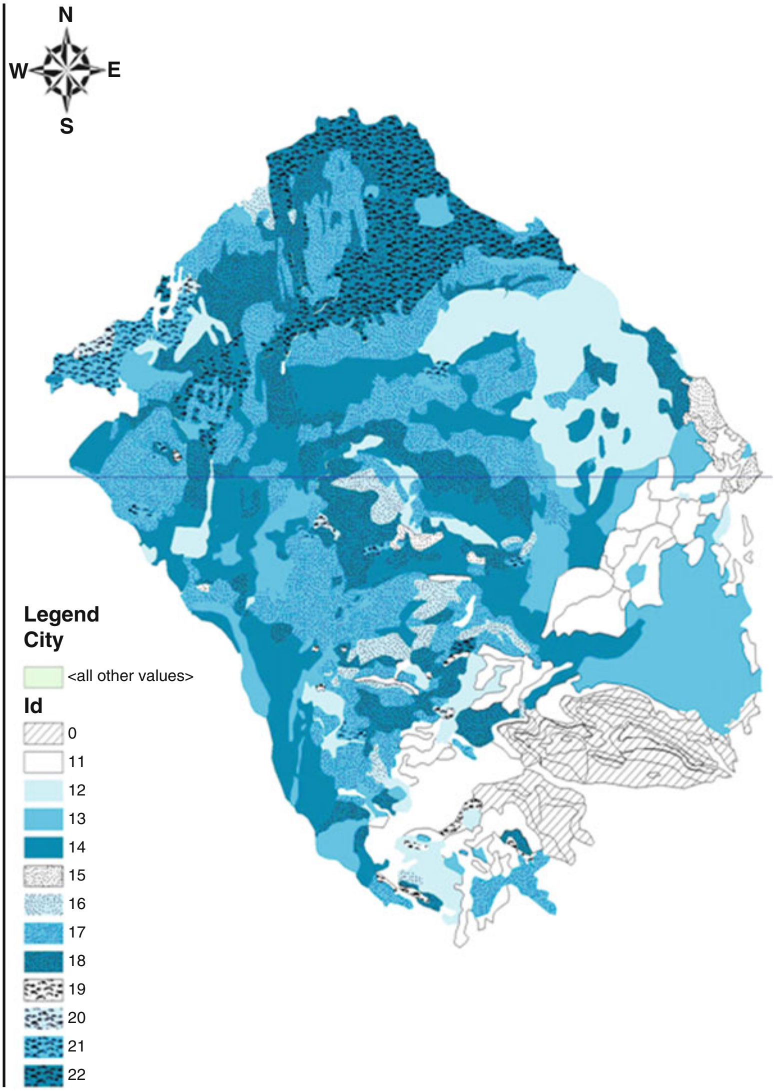

Fig. 13.6 Mapping of dominating (edificators) plant C4 species on the territories of Kyzylkum desert along a gradient of salinity (1–4 soils of low salinity; 5–8 medium salinity; 9–12 high salinity)

Plant composition, soil salinity, water table level and pasture yield were quantified in five main ecological zones. The dominating life forms are halophytes (chamaephytes) in sites of high salinity, and xerophytes (therophytes) in sites of low salinity. Spatial and temporal variations in the standing crop biomass were pronounced. The accumulation of green biomass started during spring and reached a maximum in autumn, when photosynthetic activity was maintained to account for transpiration losses. There was a general trend of increasing salinity and concentration of different ions along the salinity gradient. The periodical variation in the water table was insignificant, while a significant drop in salinity and the concentration of different ions was detected in spring, which was attributed to the diluting effect of rain water during that season. Analysis of cover vegetation of each visually divided zone along a micro-scale level has assisted to determine the dominant species in each zone, identified based on the total soluble salts in the soils. In the first zone (named as wet solonchaks), where there was a high mineral content, species of genus *Salicornia*, *Aeluropus*, *Suaeda*, *Halostachys*, *Halimocnemis*, *Climacoptera* were widely distributed. The vegetative period of all these species begins fairly late because the marshes are under water for a long part of the year.

4.2 Plant Density of C_3- and C_4 Species in Relation to Na and K Accumulation and Biomass Productivity

The highest density of xeropsammophyte and xerohalophyte plant communities belongs to C_3 species consisting of 89–94 % and 74–91 %, respectively (Fig. 13.7). The ratio of C_4 plants showed smaller values than C_3 plants for both plant communities. As its name implies, the plant density of haloxerophyte community represented considerably rapid changes during the seasons in term of the ratio of C_3 and C_4 plants. In spite of the dominancy of C_3 species in haloxerophyte community, the proportion of C_4 species noticeably increased compared with other plant communities. The contribution of C_4 species showed 19, 70 and 45 % during spring, summer and autumn seasons, respectively. However, during the summer season relatively increased values of C_4 species is observed for all plant communities.

Data collected during many field expeditions throughout Kyzylkum desert and Priaralie including plateau Ustyurt show clearly that there are changes between perennial and annual rangelands species ratio along salinity and soil moisture gradients. As is seen from Fig. 13.7 the biggest numbers of perennials occurs within semi shrub plant community on non saline soils. With increasing of soil salinity on typical halophytic plant community on solonchaks desert depression in botanic diversity the perennials is decreasing up to 50 %, while percent of annual species out of total plant diversity is sharply increased along salinity gradient.

Results showed that ratio of C_3 and C_4 plants in vegetation communities differ both along the salinity gradient and on seasons of the year. C_3 species such as *A. Lehmannii*, *A. diffusa*, *A. pseudoalhagi*, which occurred mostly on 1–3 ecological zones and some of tree species accumulate insignificant amount of sodium in leaves (0.63–7.34 g kg^{-1} of dry matter). Considerably high content of sodium (about ten times higher) was found in the leaves of *P. harmala* (52.33 g kg^{-1}) which is one of the plant components of haloxerophyte vegetation association. Such C_4 species

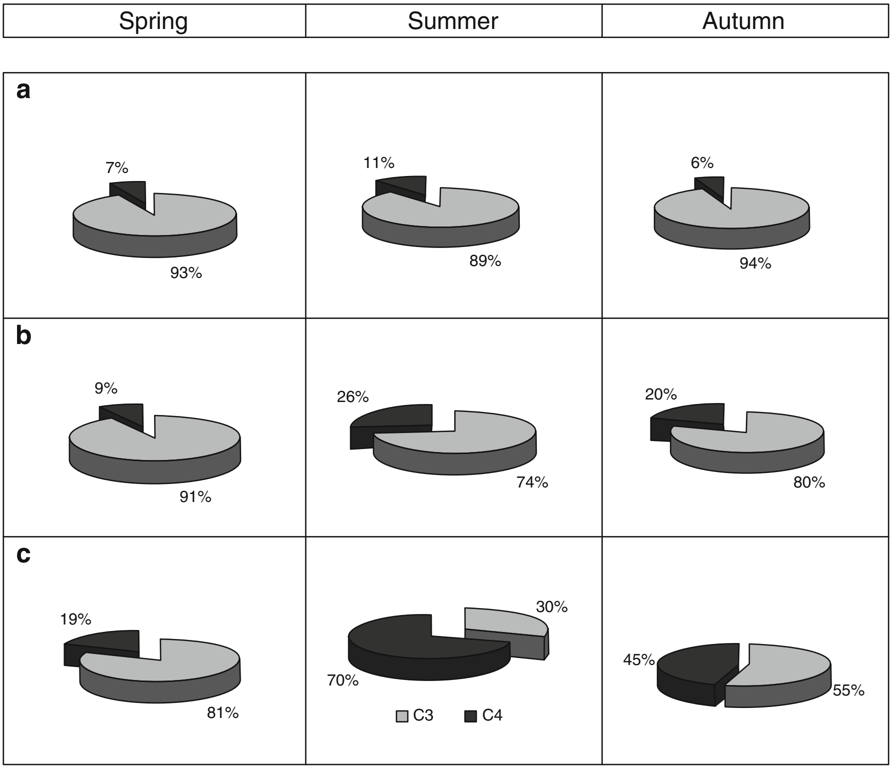

Fig. 13.7 Ratio of species with C_3 and C_4 types of photosynthesis in different plant associations (**a** – xerophytes, **b** – xerohalophytes, **c** – haloxerophytes) during vegetation season

as *H. aphyllum*, *S. paulsenii*, *H. hispida* accumulate 20–90 g kg^{-1} of sodium in green above ground parts. The representatives of C_4 species (*C. lanata*, *Sueda* sp.) of haloxerophyte plant association are capable to accumulate up to 300 g kg^{-1} of sodium. Proportion of species with C_3 and C_4 type of photosynthesis at the three plant communities considerably differentiated along the spatial and temporal scales (Fig. 13.8a, b). The highest density of xerophyte and xerohalophyte plant communities belongs to C_3 species consisting of 89–94 % and 74–91 %, respectively. The ratio of C_4 plants showed smaller values than C_3 plants for both plant communities. These plant resources have not yet been widely used as part of the arid production system of Uzbekistan by the pastoralists and farmers. Previous studies have shown that many wild halophytes grow well in association with a variety of salt tolerant traditional crops and often provide severe competition to tree/shrubs species, both in natural and improved pastures both on saline and disturbed mine sites (Toderich et al. 2007, 2008).

Investigations in 2011 identified that the ratio of C_3 and C_4 plants in vegetation communities differs both along the salinity gradient and on seasons of the year.

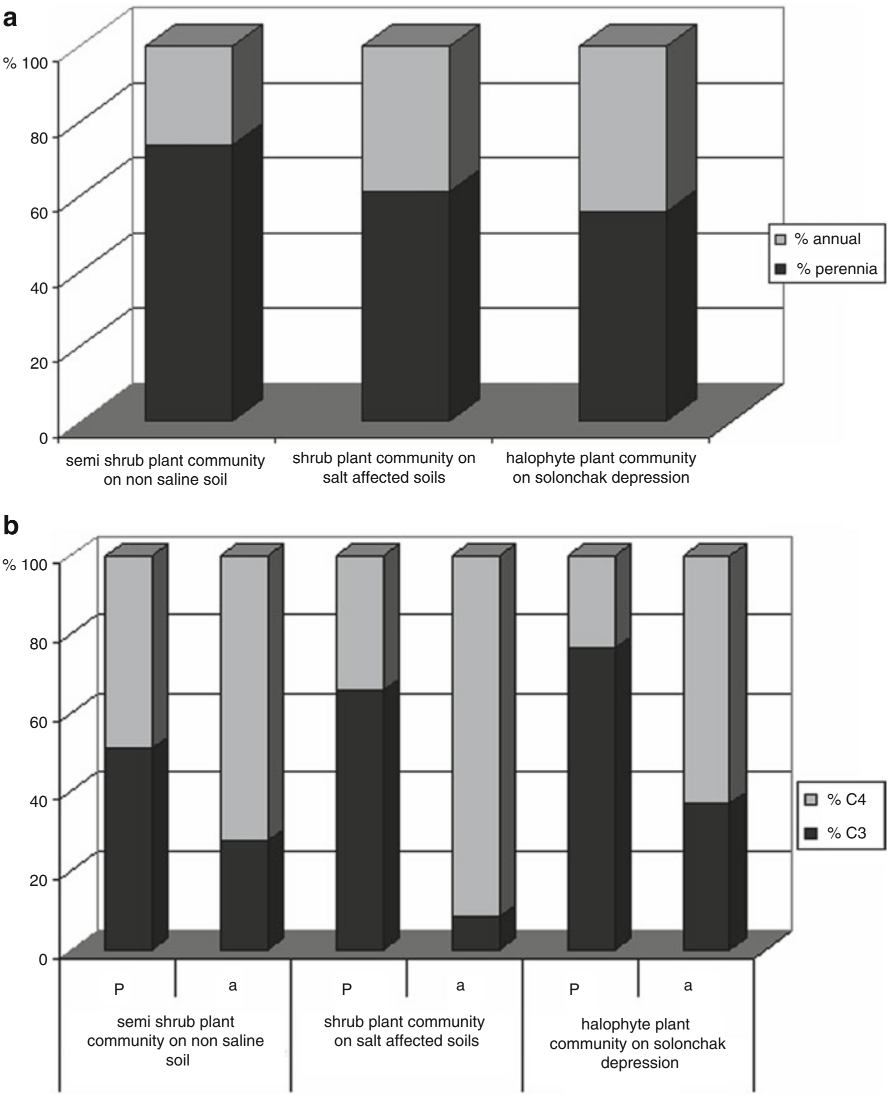

Fig. 13.8 Ratio of perennials and annuals among desert rangelands plant associations along salinity gradient. (**a**) is displayed according to location in landscape and (**b**) is displayed according to photosynthetic pathway (C_3 or C_4)

Along the salinity gradient the ratio of C_3:C_4 species (averaged over all seasons) is represented as 10:1, 10:2 and 10:9 for xero-, xerohalo-, haloxerophyte plant communities, respectively. Regular prevalence of C_3 species is observed, as proportion of C_4 species in the flora of desert vegetation of Uzbekistan does not exceed than 4 % (Pyankov et al. 2001; Toderich et al. 2007). Nevertheless, proportion of C_4 species is increased along the salinity gradient and in haloxerophyte plant

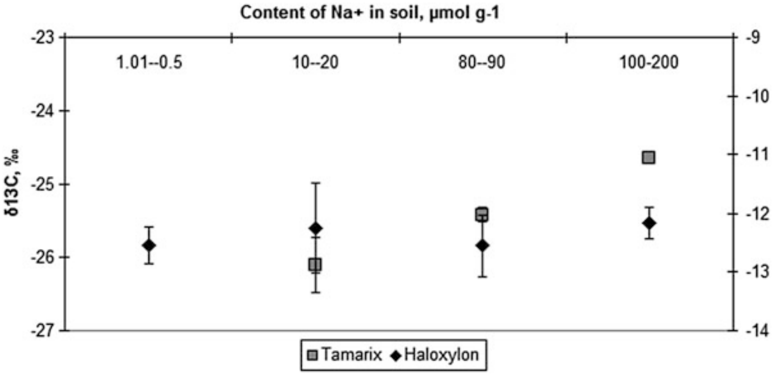

Fig. 13.9 Leaf carbon isotope ratio of C_3 (*T. hispida*) and C_4 (*H. aphyllum*) species along salinity gradient

community its amount becomes comparable to the proportion of C_3 species. C_4 species are mostly due to the salt affected soils and Na^+ is essential for C_4 species (for the translocation of pyruvate across the chloroplast envelope) where it functions as a micronutrient and to some extent all Chenopodiaceae species (studied C_4 chenopods) are halophytes (Akhani et al. 1997; Toderich et al. 2007). Although in the case of vegetation cover of Karakum desert (Pyankov et al. 2002) and grasslands of Argentina (Feldman et al. 2008) the increased amount of C_4 species compared to C_3 species has been shown along the gradient of deterioration of soil condition and soil salinization. Significant dependence of C_3 species on soil salinization indicates a reduction of carbon isotope discrimination ($\delta^{13}C$ value) of studied C_3 species along the salinity gradient (from −27.39 to −24.79‰) (Fig. 13.9). A 2 ‰ differences in $\delta^{13}C$ value of C_3 plants indicates a difference in water-use efficiency of about 30 % (Ehleringer and Cooper 1988; Ehleringer et al. 1998; Dawson 1993). In this case, C_4 species demonstrates independence of $\delta^{13}C$ value along the salinity gradient (Fig. 13.9).

A positive correlation of total productivity of main plant communities along the gradient of salinity with vegetative cover of C_4 species, especially due to the perennial C_4 tree and shrubs like *Haloxylon aphyllum* and *Calligonum leocacladum* was identified. The dominance of C_3 species in spring and early summer seasons in the studied areas is determined by abundance of short-live species of ephemerals and ephemeroids. The high ratio of C_4 species in summer comes from annuals halophytes from genus *Salsola*, *Climacoptera*, *Suaeda* etc. (more than 40 % among total C_4 species of haloxerophytic plant community). Species with C_4 type of photosynthesis with high transpiration efficiency are better adapted to soil water deficit or physiological drought that is strongly expressed in summer period, thus, the productivity of C_4 species within different desert plant communities are not very dependent on the regime of rainfall.

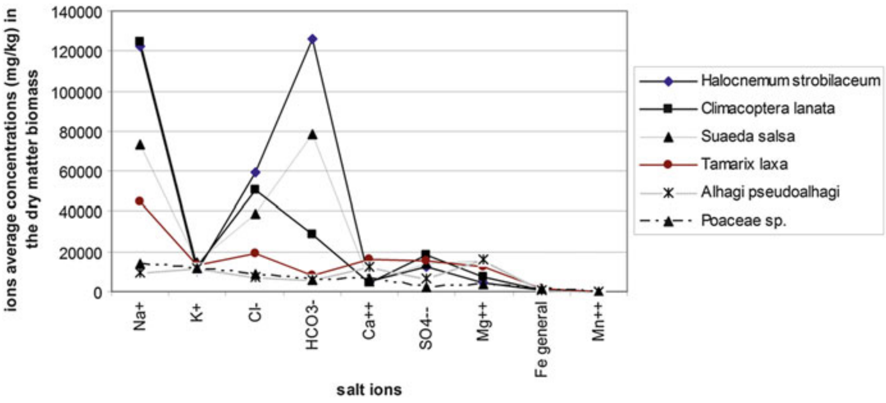

Fig. 13.10 Ion average concentrations detected in the aboveground biomass of salt tolerant rangelands species at the flowering stage

5 Mineral Composition of Forage as a Nutrition Source for Livestock

Our investigation on chemical composition of desert plants for ions like Cl^-, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, as well as phosphorus and iron, showed significant changes within different halophytic forage species. As is shown on Fig. 13.8 the naturally growing plants, e.g., *Halocnemum strobilaceum*, *Tamarix hispida*, *Climacoptera*, *Halothamnus subaphylla* contains higher Na^+ concentrations near the critical limit for livestock, while legumes (*Alhagi pseudoalhagi*) and some gramineous fodder grass mostly accumulate K^+.

Based on upon a large amount of experimental evidence accumulated over years of research (some of which we shared above) we are now able to elaborate proven practices for range improvement operations/establishment and regeneration techniques. Depending upon the particular landscape and environmental conditions about 42 rangelands fodder species proved to be of most value for range introduction and eventually forage crop cultivation and seed multiplication and production. Among them *perennial Salsolas*, *Ephedra strobilaceae*, *Haloxylon aphyllum*, *Halothamnus subaphylla Campharosma lessingii*, *Kochia scoparia*, *Zygophyllum species*, *Alhagi pseudoalhagi*, *Glycyrrhiza glabra*, *Lycium turcomanicum*, *Lycium ruthenicum*, some *Calligonum* species, *Ceratoides Ewersmannia*, *Camphorosma Lessingii*, *Kochia prostrata*, *K. scoparia*, *Limonium gmelinii*, *Salsola arbuscula*, *Psylliostachys suvorovii*, annual *Salsola* spp., *Atriplex* spp., *Bassia hyssopifolia*, *Halocnemis varia*, and others showed promising results in increasing productivity of degraded rangelands.

Fig. 13.11 (**a**) Natural pastures at Kyzylkesek site highly affected by salinity (before improvement); (**b**) rehabilitation of saline prone lands by using *Atriplex nitens* (monotypic cultivated halophytic pasture after improvement)

The main rangelands restoration techniques include:

- Establishment of artificial phytocenoesis (single and mixed species stands) by direct seeding of salt tolerant crops and halophytes for controlling water table and salt balance on abandoned non-productive pastures;
- Introduction of a range of deep rooted annuals and perennials forage species, legumes, chenopod and tree species for increasing of arid fodder production;
- Tree plantations, shelterbelts and wind breaks.

The rangelands grazing capacity and yield of green/dry biomass significantly increase, when agro-silvi pastoral management practices are applied. An integrated, landscape approach, in which both agricultural land uses and conserved forest areas are closely integrated in a mosaic landscape, can provide an important means of conserving biodiversity within agricultural landscapes, while also maintaining farm productivity. Agricultural mosaics which retain abundant tree cover (whether as forest fragments, riparian areas, live fences or dispersed trees) can conserve high plant and animal species richness, by providing complementary habitats, resources and landscape connectivity for a significant portion of the original biota. Landscape configurations that connect dryland saxaul (*Haloxylon* spp.) and other trees forest patches and retain high structural and floristic complexity will generally conserve more species than those lacking connectivity or habitat complexity.

The areas near subsoil wells (hot springs) and wet solonchaks with predominance of halophyte plant community and low botanic diversity are considered the domains with the most rapid increase of pasture degradation (Fig. 13.11a, b).

For the reclamation of these saline prone rangelands we recommended the sowing of forage halophytes from genus *Atriplex*, *Kochia*, *Climacoptera* in pure stands as monotypic halophytic pastures or mixed as a multi-component halophytic pastures designated to be grazed in fall-winter season after rains, when surplus of salts will be washed out (natural effect of soil leaching).

Mixture of C_3/C_4 desert fodder species planted within the inter-spaces of salt-tolerant trees/shrubs plantations improves productivity of degraded rangelands affected by soil salinization. Application of such approaches solves the animal feed gaps in the lands degraded both by overgrazing and salinity, and promotes increased income for farmers. Agro-silvi-pastoral trials used for rehabilitation of saline soils represent a model for preservation and/or restoration of ecosystem function/services for agropastoral communities as part of their adaptation measures to climate change. The coexistence of C_3 and C_4 species is facilitated because C_3 species can colonize nutrient rich microsites, while C_4 species can occupy nutrient poor microsites.

Comparing different species within a small scale habitat along a salinity gradient we found that short-lived annuals or herbaceous species had significantly lower values of forage biomass than perennial species. The selection for trees with low $\delta^{13}C$ and, therefore, high transpiration efficiency, has the potential to increase total tree biomass growth in water-limited arid saline environments. Results obtained in this study showed that the successful performance of dryland afforestation technique is based on partial overlapping of natural niches of C_3/C_4 species. Therefore the optimal rehabilitation technique of saline prone rangelands consists from 12 % of tree cover, 20 % wild xerohalophytes, 38 % of biennual and 30 % annual forage crops, which in mixed planting significantly increase the productivity of rangelands. They prevent the accumulation of salts in the root zone. Results of this research indicate the suitable co-existence of C_3 and C_4 species is facilitated because C_3 species can colonize nutrient rich microsites, while C_4 species can occupy nutrient poor microsites.

There are a number of both C_3 and C_4 plants suitable for reclamation of salt/affected and waterlogged drylands that have proven very useful in demonstration trials. They provide potential to re-use areas that have been abandoned by agro-pastoralists and which are not used as part of the arid fodder production system.

Incorporation of fodder halophytes into the agro-silvo pastoral system or domestication of wild halophytes species represents low cost strategies for rehabilitation of desert degraded rangelands and abandoned farmer lands affected both by soil and water salinity. Late summer and early autumn time should be considered as the optimal period for transplanting of all the above mentioned non conventional halophyte species. Introduction of strip-alley livestock-farming system increased the productivity of rangelands by 2.0–2.5 times and slowed further degradation of rangelands. The proposed system (developed by the authors) of creation of agro-phytocenosis by mixture of natural halophytes with salt tolerant crops, fodder legumes and grass allow getting forage for animals almost all of the year. Salt tolerant crops cultivated into an agro-silvo-pastoral model benefits from the improvement of soils and microclimatic conditions provided by the shrubs. Considerable reductions were observed in wind speed, potential evapotranspiration, temperature and in the intensity of sand storms. First screening of wild halophytes for their gradual domestication should be done based on the following criteria: ash composition of forages; nutritional values and needs of farmers.

6 A Role for Biosaline Agriculture in Rehabilitation of Saline Land

Studies done by International Center for Biosaline Agriculture in Central Asia in collaboration with national partners from different institutions and agropastoral farms for the period 2006–2011 identified target areas of greatest potential for successful extensive pasture improvements, such as re-seeding of shrubs etc. Among them the most important fodder and biomass production value are: *H. aphyllum*, *Calligonum* spp., *Salsola paletzkiana*, *S. Richteri*, *S. orientalis*, *S. gemmascens*, *Artemisia* complex, *Halothamnus subaphylla*, *Kochia prostrata*, *Camphorosma lessingii*, *Eurotia ewersmannia*, *Alhagi pseudoalhagi*, *Astragalus* spp., *Glycyrrhiza* spp., *Carex* complex, *Poa bulbosa*, halophytic annuals and others.

The measures include the establishment of on-farm demonstration trials for using: (i) low quality water for irrigation and cultivation of suitable native wild and cultivated tree and shrub species, as well as use of winter/summer conventional and non-conventional drought and salt tolerant crops; (ii) domestication of economic-valuable native halophytes on un-productive salt affected abandoned by farmers lands and saline prone sandy desert rangelands; (iii) seed collection, post harvesting packages and marketing to create employment opportunities for a large number of people, particularly the poor rural, women and children in summer season; (iv) establishment of tree plantations and shelterbelts that provide bio-drainage input, organic matter, improvement of the microclimate, and promote by-products such as wood, fruit or fodder. Different rations of feeding of small ruminants were tested using traditional and non-traditional fodders. Studies have revealed sustainability and resource efficiency use of the integrated crop-livestock production system.

Planting of fodder halophytes on high saline lands integrated with salt tolerant trees and shrubs the importance of farming practice in mitigation of salinity and lowering of the GW table. On the high end of the gradient, soil salinity and sodicity (a measure of exchangeable sodium) were high in the *Climacoptera lanata* zone [(EC = 5.3 dS m^{-1}, sodium adsorption ratio-SAR = 44.0 (mmoles $L^{-1})^{0.5}$] and extreme in the *Tamarix hispida* zone [(EC = 21 dS m^{-1}, SAR = 274 (mmoles $L^{-1})^{0.5}$]. Endemic species produced maximum biomass in the zone where they originated, not in any other higher or lower vegetation zone. *Tamarix* species, *Haloxylon aphyllum* and annual halophytes, which were distributed across nearly all sites, had low frequency of occurrence. Based on this we have distinguished common growth forms into distinct groups corresponding to different ground-water levels. Three clearly defined groups of growth forms were strongly associated with three distinct ground-water zones, ranging from <3, 3–5 and >5 m, respectively. Four taxa groups were found to correspond to the three ground-water zones and to several other environmental factors that suggest a major botanical gradient exists relating to ground-water depth than to the secondary gradients like soil moisture, pH and to a lesser extent alkalinity and mineralization (Table 13.1).

The overall ranking of the trees, weighing all parameters concurrently shows that species of genus *Tamarix* and *Elaeagnus angustifolia* have the highest potential for

Table 13.1 Performance indicators of native and introduced of C_3/C_4 tree and shrubs species under saline conditions in Kyzul Kum

Species	Growth rate (at 1st years)	Root establishment	Reproduction	Above ground DM	Biodrainage; feed and fire-wood value	Soil salinity level	Winter frost tolerance	Rate survival (%)
Haloxylon aphyllum[a]	+	±	a.b.c	+	±	+	+	±
Tamarix hispida		+	Invasive	±	±	+	+	+
T. androsovii	±	+	Invasive	±		+	+	±
Populus alba	±	±	a.b	±		+	±	+
P. nigrav var. Pyramidalis	±	±	a.b	±	+	±	+	−
P. euphratica	±	±	a.b	±	+		±	−
Salix babylonica	±	±	a.b.c	±	±	+	±	−
Hyppophae ramnoides	±	±	a.b.c	±	±	+	±	+
Elaeagnus angustifolia	+	+	a.b.c	+	+	+	±	+
Robinia pseudoacacia	−	+	a.b.c	+	+	−	+	±
Morus alba	+	±	a.b	+	−	±	±	+
Morus nigra	+	±	a.b	+	±	±	±	±
Malus domestica	±	±	a.b	±	±	−	−	±
Malus silvestris	±	−	a.b	±	±	±	+	±
Cynodon oblonga	±	±	a.b	±	±	±	−	+
Armeniaca vulgare	±	±	a.b.c	±	±	±	−	+
Thuja occidentalis	−	−	B	−	−	−	±	−
Dyospyrus lotus	+	+	a.b.	+	+	+	±	−
Rosa canina L.								
Atriplex undulata[a]	+	+	a.b.c	−	+	+	+	+
Artemisia diffusa	+	+	a,b,c	+	−	−	+	+

+ high potential, ± medium potential, − low potential
[a]C_4 species, while others tested species belong to C_3

growing on both loamy and sandy soils, which represent the dominant soil textures in the region. As a result, at marginal sites where a shallow, slightly-to-moderately saline groundwater is available throughout the growing season, *Elaeagnus angustifolia*, *Robinia pseudoacacia* and newly introduced *Acacia ampliceps* showed the fastest growth and highest water use. This indicates the suitability for planting on low fertility saline lands. Preliminary outcomes of the study on salt-affected soils have also indicated that tree plantations with *E. angustifolia*, *Populus nigra var. pyramidalis*, *Morus* spp. have potential for increasing the soil organic matter due to the relatively rapid leaf litter decomposition. *Morus nigra* and *Cydonia oblonga* showed reasonable DM production on degraded land, with high biomass allocation towards the root fraction. Among tree species, Poplar (*Populus alba*, *P. nigra var. pyramidalis* 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

Evaluation of survival rate, performance and productivity including biomass and seed production of non-conventional tree/shrubby halophytes firstly introduced in Central Asian flora including: *Acacia ampliceps*, *Atriplex nummularia*, *A. undulata* and *A. amnicola* by International Center for Biosaline Agriculture 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^{-1}. 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 was very fast @ 12–18 cm/month at the rooting stage and 25–30 cm/month, when the basal stems develop a woody character. Plant growth of *Acacia ampliceps* raised from direct seeding was much higher than with similar plants grown after transplanting by seedlings (from plastic bags). Among *Atriplex* spp. highest seed germination (approximately 89 %) under field condition was observed for *Atriplex undulata*, which showed a rapid growth rate and accumulation of biomass. Being grown at a high plant density of 10–12 plants m^{-2} (normal density of this shrub is 4 plants m^{-2}) in the first year, this species with its large canopy can occupy the inter-row spaces forming a dense mono-component halophytic pasture. The biomass produced in 1.5 years was 5.6 kg m^{-2} and was readily browsed by cattle and small ruminants. Biomass of *Atriplex undulata* at the Akdepe Experimental site increased with high density level of plant per square meter (5.0–5.8 thousand. plant/ha). Replacement of 30 % of individuals has been done in August 2006 in order to maintain the stand and decrease plant density. Low seed germination of about 55 % was observed in *Atriplex nummularia* and *A. amnicola* (only four shrubs of the latter plant survived). Comparative studies on seasonal plant performance, accumulation of green biomass in *Acacia ampliceps* and *A. nummularia*, *A. amnicola* and *A. undulata* was observed after transplantation into the open field.

Farmers, pastoralists and householders, especially women groups were trained and involved in the activities related to saline water and crop management practices, efficient forage bio-saline production, post-harvest by product marketing and results dissemination. Involvement of the farming and agro-pastoral communities in participatory decision-making, research approach, on-farm testing and verification, as well as faster dissemination of sustainable technologies to mange soil salinity, water table depth, irrigation and drainage water quality will lead to the understanding of salt movement as results of management practices.

The results of this study showed that spatial and temporal changes of natural rangelands vegetation in the arid area affected by salinity in order to initiate different revegetation strategies. Information about soil ion content, electrical conductivity, performance of indicator species, biomass clearly indicates which plant species are most likely to contribute to the reclamation process of saline soils. Plant species diversity and distribution is determined by local soil specificity, i.e. it's physical and chemical composition, micro-relief and soil moisture. The climate itself as has been noted by Shuyskaya et al. (2008) plays a secondary role.

We also found that halophytes as underutilized plant resources grow well in association with a variety of arid/semiarid rangeland species and often provide severe competition to perennial species, both in natural and improved pastures. Integrated Biosaline Agriculture Program for sustainable use of marginal mineralized water and salt affected soils for food-feed crops and forage legumes developed will assist to improve food security, alleviate poverty and enhance ecosystem health in smallholder crop-livestock systems. Such diversification of agro-ecosystems and development of new agricultural capacities could increase income source of rural poor and farmers which so far are often dependent on two major crops (e.g. cotton and wheat). Furthermore, the activities proposed here will also contribute to large scale biomass production, which will build up the soil organic matter. It will thus also contribute to make the poor farmers more resilient against climate change. The evaluation, domestication and large scale utilization of native and introduced halophytes and salt tolerant plant resources in sole or mixed farming system would have a significant impact on salinity control and remediation as well as on the economic development of arid/saline lands commonly observed in the whole Aral Sea Basin. 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.

An aspect that remains unstudied is the degree to which this type of afforestation effort can contribute, on a larger spatial scale, to carbon sequestration; however, methane emissions from unfertilized poplar plantations as well as natural Tugai vegetation are below the detection limit (Scheer et al. 2008). 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. 2005a, b, c; Khamzina et al. 2006).

Planting herbaceous fodder crops between fruit and fodder trees on intensive agro-forestry plantations leads to increase the productivity of land degraded by both overgrazing and salinity lands. Better plant growth, accumulation of green biomass and consequently yield of both fresh and dry matter were significant for alfalfa both in pure stand and in mixed artificial agro-phytocenosis including trees.

The biosaline agro-forestry concept evaluated in this study provides a means of on-farm drain water management, thus alleviating the need for expensive and potentially hazardous evaporation ponds. Moreover, it could create conditions for maintaining the investigated target remote desert and semi-desert areas as viable farming regions. Immediate actions to direct research towards reclamation of saline prone and desert lands, generation of useful non-timber products and achieving co-benefits of C sequestration by conserving natural resources, renewable energy sources, arresting waterlogging . One of the key motivations for government to develop and promote agroforestry is that it can generate these benefits in addition to financial benefits from the sale of commercial products. Further investigations should be done to show the significance of biosaline agroforestry to reduce poverty through improving household food and nutrition security.

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