COMBATING DESERTIFICATION

TRADITIONAL KNOWLEDGE AND MODERN TECHNOLOGY FOR THE SUSTAINABLE MANAGEMENT OF DRYLAND ECOSYSTEMS

PROCEEDINGS OF THE INTERNATIONAL WORKSHOP
ELISTA, REPUBLIC OF KALMYKIA,
RUSSIAN FEDERATION
23–27 June 2004

UNESCO–MAB Drylands Series No. 4

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The United Nations Educational, Scientific and Cultural Organization (UNESCO)

UNESCO Man and the Biosphere Programme (MAB)

Kalmyk Institute for Humanities Research

MAB National Committee of Russia

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Contents

Preface

Traditional methods of farming and range management practices in the Republic of Kalmykia (Russian Federation) had been disregarded and undervalued for many decades as regional economic growth privileged modern technology as a means of increasing productivity. Many other dryland regions of the world are in a similar situation as 'modernity' is often associated with abundance, prosperity and a certain emancipation from the hard toil of working the land. Today however, we are witnessing a reversal of this trend and a return towards traditional methods that rely on local technical know-how and practices to restore degraded lands while halting desertification processes that threaten the livelihoods of local people; combating desertification is also a fight against poverty.

The United Nations Convention to Combat Desertification (UNCCD) recognizes the role of 'traditional knowledge' in Article 18 of the Convention stating that such technology should be ensured, encouraged and facilitated when attempting to combat desertification. There is much valuable information to be learnt from the traditional lifestyles of the Kalmyk people and other rural communities the world over, which have evolved over centuries and have thus carved both the natural and cultural landscape. This traditional knowledge can form the basis of site- and context-specific solutions in combating desertification in the world's dryland areas.

One of the main objectives of the workshop on 'Traditional Knowledge and Modern Technology for the Sustainable Management of Dryland Ecosystems' held in Elista, Republic of Kalmykia (Russian Federation, 23–27 June 2004) was to explore the extent of traditional methods as a complement to existing modern technologies to assist dryland biosphere reserves in the rehabilitation of degraded areas in their transitional and buffer zones. The workshop also aimed at finding solutions to desertification that could specifically be incorporated into National Action Programmes within the context of the UN Convention to Combat Desertification. The workshop had thus a scientific but also an anthropological component as well as a policy-oriented purpose. UNESCO is pleased to offer the various case studies contained in the workshop proceedings to the UNCCD for its important work on reducing dryland degradation and combating desertification.

It was thus an important event which proved successful thanks largely to the excellent organization provided by the MAB National Committee of the Russian Federation, and notably Dr Valery Neronov, as well as by the Kalmyk Institute of Humanities Research who provided the international participants of the workshop with first-hand insight information on dryland conservation, management and sustainable development. I would like to take this opportunity to thank all the participants who attended the workshop with a special mention and thanks to the scientists whose tireless work is a continual and important reminder of the need to ensure the use of traditional knowledge and methods – coupled with modern technology – in our unified combat against desertification.

N. Ishwaran
Director, Division of Ecological
and Earth Sciences
UNESCO

Opening session

Welcoming address

Kirsan N. Ilumzhinov, President of the Republic of Kalmykia

Dear participants in the workshop,
Dear guests,

I greet you, the representatives of the different countries of the world on Kalmyk land, known for its wealth and the beauty of the wide steppe that is celebrated by poets. It is deeply symbolic that the international workshop organized by UNESCO on the traditional knowledge and modern technology in combating desertification should be conducted in Kalmykia.

The nomadic lifestyle and seasonal change of pastures allowed our ancestors to preserve the topsoil of the steppe. Modern changes in the landscape and environment have had a severe effect on the biodiversity of the steppe region. Intensive use of the land that ignored ecological factors and traditional folk knowledge has upset the natural balance. The successful adaptation of traditional knowledge to modern living conditions will enable dynamic development in all spheres of our social and economic life.

UNESCO's international workshop held in Elista is convincing evidence of the integration of scientific and practical processes. I am sure that this workshop will solve the actual ecological problems more quickly and ensure the sustainable development of Kalmykia! I wish you creative success, constructive debate, good health and personal welfare.

Kirsan N. Ilumzhinov
President of the Republic of Kalmykia

Introductory address

Valery M. Neronov, Deputy Chair of the Russian MAB Committee

Dear Dr Schaaf and all esteemed participants of the UNESCO Workshop, dear Mr Akuginov, dear Mr Kugultinov,

On behalf of the Russian MAB National Committee and the National Commission of the Russian Federation for UNESCO, I welcome you to this beautiful Palace of Chess, constructed a few years ago in the hospitable land of the Republic of Kalmykia. It is necessary to emphasize that our Committee has for a long time benefited from fruitful cooperation with the Government of the Republic of Kalmykia, and I wish to take this opportunity to express my gratitude to the Government and particularly to the President of the Republic of Kalmykia, Mr Kirsan Ilumzhinov, for supporting a number of projects initiated by our Committee in the territory of this Republic.

The first dryland Biosphere Reserve in Russia, 'Chernyje Zemli', was endorsed by UNESCO's MAB Secretariat in the Republic of Kalmykia in 1993. In 2002, in Elista, the capital of the Republic of Kalmykia, an International workshop was held on the conservation of the saiga antelope, which is a key species in the dryland ecosystems of the northwestern Pre-Caspian region and Central Asia. Following the recommendations of this workshop, the Centre for Captive Breeding of Saigas was enlarged and received funding from the Government of the Republic of Kalmykia as well as some international wildlife foundations. A visit to this centre has been included in the programme of the workshop. In 2003, with the help of the ROSTE/UNESCO Venice Office, our Committee conducted a training course for local farmers and a demonstration of renewable energy technologies, also in Elista. We hope such ecologically clean sources of energy will help to improve livelihoods in rural areas. This aspect has a direct connection with the tasks at hand in the present workshop.

The Chernyje Zemli ecoregion of the Republic of Kalmykia is well known in old Russian literature as a region of intensive livestock husbandry. In more recent times, due to irrational agricultural management in the former Soviet Union, it became known as the first human-made desert in Europe. Under the workshop programme, we will be visiting Chernyje Zemli ecoregion and will learn about activities within the transition and buffer zones of Chernyje Zemli Biosphere Reserve. In this context, the International Workshop on Traditional Knowledge and Modern Technology for the Sustainable Management of Dryland Ecosystems taking place in the Republic of Kalmykia is a very good opportunity for a wide exchange of experience and know-how gathered from the different dryland countries of Africa, the Middle East and Asia. This should help to solve certain environmental problems not only in Chernyje Zemli ecoregion but also in other dryland areas of Russia.

As you know, the Russian Federation straddles two continents: Europe and Asia. Accordingly, our Committee is participating in the activities of UNESCO/MAB, which involve such regional networks as EuroMAB and EABRN. We started our participation in UNESCO's Man and the Biosphere (MAB) Programme in 1974 and have since conducted fourteen international MAB projects, in which 3,000 scientists and specialists of various fields have taken part. All the USSR Republics took an active part in this programme, and in 1979 in Kiev, Ukraine, the first united plenum of all the MAB Committees of the Republics took place, as well as a scientific conference. So, in 2004 we celebrate two important jubilees in the history of the MAB Programme in our country.

It is worth mentioning that the practice of conducting combined meetings and conferences to evaluate the practical and scientific results of the MAB Programme continued until the break up of the USSR. Among the themes discussed at these meetings, along with other types of ecosystems, relevant attention has been given to grasslands, semi-arid and arid zones. The recommendations for restoration and enrichment of dryland pastures have been highly appreciated, and the academician N. Nechaeva and her collaborators have received the State Prize for their innovative approach. I am sure the previous scientific achievements and recommendations, in addition to traditional knowledge, will not be forgotten and will produce outstanding results in the new millennium, even bearing in mind the impacts of current global changes in environment and climate.

From the bottom of my heart I wish the participants to this workshop an enjoyable stay in Kalmykia, and the best results in analysing the different models and ways to achieve the sustainable development of drylands. I am sure these results will be very valuable for implementing the ecosystem approach, one of the priorities of the Convention on Biological Diversity.

Valery M. Neronov
Deputy Chair
Russian MAB Committee

Introductory address

Gennadiy G. Matishov, Chair of the Southern Research Centre of RAS

Dear Colleagues,

I would like to greet participants in the meeting on behalf of the Southern Scientific Centre of the Russian Academy of Sciences (RAS). The Centre was established in 2002, and its activity extends to institutes, laboratories and the stations of the Academy of Sciences located in the Republics of Adygea, Ingushetia and Kalmykia, the Karachaevo-Circassian Republic, and the Krasnodar, Stavropol, Astrakhan, Volgograd and Rostov regions. It consists of three institutes of the Russian Academy of Sciences, and encompasses the scientific activities, orientation and personnel structure of the Kalmyk Humanities Institute of the RAS, on which basis this meeting is held.

The Southern Scientific Centre aims to maintain scientific and applied research in priority areas so as to ensure real improvement of the economic, social and ecological conditions of life in the region, as well as coordination of this work, which has great value for the economic and cultural development for the south of Russia.

Our region plays an important economic and strategic role in the stable development of the Russian Federation, which possesses a potential wealth of resources and has significant oil and gas reserves, fertile soils, seas and other biological resources. The environmental problems in the region are very serious however, and demand an immediate resolution. One of the problems is soil degradation and pollution, which is now the region's greatest social and economic problem, representing an ecological and economic threat, and indeed a national security threat to Russia. This especially concerns the arid territories. The problem demands steadfast attention from the Russian Academy of Sciences and many other public and scientific organizations.

In 2003 the Southern Scientific Centre developed, and in 2004 has implemented, a complex programme for the 'Biological Bases of Water System Manych-Chograi Restoration: Water Regulations, Nature Protection Monitoring, Bioresources', with support from the Russian Academy of Sciences and the governor of the Rostov region. The need to develop such a programme has been emphasized by various factors: the accelerated deterioration of water resources as a result of an irrational water–economic policy in the region; the catastrophic loss of bioresources; the importance of the programme in terms of nature protection under the international obligations of the Russian Federation; soil desertification; advancing degradation of agricultural land due to soil salinization; flooding and pollution; and the sanitary and hygienic, social and economic dynamics of the region.

The importance of social and organizational factors must be remembered when studying the origin of these problems: the gap between science and management; the lack of integration of academic, departmental and high-school science; the gap between the development, adoption and execution of legislative and other measures for bioresource regulation and preservation.

It is very important that such a high-level meeting under the aegis of UNESCO and with the assistance of the Southern Scientific Centre of the RAS should be devoted to the application of traditional knowledge and modern technologies to develop arid ecosystems stable here in Kalmykia. I hope that the work will be fruitful, as well-known experts from many countries have gathered here. I have no doubt that the exchange of opinions and study of international experience will be useful in elaborating a strategy of development and technologies for nature management for the south of Russia.

Let me congratulate you on the beginning of the meeting and wish you success in your work.

Academician Gennadiy G. Matishov
Chair of the Southern Research Centre of RAS

Traditional knowledge and modern technology for the sustainable management of marginal drylands

Driss Fassi, Chair of UNESCO's Man and the Biosphere Programme's International Coordinating Council

Distinguished representatives of the Government of the Republic of Kalmykia and eminent members of the international scientific end environmental community, ladies and gentlemen,

Personally and on behalf of UNESCO's Man and the Biosphere (MAB) Programme's International Coordinating Council, I wish to express my great satisfaction with the programme and its astute decision to organize this international workshop. It is in fact of prime significance that the success of the workshop owes much to the benefits of a theme of great interest as well as to this ideal geographical location, which further illustrates that theme's importance. It is this ideal combination that is here proposed in the Republic of Kalmykia in this great country of the Russian Federation.

'Traditional knowledge in drylands' is the subject under study and is part of the series of high-quality workshops on 'Sustainable development and the management of drylands' that are being superbly organized by the master hand of Dr Thomas Schaaf, a distinguished member working from UNESCO's headquarters in Paris. There is a major emphasis on core concepts such as the concern for sustainability, which is a key word in all development projects. For this reason, the World Network of Biosphere Reserves is an ideal framework for application, for it spans five continents in partnership with the MAB programme and consists of more than 450 sites of varying sizes in more than a hundred countries. Furthermore, the concept of sustainability is increasingly gaining ground in the world of extreme aridity and has thus become a decisive reference. As drylands are situated at the periphery of the living world with its fluctuating rhythm, they represent a sort of barometer of health between the state of conservation and dynamism for the whole world, for both the biosphere as well as for other cultures, which are synergistic with it.

The stakes become crucially important when one considers that dry regions were the cradles of early human civilizations, and as a consequence harbour the 'backbone' of traditional knowledge. It is therefore extremely astute as well as strategically appropriate to address these civilizations in order to discover the key to adaptation by human communities to one of the more difficult environmental regions. It thus represents the best field of study for sustainable development, with its capacity to foresee and organize the longevity of resources and societies under extreme conditions of scarcity. Consequently, the degradation of drylands, and oases in particular, threatens to destroy the traces of a number of the most discerning civilizations that ever existed.

This workshop has set itself the task of reviving and safeguarding what remains of the wisdom of traditional sustainable systems, and is thus surely a saving grace of historical dimensions. Moreover, the possibilities of rediscovering clear and functional understandings diminish with time, and even when we have the chance to discover these fundamental approaches to sustainability, by witnessing them at first hand or as a result of patient reconstruction, there still remains the arduous problem of reviving and making acceptable an enlightened approach in a world that is progressively losing its foundational roots in favour of a more dominant and wasteful economy.

Finally, we offer our sincere thanks to the team who have worked to ensure that this workshop is a resounding success, with the efficient participation of local officials and the enlightened supervision of Dr Valery Neronov, Vice-President of MAB National Committee of the Russian Federation. The unique character of the Republic of Kalmykia, the venue for our workshop and a charming and unique region, is undeniably a guarantee of genuine success.

Thank you for uniting and offering us these opportunities; let us try to draw from this experience the lessons we need to move towards better management of biosphere reserves in the perpetual quest for feasible models of sustainable development, and for the benefit of all drylands around the world.

It is a pleasure to be among such a distinguished group of scientists representatives from the countries that are most highly specialized in the subject, making this an ideal occasion to benefit from their expertise. I wish you all an excellent meeting and a pleasant stay.

Professor Driss Fassi
Chair of UNESCO's Man and the Biosphere
Programme's International Coordinating Council

Keynote address

Traditional knowledge as a factor of ecological consciousness: formation and conservation of the environment. The Republic of Kalmykia experience

Nina G. Ochirova, Director, Kalmyk Institute of Humanities Research

Agriculture forms the basis of the Republic of Kalmykia's economy. Currently, 70 per cent of the agricultural land serves as pasture, 14 per cent is arable land and 7 per cent is hayfield. In the 1980s, intensive use of these areas, ignoring ecological and traditional knowledge, led to a serious disruption of the natural equilibrium. Even before that decade, 50 per cent of the entire territory of the republic had been exposed to desertification, resulting in agricultural decline, a reduction in the wildlife population and the loss of useful plants.

In the past, the Kalmyks had created a system that was well adapted to local conditions in terms of the norms of human behaviour within the environment, taking into account the fragility of the arid ecosystem. The nomadic lifestyle, the seasonal change of pastures and the special meat- and wool-producing breed (that is, the fat-tailed sheep) allowed the pasturelands to be preserved as much as possible. The recent discarding of traditions that had been practised for hundreds of years and the blind adoption of modern innovations have meant the loss of optimum management technologies and the exclusion of native cattle breeds that were well adapted to the local conditions. At present, a wide spectrum of activities and events, devoted to the realization of the President's programme for the 'Rebirth of traditional pasture livestock-raising', is being carried out in the republic. It is very important to restore the optimum numbers of different species of agricultural cattle within herds. Moreover, traditional experience shows that during harsh winters it is very important for cattle conservation that there should be sufficient horses to break up the snow in order to feed themselves and other animals.

The complexity of some distinctive national practices, prohibitions and rituals connected with the Kalmyks' household activities is worth special attention. Typically, and without any knowledge of genetics, cattle breeders preferred to group cattle according to their breed, while keeping a vigilant eye on maintaining and conserving the diversity of breeds. As with other nomadic nations, the concept of 'prosperity' is associated with the presence of numerous herds.

In the past, the Kalmyk people followed a special system of rules and taboos that helped to preserve the environment and wildlife, and harmonized the relationship between people and nature. It is worth mentioning that this system still prevails today. The Kalmyk approach to the earth was especially well thought out. Every living organism on the earth is considered to be a living child. In modern society, traditional knowledge has come to be highly demanded. It is therefore necessary to undertake urgent measures that will preserve this knowledge for future generations as part of their cultural heritage. To achieve this, it is important to analyse our accumulated experience of nature and to produce specific recommendations for how to incorporate local knowledge in the national modern economy.

For 5,000 years the northwestern part of the Precaspian was used for stockbreeding. As an inseparable part of the Russian empire, the historic territory of Kalmykia during the seventeenth and eighteenth centuries had formed a united territorial–economic region and a natural–climatic composite called the 'Kalmyk steppe'. Its nature and resource potential were fully compatible with the requirements of pasture stockbreeding, which represented a historically developed and respected type of land use that was based on the evolution at minimum cost of the main agricultural animals.

During this period there were on average more than 200,000 cows, 100,000 horses, around a million fat-tailed sheep and 20,000 camels – and all were Kalmyk breeds. Keeping so many and such a variety of animals of Kalmyk breed on the basis of pasture technology within a complex agricultural stockbreeding production system sustained the equilibrium of agro-industrial potential and a historic agrarian specialization. The management experience and traditional uses of nature were passed from generation to generation and thus provided for the natural fertility of seasonal and pasture lands.

During the twentieth century, the compulsory changes from the customary way of life (with the loss of the economic elite of steppe cattle dealers as a result of wars, repression, forced emigration and exile, and the administrative imposition of an extrinsic agricultural practice on the territory of the Republic) resulted in a considerable weakening of the traditional material and economic culture; experience in pasture stockbreeding has been diminished, and certain kinds of Kalmyk breeds adapted to local conditions have been lost. The main motives for reversing this trend are to provide for the sustainable development of rural lands on the basis of restoring traditional pasture stockbreeding as a rational agrarian use of nature. This entails developing and reviving the unique domestic agricultural animals of Kalmyk breeds: cows, horses, fat-tailed sheep and camels.

Once the General Black Lands and Kizlyar Pastures Plan for combating desertification had been elaborated, it was given the status of a regional ecological programme. The whole suite of measures provided by the general plan provides for the mitigation of desertification processes and tackles the problems of pasture restoration and rational land use. The technologies of pasture restoration elaborated by scientists from the Kalmyk Agricultural Research Institute enabled productivity to be raised by up to 14–15 per cent per ha. This result has been achieved on an area of 150,000 ha. Erosion processes have been halted and many desertified areas have been transformed into pastures able to produce 20 per cent more per ha of dry mass than they previously did. As a result of the change in the condition of the Black Lands and Kizlyar pastures region, it is now time to change our priorities in combating desertification and adjust our strategy and tactics for carrying out phytomelioration work. In this respect, reference to the historic experience of traditional cultures is necessary in order to solve the problem of ethnic culture adaptation to modern industrial and urbanized civilization by Kalmyks.

Traditional knowledge makes up a worldview aspect of the nation's culture, the ethnic experience raised to abstract notions, and is also the combined total of a nation's ideas of humankind and our place in nature. The conservatism, vitality and sustainability of traditional knowledge need to be incorporated into new systems, with their functions being preserved either directly or in a concealed form. Research into ethnically specific features aims to discover the 'rational kernel' or quintessence of ethnicity as far as that is possible; it is an urgent issue in capturing traditional knowledge, which mostly consists of a small element of traditions that are accepted as ethnic rather than religious.

Here we should take into consideration that traditional knowledge in a pure form has not been preserved: its co-existence later on with other influences, including Buddhism, left its mark. In the report under consideration, based on literary sources and modern field observations, the following cults were analysed: the cult of mountains and the cult of burial-mounds (ova), the cult of land, water and fire, and the cult of animals. There exists very little literature and archive data concerning these.

The Kalmyk steppe dwellers established a well-adapted system to regulate the norms of human behaviour in the environment and take into account the fragility of the steppe landscape. The nomadic way of life, the seasonal change of pastures and the special breeds of fat-tailed sheep with flat hooves made possible the maximum preservation of pasturelands. The ecological consciousness of the Kalmyk people has been passed from one generation to the next over many centuries in the form of traditional stereotypes. The evolution of the most general paradigms of ecological traditions is being traced in studies of traditional knowledge.

The interrelationship between the nomadic breeder and nature was formed on the basis of the primacy of nature. In his article on the nomadic way of life Dr. E. Khara-Davan wrote: 'The nomadic way of the Kalmyks is conditioned not by the barbarity of the nation, as we are accustomed to suppose, but by its being a perfect adaptation to the soil-geographic conditions of the steppe, where crops cannot be grown.' For instance, traditional agricultural methods such as pasture rotation (alternating browsing on pastures with non-use periods to allow restoration) enabled the nomads to prevent the destruction of soil cover.

The nomads preferred to winter in the south, where the livestock were not threatened by the absence of fodder. In summer the livestock accumulates fat that enables it to survive winter hunger. This is especially characteristic in places where there is no hard ice-encrusted snow that might damage the horse's legs as they attempt to dig up the snow to get to the fodder beneath. Usually the cows and sheep follow the trails made by the horses after their hooves have broken up the solid snow. Thus the horse not only represented the warrior caste and symbolized wealth, but was also a guarantee of the livestock's survival. The greater the number of horses in the string, the greater the chances of survival for the livestock in harsh conditions.

Certain aspects of the traditional Kalmyk way of life come down to us from ethnographic sources. For instance, it is known that the Kalmyks not only carried out seasonal livestock movements to solve the problem of fodder, but also performed various religious and magic rituals aimed at securing prosperity for the territory. Among such rituals were sacrifices to the masters of the land and water to procure drought prevention, land fertility and the well-being of all living beings. All four types of livestock were offered. The most important of the ritual actions, which were performed in a prescribed sequence, were the magic practices that brought rain. A variant of this rite is still carried out (locally, occasionally and spontaneously) where signs of a looming drought threaten catastrophe.

The Kalmyks still also carry out the rite of fire offering. This is seen as a link between worlds in a three-element model of the Universe, and a special day is devoted to it in the Kalmyk calendar rites. In addition to the fire-offering rite there is a life-circle rite, a curing rite (life ransom) and a rite of calling the patron divinity. The Kalmyks believe that the Goddess, Okon Tengry, is related to the fire (*lhamo* in Tibetan), and she is regarded as a patroness of the home. Another ancient divinity of the home, called Otkhon-Galakhanhas, has been embodied as a Buddhist divinity.

The Kalmyks worship of land–water expresses a notion that includes the whole space encompassing the native nomadic areas and motherland. The idea of the land is closely connected with water, as the 'earth's bowels' are inseparable from the water element. Each locality has its master. The embodiment of the land and water master, the patron of all the Kalmyks, is Tsagan Aav, who appeared in the Kalmyk culture during the struggle with pre-Buddhist beliefs and is related to the loss of traditional nomadic areas. Buddhist divinities started to be esteemed as patrons of clans, and the nomadic areas thus acquired an additional characteristic as markers of kin groups.

In modern offering rites to water, the donations are placed on small rafts that are destined for the master of water. In the past the rite was carried out before the fishing season, and the offerings included the skin of a dead sheep or goat with the head still attached, and containing the windpipe, heart, lungs, liver and kidneys. The head was hung on a high pole so that the skin would droop. The pole was fixed on the river's bed at the point of main flow (where the fish appeared) by people who either sailed to the middle of the river or lake, or just waded out to it. A nine-tasselled raft was placed by the pole.

The cult of land–water embodied in the rites of the land–water offering is intertwined with worship of the mountains – both real and abstract. The cult of the mountains was formed at the early stage of the Oirats' ethnogenesis and is connected with both the ethnic history of the Oirats living near Altay and Khangay and the mythological belief in mountains as the world's centre, the pillar, the hub of the world, the embodiment of the world tree, the link between the worlds. The Summery Mountain, the central mountain in mythological terms of the Kalmyks, is seen as being, like the Polar Star on the horizon, a point that defines the earth: the whole world was formed with regard to this four-sided peak. In the mythical account, the central mountain is a white mountain called Manghan Tsagan, situated in the nomadic areas of Djangar-Khan. Bogdo Mountain, situated near Baskunchak Lake, was venerated as a holy mountain. Burial mounds were also esteemed as holy sites and are still awarded water and fire offerings.

The ethnic ancestors of Kalmyks-Oirats had a complex economy combining hunting, gathering and stockbreeding, followed later by agriculture. The hunting cults of the Kalmyks lost their significance in economic and cultural life a long time ago and have therefore been forgotten, but the veneration of animals still exists today. The notion of the relationship between man and animal is the basis of the worship of certain animals. For example:

- The totemic vision of a swan is connected with Turkik roots.
- The Kalmyks worshipped an eagle which was connected with the sun in an Kalmyk epic. One of its heroes – a Khongor warrior – is given the name of an eagle, Gerfalcon hawk.
- Among the Kalmyks who lived on the steppes by the river Don was a group called *burgud* (meaning 'eagles'), and this bird was their totem.
- Researchers have discovered ethnic Kalmyk groups whose origins are connected with the names of their totem birds. There are: *shonkhormud* (hawks) among the Kalmyk ethnic group called '*Derbets*', *shontols* (woodpeckers) among the Torgoud ethnic group, and *kharada* (swallows) among the Don Kalmyk. Scholars are also attempting to connect the ethnic name *kereit* (their representatives were among Torgoud and Don Kalmyk) with totemic beliefs (*kerya* means crow).
- There were conjectural books of the magpie and the appearance of a white harrier was regarded as an omen; upon seeing this sacred bird believers had to bow and pray. Conversely, a hoopoe was the sign of misfortune while a cuckoo, regarded as sinister in many cultures, was not a bad omen to the Kalmyks. It was considered as a water-bearing bird, because its song was the sign of riverine tides and other water bodies.

Among totemic animals, which can be seen in the cultures of all Mongolian-speaking people, there was a wolf that was considered a sky dog. Among the Derbet and Don-Kalmyks, there were ethnic groups called *chonos* (named after a wolf). Dogs were believed to be the intermediaries between the world of people and the world of the dead, and the main dog was called Khasyr. Epic singers tell us about the special treatment of wild boars. The Kalmyks also worshipped the hare, and used to sew its bones to the winter clothes of little children to prevent misfortune. Goats or sheep were the most common animals for sacrifice. On rare occasions, on the eve of a holiday, the Kalmyks would kill a horse. Aversion to certain animals can be seen by the example of polecats and foxes; it was forbidden to bring a polecat's skin into a house. According to many researchers, the cult of the dragon (*Lu*) is borrowed from another culture.

The memory of wonder-workers who could bring rain and thunderstorms, or prevent these natural phenomena from occurring, has been preserved to this day. In spite of their conflict with shaman beliefs, such people were highly regarded in Kalmyk society at the beginning of the twentieth century; both laymen and Buddhist priests could be 'rain-callers'.

A system of folk totems, beliefs, taboos and rites connected with the economic activity of the Kalmyks deserves special attention. In order to strengthen the livestock's gene pool, the Kalmyks preferred to keep an animal unit of one colour in a herd or flock. This was also the reason for keeping pedigree records and preserving the pedigree of the herd. They believed that the vital strength of the herd was concentrated in its leading animal, and this animal could not be sold, passed on to another herd or killed unless it had attained the status of a sacrificial animal (*setre*). If the animal had to be sold, its owner would shave parts of its coat (from the backbone of a cow or a camel, but from the tail and mane of a horse). This rite was termed 'leaving happiness'. In order to ensure that the evil eye was averted from a dairy cow, the Kalmyks used to draw a blade over its udder about three times. Cutting utensils were hung above the entrance to the animal yard to protect the animals from various disasters.

The Kalmyks have always associated the idea of human well-being and the presence of numerous herds and rich flocks with the whole system of protective rituals that they carry out during the animal breeding season. Among the blessings spoken in this period were special ones dedicated to four kinds of livestock. The rite of returning an animal's straying young to its mother was considered to be one of the most emotional and complicated to perform. The obligatory participants of the rite were smartly dressed, young married women as well as the woman who sang the ritual songs. The Kalmyks had a system of taboos that contributed to nature and fauna conservation and the maintenance of relations between humans and nature. The land was treated with special care as it was considered to be the mother of all the living beings human, animal and vegetable. That is why it was forbidden to dig the land, pull up the grass or break the branches of bushes.

Traditional knowledge is more and more required in modern Kalmyk society. It is not only the heritage of the past; it exists and is developing today, and is the most important element of the Kalmyk people's cultural heritage. Folk knowledge and economic traditions serve as a reliable guarantee of a nation's existence, because the economic–cultural declaration is directly reflected in the development and conservation of language, folk rites and customs. It is necessary to carry out an analysis of traditional knowledge that will allow us to use it effectively and in harmony with the high morale principles that lay responsibility on the present generation for the future to come.

Session 1: General problems and management of agricultural systems

1 Traditional knowledge and modern technology for the sustainable management of dryland ecosystems: UNESCO's objectives for the workshop

Thomas Schaaf, UNESCO, MAB Programme, Division of Ecological and Earth Sciences

This international workshop has been organized by the international Secretariat for the UNESCO Programme on Man and the Biosphere (MAB) in close collaboration with the MAB National Committee of the Russian Federation, the Kalmyk Institute for Humanities of the Russian Academy of Sciences, and the authorities of the Republic of Kalmykia of the Russian Federation. On behalf of UNESCO, I wish to thank all the people and institutions that have worked so hard over the last few months to make this international workshop a full success.

The theme of the workshop – traditional knowledge and modern technology for the sustainable management of dryland ecosystems – has been chosen in the light of the work of the United Nations Convention to Combat Desertification (UNCCD), with which UNESCO has fostered close and fruitful cooperation on a variety of different issues, including education, capacity building and research on dryland ecosystems. Article 18 of the text of the Convention refers specifically to 'traditional knowledge' in the following manner:

> 2. The Parties shall ... protect, promote and use in particular relevant traditional and local technology, knowledge, know-how and practices and, to that end, they undertake to:
>   (a) make inventories of such technology, knowledge, know-how and practices and their potential uses with the participation of local populations, and disseminate such information, where appropriate, in cooperation with relevant intergovernmental and non-governmental organizations;
>   (b) ensure that such technology, knowledge, know-how and practices are adequately protected and that local populations benefit directly, on an equitable basis and as mutually agreed, from any commercial utilization of them or from any technological development derived therefrom;
>   (c) encourage and actively support the improvement and dissemination of such technology, knowledge, know-how and practices or of the development of new technology based on them; and
>   (d) facilitate, as appropriate, the adaptation of such technology, knowledge, know-how and practices to wide use and integrate them with modern technology, as appropriate.
>
> (UNCCD, 1995)

It has been argued at several Conferences of the Parties of the UNCCD that 'traditional knowledge' has various advantages and benefits with regard to combating desertification: it is often considered a relatively inexpensive technology (compared with modern technology and computer-driven irrigation schemes, for example, or with drought-resistant genetically modified organisms), and therefore represents an affordable corpus of technology for developing countries and their populations. As is well known, many dryland countries that are suffering from land degradation and desertification also rank among the poorest nations of the planet. Moreover, traditional knowledge has often been highlighted as a particularly 'environmentally-friendly' technology that also blends in with environmental conservation objectives in dryland ecosystems.

At the Sixth Conference of the Parties of the UNCCD, which was held in Havana (Cuba) from 25 August to 5 September 2003, and following the work of the Convention's Committee on Science and Technology (CST), the UNCCD Conference of Parties adopted Decision 16/COP 6 on 'traditional knowledge' as follows:

Decision 16/COP 6: Traditional Knowledge

1. Invites the Parties through their national focal points to involve relevant governmental and non-governmental organizations, research institutions and local and indigenous communities in formulating views on how traditional knowledge can contribute to fulfilling the objectives of the Convention, and especially on the elements proposed for establishing a network on traditional knowledge to combat desertification, and to submit them to the secretariat no later than six months before the next session of the Conference;
2. Further invites the Parties through their national focal points to involve relevant governmental and non-governmental organizations, research institutions, and local and indigenous communities, in compiling case studies and lessons learned at national, sub regional and regional levels on the management and protection of traditional knowledge and to submit them to the secretariat no later than six months before the next session of the Conference of the Parties;
3. Requests the secretariat to compile the submissions and to report at the next session of the CST on this subject.

What is the relevance of traditional knowledge to the UNESCO Programme on Man and the Biosphere (MAB)? In the early 1970s, the MAB Programme was conceived as an international and intergovernmental research programme to study human–environment interactions in different ecosystems including arid and semi-arid zones. The specific MAB Project Area No. 4 on 'The Impact of Human Activities on the Dynamics of Arid and Semi-arid Zones' Ecosystems' endeavours to research and improve the relationship between people and their environment using a holistic and interdisciplinary approach that includes both the natural and the social sciences.

In addition, the work of the UNESCO–MAB Programme on a people-centred approach to environmental conservation, through the promotion of sustainable development in line with conservation objectives and bolstered by scientific research, has become a hallmark of the MAB Programme with its biosphere reserve concept. As of June 2004, a total of 440 biosphere reserves in ninety-seven countries have been recognized within UNESCO–MAB's World Network of Biosphere Reserves. These sites demonstrate that the conservation of the environment can be accomplished by associating people in decision-making processes for the sustainable management of dryland and other ecosystems.

Biosphere reserves combine environmental conservation with economic activities based on spatial analysis and scientific land-use and land-management studies.

Biosphere reserves can be briefly defined as areas of terrestrial and coastal ecosystems that are internationally recognized within the framework of UNESCO's Man and the Biosphere (MAB) Programme. Collectively, they constitute a World Network. They are nominated by national governments and must meet a set of criteria and adhere to a set of conditions before being admitted into the World Network. Each biosphere reserve is intended to fulfil three basic functions, which are complementary and mutually reinforcing:

- *A conservation function*: to contribute to the conservation of landscapes, ecosystems, species and genetic variation.
- *A development function*: to foster economic and human development that is socioculturally and ecologically sustainable.
- *A logistic function*: to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

To carry out the complementary activities of nature conservation and use of natural resources, biosphere reserves are organized into three interrelated zones, known as the core area, the buffer zone and the transition area (Figure 1.1).

- The *core area* needs to be legally established and give long-term protection to the landscape, ecosystem and species it contains. It should be sufficiently large to meet these conservation objectives. As nature is rarely uniform, and as historical land-use constraints exist in many parts of the world, there may be several core areas in a single biosphere reserve to ensure a representative coverage of the mosaic of ecological systems. Normally, the core area is not subject to human activity except research and monitoring and, as the case may be, to traditional extractive uses by local communities.
- A *buffer zone* (or zones) which is clearly delineated and which surrounds or is contiguous to the core area. Activities are organized here so that they do not hinder the conservation objectives of the core area but rather help to protect it, hence the idea of 'buffering'. It can be an area for experimental research, for example to discover ways to manage natural vegetation, croplands, forests and fisheries, to enhance high-quality production while conserving natural processes and biodiversity, including soil resources, to the maximum extent possible. In a similar manner, experiments can be carried out in the buffer zone to explore how to rehabilitate degraded areas.
- An *outer transition area*, or area of cooperation extending outwards, which may incorporate a variety of agricultural activities, human settlements and other uses. It is here that the local communities,

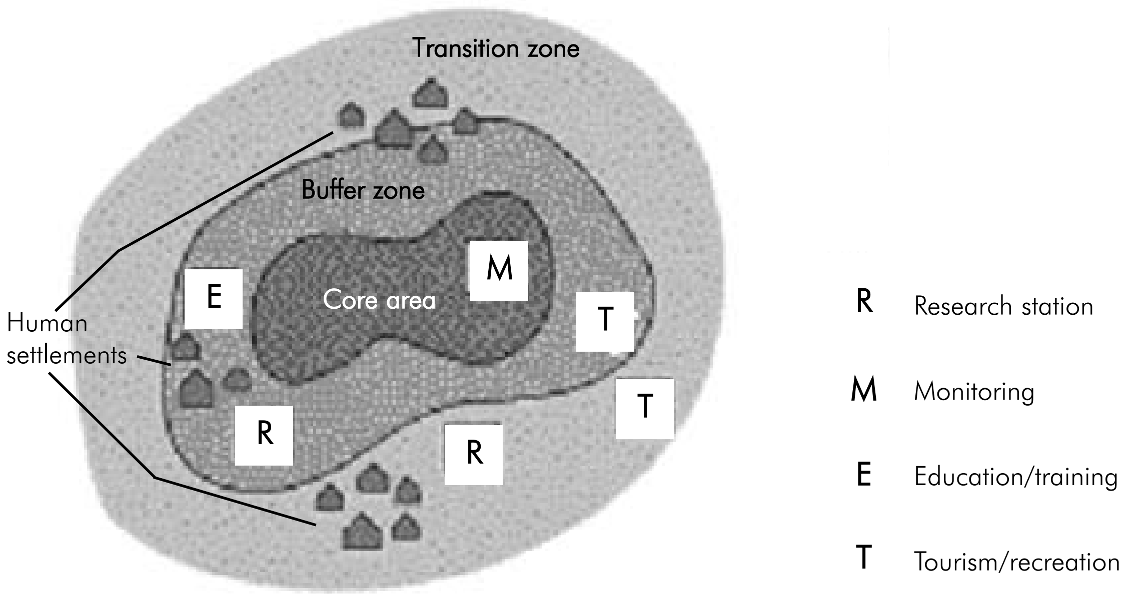

Figure 1.1 Biosphere reserve zonation

> conservation agencies, scientists, civil associations, cultural groups, private enterprises and other stakeholders must agree to work together to manage and sustainably develop the area's resources for the benefit of the people who live there. Given the role that biosphere reserves should play in promoting the sustainable management of the natural resources of the region in which they lie, the transition area is of great economic and social significance for regional development.

Although presented schematically as a series of concentric rings, the three zones are usually established in many different ways to accommodate local geographic conditions and constraints. This flexibility allows for creativity and adaptability, and is one of the greatest strengths of the concept.

There is a strong concentration of biosphere reserves in humid tropical forest zones, mountain ecosystems and temperate zones, but there are fewer such reserves in the world's drylands. However, some have been nominated in arid and semi-arid areas, including the Chernyie Zemli Biosphere Reserve in the Republic of Kalmykia of the Russian Federation, the Omo and Wadi Allaqi biosphere reserves in Egypt, and the Great Gobi Biosphere Reserve in Mongolia. Case studies on these reserves are to be presented at this international workshop.

Many of the dryland biosphere reserves have been inhabited for millennia, and people have long used the natural resources for their specific economic activities and well-being. They therefore contain a wide corpus of traditional knowledge for dryland management, as evidenced by traditional forms of nomadism and dryland agriculture, which has been complemented by modern technology in more recent decades. Some of this traditional knowledge, however, may be lost if not documented and recorded, as modern technologies often supplant traditional ways. UNESCO considers that the preservation of traditional and local knowledge is an intangible heritage that should be preserved for future generations.

This workshop, therefore, aims at raising questions and finding answers to them at several levels:

- Can the UNESCO–MAB Programme with its MAB national committees contribute to the UNCCD's ongoing work on traditional knowledge so as to minimize the effects of land degradation?
- Is traditional knowledge indeed an effective means to combat desertification, or do we need to promote modern technologies in the interest of generating higher yields in the fields of agriculture, forestry and livestock husbandry?
- Is it possible to combine both traditional knowledge and modern technologies for effective and sustainable dryland management?
- Can we use dryland biosphere reserves from the World Network of Biosphere Reserves as study and monitoring sites to address issues related to traditional knowledge and modern technologies?
- In what way can biosphere reserves help to contribute to conserving dryland environments while ensuring sustainable development for local people at the same time?

These and other related questions on sustainable dryland management are being considered at this workshop by researchers and government officials within the context of the UNESCO–MAB Programme. It should not be overlooked that we human beings have the capacity not only to destroy the physical environment with its biotic resources, but also to conserve nature, which is the basis of our existence. We all need to pool our efforts and knowledge – past and present – to safeguard and wisely use our natural resources; a task that is particularly important in the world's marginal areas, the drylands.

References

UNCCD. United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. Switzerland, UNEP, CCD/95/2, 1995.

2 Local knowledge systems and the management of dryland agro-ecosystems: some principles for an approach

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Introduction

Local agricultural knowledge in dry-land land-use systems is centred on the conservation, use and optimization of soil moisture and soil organic matter.[1] Biodiversity is carefully managed and nurtured to interface with hydrological and nutrient cycling and provide for ecosystem resilience, food security and diversity, and risk minimization. Examples of such traditional livelihood systems are the water-harvesting systems on alluvial fans (Zuni, USA), oasis systems in North Africa, *chacras hundidas* (sunken fields) in Peru, and *qanat* subsoil irrigation systems throughout Central Asia. These systems are mainly crop based, with various degrees of livestock integration.

Others types of traditional dryland livelihood systems are nomadic, animal-based systems, which optimize resource use and mitigate risk by moving according to the dynamics of water availability and pasture resources. These are particularly adapted to highly variable ecosystems, especially those with high climatic variability. Examples are the herding strategies of pastoral peoples in East and Northwest Africa and transhumant highland systems like the Yak-based systems of Ladakh in India.

Most such traditional land-use systems are associated with carefully adapted forms of social organization and regulatory frameworks for access to common resources and ecosystems management, combined with a deep knowledge of the dynamics of the ecosystem over a large territory that is made up of various ecological niches. Such often highly ingenious traditional management systems and cultures have co-evolved over centuries with the landscape and its components, including genetic resources. They are noteworthy for their contribution to biodiversity conservation, sustainable land, water and landscape management and to ensuring security of food, livelihood and quality of life. Many provide globally important goods and services well beyond their geographical limits.

There is little doubt that local knowledge systems are a valuable resource for the management of drylands, as they are in other types of ecosystems. However, in many parts of the world, local or traditional management strategies are weakening or losing their relevance, due to rapid changes in their biophysical and socio-economic environments. These changes, some of which are driven by processes of globalization, outpace the evolutionary adaptive capacity of the local systems. The focus over recent decades on agricultural productivity, specialization and global markets, and the associated disregard for externalities and adaptive management strategies, has led to a relative and general neglect of research and development support for diversified, ingenious systems. Pressures are constraining farmer innovation and are leading to the adoption of unsustainable practices, overexploitation of resources and declining productivity, as well as agricultural specialization and the adoption of exotic domesticated species. The result can be biodiversity loss, ecosystem degradation, poverty and loss of people's livelihoods. We are at risk of a severe erosion of the diverse base of agricultural systems and their associated biodiversity, knowledge systems and cultures that ensure human livelihoods and healthy and resilient environments.

Under these circumstances, and viewed from the perspective of the farmers and pastoralist communities, it is not particularly relevant to dwell upon the limits of applicability of local knowledge systems versus scientific knowledge. What is more interesting and urgent is how to develop approaches that successfully integrate the comparative strengths of both types of knowledge system. This paper sets out to find answers to three questions:

- What are the different natures of local knowledge systems in drylands and of modern or scientific knowledge systems?
- What challenges, constraints and obstacles are there to strengthening traditional sustainable agricultural practices and their knowledge systems?
- What are the principles for an approach to safeguard traditional management systems for the sustainable use of drylands?

First, two case studies of traditional agricultural systems in drylands will be briefly described. Second, this paper will analyse local knowledge and scientific knowledge systems and their social and institutional settings. Third, it will propose some principles for an approach to strengthen traditional agricultural systems. Finally, it will present an initiative by the FAO (in partnership with UNESCO, UNDP, GEF, governments, NGOs and other bodies) for the global recognition, conservation and sustainable management of globally important ingenious agricultural heritage systems (GIAHS) that seeks to take on the challenges outlined.

The example of the Gafsa oases in Tunisia

Oases are complex agro-ecosystems characterized by agronomic, ecological, economic, social, cultural and political dimensions. The Gafsa oases are exemplary models of agricultural biodiversity in a constraining and harsh environment. The oasis of Kasba, covering approximately 700 ha, lies within 2,000 ha of oases bordering the town of Gafsa (Kasba, Southwest and Ksar).

The endemic and non-endemic wild and cultivated plants that grow in Gafsa have high resilience under adverse conditions. Varieties of cultivated species have been carefully selected from natural ecosystems over centuries of experimentation. For example, more than 300 named cultivars of date palm trees have been recorded across Tunisia and many of these have their origin in the Gafsa oases. The oases also contain many varieties of fruit trees (pear, apple, plum, peach, mulberry, apricot, olive, citrus and so on), vines, fruits (cucumber, melon, zucchini), vegetables (parsley, celery, spinach and cabbage), roots and bulbs, pulses, aromatics, cereals, fodder and ornamental plants. Each variety is characterized by distinct and valuable quality traits selected according to local needs and culturally determined criteria. Furthermore, oasis agro-ecosystems provide habitat and resources for numerous wild species of fauna and flora.

Species and varieties are carefully chosen to be adaptable to local environmental constraints. For instance, the olive tree is prevalent in the periphery of the oases because of its resistance to drought; the Degla date palms are widely planted in southwest Tunisia, where climatic conditions are favourable for fructification, whereas common date palm varieties are more frequently found in coastal areas. There, space is used intensively so as to optimize use of water resources and to regulate the oasis microclimate. The security of the harvest is maximized by producing plants that provide for multiple products and through carefully diversified spacing and timing of production (cropping pattern and rotation). The latter is done using a three-tier canopy level system, which includes date palm (the highest tier), arboriculture (middle tier) and annual/pluri-annual crops at the lowest tier.

The livestock in the strict oasis area is limited to a few individual sheep, goats, donkeys and/or camels. These serve the system by providing food (meat, milk), transport (for people, agricultural produce and so on) and manure (for soil amendment). The management practices and techniques reveal the ingenuity of the local population in using biodiversity, for instance in terms of crop management (plantation, pollen transfer and thinning techniques, biological control of pests and diseases, and so on) and irrigation techniques (plant flexibility, water stock in soil, management of and adaptation to salt, sand and wind). The oasis inhabitants have inherited important bodies of local knowledge in various fields such as systems of irrigation and management of seeds, palm and fruit trees. The local knowledge is also rich in techniques for the conservation and storage of the agricultural harvests. In spite of attempts to introduce mechanization, the old working tools have proved to be the best adapted to the oases (some of these tools exist only in this area).

The constraining environment and the opportunity (and climatological requirement) for irrigation leads to necessary intensification and diversification. The growing of different crops in space and time allows oasis communities to meet their essential needs for home consumption: food, domestic (building, crafts and so on), energy and medical requirements. The surplus production is sold in the market and there is a trend to increasing cultivation of cash crops in order to generate income.

This diversity and its associated knowledge are fundamental assets for the inhabitants of the oases and continue to ensure the inhabitants economic returns and a fair level of quality food security during most of the year. The various annual cultures allow a daily production, though collection of arboreal fruit is spread out: apricots are collected in April and May, followed by the maturation and collection of figs, vine, dates and finally olives. Much of the agricultural production is for the inhabitants' own consumption and storage. The oases are an important source of wood for building homes and cattle sheds, heating and furniture. The oasis is less vulnerable to the shocks and risks of climate than the surrounding areas. In an arid environment of strong heat, the oases' plant communities lower the ambient temperatures and reduce evapotranspiration. The harsh environment thus explains the antiquity and rich culture of the old town of Gafsa.

Threats and challenges

Recent socio-economic developments have introduced modifications in these farming systems, especially on the level of annual crops. Today in the oases, people's livelihoods and their farming ecosystems are under heavy pressure. A number of interlinked factors of an ecological and socio-economic nature are affecting the delicate equilibrium of the oases. Ecological factors include land degradation, genetic erosion of biodiversity, use of inappropriate agronomic practices, falling aquifer levels, frequent droughts and the introduction of foreign species. Among the socio-economic factors that affect farmers' livelihoods are the marginalization of indigenous communities (particularly fragile and silent groups, most notably women) and cultural erosion of traditional agricultural knowledge and practices. In particular, the traditional social water management institutions have been largely replaced by the association of irrigation (GIC), the cooperative of agricultural services, Omda (responsible for the smallest administrative unit), the agricultural engineering services and local farmers' unions. As there is no integrated collaborative community approach towards water management, disputes among water users over access to the principal natural water sources are beginning to pose a problem, which may lead to unsustainable use. Oases are havens of agricultural biodiversity in a constraining environment, and their degradation inevitably entails high genetic erosion.

The example of Maasai rangeland management

The history of Maasai pastoralism is closely entwined with the evolution of the savannah and highland landscapes of southern Kenya and northern Tanzania. These landscapes are world renowned for their stunning views and rich wildlife. Tourist revenues from these areas benefit the national economies of the countries involved as well as private tourism companies worldwide. What is often overlooked, when policies and management interventions are designed and implemented in these areas, is that these landscapes and their wildlife habitats were shaped over centuries by the knowledge-intensive and highly flexible nomadic pastoral strategy of the Maasai and other pastoral communities.

The ecological and human rationale of a well-regulated opportunistic strategy

The pastoral strategy is highly adaptive to the space–temporal fluctuations of the environment. The moving around of cattle herds means that resources (pasture, water, salt) are used where and when they are most available. All habitats are used and there is no functional distinction between wild and cultured lands. The Maasai have a complex strategy of customary arrangements to commonly manage and use these resources with the aid of a rich and diversified knowledge of their environment. Their settlement patterns and social organization are built on the need to spread resource use over a large area to avoid concentrations of livestock and consequent overgrazing. Their grazing and burning strategies have turned bushland into pasture and they have controlled pests, thus also creating a habitat and food source for large wild grazers and their predators.

In many ways the abundance of wildlife in these systems is largely due to the pastoral strategy, which strikes a fine balance between the competition of livestock and wildlife, and their common interest in maintaining their joint habitat. The presence of cattle in the grazing sequence alongside wild grazers favours the growth of grasses that are preferred by these wild herbivores. Overgrazing is sometimes deliberately used to re-open bush-invaded pasture. The Maasai adjust their herd composition and size to the availability and carrying capacity of certain areas and the availability of water (for example, dark cows get warmer in the sun and drink more). There is a fine balance between competition over resources and interdependence between the human/domesticated and the wild components of the ecosystem.

The Maasai manage to cope with the great fluctuations of the environment (seasons, droughts), making the entire system more resilient and sustainable while providing for their own food and livelihood needs. Their customary institutions for resource access ensure not only environmentally sustainable use of resources but also equitable access and benefit sharing, with high levels of reciprocity and social security for those who suffer misfortune, while being flexible enough to adjust to environmental circumstances. The many and complex exchanges of cattle taking place not only provide for a rich genetic diversity of cattle in each herd, but serve also as a social strategy to deal with hardship. Other users (ethnic groups, including agriculturist and hunter–gatherer groups) are allowed to live and use resources on Maasai territory, which is beneficial for the exchange of goods and services between social groups and livelihood systems, but is also a potential source of conflict in times of scarcity.

The knowledge base of pastoralism

The Maasai have an intense practical experience and rich knowledge of their environment and the ecological relations between various areas, accrued by moving around over large areas and passed on over many generations. They have a vast knowledge of plants and their nutritional and medicinal properties (for humans and animals), as well as of animal breeding, health and behaviour. This is born from the necessity to be able to move their cattle safely through various areas and make use of the resources available there, as such resources cannot be brought along whilst moving.

Their knowledge is safeguarded and passed on through many cultural institutions and expressions. One of these is the considerable freedom for children to move around and discover their environment. Another crucial sociocultural institution is the stage of warriorhood for young men, now in steep decline. This three to seven-year period combines intensive education by elders in livestock, ecology, social values, justice and leadership, with challenges, rituals and a 'military service'. The young warriors are expected to take care of themselves and to provide for their needs without the care of their mothers, challenging them to acquire knowledge of plants and their uses, and building social networks with people outside their families. There are also many stories, jokes, sayings, riddles and other cultural expressions that convey knowledge of the environment and social values for the appropriate use thereof.

Threats and challenges

When British colonialists first arrived in the Rift Valley they perceived its landscape as a wild habitat. The presence of people and cattle was not considered a constructive component but a threat to the landscape and its wildlife. The colonialists' background in a sedentary culture made them fail to see the interconnections and rationale of the nomadic strategy and its role in creating and maintaining the landscape. They also failed to see the resource-use efficiency of the pastoral systems that integrate various ecological niches with varying productive capacities over time. One can only understand this rationale when the system is viewed from a larger space–temporal scale than that of the agricultural zone for a single all-year-round use.

Many of the old perceptions persist today. Wildlife conservationists and land-use planners are often trained in land zoning and planning for a single use; they continue to have rigid perceptions of how land and resources should be managed in space and time, with a clear Cartesian separation of 'natural' and 'agricultural use' areas. This has consequences for policies, resource access legislation, institutional arrangements for land management and delivery of services, causing great disturbances to the pastoral-ecological dynamics, and the culture and social organization that underpin the management of the system. These perceptions are largely manifest in land tenure legislation that creates restrictions on livestock movement, loss of access to key areas and resources, and subsequent and sometimes deliberate erosion of the Maasai culture.

This in turn damages the capacity to deal with ecological risk, causing a decline in food and livelihood security – and increasingly in land quality and wildlife abundance – through invasion of the shared habitats of livestock and wildlife by bush and pests in some parts and overgrazing in other areas. Many customary institutions for land management and access to resources have been delegitimized and/or replaced. Also, the open system of resource use is not sufficiently protected against agricultural settlement (due to population pressures outside the system) and land grabbing through corruption, which are both threats of a growing magnitude. Population growth and changing lifestyles add to the pressures. HIV/AIDS is another increasing problem, causing losses in leadership, parental care, labour force and knowledge.

Key characteristics of knowledge systems

All knowledge and technology are generated, passed on and adapted in specific ecological, socio-economic and cultural contexts. They are the result of a human process of interaction among individuals and with the environment, which is organized through and guided by specific institutional settings, power relations, values and perceptions. Therefore 'any analysis of technology must be situated within a social and economic understanding of the role of technology, the rationale and purpose of its design' (Scoones et al., 1996). If we want to understand the different natures of various knowledge systems, we should not only look at the content and forms of knowledge and technologies, but also at the processes through which they are generated and managed. Because of the interconnectedness of the social process and the social and ecological context of knowledge generation, the term 'knowledge systems' is used in this paper rather than 'knowledge' in order to suggest the full scope of the relevant processes.

Before we provide a description of the typical characteristics of local and modern knowledge systems, it is important to acknowledge that the terms 'traditional', 'indigenous' and/or 'local' (and the juxtaposed 'modern' and 'scientific') are contested terms. In certain arenas the conceptual juxtaposition of traditional versus scientific or modern knowledge may be useful. In cases where people are establishing their historical ties to land and territory, as is the case for many indigenous peoples, when rights over natural resources and/or benefit sharing mechanisms have to be established, or when cultural groups are going through a collective process of strengthening their identities, the concept of traditional knowledge is a key tool. However, for the practical management of ecosystems and for the problems that farmers face in providing for their livelihood, the distinction is often immaterial and in many cases counterproductive, particularly in cases where changes outpace the adaptive capacity of traditional knowledge systems which can then produce no viable options. What counts for the farmers or pastoralists is that the technology or management intervention offers a good solution from their point of view, which is almost by definition the whole interdisciplinary context that they operate in. Whether a solution is traditional or scientific is irrelevant for the actors. The point is that it works. Additionally, in practice, it is very difficult to establish where one knowledge system begins and another ends. Over history, all knowledge systems have incorporated elements of other knowledge systems, transformed them and given them new meaning. A successfully adopted modern technology can quickly become part of the local knowledge system. In the locality it will acquire new meaning and application, and it will most certainly be adapted. Table 2.1 gives an overview of typical characteristics of local and scientific knowledge systems.

A key characteristic of local knowledge systems is that they have co-evolved with the surrounding biophysical environment from landscape-level to the genetic resources and with other social, economic and cultural institutions. Thus the values, ethics and social relations of production are incorporated either implicitly or explicitly into the technologies and management practices. Additionally, they have also incorporated the specific relationships of people and the functioning of the ecosystem. These knowledge systems are by definition interdisciplinary as any farmer or pastoralist takes all factors of production, social and biophysical, into account when making management decisions. Modern or scientific knowledge and technology are by contrast often developed outside the locality and are usually defined by their particular disciplines. This may entail unforeseen and unwelcome side effects as implicit values, and relations of production can be introduced into culturally different contexts, and factors not considered in the scientific definition of the problem may come into play in practice. 'Particularly, when introduced technologies are imposed, and prospects for local adaptation are constrained, problems arise' (Scoones et al., 1996).

Local knowledge is generated in the specific practical relationships of different actors with the ecosystem and the land, water or biological resources that are contained therein. These relationships are legitimized, regulated and guided by rights of access to resources, which are codified in customary law or other regulatory frameworks. To safeguard the existing knowledge systems and their continuing evolution, one must safeguard the continuation of the specific relationships between people and their environment. Access to resources and resource rights, individual or collective, are therefore of crucial importance to the survival of local knowledge systems and the sustainable management of ecosystems. The role of customary law and governance, and its relationship to formal land tenure and other regulatory systems, deserve specific attention.

One of the important social dimensions of knowledge systems is the difference in the roles of men and women in the generation and management of knowledge and the specialization of different social groups. This holds true for any knowledge system, modern or traditional, local or formal. However, unlike in science, in the case of local knowledge special attention should be given to the different relations men and women have to the ecosystem and natural resources, including aspects of access and rights. In many parts of the world, women have a specific custodial role in maintaining local knowledge and biodiversity. Women also tend to operate in economic niches that depend heavily on the ecosystem and to be more subsistence oriented, though there are notable exceptions.

Additionally, it is worth noting that there is often a convergence of customary institutions for the management of natural resources, which hold most of the knowledge associated with that function, and other social, economic and political functions. In most indigenous and local communities the local knowledge systems are the same as, or closely intertwined with, other such social institutions and practices.

Table 2.1 Typical characteristics of local and scientific knowledge systems

Local knowledge systems	Scientific knowledge systems
Integrated and holistic	Disciplinary and reductionist
Humans and ecosystem considered as one	Humans and ecosystem approached separately
Relatively low degree of specialization	Relatively high degree of specialization
Co-evolved with local ecosystems and cultures	Derived under isolated, controlled and/or generalized circumstances
Symbolically represented orally or visually in stories, rituals, arts, riddles etc.	Represented in writing
Derived through rational conscious process plus experiential, intuitive and spiritual cognitive processes	Derived and validated through rational conscious process only
Includes knowledge, technologies, philosophies and concepts, skills, arts and practices, values and spirituality/religion	Includes knowledge, technologies and concepts
On the spot problem solving with high validity in context	Slow problem solving with good validity and wide applicability of principles.
Learning by doing and experiencing	Learning through formal education

Cognitive processes of knowledge systems

Another key characteristic of local knowledge systems is that they are broader in cognitive scope than scientific ones. In scientific knowledge every step is ideally achieved through a conscious rational process, whether or not validated by field experimentation or observation. The advantage of this is the relative certainty about the validity of such knowledge under known circumstances, and hence the possibility of deriving general principles that are widely applicable.

By contrast, the cognitive processes in local knowledge systems also include conscious rational process but have a much broader 'bandwidth'. Local and indigenous peoples integrate previous experiences (sensory input, prior knowledge, social and spiritual values and relationships, and so on) on the spot, without necessarily being conscious of all the deductive steps involved. The involvement of this broad range of human faculties, including intuition and spiritual insight, helps provide for quick decision making in complex interdisciplinary situations. One of its disadvantages can be its lack of rationalization, which limits its wider application. In particular, bodies of skills and experience can only be transferred by example or learning by doing. The different cognitive processes and contents of knowledge systems are also reflected in the way knowledge is codified and transferred. In local knowledge systems learning by example, stories, riddles, rituals and other forms of art and symbolic representation are used, while scientific knowledge is codified in written and numbered form and is transferred through formal education.

A note on the role of culture

Historically, culture and tradition have been treated as an obstacle to development and sustainable and/or efficient use of natural resources. At best, tradition was viewed by administrators as a heritage in its own right. What many policy makers and scientists alike have failed to see is that the values, customary regulatory systems for access to resources and local knowledge, and the understanding and attribution of meaning to the landscape and its components are key elements in the sustainable management of ecosystems. Religious codes and taboos, as well as rituals and ceremonies, often have key functions in the sustainable management of ecosystems. The relationship between a cultural group and the landscape may be defined and acknowledged through such practices, which are also a way to convey knowledge about the environment to subsequent generations. In many cultures it is through the sacred that ecosystems are managed (Eyzaguirre and Woods-Perez, 2004).

Challenges for strengthening traditional land-use practices and local knowledge systems

As observed in the Introduction, many traditional sustainable land-use practices and their associated local knowledge systems are under pressure. Unless their evolutionary, adaptive capacities are strengthened or the threats are mitigated through policy intervention, an invaluable resource in terms of knowledge may be lost for good, as may outstanding landscapes and ecosystems that provide for food security livelihood and ecosystem services.

Beyond the need to recognize, salvage and protect local knowledge systems, one of the questions and challenges relates to the potential for integrating different knowledge systems. There are already many examples of successful integration. For instance, the introduction of agro-ecological principles, community mapping with GPS and GIS tools, community media, conservation agriculture and integrated pest and plant management (IPPM) techniques into traditional agricultural systems have proven successful. Often the success was based not only on the quality and appropriateness of the technologies and management practices offered, but also on the processes by which they were introduced. In the case of IPPM and integrated land management, farmer field schools have been effective.

Apart from offering the right products through the right processes, science can also help systematize and derive principles from local knowledge systems and experiences to help integrate them with modern technologies. Such principles can improve replicability and help development workers and policy makers alike.

The challenge of integration is twofold:

- How can we integrate local and scientific knowledge systems and technologies in order to strengthen sustainable land–livelihood systems?
- How can we integrate different scientific disciplines and come up with a holistic approach to the management of dryland ecosystems in order to be able to respond to the reality and problems of farmers, herders and their communities?

When we recognize the social processes underlying knowledge systems it becomes clear that, in order to integrate different knowledge systems and disciplines, we have to integrate the processes underlying the development and innovation of knowledge and technology. We need a participatory approach to knowledge and innovation. Participation is not only a politically correct or socially desirable goal, but a precondition for necessary integration. In order to integrate different knowledge systems we need a dialogue of wisdoms (Altieri, 2002).

This should be based on respect and the tackling of problems that are commonly defined and understood by different stakeholders. To integrate different scientific and policy-making disciplines, we need institutional innovation and partnerships to break down barriers between sectors and disciplines, and joint efforts in working on common problems and fields of interest.

Currently, there are various constraints in the social organization and institutional setting of drylands development. Technologies and innovations for sustainable drylands development are developed outside and with little consideration for the whole human–ecological context of the land-user communities. As long as institutions, ministries, sciences and international organizations are organized along disciplinary lines with a general and deep divide between the human and biophysical disciplines, we will continue to reproduce the same dichotomies and contradictions in scientific – and conservation and development – planning and practice. We need partnerships and new ways of organizing our institutions as well as new interdisciplinary concepts and methodologies to frame interdisciplinary work and facilitate communication and common understanding of the problematics across disciplines and sectors.

The most widely recognized attempt to provide such a framework is the Convention on Biological Diversity's (CBD) ecosystems approach, which amalgamates new ethics, epistemology and methodology for this purpose. A further constraint is that problems are defined at higher levels of planning and research, but solutions are expected to be carried out by farmers and herders. The power relationships between these groups are such that local people have little influence on technology development, planning or policy making. With many newly introduced technologies, farmers lose some of their autonomous capacity to manage their livelihoods and environment in a sustainable manner.

Some principles for an approach

By their very nature, sustainable traditional agricultural systems and their associated knowledge systems can only be maintained and allowed to evolve *in situ*. The specific relationships of humans and the environment have to be sustained in order to safeguard local knowledge systems. Most knowledge cannot be extracted, recorded or transferred without changing its meaning dramatically. Modern technology can offer tools, but can never replace local knowledge systems. When introduced technologies are imposed, and prospects for local adaptation are constrained, problems arise. For a technology to be attuned to people's needs, local environmental conditions and economic factors, it must be flexible and adaptable. Rigid prescriptions and designs do not work. (Scoones et al., 1996)

A key step in the knowledge and innovation process is the way problems are defined. This should be done in a participatory way, incorporating the complexities of the context of the main agents of land use and management. A guiding principle can be derived from the ecosystems approach. Principle 2 of the ecosystems approach of the Convention on Biological Diversity reads: 'management should be decentralized to the lowest appropriate level'. Following this principle, we can identify the level at which any technology, management intervention or innovation has to make sense. Therefore, problems and innovation challenges have to be (co-)defined at the lowest appropriate level at which the innovations will be used and applied.

In the case of most human management and use of ecosystems, which is done largely by individuals, households and communities of farmers and herders, this principle indicates that the problems will have to be formulated largely by these actors and with regard to their socio-economic and ecological context. Experts can participate in this process, offering windows to other knowledge and options. This approach would have implications for the role of the expert, moving from being a planner and decision maker to providing a nexus between scientific knowledge systems and farming/ herder communities. Such an approach should be carried forward throughout the planning and innovation processes: during testing, implementing, monitoring and evaluating. It requires changes in concepts and personal attitudes on the part of the expert.

When we design participatory processes we need to ask who is participating. We should recognize that there are different roles and power relationships within communities and households, between men and women and different social classes or ethnic groups. Any participatory process that does not acknowledge this runs the risk of causing greater inequalities, providing options for some and excluding others. In this respect, we also need to bear in mind the advantages of working with customary forms of consultation and governance. It is not desirable to create new institutions that overlap or compete with the structures and processes that are considered legitimate within a land-user group, even if we wish to promote social change. Doing this may cause more harm than good. Additionally, we need to respect sacred and spiritual elements of local knowledge systems, not only because of their value as perceived by local populations, but also because they often have key functions in the sustainable management of ecosystems.

There is a need and scope for the development of information systems that are designed along principles of knowledge participation. This means that different actors should be empowered to contribute information and perspectives in different forms to knowledge systems from their own perspectives, rather than in a situation where an expert collects data and tells the stories of others. Such tools are emerging and they may greatly facilitate dialogue and support in integrated knowledge systems, both between disciplines and between experts and farming and herding communities.

To summarize, the conditions for success are multiple, combining a conducive policy environment, an effective institutional setting, access to a range of participatory methods and approaches, and personal changes among researchers and development workers (Pretty and Chambers, 1994). The researcher must acquire new skills, new technologies and new behaviours (Chambers, 1993). Rather than planning, directing and enforcing s/he must facilitate, convene, catalyse and negotiate. The focus is on the process by which technologies arise, become adapted and spread, rather than on technological outputs. Rather than dividing responsibilities between researchers, extentionists and farmers, roles combine and joint activities are central. These are big changes to the conventional, linear model of technology development but they are proving successful (Scoones et al., 1996)

Globally important ingenious agricultural heritage systems (GIAHS)

In 2002 the FAO, together with UNESCO, UNDP, GEF, governments, NGOs and other partners, started an initiative for the global recognition, conservation and sustainable management of globally important ingenious agricultural heritage systems (GIAHS). GIAHS have been defined by the FAO as:

> Remarkable land-use systems and landscapes, which are rich in biological diversity evolving from the ingenious and dynamic adaptation of a rural community to its environment, in order to realise their socio-economical, cultural and livelihood needs and aspirations for sustainable development.

In many countries, specific agricultural systems and landscapes have been created, shaped and maintained by generations of farmers and herders working with diverse species and their interactions and using locally adapted, distinctive and often ingenious combinations of management practices and techniques.

Built on dynamic local knowledge and experience, these ingenious agricultural systems reflect the evolution of humanity and its profound relationship with nature. They have resulted not only in landscapes of outstanding beauty, the maintenance of globally significant agricultural biodiversity and resilient ecosystems, as well as highly adapted forms of social organization and valuable cultural inheritances, but, above all, in the sustained provision of multiple goods and services, food and livelihood security, and quality of life.

Such agricultural and agro-silvo-pastoral systems can be found, in particular, in areas where the population has, for various reasons, had to establish complex and innovative land-use/management practices, for example due to geographic isolation, fragile ecosystems, political marginalization, limited natural resources and/or extreme climatic conditions. As such, agricultural heritage systems are an invaluable pool of diverse biological resources and agro-ecological management solutions to help ensure the sustainable provision of food and other goods and services in the future.

The rapidity and global extent of today's technological and socio-economic changes threaten many of these agricultural heritage systems, including the biodiversity on which they are based, and their associated societies. The focus over recent decades on agricultural productivity, specialization and global markets, and the associated disregard of externalities and adaptive management strategies, has led to the adoption of unsustainable practices, overexploitation of resources, and declining productivity, as well as agricultural specialization and adoption of exotic domesticated species. This poses a severe risk of genetic erosion and loss of associated knowledge systems, as well as socio-economic destabilization, loss of cultures and diversified food systems, poverty and threats to livelihoods.

The GIAHS initiative aims to establish a basis for international recognition, dynamic conservation and sustainable management of GIAHS and their associated biodiversity, knowledge systems and cultures throughout the world. The initiative will be implemented through a GEF project in five to ten pilot systems worldwide with a view to establishing a long-term programme for the safeguard and sustainable management of GIAHS. A new category of World Heritage Sites is expected to be created, as well as activities to leverage global, regional and national policies and institutional support.

Most outstanding agricultural heritage systems have evolved under particular environmental or socio-economic constraints, such as lack of abundant moisture, high altitudes, population pressures or remoteness. Many GIAHS can therefore be found in dryland areas, as well as in mountainous regions or areas with high population densities. Examples of such systems include:

- Ingenious irrigation and soil and water management systems in drylands with a high diversity of adapted species (crops and animals) for such environments. These include ancient underground water distribution systems (*qanats*) that allow specialized and diverse cropping systems in Iran, Afghanistan and other central Asian countries, with associated domestic gardens and endemic blind fish species living in under-ground waterways; integrated oases in deserts of North Africa and Sahara; traditional valley bottom and wetland management, for example in Lake Chad, the Niger river basin and interior delta (for instance, floating rice system) and similar ingenious systems in Bamileke (Cameroon), Dogon (Mali) and Diola (Senegal).

- Remarkable pastoral systems based on adaptive use of pasture, water, salt and forest resources through mobility and herd-composition in harsh non-equilibrium environments with high animal genetic diversity and outstanding cultural landscapes. These include highland, tropical and sub-tropical dryland, and arctic systems such as yak-based pastoral management in Ladakh, the high Tibetan plateau, India, and parts of Mongolia; cattle and mixed animal-based pastoral systems, as among the Maasai in East Africa; and reindeer-based management of tundra and temperate forest areas in Siberia such as those of the Saami and Nenets.
- Outstanding rice-based systems. This type includes remarkable terraced systems with integrated forest use (swidden agriculture/agro-forestry and hunting/gathering), such as rice terraces and the

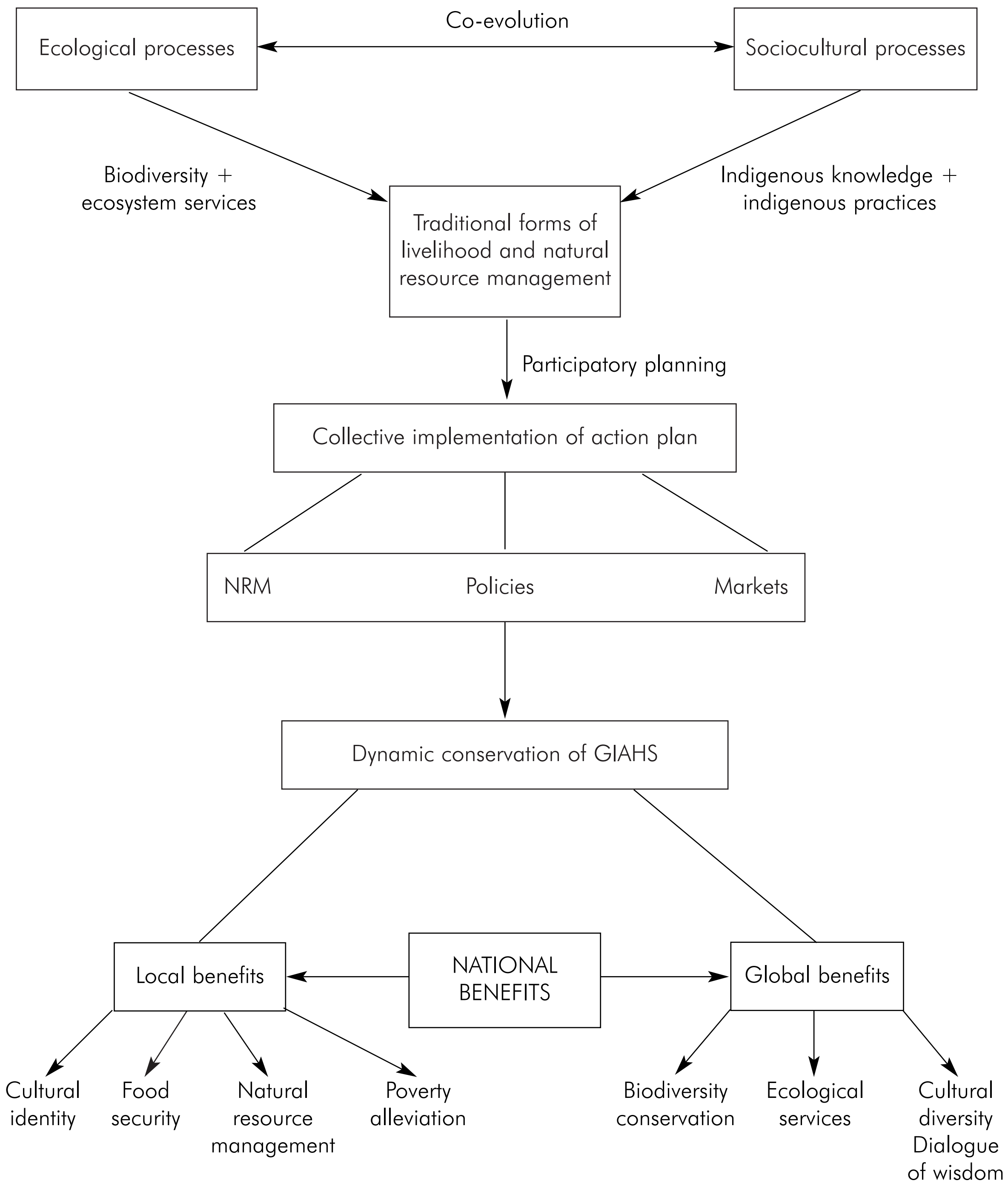

Figure 2.1 Framework for an approach to the dynamic conservation of GIAHS

combined agro-forestry vanilla system in Pays Betsileo, Betafo and Mananara in Madagascar, and diverse rice–fish systems with numerous rice and fish varieties/genotypes and other integrated forest, land and water uses in East Asia and the Himalayas.

- Maize and rootcrop-based agro-ecosystems developed by the Aztecs (Chinampas in Mexico) and Incas in the Andes (Waru-Waru, around lake Titicaca in Peru and Bolivia), with ingenious microclimate and soil and water management, adaptive use of numerous varieties of crops to deal with climate variability, integrated agro-forestry, and rich resources of indigenous knowledge and associated cultural heritage.
- Taro-based systems with unique and endemic genetic resources in Papua New Guinea, Vanuatu, the Solomon Islands and other Pacific small-island developing countries.
- Complex multi-layered domestic gardens, with wild and domesticated trees, shrubs and plants for multiple foods, medicines, ornamental and other materials, possibly with integrated agro-forestry, swidden fields, hunting-gathering or livestock, such as domestic garden systems in China, India, the Caribbean, the Amazon (Kayapó) and Indonesia (for example, East Kalimantan and Butitingui).
- Hunter-gatherer systems such as harvesting of wild rice in Chad and honey gathering by forest dwelling peoples in Central and East Africa.

The approach will put participatory frameworks in place in pilot systems to strengthen the management and knowledge systems that underpin the functioning of the agricultural ecosystem and enhance its viability. Parallel processes will be put in place at national and international levels in order to provide support and develop ways to increase the impact of the initiative by incorporating lessons learned into policy and incentive structures, and by creating national and international mechanisms to safeguard these systems. The initiative will develop participatory methods to preserve GIAHS without fossilizing them. It aims to support their continued evolution and adaptation while preserving their inherently sustainable characteristics and enhancing their socio-economic and ecosystem functions.

Other initiatives of the FAO on local knowledge systems

The FAO has various ongoing activities and programmes that involve local knowledge systems and/or are focused on drylands. A list of activities and publications is provided in Annex 1.

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Convention on Biological Diversity (CBD) www.biodiv.org

Annex 1. FAO activities and publications on local knowledge systems and/or drylands

FAO activities and programmes

Commission on Genetic Resources for Food and Agriculture. www.fao.org/cgrfa

International Treaty on Plant genetic Resources for Food and Agriculture. This internationally binding instrument includes provisions on Farmers' Rights regarding farmer's genetic resources for food and agriculture and their associated knowledge.
www.fao.org/cgrfa

Interdepartmental Working Group on Biological Diversity. www.fao.org/biodiversity

The Globally Important Ingenious Agricultural Heritage Systems (GIAHS) initiative.
www.fao.org/landandwater/giahs

Land Degradations Assessment in Drylands (LADA).
www.fao.org/ag/agl/agll/lada

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Contact: Regina.Laub@fao.org

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Note

1. Each time the word agriculture (or agricultural) is used in this paper it is meant to include cropping, livestock, forestry, fisheries, hunter-gatherer livelihood systems or various combinations thereof.

3 Poverty of the environment and the environment of poverty: constraints on adopting modern technology and promoting traditional knowledge in combating degradation and poverty

Mohammed A. Kishk, Dean, Faculty of Agriculture, Minia University, Egypt

This paper discusses the difficulties, contradictions and dilemmas faced when trying to link technology to attempts at combating desertification and poverty without thorough consideration of the prevailing global and national powers and trends that usually deny the poor a fair and equal share in resources.

The paper makes it obvious that much traditional knowledge and know-how and many traditional practices are cost effective, energy saving and environmentally friendly. However, in many communities, they are gradually or suddenly eroded while, at the same time, poor communities have no access to appropriate modern technology and are obliged to use the most inappropriate forms, with sometimes disastrous consequences. The paper gives some explanations for this and tries to suggest some remedial actions.

Introduction

There is a wealth of both traditional knowledge and modern technology for the sustainable management of dryland ecosystems, and that is available everywhere. In many cases, however, particularly in poor countries and communities, arid land ecosystems are managed unsustainably, resulting in accelerating desertification and millions of people helplessly and perhaps hopelessly suffering the consequences.

There are many human (political, socio-economic, cultural and institutional) challenges that hinder the adoption of available modern technology, and at the same time result in neglecting and ultimately eroding traditional knowledge, know-how and practices that have been used in a sustainable manner for many centuries.

If poverty reduction is the ultimate goal for all research and intervention towards the sustainable management of dryland ecosystems, then reducing poverty is also a prerequisite for the sustainability of such efforts. This means that helping the poor land users and allowing them to voice their opinions in the process of decision making is the way of breaking the vicious circle. It enables the poor to respect and use their traditional knowledge while choosing the most appropriate modern technologies.

Development aid, and the introduction of associated modern Western technology, has led to mounting debt and the dependency of developing countries, with ultimately disappointing results, particularly in the improvement of living standards for the poor. This is perhaps the main reason and motive behind the growing interest in indigenous/traditional knowledge. It is hoped that this can play a major role in participatory approaches to sustainable development and poverty alleviation. However, fears are often expressed that this might be another false hope and may again lead to disappointment, further widening the gap between the rich and poor.

There are indeed many obstacles and constraints that undermine the results of international, national and local efforts in the closely interrelated fields of combating desertification, reducing poverty and making use of technology.

In this highly complex issue, it will be difficult, and perhaps impossible, to be all-inclusive. This short paper will therefore focus on the difficulties, contradictions and dilemmas faced when trying to link technology to combating desertification and reducing poverty without giving enough consideration to the prevailing global and national powers and trends that usually deny the poor a fair share of the resources.

Poverty and resources degradation: which comes first?

In the vicious circle that involves poverty, hunger and desertification, the fallacy of confusing cause and effect is quite common, particularly among policy makers. It is important, therefore, to answer one important question: Which comes first, poverty and hunger, or land degradation? Obviously, problems of land degradation spread poverty and hunger to a greater number of people in the affected areas and to newer areas. On the other hand, anti-desertification measures in the poor nations have failed so far, and desertification has been dramatically accelerated almost everywhere. In this context, some people like to analyse the situation and jump to the conclusion, in one way or another, that 'the poor deserve what happens to them'. It is not usually stated in such plain or frank terms, but it does represent the official view adopted by policy makers who fail to achieve sustainable development for their people.

Governments in poor countries are too busy dealing with many urgent problems to think about soil and water conservation, so they tend to blame the poor farmers for not taking the appropriate conservation measures. Given the present situation of poor small-scale farmers, the basic question is this: Are they to blame? Quite plainly they are not. Similarly, the simple straight answer to the question is this: Poverty comes first and other things follow. If we keep talking about lack of funds, lack of coordination, lack of appropriate technologies or other things that are lacking to combat desertification, then we are not applying the right approach to tackling the problem. It is a simple and plain fact that we must come to terms with: resource conservation and poverty are incompatible.

The English saying 'where there is a will, there is a way' is perhaps encouraging, but it is certainly not true. In reality, we often come across many situations where there is a will but all ways or solutions are closed. The Egyptians have met with such situations throughout their long history and their saying is therefore more realistic: 'The sight is long but the hand is short'. When the hand is short and the focus is on problems and crises, many opportunities are missed.

The growing disparity in income between rich and poor, supported by government bias, has enabled the wealthy to divert the resources of countries from the production of food staples to the production of luxury items. As a result, in the agricultural sector of many countries, there is more food grown for animals than for humans, and for the rich than for the poor; and even the smallest farmers have been forced to shift from self-sufficiency to the production of animal products, increasingly relying on subsidized imported flour as their staple diet (Mitchell, 1991).

The notion of appropriate technology

When I started thinking of what can be said about appropriate technology and technology transfer, an old Egyptian saying came to my mind: 'The smart woman can spin using a donkey's leg'. The same concept might be found in almost every culture. I also recalled what the late President Sadat of Egypt used to say proudly: 'We are using the most modern technology of our time'.

It goes without saying, however, that most wise people now, in both developed and developing countries, know that the complex issue of development cannot be resolved by using a donkey's leg in spinning or by aiming at the most modern technology.

To me it makes no sense to spend much time and effort trying to show the advantages of traditional knowledge or exploring the differences between modern technology and traditional/indigenous knowledge. There is near consensus now that neither modern/scientific technology nor traditional/indigenous knowledge is static. They are constantly changing and they are mutually exchanging and making use of each other. There are differences between them, but there are also similarities. It is reasonable to assume that there is a continuum that has the traditional knowledge, practices and know-how at one extreme and the most sophisticated forms of modern technology at the other.

The pertinent question is not 'which is better, the traditional or the modern?' but instead 'what technologies, either traditional or modern, will enable the poor to work their way out of poverty?' Another question should follow on: 'To what extent can the marginalized poor benefit from the boom in information technology and biotechnology?' There is indeed much evidence to support the idea that such modern technology in the hands of multinational corporations undermines the livelihoods of hundreds of millions of small-scale farmers (Coventry, 2003).

By appropriate technology, we imply technology that can better serve socio-economic development. There is near consensus that for any approach to be appropriate it should involve technology that:

- is self-perpetuating, that is, intended to stimulate the innovative processes that will allow for continuing advances
- is adaptive or easily transformed or begun on a different level depending on the social and cultural needs and the technical capacity of the country
- is cost-effective, at least in the long run
- provides for optimum use of local resources
- promotes self-help and self-reliance
- makes use of local experiences and promotes local participation
- is ecologically sound
- implies increased education
- builds the capacities of local institutions
- is relatively easily learned by the people who are going to use it
- is equally accessible to poor and rich groups
- ensures its side effects can be handled efficiently by local institutions
- does not create or increase unemployment problems.

For more details see: Uchendu (1974); Villagas (1974); Martinez (1974); McDowell (1975); Jequier (1975) Bulfin and Weaver (1977) and Coventry (2003).

As Coventry (2003) so nicely put it:

> The challenge is to help poor women and men choose and use technology; to adapt, develop and to improve it; and to manage it sustainably over time. It means subjecting the choice of technology to the test of the three As: is it affordable? accessible? and appropriate?

Access to such appropriate technology can be a critical lever out of poverty, and its absence a key feature of living in extreme poverty. Nevertheless, there have been many cases in which technology transfer has been inevitably unsuccessful. As this can be the case, it is essential that developing countries select what is appropriate for each particular situation. Therefore, they should clearly define what is appropriate for them, and even more importantly, what is appropriate for the poor.

The hardware and software components of the technology

Technology has two distinct components: the first is usually visible and overrated and can be called the 'hardware'; it includes factories, machines or other products. The other component, which can be called the 'software', includes such immaterial things as knowledge, know-how, experience, education and organizational forms. The importance of these immaterial innovations often tends to be underrated by many people in the developing countries. Any developing country can easily import or transfer a highly sophisticated industry, or agricultural machines or laboratory equipment. Often, problems very quickly arise in their maintenance, management and use, and increase to the extent such that the equipment might be rendered useless. This happens on a daily basis and is mainly the result of a lack of software.

Hardware and the technical ability to produce it in an innovative way can generally be transferred from one country or culture to another. Organizational forms and social values are, by contrast, much more culture-specific and hence more difficult to transfer (Jequier, 1975). In other words, the problems associated with the transfer and adaptation of software are much more difficult and complex than those for hardware. These problems are not encountered when traditional technologies are used, because hardware and software have been developed simultaneously and are therefore compatible.

As mentioned earlier, appropriate technology could be either traditional or modern. Traditional technologies are likely to be more appropriate than modern forms, but there are cases in which some forms of traditional technologies are becoming outdated and are no longer appropriate. Nevertheless, in using traditional technology we automatically avoid the serious problems that arise from transferring modern technology: that is, the contrast between hardware and software components of the technology.

International trade in technology

It should be kept in mind that technology is not simply an effective means to meet only urgent basic needs for food, health, energy or shelter, but that it also helps to initiate a process of development by stimulating the innovative forces that exist in any society.

In today's world, the invisible hand of the market is the decisive factor in shaping and deciding the scientific and technological advances that are developed, and for whom. It is unlikely that private shareholders in developed nations will voluntarily invest substantial resources simply to help their 'brothers and sisters' in the less developed countries. The nature of the system is such that there is a tendency towards benefiting from the poor to increase profits. There have been, and still are, many regrettable examples of obsolete, outdated and unwanted Western technologies being sold to developing countries at very high prices that in some cases resulted in economic, social or ecological catastrophes. For these reasons, among others, new technologies should be tailored to developing nations by local businesses and institutions. As each country has specific scientific, technological and developmental needs, development aid should help developing countries strengthen their own capabilities rather than buy in ready-made products or turnkey projects.

The global trends led by international institutions such as the World Bank, the International Monetary Fund (IMF) and the World Trade Organization (WTO) promote the apparently irreversible advance of liberalized trade and investment. One result is that agricultural producers will decline in the face of competitive export agriculture, and that the rural poor will continue to join the informal marginalized sectors of our growing cities.

Exclusion of the poor and erosion of their knowledge

It was once said 'to ignore people's knowledge is almost to ensure failure in development' (Brokensha et al., 1980). However, the current global trends that can be referred to as 'globalization' make it almost impossible not to ignore people's knowledge.

> If indigenous knowledge systems are disappearing, it is primarily because the pressures of modernization and cultural homogenization, under the auspices of the modern nation-state and the international trade systems, threaten the lifestyles, practices and cultures of nomadic populations, small agricultural procedures and indigenous people.
>
> (Agrawal, 1995)

The United Nations Convention to Combat Desertification (UNCCD) made a clear link between combating desertification and reducing poverty, and it recognized the role of traditional knowledge in achieving this. However, I see a serious problem here. The marginalized poor are more and more excluded by having no access to, or control over, the resources on which they depend. The global powers and trends tend to deny the marginalized poor any voice in development and their right to determine their own future. How then will they be able to preserve their own knowledge? 'Those who are seen to possess knowledge must also possess the right to decide on how to conserve their knowledge, and how and by whom it will be used' (Agrawal, 1995).

I therefore suppose that it does not make sense to talk much about the advantages of using, promoting and preserving traditional knowledge to combat desertification and reduce poverty, as this will lead us nowhere. Instead, it might be more useful and helpful to reorient and, if possible, reverse global and state policies in order to empower the populations under threat. Those who unwillingly contribute to desertification, and suffer most of the consequences, should be allowed greater access to resources, including knowledge, and be permitted to decide and choose the most appropriate and accessible knowledge-set for them, whether it is modern or traditional.

Conserving traditional knowledge for whom?

Many documents and writings – including UNCCD's call to conserve traditional knowledge – were very nicely criticized by Agrawal (1995). He sees the prime strategy for conserving indigenous knowledge as *ex situ* conservation, that is, isolation, documentation and storage in regional, national and international archives. He then argues that the attempt to prioritize, isolate, archive and transfer traditional knowledge can only seem contradictory and is likely to fail in preserving knowledge that is integrally linked with the lives of people and is thus constantly changing. Agrawal concludes by reporting the most important criticism; he says:

> *Ex situ* conservation, even if it is successful in unearthing useful information, is likely to benefit the richer, or powerful constituencies – those who have access to international centres of knowledge preservation – thus undermining the major stated objective of conserving such knowledge: to benefit the poor, the oppressed and the disadvantaged.
>
> (Agrawal, 1995)

Unfair competition and biased decisions

Everywhere, there are often many (individuals, groups, classes, regions, generations, enterprises, technologies and so on) competing for few opportunities. This is particularly the case in less developed countries. The competition between rich and poor countries or classes within countries is even worse, and the adverse effects of this competition always apply to the poor.

The decisions, at every level, regarding the use of resources and technologies will normally favour some of the competing parties at the cost of others, depending on the power structure directing the decision-making process. Even if the needs of all parties are taken into account, decisions will directly affect people in other places/countries or at other times (future generations). Conflicts are unavoidable, mainly because both the poor and future generations are not represented, and therefore their needs are not fully considered in our decision making. Occasionally, either by design or by circumstance, their needs are completely neglected.

Considering future needs at the expense of the needs of the current generation, or what is called 'sustainable development', is like simply asking the poor people 'to die today in order to live well tomorrow'. The poor cannot exercise this option, as Robert Mugabe put it in his address to the UN General Assembly in 1987. The only option the poor might have is to repeat the famous Egyptian saying 'let me live today and you may kill me tomorrow'. After all, why should people work or look to the future if they can see no future?

Let us have a closer look at some examples. The international financial institutions (the IMF, World Bank and USAID) exert pressure on Egypt and many other countries to implement what are called 'Structural Adjustment' policies. Those countries are requested to radically increase the share of the market within their political economies through privatization. The main argument is that competition is the judge of efficiency (Brombley and Bush, 1994). This is also the main feature of USAID's strategy for Egypt (USAID, 1992), which stresses that Egyptian agriculture must capitalize on its comparative advantage. This entails a shift towards the production of high-value low-nutrition foodstuffs for the Egyptian market and for export. This not only favours large commercial farmers at the expense of the majority of rural producers, but also entails the use of imported Western technology and neglect of the traditional knowledge of local communities.

More constraints on indigenous knowledge

So far, we have been talking about what might be called 'strategic constraints and problems' on the use of appropriate technology to combat resources degradation and fight poverty. There are still many more constraints that apply, particularly to the adoption of traditional knowledge, know-how, practices and experience of local communities. Among many of those constraints, the following are mentioned as just a few examples:

- Education systems in many developing countries are undemocratic. The planning, implementation and evaluation of the systems and institutions are made by high-ranking government officials alone. The families, the local communities, the students and even the teachers have no say, and their needs and knowledge are ignored.
- The majority of scientists, researchers, technicians and policy makers in developing countries, being the product of their education system and of further training in the West, are proud of sophisticated Western science and technology and the way of life they have learned. In fact, many of them have no respect for local traditional knowledge. It is therefore not integrated in the research and development process.
- The undemocratic societies in developing countries are marching to copy the modern industrial societies of the West. The process of modernizing has been distorted in many ways. This has led to the erosion of traditional knowledge and the innovative capacity of the society as a whole, without replacing them with appropriate, affordable and accessible modern technologies.
- The process of privatization, commercialization and promoting mass production for marketing on a global scale has left many traditional technologies unable to compete with modern technologies.
- The homogenization of cultures and lifestyles and the attractiveness of fast food have contributed to a massive erosion of the traditional healthy foods and cooking materials and methods that supported local communities for centuries.
- Multinationals and national corporations aim to maximize profits and are more interested in advertising their modern technological products than in investing and promoting the traditional technologies of the poor.

Conclusions and recommendations

In this study, we have attempted to show that the very difficult and complex task of technology transfer, adaptation, invention and diffusion is to be carried out by every developing nation. The appropriate technologies required by developing countries can either be low-cost and intermediate or highly sophisticated and very advanced. In all cases, technology should serve and suit the socio-economic needs and conditions of the society. In trying to make some recommendations, I have found it very difficult to come up with anything new.

Most, if not all, the recommendations I make have been made and repeated several times before. Anyway, it will bring no harm to repeat them once again, just to remind those concerned that something still has to be done.

- Development aid should help developing countries strengthen their own technological capabilities.
- The less developed countries should realize that progress cannot be imported. Progress should be made from within the society itself.
- Technology transfer without a local technical and scientific base should be avoided because very often it will inhibit the growth of indigenous innovative capabilities.
- The less developed countries should stress the importance of developing appropriate software to make better use of the hardware.
- A range of measures to correct the curriculum, the promotion system and research priorities should be taken at universities in the less developed countries if they want to play a useful role in the development of their societies. It is not uncommon for universities and other educational institutions to act as inhibitors to the process of development.
- For the development and diffusion of new technology to a rural community, there is a need to know the limiting and facilitating factors, which should be taken into consideration when strategies for introducing the new technologies are developed.
- Due to the very participatory character of the choice and adaptation of technology and of the development process in general, there is no substitute for very active participation of the local population in every step of the process. If progress and improvements are made for them, then they should carry them out.
- To make this possible, the poor should have a fair share in the resources, and should be empowered to decide on the type of development they want and the type of technologies that will serve their needs.

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4 Reinventing the wheel: floodwater management for the rehabilitation of degraded lands

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Abstract

Soil erosion, which is aggravated during droughts, is the main cause of desertification in drylands. As both too much and too little water may lead to soil erosion, water management is often an important key to desertification control. Floods, being the only relatively large water resource in deserts, play a pivotal role in the rehabilitation of degraded lands in these areas. Integrated management of floodwater at a research station in a sandy plain in southern Iran has proven a logical method to convert a degraded area into a verdant landscape. This has improved the living conditions for both people and wildlife. The artificial recharge of groundwater and its prudent utilization (*Abkhandari* in Persian) provide food, fodder, fuelwood and fibre, and mitigate flooding damage and disasters. Modern technology and traditional knowledge have complemented each other at our station. The immigration of the nomadic farmers, who had previously left the plain due to looming poverty, is a clear sign of the success of this improved ancient technology.

Introduction

The presence of numerous farming communities in the very dry areas of the Islamic Republic of Iran (I.R. Iran) is irrefutable proof that humankind can live a fruitful life under extremely harsh conditions. Drylands, by definition, receive relatively insignificant amounts of precipitation. Moreover, the distribution of this small amount is erratic. What is described as the mean annual precipitation might occur only in a very few events. Furthermore, drylands usually experience irregular droughts, sometimes for several years in succession. It is during such periods that inappropriate land use, which culminates in desertification, is likely to take place.

The occurrence of torrential rains in arid and semi-arid zones is the rule, rather than an exception. These events happen even during the most severe droughts. This is the main reason that sedentary populations in deserts had to develop ingenious techniques to harness the torrents and utilize the water for growing food, fodder, fuel and fibre crops. 'The land of droughts and floods' best describes the pre-*qanat* period of our country, the I.R. Iran.

The fairly direct relationship between the amount of precipitation and elevation encouraged the establishment of settlements in mountainous regions. As the grass is more abundant and greener at higher elevations, both pastoralists and mixed farmers chose mountain valleys and foothills for grazing and dry farming. Mountains have served humankind as water towers from time immemorial, and Persians were intelligent enough to exploit this potential. The potential energy of the descending water was utilized to operate watermills, many in tandem.

As the steep slopes necessitated construction of narrow terraces requiring strong stone walls, and cultivation was much easier on sites with milder gradients, larger basins were constructed on debris cones and on the upper and middle reaches of coarse alluvial fans. Persians had learned that they could easily harness meagre flows, divert them into small basins, and grow crops in both flat and sloping terrains.

Runoff farming, which was probably the forerunner of the *qanat* technology, was most certainly gleaned from nature. Seepage of water downstream of the runoff farms led to the serendipitous discovery of groundwater flow and development of the very sophisticated *qanat* technology. The emergence of alluvial springs, where the vadose zone texture became finer than the overlying strata, was an inevitable outcome of over-irrigation of such farms. This, perhaps, encouraged the ancient Persians to dig mildly sloping tunnels that drained the alluvial strata. The presence of seemingly prehistoric flood-irrigated farms on the recharge area of many of the *qanats* in the northeastern province of Khorasan lends support to the contention that our ancestors replenished their aquifers, albeit unknowingly (Kowsar, 1992). The *qanats* supplied the lower lying farm fields and agrarian communities. This made our country into the 'land of droughts, floods and *qanats*'.

A variation on the same theme was floodwater irrigation of very large basins in vast floodplains with extremely low slopes. These plains had been formed by millions of years of erosion of siltstone and marl outcrops of the tertiary age. As these fine materials were not conducive to the formation of productive aquifers, the Persians used them for growing small food grains, particularly wheat and barley. They certainly were, and still are, strong believers in the so-called 'Genesis Strategy': produce in fat years, economize in lean years.

As self-sufficiency in food became a tenet of the I.R. Iran in its formative years, detailed examinations of the runoff farming systems were performed to find the most appropriate methods for application on large scales. We were facing serious problems. Most of our *qanats* had dried up due to the use of an inappropriate technology: overexploitation of groundwater through deep wells. More than 50 per cent of our irrigation water is supplied through underground resources. Therefore, artificial recharge of groundwater (ARG) was strongly advocated in planning and implementing the floodwater spreading (FWS) schemes. This was the main reason that we integrated traditional knowledge with modern technology and coined the term *Abkhandari* (aquifer management in Persian), to signify the importance of all activities that result in the development of groundwater and optimization of its use (Kowsar, 1998a).

The most widespread design used in present-day Iran is based on the pioneering work of three Australians: Phillips (1957), Newman (1963), and Quilty (1972). In this system floodwater is spread as a thin sheet from level-silled channels constructed at specified intervals. The overland flow in FWS events (theoretically) does not acquire erosive velocities. We have modified the Australian design to suit our intended purposes, the ephemeral flow regimes and the lay of the land, the texture of soils and the machinery available for construction. It should be emphasized that we are still undertaking research on different aspects of FWS and the artificial recharge of groundwater (ARG). Our principal objective in such methodical activities is to elevate these ancient arts into the level of science.

Some applications of modern technologies in improving an ancient art

The following are some of the modifications that we have made, and the new techniques that we are trying to develop that benefit from modern technology.

- *Development of sloping stilling basins*. Flowing water has potential and kinetic energies by virtue of its elevation, depth, mass and velocity; it imparts shear stress on, and impact force to, the objects that obstruct its flow. It is therefore essential to decrease the depth and velocity of flow if floodwater is to become manageable. This is achieved in very long stilling basins termed 'conveyor-spreader channels'. The most suitable slope for these channels is 0.0003 (Kowsar, 1991). Only very precise engineering levels may be used in surveying this slope.
- *Construction of floodwater spreading systems using heavy machinery*. Manual labour and beasts of burden were used until the very recent past in the construction of FWS systems. Although this is a good way to provide jobs for millions of unemployed workers, we use bulldozers, loaders, graders and even farm tractors equipped with bulldozer blades for excavating channels and building embankments.
- *Identification of clay minerals.* Translocation of minute clay minerals in the vadose zone clogs the soil pores and obstructs the flow of water towards the water table. We have used both x-ray diffraction (XRD) and transmission electron microscopy (TEM) to identify clay minerals that could potentially stop the flow (Mohammadnia and Kowsar, 2003).
- *Application of remote sensing and geographical information systems in site selection and performance assessment.* Remote sensing and GIS techniques are being used to find potential sites for the ARG projects. We have used remote sensing to assess the benefits of ARG activities carried out during the first twenty years of operation in the Gareh Bygone Plain, and five years of sediment deposition in an ARG system at Ab Bareek, Bam, southeastern Iran.
- *Application of a global positioning system in surveying and sampling.* We have recently employed the GPS technique in surveying a 21-year-old ARG system at our station in the Gareh Bygone Plain, and located upwards of 170 sampling points to study the depth and texture of sediments, and determine infiltration rate and hydraulic conductivity at some of those locations. The same system, but with fewer points, was used on the watershed. Geostatistical techniques and modern computers will be employed in analysing the data.
- *Fertilization of the runoff farms, rangeland and afforested area with geological nitrogen*. The presence of nitrate and ammonium in the tertiary outcrops of the watershed that supplies floodwater to the ARG systems is simultaneously beneficial and harmful. As our sandy soil is extremely low in nitrogen, the nitrate-polluted floodwater is a great advantage in the fertilization of the planted and indigenous vegetation (Yazdian and Kowsar, 2003). On the other hand, contamination of groundwater that is also used for domestic purposes poses a dilemma: to drink or not to drink, that is the question! We have measured both soil and water nitrate and ammonium with the most modern laboratory instruments and established the innocuous composition of the groundwater.
- *Sequestration of carbon*. We have a tremendous potential in Iran to sequester carbon in photosynthesizing plants. *Eucalyptus camaldulensis* Dehnh., planted at 1,100 stems per ha, annually sequesters 2.9 tons of carbon per ha at our station. Should the signatories of the Kyoto Protocol decide to pay the carbon rent, we will be glad to oblige!

- *Application of time-domain reflectrometry in soil water measurement*. We have acquired a number of TDR sensors to install at regular intervals in the wells, dug to a depth of about 30 m to monitor the flow of water towards the water table. We have already used a neutron probe in studying water consumption by *Euc. camaldulensis* trees.
- *Characterization of soil microorganisms*. As microbial populations and their characteristics are indicators of soil quality, we hypothesized that floodwater spreading has affected both of these indicators. We have used modern techniques in determining the species and abundance of the soil microorganisms. Identification of associative nitrogen-fixing bacteria of *Panicum antidotale* Retz. is currently under way at our station.

Rehabilitation of a sandy desert

The Gareh Bygone Plain measures 18,000 ha, of which more than 6,000 ha were covered with moving sand in 1983 when FWS activities were initiated. Weathering of the Agha Jari sandstone outcrops on the Bisheh Zard Watershed produces fine sand, which is carried as suspended and bed load. Sedimentation of some of this material in the streambed and on the floodplain provides the charge that is carried by the wind, which blows mostly in the spring and summer months.

Turbidity of floodwater, which is the nemesis of water resource developers, is a great advantage here. Silt and clay-sized particles, and the suspended and dissolved organic matter, provide an environmentally friendly adhesive that glues sand grains together; thus, stabilization of the moving sand and enhancement of soil quality are achieved simultaneously. As available water capacity is the most direct driver of primary production, and this in turn depends on the texture and depth of soils, deposition of fine materials on sand enhances this property and makes it a better growth medium. It is true that tree windbreaks decrease wind erosion, but stabilization by adhesive materials is required to prevent dust formation. We still witness dust between windbreaks where the ground surface has not been covered with turbid floodwater. This is particularly important in more humid areas where the vegetation cover has been compromised.

Overgrazing has been singled out as the principal cause of degradation of rangelands. This is certainly true today, but it was not so in the recent past. Nomadic chieftains managed their allocated rangelands to some extent to avoid overexploitation. Although transhumance is blamed for this problem, implementation of the ill-conceived 'Sedentarization of Nomads' in the 1930s, 'Land Reform' in the 1960s, and 'Save the Lambs' in the 1980s delivered the *coup de grâce* to this vital resource. The encroachment of farm fields onto the grazing areas, which was facilitated by an inappropriate technology (the tractor-drawn mouldboard-plough) robbed the nomads and mixed farmers of their rightful pastures, which had been grazed for millennia by their ancestors' herds. It is thus of the utmost importance to provide forage for herders if degraded land rehabilitation is seriously intended (Kowsar, 1998b).

Fuelwood collection is another major cause of land degradation. Although the government does its best to supply even the remotest villages with fossil fuels, there are still reported cases of deforestation for charcoal making, cooking, and heating houses and tents. In a recent inventory of an eighteen-year-old *Eucalyptus camaldulensis* plantation, we discovered that the annual fuelwood yield of this species at our site was 813 kg per ha.

FWS on a sandy expanse in the Gareh Bygone Plain in southern Iran has converted it into an arable land that produces relatively abundant and nutritious forage. Invasion by a few palatable forage species of the sediment-covered areas indicates that site quality has been enhanced. *Artemisia sieberi* Besser., *Atriplex leucoclada* Boiss., *Cymbopogon olivieri* (Boiss.) and *Cynodon dactylon* L. are the most prominent additions to the vegetation list. The ten-year average of forage yield of indigenous species has been 445 kg per ha, a fivefold increase relative to the control. The mean annual yield of quailbush (*Atriplex lentiformis* (Torr.) Wats.) at 625 bushes per ha has been 1,500 kg per ha. Australian fodder trees such as *Acacia cyanophylla* Lindl. and *Acacia salicina* Lindl. have added to the grazing potential of the station. What raises an intriguing question is that sheep and goats browse some of the *Euc. camaldulensis* Dehnh. trees without apparent ill effects. This reportedly unpalatable tree may save a large number of livestock during prolonged droughts.

It is interesting to know that most of the water that is consumed in producing these plants would have been evaporated in sedimentation basins of the ARG systems. This demonstrates the philosophy of taking an integrated approach in desertification control: If a project is technically practicable, environmentally sound, economically feasible, and socially acceptable, implement it by all means.

Making a detour

Although 'sustainably managing freshwater resources for biodiversity conservation' is one of the objectives of this workshop, our setting has compelled us to ignore the above-ground freshwater biodiversity. A mean annual Class A pan evaporation of 3,200 mm, a highly turbid floodwater, an unsuitable geological setting, exorbitant costs, and the presence of a huge potential shallow aquifer have made the ARG the best alternative in a water resource development project. Moreover, if the floodwater is not harnessed and utilized at our station, it would drain into the *Shur* (saline in Persian) River of Jahrom, whose summertime electrical conductivity reaches 43 dS per m. We therefore had to compromise on biodiversity in favour of the present human population by storing water underground. On balance, we think we have enhanced the quality of the environment.

Traditional knowledge about conservation of soil fertility is limited to four simple practices:

- fallowing the farm fields in alternate years
- direct manuring by overnight corralling of livestock in mild weather in different parts of farm fields
- mixing ash with faeces and spreading it on irrigated fields
- using floodwater as a carrier of livestock manure from watersheds to the runoff farms.

As some mixed farmers keep their livestock in caves on watersheds at night, they pile the manure in protected areas by gulches. They throw the manure in torrents when they are relatively sure that flood will transport the precious load to their farms and spread it evenly onto their fields.

Economy versus ecology

Hunger, thirst and feeling cold know no bounds. Therefore, if biosphere reserves and similarly managed areas that are supposed to function as models for rehabilitation of degraded areas are to remain protected, the basic needs of the inhabitants of their buffer and transition zones *must* be met. As having permanent work and a steady income is considered to alleviate many social ills in our culture, we believe we can help people and protect our research sites by creating job opportunities for those inhabitants of the above mentioned zones who are willing to work. This, in turn, *may* restore the degraded environment by offering alternatives to those whose poverty makes them have recourse to ravaging what is left of the vegetative cover. We would like to emphasize that teaching respect for the environment is a long-term process, and compromise and tolerance are virtues in dealing with people who believe the grass is greener on the other side of the fence.

On average, the water recharged by each 4 ha of an ARG system, and the forage produced on the same tract, create one job at our research site. As of 1997, 340 families were totally or partially dependent on the income generated by 1,365 ha of the ARG systems in the Gareh Bygone Plain, I.R. Iran. We annually harness approximately 10 million m^3 of floodwater, of which about 80 per cent recharges the aquifers. This has increased the area of irrigated crops eightfold to 1,193 ha as of August 2002 (Figure 4.1). The very farmers who had emigrated prior to 1983, when our ARG project was started, now manage these farm fields.

Economy and ecology could proceed in harmony if the former common sense prevails; that is, doing what our ancestors did. We believe that our policy makers should be ecologists, or at least their strong advocates. Issuing a command or passing a piece of legislation without knowing the expected outcomes is an invitation to disaster. We have reversed a trend of degradation at our station. No doubt, there is room for improvement. Optimization of resource use enables us to expand desertification control activities with less funding on a unit area basis.

A wildlife refuge, if ...

Provision of food and shelter has attracted many birds, mammals and reptiles to the site (Kowsar, 1991). The most endangered species among them are houbara bustards (*Chlamidotis undulata* Jaqu.), Persian gazelles (*Gazella subgutturosa* Guldenstaedt) and Indian crested porcupines (*Hystrix indica*). These are auspicious signs that we have succeeded in rehabilitating a degraded environment. Unfortunately, poachers hunt gazelles and houbara bustards for their excellent meat, and porcupines for their supposed aphrodisiac properties. Wild pigs (*Sus scrofa* L.) churn up the mud in sedimentation basins and bring up the buried seeds, and boars plough the crust with their tusks, so we welcome their presence. Also, the boars have become a source of income to a few hunters; as Muslims do not eat pork, the hunted pigs are sold to Christians.

Wolves (*Canis lupus* L.) are our best guards against unlawful grazing. We issue grazing permits in autumn when the forage is at its lowest level on rangelands, and wheat and barley stubble has been grazed by sheep and goats. Some herders, however, played hide-and-seek with our watchmen and their flocks grazed the station grounds all year round, particularly at night. The advent of wolves, and the loss of a few sheep, put an end to the infringement.

Burrowing mammals, particularly rats, help increase the infiltration rate of the crusted sedimentation basins; however, they become a nuisance when they occupy embankments. The cool, moist soil in a hot desert is very inviting for the burrowers. The passage of floodwater inside the burrow results in embankment breaching. Fortunately, snakes curb the rapid growth of rat population; owls and eagles do the same for snakes, and the hunter–hunted cycle continues.

The most important newcomer to our station is a crustacean named the sowbug (*Hemilepistus shirazi* Schuttz). This 22–25 mm creature drills holes 7 mm in diameter and up to 180 cm deep. Were it not for this burrower the ARG systems would not have functioned properly. The crust formed by deposition of fine particles substantially decreases infiltration rates and eventually makes the soil surface impermeable. This engineering marvel lines its burrow in fine sand

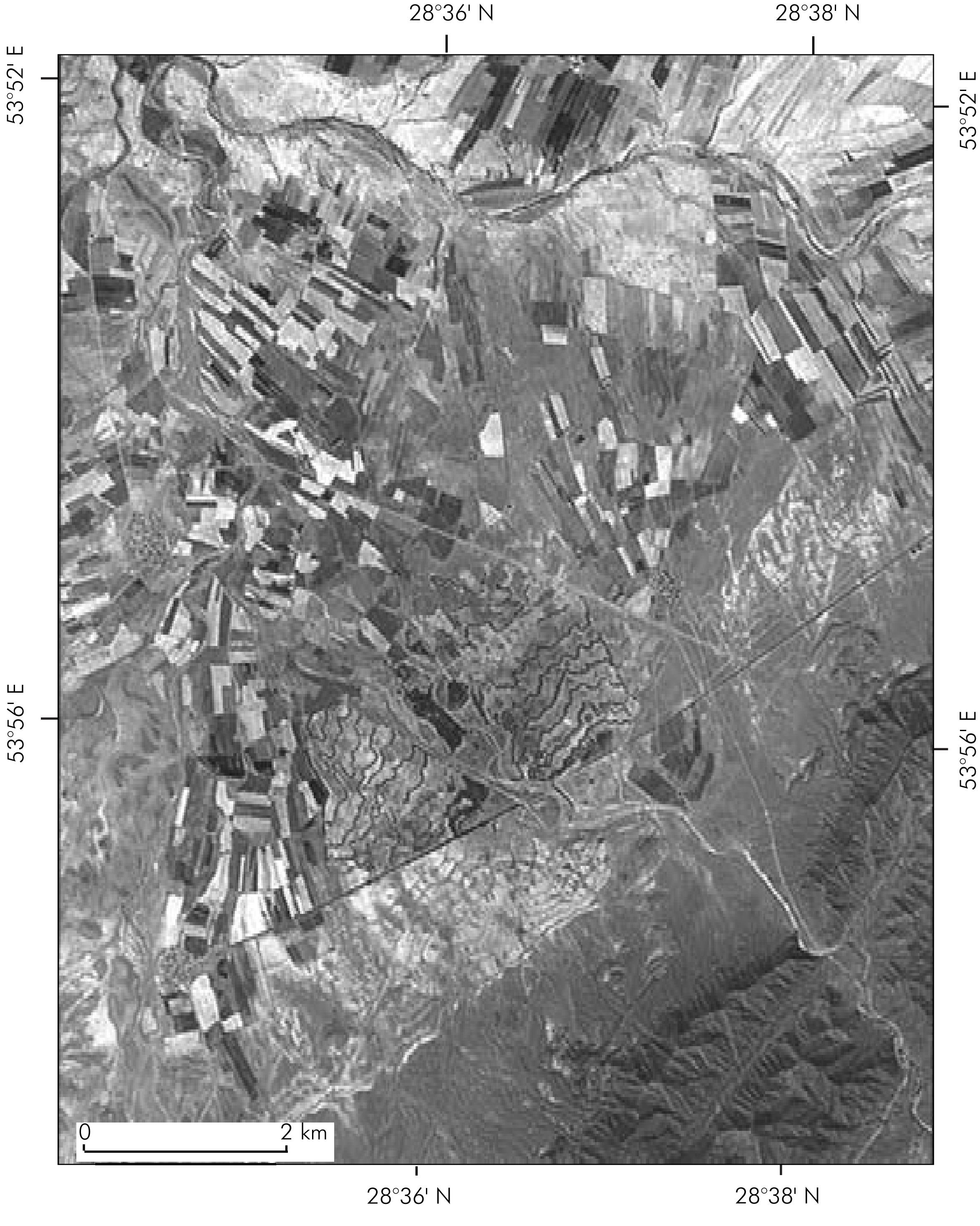

Figure 4.1 The artificial recharge of groundwater systems is shown on the upper centre and right centre of this ASTER false image acquired on 26/7/2002. The contour lines signify the eucalyptus windbreaks. The area of irrigated farms has increased eightfold to 1,198 ha due to the recharge of the alluvial aquifers. The empty space lying under this plain can store more than ten times the mean annual precipitation of 243 mm.

Alluvial aquifers are more precious than oil for desert dwellers!

Photo, courtesy of JICA and ERSDAC, Japan.

with a body fluid that prevents its collapse. We hope to synthesize this material and build thin-shelled houses in sandy plains. Quailbush is the favourite fodder of the sowbug.

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5 Traditional knowledge and modern technology for sustainable development of dryland ecosystems: the Indian experience

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Land degradation

Land degradation occurs as an outcome of adverse changes in the land, vegetation and hydrological regime that change its ecological characteristics to the extent that that the integrity of the ecosystem is either threatened or lost. The interaction between vegetation, soil type, limnology, climatic variability and land-use pressures determines the extent of degradation. Desertification occurs when a landmass undergoes degradation in arid, semi-arid and dry sub-humid areas.

Of the 328 million ha that comprise the Indian subcontinent, 173 million ha are degraded. With 2.4 per cent of the world's landmass supporting 16.2 per cent of the global population, and with a bare 0.5 per cent of the grazing land sustaining 18 per cent of the world's livestock, India is one of the few countries in the world with extremely strong and clearly identifiable linkages between land degradation and poverty. The geo-hydro-thermal regime of India renders large parts of the country vulnerable to water and wind erosion, salinization, waterlogging, drought and desertification. The Indian experience seems clearly to reveal that sustainable land use does not entirely depend on the 'carrying capacity of the land' but also on the 'caring capacity of the land users/managers'.

In large tracts of the dry western part of Rajasthan, a state in the northwest of India, an indigenous rainwater management system called *khadin* promotes crop cultivation during the winter months in the post-rainy season. Here the critical role of livestock, not fully appreciated by outsiders, is well understood by the local farmers. There is virtually no microbial activity in the soil as the moisture level falls below critical levels in the winter and summer months. In such a situation it is the livestock that collects the dry biomass, digests it and delivers it in a decomposed form. The addition of compost in the cultivated fields at the onset of the monsoon provides nutrients and inoculates the soil with microbes.

Regions of degraded land

The degraded landmass has been categorized into five priority regions with respect to established biophysical, socio-economical and human development indicators. These five regions are:

- arid and semi-arid northwestern India
- semi-arid Central Deccan Plateau
- semi-arid central eastern region
- sub-humid areas suffering salinization, sodification and water logging
- degraded forest lands in arid, semi-arid and dry sub-humid regions.

Watershed-based approach

Until March 1995 the degraded areas were managed through a sectoral approach within the framework of programmes such as the Drought Prone Areas Programme (DPAP) launched in 1973–4 and the Desert Development Programme (DDP) launched in 1977–8. In 1995, the central government adopted the recommendations of an expert group called the Hanumantha Rao Committee, which favoured a watershed-based approach. This shift also witnessed an approach that favoured the participation of people and the Panchayati Raj Institutions in the watershed programmes on a massive scale. Thus, the erstwhile sectoral and centralized approach has been transformed into a watershed-based and participatory approach.

The watershed-based approach has been widely adopted by various agencies such as the Ministry of Agriculture in its programme for rain-fed areas. Under this approach, emphasis is placed on the harvesting of rainwater and on promoting recharge devices. The micro-watershed, created by the interplay of rainfall and landmass, is the primary domain of planning and action. The area draining at a common point on the natural drainage line and bounded by ridgelines with local modifications constitutes the fundamental unit of rainwater management and thus provides a buffer to the local communities.

The Man and the Biosphere Programme (MAB)

As regards the Man and the Biosphere Programme, the Indian government has identified fourteen sites to be designated as biosphere reserves within the guidelines set by UNESCO and MAB. Management action plans are under implementation in thirteen of the fourteen identified sites. However, the inclusion of a dryland ecosystem in the category of MAB biosphere reserves is still at the proposal stage.

The combination of indigenous traditional knowledge (ITK) with modern technologies in the Thar Desert area

A beautiful book entitled *The Dying Wisdom,* published by the Centre for Science and Environment in New Delhi, is a vivid and comprehensive account of different types of systems and water harvesting practices in different parts of the country. One of these is the Thar Desert, which comprises twelve districts of Rajasthan and parts of the states of Haryana and Gujarat. There is a proposal for a biosphere reserve encompassing 3,100 km² in the Jaisalmer and Barmer districts of Western Rajasthan. In view of the high pressures of human and livestock needs, an area of only 600 km² is being proposed to constitute the two core areas. It is felt that a strict application of the core–buffer relationship is not feasible and may affect the buffer areas in the harsh desert environment. The proposal places heavy reliance on intensive management, characterized by rotational grazing and plantation along water points and in villages. The Thar Biosphere Reserve (TBR) aims to promote livestock rearing on a scientific basis, improve the economic conditions of local people and provide exemplary planned development without incurring ecological sacrifice. The strategy envisages:

- Setting aside representative areas as a national park or sanctuary.
- The protection of flora and fauna of the entire Reserve; no extraction of fuelwood is allowed for any purpose other than for domestic use by villagers living within the reserve.
- The management of grazing lands by rotational grazing for rational land use.
- Ensuring the welfare of the people living in the reserve.
- Having a sufficiently large area in the reserve to effective insulate it from external biotic disturbances.
- Site-specific wildlife management: fencing off the selected wildlife habitat, and closing it to grazing, locating water points at appropriate spots so that animal movement is distributed over a wide area, increased monitoring, protection of endangered flora and fauna, and deciding on the appropriate size of the wildlife-protected area while keeping in mind the demographic and topographic features of the area. Application of these measures on an experimental basis saw the growth of flocks of the great Indian bustard and a significant increase in the number of desert fox and chinkaras.
- The aggressive promotion of rotational grazing by dividing the grazing range into units consistent with the number of villages, with each unit having four paddocks.
- The use of barbed wire fencing, which is topographically more suited than trench or stonewall or brushwood fencing. It is initially expensive in capital cost but has low maintenance costs in the long term.
- The reseeding of appropriate perennial grasses that are compatible with the agro-climatic conditions so as to increase the forage and animal productivity.
- Proceeding with a site-specific methodology with seed planting not below 1–2 cm of the mound, as well as broadcasting just before or at the onset of the first effective showers. Pelleting of seeds with lime, clay and farmyard manure has not proved to be advantageous. Direct seeding by mixing the seed in moist sand obtains better results.
- De-fuzzing the seed of toxic inhibitors by seed soaking for eight to twelve hours just before sowing. Implementation of these practices has seen an increase in forage productivity by about 20 q/ha.
- The use of genetically improved strains of grasses may increase the forage production by up to 40 q/ha. Some of the better strains developed by the Centre for Arid Zone Research Institute (CAZRI) and the Indian Grassland and Forage Research Institute (IGFRI) such as *Cenchrus Ciliaris, Cenchrus Setigerus* and *Lasiurus Sindicus* have proved their stability of production and better persistence.
- The topography does not lend itself to afforestation in the conventional sense. However tree planting at suitable sites in the villages can be carried out around desert posts and water points, primarily to provide shade. Shady and fast-growing species like *Azadirachta indica (Neem), Albizzia lebbek (Cirus), Tecomella Undulata (Rohida), Prosopis Cineraria (Khejri)* and *Ficus Religiosa (Peepal)* are extensively planted.
- Efficient water management by providing each paddock with a source of water. Under normal conditions there is no water flow in the topography of scattered sand dunes and porous soil. Water conservation can be achieved through *nadis* and guzzlers (*tankas*), which can be supplemented by tubewells drilled to considerable depths.

Current strategy

A number of measures have now been taken under the Desert Development Programme (DDP) and the Integrated Wasteland Development Project (IWDP) in the districts of the Thar Desert. These include shelterbelt plantations, grassland developments, soil and moisture conservation, pasture development, farm forestry, village fuelwood and fodder plantation, and the establishment of nurseries and water resources development. Some of the key measures are described below:

- Planting activities emphasize the reliance on indigenous species, especially regarding the under-canopy vegetation for the effective control of sand-drift.
- With the backing of a series of on-site research-based trials, people are encouraged to cultivate a range of vegetation. *Acacia senegal* locally known as *Kumat*, used for gum extraction and fodder, grows in arid areas only; *Prosopis cineraria* (locally known as *Khejri*) is the most multi-purpose tree of the desert, with fodder and pods that are used as vegetables while the bark is consumed by human beings during severe drought; *Acacia nilotica* (locally known as *Babul*) is used for fodder, gum and small timber; *Capparis deciduas* (locally known as *Ber*) is used for controlling sand drift and its fruit is pickled; plants like *Withania somnifera* (Aswa gandha), *Cassia angustifolia* (Sonamukh) and *Azadirachta indica* (Neem) are used for medicinal purposes.
- The *P. Cineraria*-based agroforestry model is recommended, as this species exerts the least competition with agricultural crops. It provides utilizable biomass of nearly 20 tonnes/ha including leaf fodder of 0.85 tonnes/ha at twelve years of age, in addition to agricultural production.
- Among other propagated species are *Colophospermum mopane*, to be raised through direct seeding, which produces 3–4 kg of dry fodder as well as the same quantity of fuelwood per tree at seven to eight years of age. Another good and useful variety is *Hardwickia binata*, which has a slightly lower yield of fodder and fuel than *Colophospermum mopane*.
- Sand dune stabilization is expected to be achieved by planting *C. polygonoides*, which produces higher biomass and uses less soil water than *A. Tortilis* and *P. Juliflora*. Micro-windbreaks are erected in a chequerboard configuration across the dunes using local shrubs such as *Leptadenia pyrotechnica* and *Aerva Pseudotomentosa* to protect the seedlings from sand drifts. Alternatively, sowing *Cassia angustifolia* and *Cenchrus* species in a chequerboard configuration can help reduce the cost of erecting micro-windbreaks.
- In view of the multiple uses of *P. Cineraria*, its needs to be effectively managed. A combination of biotic and abiotic factors can be dealt with by timely lopping management (observing a gap of one year between loppings), and by discouraging complete lopping (which is detrimental to diameter growth), effective treatment of wounds and the removal of heavily attacked trees.
- Practising rainwater harvesting and water conservation through a host of indigenous practices such as *nadis* (deep, narrow streams), *tankas* (cemented underground pits for storage), *khadins* (deep ditches), *beris* (cemented storage structures), *sagars* and *samands* (pools and ponds).
- Different traditional strategies for agricultural production consist of:
  - thinning, weeding and soil mulching when normal showers are followed by inadequate showers
  - sowing of pearl millet, mung beans and cluster beans when the late onset of the monsoon is followed by normal showers
  - sowing of cluster beans, mung beans, cowpea, moth beans, sesame, and other leguminous crops during late and low monsoon conditions.
- Soil moisture conservation is practised by applying contour bunding, contour furrowing, contour vegetative barriers, reducing runoff losses and mulching.
- The traditional methods of biodiversity conservation include *Orans* (protected forests dedicated to deities and legendary heroes) and *Gauchars* (management of designated lands for grazing, and reseeding of pastures through improved strain of *C. Ciliaris).*

Fusion of appropriate technologies with traditional practices – case studies of two districts: Jodhpur and Bundi in the Thar Desert area

The district of Jodhpur is an arid region whereas Bundi is a semi-arid region of the Thar Desert in Rajasthan. The secondary data collected by CAZRI and AFRI in Jodhpur and IGFRI in Jhansi illustrate that there is no shortage of technology for the successful revegetation of degraded rangelands in arid and semi-arid areas. The real challenge lies in the adoption, absorption and assimilation of the techniques that combine newer technologies with traditional practices. Among the technologies recommended by the above-mentioned institutes, the ones described below deserve specific mention.

Silvi-pastoral system

The silvi-pastoral system is most favourable for preserving the ecological environment and for maximizing production from refractory lands.

A combination of grasses, legumes and trees optimizes land productivity and conserves soil, moisture and soil nutrients while producing forage, timber and fuelwood on a sustainable basis. In a sound silvi-pastoral system, grasslands need to have twenty-five to thirty trees per ha of suitable species. These trees, in combination with legumes, not only provide nutritionally better quality fodder but also help to build up nitrogen in the soil. The deep and lateral root system also helps in moisture retention in soil. This technology increases land productivity by eight to tenfold in terms of forage, fuelwood and small timber. The quality of the produce also improves by around sevenfold. The figures in Table 5.1 make interesting reading.

A multi-purpose tree (MPT) species, which can be introduced to good effect even in severely degraded ecosystems, is *Acacia senegal*. Its leaves and pod husks make good fodder, the seeds are dried and preserved for human consumption, the gum is used in food products and the wood is used for domestic and agricultural timber. *Cenchrus ciliaris* and *Cenchrus setigerus* are two highly beneficial strains of grasses that are adapted to light to medium soils that have around 300 mm of rainfall. On sandy soils with less than 250 mm rainfall *Lasiurus sindicus* gives a yield of 4 t/ha.

Advantages of systematic lopping

Experimental studies have shown the maximum yield of leaf fodder is achieved by the systematic lopping of trees twice a year, in November/December and May/June. The lopping is performed to the extent of 25 to 33 per cent of the crown and it is evenly distributed on all sides of the canopy. Lopping of this kind yields 0.16 to 0.20 t/ha of leaf fodder in a year without any damage to the health of the tree.

Watershed approach

As water is the key to vegetational growth, it is important that the entire watershed be covered by treatment measures and every drop of rainfall be retained in the rangeland while eliminating erosion due to runoff. This involves the digging of contour trenches/furrows, with the excavated earth dumped on their lower edge, and the construction of check-dams, ponds and anicuts. Trenches/furrows are cleared in the second year, after which the rate of silting will be dramatically reduced if the grass cover that develops is protected and maintained. A field study reported the case of Jhanwar watershed, where with 440 mm of rainfall in the first year a rise of 0.48 m in the water table was observed. In the anicuts, the deposition of silt also dropped by 20 to 30 per cent. Surface accumulation of water was equal to 2,500 m^3 in twelve farm ponds and 6,050 m^3 in three anicuts, and 211.9 tonnes of silt was deposited in seven earthen check-dams. The following years witnessed a substantial increase in water conservation and a decrease in erosion and silting due to the growth of grasses, legumes and trees.

Table 5.1 Produce of treated and degraded rangeland

Produce	From degraded rangeland (t/ha/year)	From treated rangeland (t/ha/year)
Forage	0.5–1.0	4.0–5.5
Fuelwood	Negligible	2.0–3.0
Small timber	Negligible	1.6–2.5

Protection against biotic stresses

Ditch-cum-mound fencing is the most practical measure in arid areas. It is useful for water conservation as the trench arrests the flow of water, although it is labour intensive. The mounds are used to raise the fence level as a second line of protection.

Soil working

The type of soil working that is used depends on the nature of the soil and the slope. Broadly speaking it is dependant on topography:

- On a flat gradient, the area is ploughed and broad bunds created at a spacing of 30 to 50 m along contours.
- In sloping land, staggered contour trenches or furrows are dug and soil heaped in mounds on their lower sides. While furrows are more convenient in shallow gravely soils, trenches are dug in deeper, loosely textured soils. In the desert areas of Rajasthan, 1,500 running metres of furrows/trenches are dug per ha. They are spaced 15 m apart in areas with a slope of up to 15 per cent, and at 10 intervals m for a slope above 15 per cent. This measure can detain 540 m^3 of water per hectare of rainfall. Studies have shown that the contour furrows increase forage production of perennial grass species by 130.6 per cent in the first year alone. Another experiment, called the 'inter-row water harvesting system', involved the creation of 30 cm wide furrows alternating with 70 cm wide raised beds, with two rows of pasture, legumes or grasses sown on the edges of furrow. An increase of fodder yield of between 66 and 124 per cent was reported on different status rangelands.

Water harvesting devices

The improvement in the moisture regime is of vital importance. If the soil remains wet for a longer period of time, wind erosion is greatly minimized. Hence the absolutely crucial need to construct vegetation-aided check-dams in the nullahas and anicuts to store runoff water; allowing water to flow only through sub-soil seepage is a means to provide sustained moisture to the land located in the lower regions of watershed. In areas where suitable water harvesting devices were provided, the underground water table improved by 15 to 20 m.

Agro-forestry systems

Agro-forestry is a land management system that on the one hand seeks to optimize the yield of grain, forage, timber and animal products, and on the other hand, to conserve soil nutrients and improve the environment. It combines the production of agricultural and fodder crops either simultaneously or sequentially on the same unit of land.

Silvi-horticulture

Fruit plants combined with a fair sprinkling of fodder trees are economical and yield greater productivity. Suitable fruit species include *Emblica officianalis* (Aonla), *Zizyphus mauritania* (Ber), *Citrus aurantifolia* (Nimbu) and *Psidium guajava* (Amrud). The fruit plants need to be planted very carefully in a pit of 1 m^3 after adding farm-yard manure and bone-meal to the soil. They will require irrigation for the first two to three years and benefit from methods such as pitcher irrigation and drip irrigation. In the former, a pitcher with a small hole at its bottom is dug in the ground near the root zone of the plant. Water seeps through the small hole, providing the area with constant moisture. Another method in use is the sub-soil water injector system for providing a controlled quantity of water directly to the root zone of the fruit plants.

These methods have increased the survival rate of plants considerably by the use of small quantities of water in the highly porous soils of the region. The proportion of fruit to fodder trees should be 40:60 or 50:50 in the first rotation to keep irrigation costs low. A spacing of 10 to 15 m between plants will provide 90 to 100 trees per ha, and the intervening space between plant rows can be used to grow less demanding agricultural crops in the first two years, with grasses grown in subsequent years. In areas where traditional practices and appropriate technologies of local people have been adopted, this has resulted in ecological regeneration, biological diversity, floral and faunal succession, irrigated land augmentation, fallow lands deceleration, accrual of socio-economic benefits, employment generation and decreased migration. The real key to success lies in the extent of involvement and participation of the local people, as without their cooperation and conviction the proposed techniques would achieve little, if any, success. The ability to secure the participation of local people may herald a success that will be sustainable, affordable, replicable and long lasting.

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6 Traditional knowledge and modern technology for sustainable agricultural development in the drylands of Sudan

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Abstract

Sudan is the largest country in Africa (2.5 million km^2) and is dominated by hyper-arid, arid, semi-arid and dry sub-humid regions, which cover about 72 per cent of the total area of the country. Thus, desertification is active to varying degrees in the areas lying between latitudes 10° and 18° N and traversing the country from the eastern to the western borders. Thirteen states are affected to varying degrees by desertification, and the River Nile is endangered by sand encroachment, particularly in the north.

There are three main farming systems in Sudan: irrigated, semi-mechanized rain-fed (SMRF) and traditional agriculture, which includes rain-fed and irrigated subsectors. The traditional system is practised in desertification-prone rural areas inhabited by 65 per cent of the population, who rely heavily on the natural resources for subsistence. Poverty leads to a subsistence livelihood, which impoverishes the fragile ecosystems and increases land degradation, consequently aggravating poverty. This vicious circle can only be broken if programmes for combating desertification are integrated with strategies for poverty alleviation.

In spite of the development of the oil industry in 1999, agriculture remains the predominant sector in Sudan's economy. In 1998 it was estimated that the irrigated, semi-mechanized and traditional rain-fed agriculture (TRF) accounted respectively for about 21.3, 6.4 and 16.3 per cent of the value of the total agricultural production in 1998. Local small-scale farmers use traditional knowledge and technology such as multiple- and intercropping, manual cultivation by hand tools, weeding and water lifting devices. Their farms provide a subsistence livelihood for more than 70 per cent of the population and contribute significantly to foreign exchange earnings. Rain-fed traditional farming includes nomadic transhumance (moving with livestock and growing short-maturity subsistence crops), and sedentary agriculture with significant numbers of livestock. This system exists to some extent in most states.

A remarkable feature of the growth in the TRF subsector during the 1990s was the strong annual growth in the production of oil seeds such as sesame (14.9 per cent), and groundnut (25.5 per cent), which was largely due to an increase in the cultivated area. Non-traditional crops such as melon seed and karkade (*Hibiscus sabdariffa*) have also become prominent in this subsector, with sharply increased exports in recent years. The Food and Agriculture Organization (FAO) estimated that sesame exports accounted for an average of 24 per cent of the world market from 1995 to 2000. In spite of its important role in the Sudanese economy, this sector is marginalized and constrained by many factors. The paper outlines these constraints and shows how traditional knowledge and technologies can support sustainable agricultural development; it also calls for integration between indigenous knowledge and modern technology for sustainable agricultural development.

Introduction

Environmental and physical setting

Sudan is the largest country in Africa (2.5 million km^2) and is severely affected by desertification. It has a population of 30 million, of which 70 per cent inhabit rural areas. The country is generally flat, with the exception of the Red Sea Hills and the Ingessana Hills in the east, and Jebel Marra and the Nuba Mountains in the west. The Nile and its tributaries traverse it for about 900 km. Rainfall ranges from 50 mm in the northern desert to more than 1,500 mm in the tropical rainforest in the south. Variations in rainfall, vegetation and soils resulted in the formation of seven main ecological zones classified as follows:

- desert (0 to 75 mm, covering 28.1 per cent of the country)
- semi-desert (75 to 300 mm, 19.0 per cent)
- low-rainfall savanna on sand (300 to 400 mm, 26.6 per cent)
- low-rainfall savanna on clay (400 to 800 mm, 13.3 per cent)
- high-rainfall savanna (800 to 1,300 mm, 9.5 per cent)

- montane vegetation region (800 to 1,000 mm, 0.3 per cent)
- flood region (800 to 1,000 mm, 3.2 per cent) (Harrison and Jackson, 1958).

In general, the soils are subdivided into desert, central clay plain and *goz* soils. The desert soils in the north include superficial deposits of sands, stabilized and shifting sand dunes, and alluvial soils. As one proceeds from the Nile outwards, the alluvial soils are subdivided into first-terrace *gerif* soils, second-terrace basin soils, and third-terrace (upper) soils. The *gerif* soils are deep, dark brown, well-drained, non-saline, non-sodic, non-calcareous loamy soils. They receive fresh alluvium at intervals, with very little time for profile differentiation to show (entisols). They are very productive and are used, traditionally, for growing vegetables, fruit trees and high-value field crops such as broad beans. However, they are endangered by wind erosion and desert encroachment, particularly in the northern parts of the country. The River Nile itself is endangered by sand encroachment from the Nubian Desert. The second-terrace soils are brown to dark greyish-brown, moderately well drained, calcareous, non-saline and non-sodic. On low-lying lands that receive runoff from surrounding areas, the soils become saline and/or sodic (aridisols). The third-terrace soils are saline and sodic (aridisols).

The soils of the central clay plain (vertisols) extend over the arid, semi-arid, and dry sub-humid climatic zones. The soils of the Gash Delta resemble those of the Toker Delta and vary from medium-textured (entisols) to fine-textured soils (vertisols). The soils of southern Darfur are of fluvial origin and are subdivided into *gardud* (compacted) soils on the levees and clay soils on the plains.

The *goz* soils are quartz sands deposited in northern Darfur and Kordufan and some parts of the White Nile. They lie to the west of the middle clay plain. The *goz* soils are bordered by the desert in the north and by the Nuba Mountains and the narrow strip of the southern clay plain in the south.

Desertification: processes, causes and effects

Sudan is dominated by arid, semi-arid and dry sub-humid areas, which are affected by desertification processes that include degradation of vegetation cover, wind erosion, water erosion, salinization/sodication, reduction in soil organic matter, soil crusting and compaction, and accumulation of substances toxic to plants or animals (FAO, 1979). These processes are caused by climatic variations, human-related activities and climate change.

In Sudan, desertification operates to varying degrees in the areas lying between latitudes 10° and 18° N, and traverses the country from the eastern to the western borders. It also covers a narrow strip of land along the River Nile, stretching northward to the Egyptian boarder between longitudes 30° and 32° E. Thirteen states are affected by desertification: Northern, El Neil, Red Sea, N. Kordufan, N. Darfur, W. Kordufan, W. Darfur, Kassala, Gedarif, Khartoum, White Nile, Gezira and Sennar. The areas of desert, semi-desert and low-rainfall savanna on sand and clay cover 87 per cent of the country. Desertification ranges from very severe in the northern fringe of the semi-desert ecological zone to moderate in the southern fringe of the low rainfall savanna (Ministry of Agriculture, 1985). Recent estimates have shown that wind and water erosion, and chemical and physical deterioration of the soil affected 27.0, 18.2, 15.8 and 3.0 million hectares, respectively (Ayoub, 1998).

Soil degradation is highly correlated with human population density. The most degraded zones are the arid and semi-arid zones where 76 per cent of the human population lives. Most of the people in the affected States are poor and rely heavily on the natural resources for subsistence (cultivating marginal sandy soils, cutting trees and vegetation for fuel and construction of huts, and overgrazing). Degradation of the vegetation cover increases soil erosion, which results in loss of soil fertility or the complete loss of soil itself. Thus, in the drylands of developing countries such as Sudan, desertification is visualized as a problem caused by humans.

Under moist sub-humid or humid conditions, the soil is naturally resilient; that is, it has an inherent ability to restore its life support processes if the land degradation is not too severe. However, under arid, semi-arid and dry sub-humid conditions, the soil is not resilient and prompt human intervention is essential for soil protection, remediation or rehabilitation.

The overall impact of desertification is reflected by stagnating or declining crop yields and the reduced carrying capacity of range and pasturelands, culminating in food insecurity and increasing levels of poverty. Thus, there is a direct correlation between desertification and food insecurity in western and eastern Sudan. Poverty leads to subsistence agriculture, which enhances land degradation and leads to desertification, which in turn aggravates poverty. This vicious circle can only be broken if national programmes for combating desertification are integrated with strategies of poverty alleviation (UNCCD, 1995; Mustafa, 1998).

The agricultural sector

Subsectors

The diverse ecological zones of Sudan reflect the country's great agricultural potential. In spite of the development of the oil industry in 1999, agriculture is still the predominant sector in Sudan's economy, and is the main source of employment and livelihood for over 85 per cent of the population (Ahmed, 1994). In the mid-1980s, it was estimated that this sector contributed 37 per cent to GDP and generated 95 per cent of the foreign exchange earnings (Shaa Eldin, 1986). As agriculture declined in the mid-1980s and the early 1990s due to serious droughts that persisted for two successive periods (1983–85 and 1991–92), its share of total GDP fell to 28 per cent. However, it recovered to about 37 per cent by the year 2000 (World Bank, 2003).

A 1978 estimate (based on surveys), indicated that 35.4 per cent of the total area of the country was suitable for agriculture, with around 3.3 cultivated at any one time, 10.1 per cent was pasture, 38.5 per cent was forest and scrub, and 16.0 per cent was not usable for agriculture, grazing or forestry (World Bank, 1978). Since then, there have been changes in these proportions. For example, the area under cultivation has probably doubled and the currently cropped area is estimated at 16.4 million ha, about 20 per cent of the potential arable land.

In Sudan, the agricultural sector comprises both plant and animal production. Plant production, referred to in this paper as the agricultural sector, has three main subsectors: irrigated, semi-mechanized rain-fed (SMRF) and traditional agriculture. The traditional subsector consists of a traditional rain-fed (TRF) and a traditional irrigated (TI) farming system. The Ministry of Environment and Tourism of the Sudan Government (1996) indicated that out of 14 million ha of cultivated arable land, 2.1, 5.0 and 6.9 million ha are farmed under irrigated, semi-mechanized and traditional methods. The Central Bureau of Statistics estimated that the irrigated, semi-mechanized and traditional rain-fed agriculture accounted for about 21.3, 6.4 and 16.3 per cent of the value of the total agriculture production in 1998, respectively. In the same year, the value of livestock production accounted for almost 40 per cent of the total value of production in Sudan. The production of oil slightly reduced the overall predominance of agriculture, but did not affect the relative importance of the farming systems within agriculture.

The irrigated subsector is one of the pillars of Sudan's strategy for agricultural development. There are between 1.7 and 2.1 million ha of land suitable for irrigation in Sudan within the Nile basin in the Northern, Khartoum, Gezira, Sennar, Blue and White Nile states. The Gezira irrigation scheme, established in 1925, accounts for almost half of that area, about 0.84 million ha under gravity irrigation. Three other schemes along the Nile (Rahad, Suki and New Halfa) have a total command area of 0.42 million ha. These are owned and managed by the central government. There are three sugarcane schemes and many other small private irrigated schemes (World Bank, 2003).

The SMRF subsector was developed in 1945 under the auspices of the government through crop production schemes on generally alkaline clays and loams that are not suitable for cultivation by hand or with animals. These government leasehold schemes are now well over 420 ha each, which was the initial allotted area. The government also allocated large areas (between 21,000 and 420,000 ha) to Sudanese and foreign investors. The farms of this subsector spread over 5.9 million ha in the states of El Gedarif, Blue Nile, Upper Nile, White Nile, Sennar and Southern Kordufan (Nuba Mountains). Land preparation, seeding and most threshing on these farms are mechanized, while weeding, harvesting and some threshing are for the most part done by seasonal labour. It is estimated that approximately 80 per cent of the SMRF subsector is devoted to sorghum, which is central to national food security and also earns some foreign exchange. In the traditional subsector, by contrast, most of the sorghum is produced for subsistence (UNDP, 1990).

The TI farming system consists of three types: *gerif*, island and basin cultivation. The *gerif* is the local name for the narrow strip of the flood plain in close proximity to the River Nile system, which is normally flooded by the river during the rainy season. The land is used for growing fodder and vegetable crops after the Nile recedes. Islands and basins are partially or fully flooded by the River Nile, and they too are cultivated after the flood period. Most of the farms are small, ranging between 0.42 and 2.1 ha.

The TRF farming system includes nomadic transhumance (moving with livestock and growing short-maturity subsistence crops), and sedentary agriculture with a significant number of livestock. This system exists to some extent in most states, but is most prevalent in the three Kordufan states, the three Darfur states, Sennar, and the Blue and White Nile states. Animal production is an important element of this system since it provides a major capital asset and a risk management tool for pastoralists and farmers. The non-nomadic small farmers typically have 4.2 to 6.3 ha in which they produce food crops (e.g. sorghum and millet) as well as cash crops such as karkade, sesame and watermelon seeds. The total cropped area in this system is estimated at 7.5 million ha. Gum Arabic is harvested in the woodland forest areas (World Bank, 2003).

Performance

Table 6.1 shows that the mean annual growth rate of irrigated crops increased from 2.3 in the late 1980s (1985–91) to 7.9 in the 1990s (1991–8), whereas the SMRF subsector experienced a decline, which was much higher in the earlier (–31.4 per cent/year) than the later period (–2.9 per cent/year). Although TRF

Table 6.1 Growth rates and GDP shares for subsectors in agriculture

Item	Per cent per annum (1985/86–1990/91)	Per cent per annum (1991/92–1998)	GDP (1998) (%)
Irrigated crops	2.3	7.9	21.3
Rain-fed semi-mechanized crops	–31.4	–2.9	6.4
Rain-fed traditional	–12.2	24.2	16.3
Minor	–8.6	–0.2	0.8
By-products	4.7	0.1	4.8
Total crops	–3.7	8.6	49.6
Livestock	5.1	10.4	39.9
Forestry	–0.1	–12.6	9.1
Fisheries	4.1	11.0	1.4
Total	0.4	8.5	100.0

declined in the late 1980s, it showed the highest growth rate (24 per cent/year) in following decade. The decline in both SMRF and TRF was caused by the severe drought of 1983–85 and the less severe one of 1990–91. In the agricultural sector as a whole, the contribution of TRF to GDP was more than double that of the SMRF subsector. The variation in growth rate is related to the variation in cropped area and yield. The change in the harvested area is a result of government pressures to change the cropping patterns in the large government irrigated schemes. In the early 1990s, the government requested irrigation schemes to increase the production of wheat and sorghum as a contribution to the food security policy that it initiated after the drought period. The area of wheat increased sharply in 1990/91, but then declined steadily because of disappointing profits. The fluctuations in the SMRF subsector were due partly to the unpredictability of government policy on restricting exports of sorghum, and partly to low and erratic rainfall.

A remarkable feature of the growth in the TRF system during the 1990s was the marked increase in the production of oil seeds such as sesame (14.9 per cent per annum), and groundnut (25.5 per cent per annum), largely due to an increase in the harvested area. Non-traditional crops such as melon seed and karkade also became prominent in this subsector, with sharply increased exports in recent years. FAO statistics showed that sesame exports accounted for an average of 24 per cent of the world market from 1995 to 2000 (World Bank, 2003).

Trends in crop yields vary widely among the different farming systems (Table 6.2). The yields of SMRF- and TRF-sorghum, which is the most important food crop in Sudan, ranged from 0.5 to 1.5 ton/ha. Its yield trend line showed a sharp increase in the late 1970s, very low and nearly similar yields in the late 1990s and fluctuating declines in between. The trends for both rain-fed sectors were similar.

Linkage with sustainable development

Sustainable development is defined as 'the development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). The essential human needs include food, housing and clothing; this explains why sustainable development is closely related to sustainable agriculture, which means making optimum use of natural resources to satisfy basic human needs without degrading these resources for present and future generations. Thus, sustainable development in the developing world is closely linked to sustainable land use and management (SLUAM) of natural resources at the local level. There are several technological options for SLUAM that enhance soil resilience and sustain a desirable socio-economic level of the local community (Mustafa and Saeed, 2004). The World Commission on Environment and Development (WCED, 1987) pointed to the urgent need to consider and value traditional knowledge and technology as important factors in achieving sustainable development. There is a clear link between traditional knowledge and sustainable development.

Table 6.2 Growth rates of production, area and yields for major annual crops in three main farming systems (Per cent per annum)

Period	Irrigated			Semi-mechanized			Traditional		
	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield
1971/72–80/81	–5.4	–8.3	2.9	4.1	–6.4	10.5	7.5	–0.5	8.0
1981/82–90/91	2.5	1.6	0.9	–3.1	2.2	–5.4	–11.7	–1.9	–9.8
1991/92–00/01	–3.7	–4.9	1.2	–7.5	–2.4	–5.0	12.8	9.9	2.9

Traditional farming and sustainable development

Traditional farming (TF), as part of traditional knowledge, relies upon the indigenous information base of farming in a given area, and for many decades it has helped local communities in Sudan to thrive and cope with their harsh environments and significantly supported their livelihood. The following components of TF promote soil resilience and sustainable agriculture:

- *The adoption of a cultivation bush–fallow rotational system*. The *Acacia senegal*–millet/sesame/groundnut system is adopted in many parts of Sudan (for example, Kordufan, western Sudan). The land supports trees for twelve years, yielding gum Arabic from mature *Acacia senegal* (Hashab) trees during the last eight years. The trees are then felled to produce firewood and the land is cultivated for four years, usually with millet, sesame or groundnut. When loss of soil fertility becomes apparent, as indicated by low yields of crops and infestation by buda (*Striga* spp.), the land is left fallow. After Hashab trees degenerate, the field is cleared and the land is cultivated. To support an average family requires about 24 ha of land, divided into sixteen plots of 1.5 ha arranged in a series of normal age classes (Skoupy, 1993). *Acacia senegal* produces gum Arabic, which is a very important cash crop. The trees control soil erosion, improve infiltration rates, restore soil structure, regenerate the fertility of exhausted soil by fixing nitrogen, and act as a good fodder reserve for camels.
- *Combined production systems*. These are sustainable land-use systems, because they create diversity and maximize the benefits from their various components. The sylvo-pastoral system is practised in western Sudan, and many Acacia trees and shrubs, which are rich in proteins, vitamins and mineral elements, provide good green fodder (leaves, flowers and fruits) for the nomads' livestock. An agro-pastoral (mixed farming) system is practised to a limited extent in the traditional sector. Mixed farming can be a stable system for small landholders if pastures are lightly grazed, the stocking rate is low, and animal waste is applied to the land to replenish soil fertility. Agroforestry is another sustainable land-use system because it restores the soil, protects the crops and animals against winds and extreme temperatures, and provides wood, fuelwood, and fodder for the population. Some agroforestry is practised in TRF, with some trees being left on the land.
- *Multiple cropping*. Farmers sow a combination of crops in the same field or a number of crops at one point (for example, intercropping watermelon with millet or sorghum in western Sudan). Multiple cropping is suitable for traditional farming systems. It increases crop productivity per unit area, provides shelter for planted crops, and soil cover against weeds and erosion.
- *Intercropping*. In western Sudan (for example, En Nahud) two types of intercropping are practised. Karkade and watermelon are intercropped with millet and sorghum in the same field. Millet and sorghum are also intercropped with sesame in the same hole to serve as windbreaks, because sesame is susceptible to wind damage. Intercropping has several advantages: it helps farmers who cannot afford to expand their operations through land clearance; the various crops are weeded together; a failure of one crop may be compensated by the success of others; and crops will protect each other from wind damage.
- *Use of traditional farming tools*. These are an important heritage of rural communities in Sudan. They include all the tools used in land preparation, sowing, weeding, harvesting, water lifting and storing (Al-Batal, 1994). They are inexpensive and environmentally friendly; they conserve soil and water, saving the soil from compaction caused by other implements, and hence promote sustainable land use.
- *Indigenous weeding practices protect the land from pollution or accumulation of toxic pesticides in soils and plants* (Sharland, 1989). The use of the traditional plough for weeding is environmentally friendly since it pollutes neither the soil nor the crops. The farmers know how to identify the types, behaviour and growth of vigorous weeds.
- *Mulching*. In most traditional farms, the crop residues are left on the soil surface after weeding. This surface mulch promotes soil and water conservation, regulates the soil temperature regime and improves soil structure, enhances microbiological activity, and protects the soil from wind and water erosion and from extreme desiccation. Mulches also suppress weed growth. Live mulch, a system of growing grain/food crops through low canopy cover crop, may also achieve the benefits of crop residue mulch.
- *Application of animal manures*. Traditional farmers in the rural areas have long known that animal manure enriches soil fertility. In northern Sudan, the farmers tie their cattle in a fallow field at night to manure the land *in situ*. After four or five nights, the cattle are moved to a different plot to manure it. A partially fermented mix of animal manure and soil (compost) is also used as a fertilizer.
- *Use of indigenous seeds*. Traditional farmers know how to produce and select high-potential seeds by observation and single plant selection, and how to conserve and store them. They plant local sorghum and millet varieties for their stable food. For centuries, they have been the main custodians

of the various varieties of seeds. The introduction of hybrids has caused the loss of many indigenous varieties.

- *Traditional water harvesting techniques*. The people of western Sudan have developed ways of harvesting rain water in time of need. The systems that have been used since time immemorial include various versions of pits, bunds and 'terraces'.

Selected case studies

Northern Sudan (Mahas area)

Traditional irrigated agriculture has been practised since time immemorial (Al-Batal, 1994) in the Mahas area, which lies in the desert region between latitudes 14° 42' and 21° N. In the flood season (August to mid-October), the farmers cultivate millet (grain and fodder), maize, cowpeas, watermelons and vegetables. In winter (October to April), wheat, barley, maize, sorghum, safflower, chicken vetch, chickpeas, haricot beans, fenugreek, field peas, faba beans, lupins, *dolichos lablab*, onions, garlic, tomatoes, rocket cress, cumin, caraway and coriander are grown. In the summer season (May to August), some millet, *dolichos lablab*, is cultivated.

Land preparation begins with the maintenance of the water wheel (*sagia)*, which is shared by a number of farmers. In the past, the timing of the start of cultivation was decided by a religious leader or an experienced elder. Land is divided randomly between farmers by a traditional method, weeded and tilled by a traditional plough. This is done by the family or by the group of farmers (*faz'a*). The land is sometimes watered to allow the new weeds to germinate, and then weeded with a hoe or a traditional plough. A rake is used to collect the dry weeds, which are burned or used as fodder.

After land preparation, sowing is done by broadcasting for wheat and barley, or by placing seeds in holes made by hoes or sowing sticks for millet, maize, okra, sesame, sorghum and similar crops. The crop is then watered, through main earth and subsidiary canals, with stones or buckets placed at the water entry point to protect the canals from erosion. Millet, leguminous crops and wheat are rotated, with frequent fallow periods to alleviate soil deterioration. The farmers tie their cattle in fallow fields at night to manure the land *in situ*, moving the cattle to a different plot every four or five nights. Children are employed to scare away birds, which are natural enemies.

Harvesting is a cooperative effort of the farmers' *faz'a*. Wheat straw is chopped by sickles at the middle level, tied in bundles and left to dry in the sun near the threshing floor. Millet and maize are cut at the ground level and lined up on the field. The cobs are then cut, by hand or with a sickle, placed in buckets or sacks, and transferred to the threshing field to dry in the sun. Sesame and faba bean plants are cut below fruit level, tied into bundles and placed on the threshing floor. They may be threshed by an animal-powered device or by the treading of donkeys. A rake is used to separate the seeds from small straw pieces. Winnowing is then carried out by old women.

The system has changed very little since the *sagia* era. The operations have remained almost the same. Commercial chemical fertilizers have to some extent replaced animal manure, which is now used only on a limited scale. The diesel pump has replaced the water wheel, making it unnecessary to divide up the watering time or for farmers to communally establish and administer a *sagia*. The *faz'a* system is still in use because of scarcity of labour. Al-Batal (1994) concluded that the introduction of the modern water-lifting pump had not been followed by any major change in the traditional agricultural system.

Western Sudan (En Nahud district)

This TRF case study was based on a field survey involving eighty-eight farmers: sixty-four men, and twenty-four women (Abd Elgadir, 1994). Like all traditional rain-fed agricultural systems, farming in the area is land extensive, labour intensive, and constrained by low and erratic rainfall, low soil fertility and pests. Staple food (millet and sorghum) and cash (groundnut sesame and karkade) crops are grown in a long cultivation–fallow rotational system, with *Acacia senegal* trees dominating other trees and bushes during the fallow period. Sorghum is intercropped with sesame, and watermelon is intercropped with millet and karkade in the same field. The cultivated area of all crops has increased markedly (Table 6.3). The yields of all crops were extremely low and showed trends of overall decline between 1982/83 and 1992/93, due to declines in rainfall, crop damage by pests (rats and locusts) and lack of finance.

Farmers in the study area as well as in other areas of traditional rain-fed agriculture have developed methods and strategies to cope with the limitations imposed by the natural environment and the socio-economic conditions. These methods include:

- *Land clearance*. Farmers attempt to clear their land well in advance of the growing season to reduce carry-over of pests from one season to the other. Farmers also attempt to avoid planting their crops close to fallow fields because of the pests inhabiting them.
- *Mulching*. Crop residues are left in the field to protect the soil from wind erosion.
- *Early sowing*. About 90 per cent of the farmers sow between June 1 and July 1. Unless the rains are followed by dry spells or rats remove the seeds, early sowing will give good yields.

Table 6.3 Cultivated area (ha) and yield (kg/ha) of various crops grown in En-Nahud province (1982/83–1992/93)

Year	Sorghum		Millet		Sesame		Karkade	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield
1982/83	110,885	105	271,407	136	222,747	267	7,856	79
1983/84	102,806	83	319,805	169	41,203	107	6,854	67
1984/85	62696	48	462,410	33	55,430	29	5,502	31
1985/86	32263	286	483,390	190	53,143	171	6,930	71
1986/87	33238	357	345,970	229	61,694	262	17,501	71
1987/88	9772	214	46,315	29	23,598	160	8,956	36
1988/89	34090	214	2,318	117	65,825	207	8,313	110
1989/90	38953	24	26,213	45	65,113	7	10,714	12
1990/91	2171	24	2,158	21	13,944	29	2,158	21
1991/92	81878	71	527,882	81	33,633	38	27,329	19

Source: Regional Ministry of Agriculture, El Obied.

ND = No data

- *Intercropping*. This technique is adopted in this village.
- *Regular intensive weeding*. This is essential for the control of weeds especially buda (*Striga spp.*) to protect the crop establishment.
- *Seed dressing and improved seeds*. The study indicated that improved seeds increased yields of groundnut more than seed dressing and/or pesticides.
- *Cultivation–bush fallow rotational system*. Rotation is practised.
- *Pest control*. Children carry noisemakers through the fields to scare birds and locusts. Farmers erect scarecrows and destroy bird nests in trees.

Blue Nile State (Abu Gumi village)

This is a case of TI and TRF farming systems (El Medani, 1994). The village of Abu Gumi lies on the western bank of the Blue Nile about 6 km south of Al Damazin town. It lies in a semi-arid ecosystem with mean annual rainfall ranging between 500 and 600 mm (June to October). The rainfall is higher in the north than in the south.

Before the construction of the Roseris Dam in 1960, the Nile used to rise about early June and recede gradually by the end of September or early October, reaching its lowest level by December. The area uncovered by the receding river, known as *gerif*, was cultivated twice a year by villagers (each having an area of 2–10 feddans) who grow maize, tobacco and vegetables there.

Since the dam was built, cultivation has depended on the opening of the dam gates and recession of the water. The area is cultivated once a year to harvest one or two crops. Seeding starts after the dam's opening and continues until the river reaches its lowest level in March or April. Seeds are sown on the slopes of the riverbank where water recedes first. Cultivation of *gerif* is easier than the upper terrace soil classified as vertisol and known locally as *dahara* or *bildat*, since the soil is more fertile, easier to plant and requires no weeding. However, it also has some disadvantage. First, the farmers will sometimes be busy with their *bildat* cultivation; second, if the dam gates are closed early, the rising water will damage the crop; and third, trespassing livestock owned by nomads may damage the crop.

Shifting cultivation is practised in the *bildat*, with the field being changed every seven to ten years. Each household cultivates 5–35 feddans, depending upon the size of the family (and thus the available labour). The two main crops are sorghum (the staple crop) and sesame (for cash). There are small household gardens close to the houses for growing vegetables for home consumption. The farmers clear their land by cutting the tall, weedy grass (*diwairata*) first, before it matures and scatters its seeds, and then the small bushes, shrubs and herbs. Plant residues are left on the ground to be burnt later. *Acacia senegal* and *Acacia seyal* are cut four feet above the ground in the dry season. Hegleig (*Balanites aegyptiaca*) is never cut because it is believed that it brings rains and protects the field from wind. Villagers believe that it is possible to grow crops under hegleig, but not under acacia trees.

The Hamaj tribe divides the rainy season, *kharif,* into a sequence of events grouped into ten thirteen-day periods; each is locally referred to as *manzila*. These periods are used as indicators for the various agricultural practices (for example, planting, weeding and scaring away birds). In the last two periods, *iwa* and *simak*, recognized by the appearance of a star, *Irieq*, the activities include driving away birds and harvesting. Sesame is harvested first with the help of hired labour. Men use a sickle to cut down sorghum plants, and women cut off the sorghum heads. Some is threshed in the house and the rest in the field. If there is a good amount of rain at this time, a second harvest may be taken and used as a fodder or sold to nomads. During this period, the farmers start clearing their new fields.

The Hamaj tribe are able to use and manage their land to meet their needs with minimum labour input: family members, and the cultural and social institution of *nafir*. Some hired labour is used for harvesting sesame.

Conclusions and recommendations

Traditional agriculture has many sustainable features. At present, it occupies about 40 per cent of the total cultivated land and provides a subsistence livelihood for more than 70 per cent of the total population. Nevertheless, it is marginalized and deprived of financial and technical support. Since independence, the agricultural policies and strategies have favoured the modern sectors, the irrigated subsector much more than the semi-mechanized rain-fed subsector. In the early 1990s it was estimated that 75 per cent of agricultural finance was allocated to irrigation and expansion of irrigated areas, 15 per cent to agricultural industries, and only 10 per cent livestock, fisheries and forestry (Ahmed, 1994).

Crop yields in this sector are very low and progressively declining because of low and erratic rainfall, land degradation, low soil fertility, pests and lack of financial, research and other support. At present, due to these constraining factors, traditional farming does not meet the needs and aspirations of the local poor people in the rural areas of Sudan. Thus, it is important to address these constraints and integrate sustainable features of both traditional and modern farming systems to enhance sustainable agriculture and promote the overall economic development. In this respect it is recommended that:

- Traditional farming knowledge and technology (TFKAT) should be considered an integral part of the broad spectrum of traditional knowledge and technology in all fields.
- The development of traditional farming should be considered a priority area in the national agricultural development plan at the local level.
- A thorough inventory of TFKAT should be made. The development of this inventory should be one of the mandates of the Agricultural Research Corporation (ARC), which will then be required to collect, sort, package and document TFKAT into operational formal forms for national use at all levels.
- An institutional channel should be formed for transmission and dissemination of TFKAT.
- A TFKAT syllabus should be developed and offered to the students at all levels of the agricultural education system.
- The ARC should develop a research programme to address the constraints of traditional farming and its integration with modern technology.

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7 Management of degraded soil rehabilitation processes in Azerbaijan by traditional methods

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The problems of soil degradation and soil exhaustion around the world are a cause for alarm. They are closely associated with the process of active development in many countries, and particularly in arid zones. Azerbaijan also encounters these problems, which include erosion, desertification and other aspects of soil degradation.

The work of various scientists (including, in the last few years, Ruellan and colleagues, Zimovetz, Dobrovolskiy, Mirukhlava and Chernyavskaya) and of the Institute of Soil science and agrochemistry of ANS of Azerbaijan has been summarized here. They recommend the following lines of investigation:

- Determine the cause of soil degradation for the relevant regions in Azerbaijan.
- Determine the degree of soil degradation.
- Compose a soil degradation map of the site.
- Define recommendations for prophylactic measures against soil degradation.
- Create a systematic expert system for the evaluation of soil degradation.

The Azerbaijan Republic is situated in the southeastern part of the Trans-Caucasus at latitudes of 39°–42° and longitudes 45°–50°. It covers an area of 86,600 km^2 and has a population of more than 8 million. In the eastern part, 800 km of the territory borders the shore of the Caspian Sea, while in the north the territory is bounded by the watersheds of the main Caucasus mountain range. The extremely varied and rich natural conditions of the republic are a result of the exceptional diversity of soil cover and the different specializations of multi-branch agricultural and industrial production.

The structure of the relief is sharply complex: starting with lowland, which is 28 m below sea level, and rising to 5,000 m at the mountain summits. The characteristics of the altitudinal zone in terms of natural water, vegetative and soil resources are similar to the relief found throughout the republic.

The degenerative and accumulative processes are complicated by the intensity of human activity, which uses natural resources in an irrational way. Of the total area of the Republic (8,641,566 ha): 4,540,581 ha or 52 per cent is agricultural land; 1,454,258 ha is irrigated; arable land occupies 1,673,949 ha; irrigated fields make up 1,000,360 ha; long-standing plantations comprise 245,600 ha with 0.18 ha of arable land per head of the population. About 4,210,000 ha or 60 per cent of the area consists of mountain areas.

The main types of soil degradation in Azerbaijan are a result of:

- loss of organic matter (degumification)
- weakening of biological activity
- physical degradation
- wind, water and irrigated erosion
- salinization
- saline–alkaline conditions
- lack of nutrients
- lack of moisture
- technological and chemical pollution
- soil loss
- increased acidity.

The intensive use of soil for monoculture is one of the main causes of the onset of soil degradation. In this regard, use of inappropriate technical measures has led to the loss of soil organic matter in an area covering more than 1.5 million ha, decreasing their biological activity by 1.5–2.0 times.

The physical degradation of the soil as a result of the influence of intensive agricultural techniques leads to structural disturbance: concentration of the soil layer under tillage, and decreasing porosity in some cases due to the loss of the upper layers (affecting an area of up to 0.5 million ha).

The mountainous areas of the Republic are characterized by remarkable differences in height and sharp relief. This is why about 41.8 per cent of their soils (3.61 million ha) are exposed to erosion to various degrees. The most widespread types of erosion in these areas are a result of the action of wind and water irrigation. Here the influence of natural factors is further aggravated by disturbances from zonal agrotechniques.

The salinized soils of Azerbaijan are mainly found in the Kura-Araks lowland and Apsheron peninsula, which have an area of 1.5 million ha. The soil structure is affected by the following salts: soda, chloride, sulphate, sulphate-chlorite and chloride-sulphate. 500,000 ha of salted soils are meliorated.

In these regions the irrigated drainage systems are out of order everywhere. This fact, together with the disruption of the irrigated regime, has led to repeated soil salinization with the formation of saline–alkaline areas.

The incomplete restoration of nutrients carried away through the harvesting of agricultural plants, the inefficient use of organic fertilizers and the inappropriate use of crop rotation (or a complete absence of it) has led to a twofold or threefold loss of nutrients in an area of 1.5–2 million ha.

Oil-polluted soils in Azerbaijan occupy about 30,000 ha – most notably in the Apsheron peninsula (13,000 ha) – and are heavily polluted by oil waste and bitumen.

Chemical pollution of soils in the Republic affects an area of 840,000 ha, and is mainly caused by residues of pesticides, herbicides, radioactive elements and heavy metals. These areas extend into the zone of the mining extractive industry and the zone of military operations.

In the arid zone of the Republic (with an area of 2.5–3 million ha) the moisture and aridity observed is not only due to natural factors but also to the irrational use of irrigation, ineffective methods of irrigation, water loss and a reduction of vegetative cover.

In the zone of humid subtropics, and in particular in the Lenkoran region, soil acidity has increased due to long-term tea plantations (13–15,000 ha).

When speaking about types of degradation, it is important to note the loss of fertile soils because of industry, urban structures, roads, airports and other construction.

To combat the process of degradation, scientifically tested technologies need to be developed, thus promoting the optimization of the natural environment and the stable management of the process of degraded soil restoration. To develop these technologies it is necessary to take into account traditional methods and consider which of them are acceptable in terms of time and the conditions of regional use. The technologies include agro- and phytomeliorative measures to restore carbon (organic), nitrogen (total), soil biological activity and vegetation in the degraded pastures and Tugay ecosystems. Account must also be taken of the zonal soil–climatic conditions and the use of combined meliorative and agrotechnical methods to protect soil from erosion (soil-protective crop rotation, anti-deflation forestry zones, link sowing, soil-protective technology of cultivation including non-mouldboard friability with root remnants, minimalization methods). The irrigation system must incorporate progressive methods of surface watering (discrete watering on furrows, automatic watering and so on) in addition to the technology of dropping irrigation, to make economic use of irrigation water.

In order to prevent excessive evaporation of the scarce moisture and to allow for microelement improvement, mulching techniques can be applied by using vegetative residues such as silt from river water, ceolite, turf, and waste from the fish, wine and silk-production industries. Another meliorative measures that can be used is crop rotation with salt-stable plants.

In the last sixty to seventy years, soil resources have been severely depleted, largely through anthropogenic influence. In order to protect and reconstruct the natural resources, it is necessary to examine them in terms of their evolutionary order: that is, to analyse their current situation, identify changes and determine methods to begin the processes of improvement.

In order to ascertain the extent of soil degradation, we need to examine six indices relating to biological activity, seven indices reflecting physical degradation, and five indices relating to the salt condition of the soil. Erosion, food shortage, moisture and soil pollution are other factors that are also relevant. In total, twenty-eight indices need to analysed. Every index of degradation is marked at one of five degrees of the degradation: from '0' reflecting normal soil conditions to '4' representing maximum disturbance (Table 7.1).

Examples of the first soil degradation maps include maps of Albania (Zdruly and Lusnay, 2000), Hungary (Varalyay, 2000), Romania (Ladjatza, 2000), Russia (Sanin, 2000) and Bielorussia (Medvedyev, 2000). The country maps of soil degradation differ in how they calculate soil and climatic conditions. The complex maps are compiled for various kinds of degradation (erosion, salt and others) due to anthropogenic influences. Soil degradation maps are compiled on the basis of exact soil maps. In this way the natural and anthropogenic factors influencing soil cover can be given significant meaning. As an example we may take the map of the soil cover degradation of Mil-Karabakh plain. The plain is a spacious territory (772,000 ha) and is used for agricultural production (40 per cent of the general area). Its soil–climatic conditions are favourable for cultivating valuable agricultural plants (cereals, bean, grape, pomegranate, cotton and others).

On the basis of the Mil-Karabakh plain soil map (scale 1:200000) a map of soil cover degradation has been composed for this zone (Figure 7.1). It reflects the geographical location of types of soil cover degradation. In the key to the map, all degradation types and sub-types of soils are shown, as well as the area they occupy, agro-industrial characteristics and limiting factors, agromeliorative measures and potential for changing use.

By bringing together experience of long-standing complex soil investigations in the Azerbaijan Republic, a system of expertise of the state of soil degradation in Azerbaijan has been created. This approach differentiates the level of soil degradation that applies. Maps of soil cover degradation are therefore drawn up for the separate regions of the Republic and a choice of prophylactic measures for removing negative processes is recommended. Methodical recommendations about soil degradation in Azerbaijan Republic are prepared, and on this basis a computer database of soil degradation expertise is composed.

These technologies are parts of the struggle to solve the problems of soil degradation and desertification. We are not attempting to go against nature's strength; on the contrary, we aspire to restore the regional natural ecological balance.

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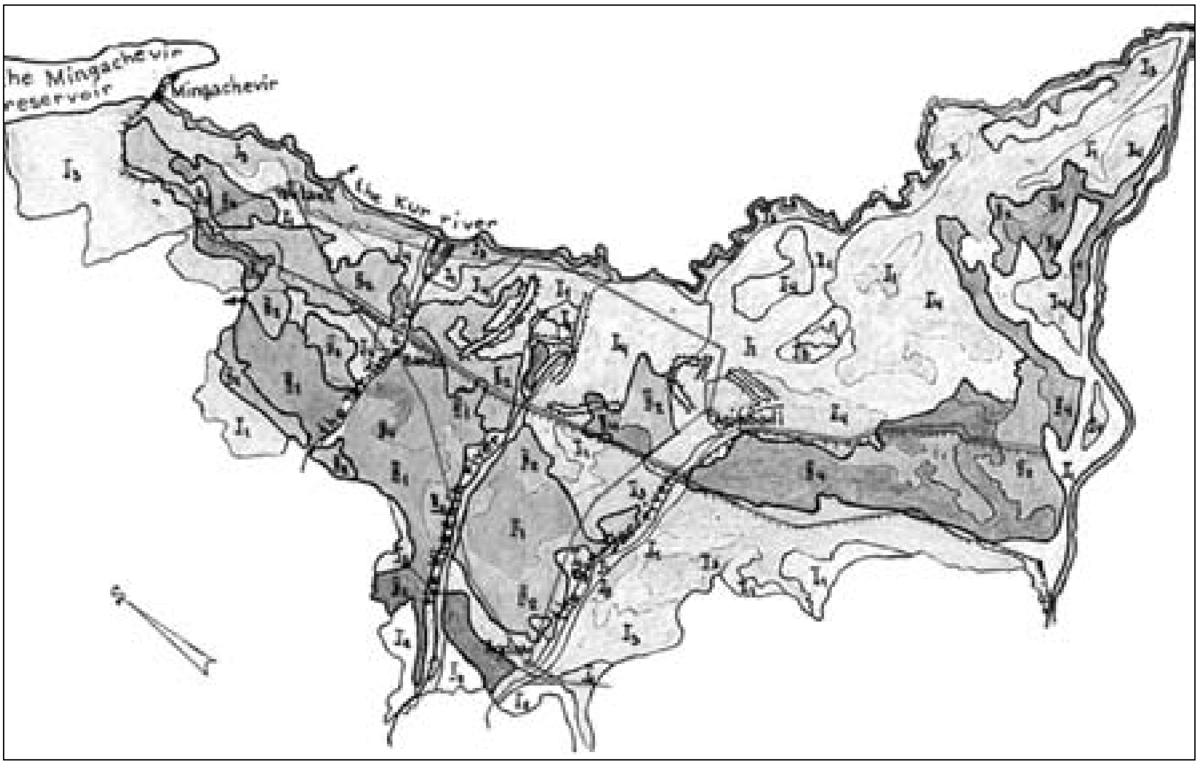

Figure 7.1 Soil cover degradation map of Mil-Karabakh plain of Azerbaijan, 2002
(See next page for key)

Key to soil cover degradation map of Mil-Karabakh plain

Soil degradation	Soils	Extent (ha)	Agro-industrial differences and limited factors	Agromeliorative measures	Agricultural potential
			I. Influence of natural factors		
Normal soils I1	Virgin, greyish-brown (chestnut), meadow	163,000	An even surface, with slight slope; under ground water level (UWL) 3–5 m, humus layer 30–50 cm, with N,P,K; schistous, with signs of claying	Regulating pasturage, grass sowing, afforestation, planning surface, irrigation-drainage system; agricultural direction – forage preparation, crop rotation, mineral organic and local fertilizer	Cattle breeding, cultivated grasses, watering, technical and cereals, gardening and sericulture
Soil erosion I2	Brown exposing to erosion of soil	20,000	Surface severely degraded (sharply changing); concentrations of carbonate; little thickness, stony	Unfit for watering, concentrating crack, phytomelioration, hydrological structure, afforestation, grass sowing	Cattle breeding, gardening, grape production
Salinity, concentrating I3	Salting, greyish-brown serozem, meadow and meadow-swampy virgin soils	115,000	Somewhat degraded surface, good for watering; carbonate, develops on loess forming stratum and affected by salinity, condensation; signs of claying; thick layer of fine soil, provided by elements of nutrition	Complex of meliorative measures: appropriate irrigation, improvement of collector-drainage system, planning of surface, deep ploughing, sowing of bean fodder crops	Cereals and technical cultures, grape production, grass of high crop capacity, stockbreeding
Salinity-solonetz garden and repeated salting soils I4	Garden-saline meadow–marl soils	114,000	An even surface, with a slight slope, UWL 1.0–2.5 m, strong salinity, solonetz, clayey	Planning of surface, watering on the collector-drainage, use of meliorant on clayey soils	Cotton growing, cereals, growing vegetables and melons, grain–bean, cultural pasturage

Soil degradation	Soils	Extent (ha)	Agro-industrial differences and limited factors	Agromeliorative measures	Agricultural potential
			II. Influence of human factors		
Normal soils II_1	Normal soils Cultured greyish-brown irrigated	57,000	An even surface with a slight slope; UWL 3–5 m; thickness of layer of the fine fertile soils 25–40 cm, average provided by nutritious matter	Terracing in mountain zone, irrigation with rain water, organically, mineral and local fertilizers; crop rotation in plain zone, bean culture planting, wide use of siderates etc.	Cereals and technical culture, viticulture, sericulture, melon growing
Salinity, concentrating II_2	Salinity, concentrating Irrigation, saline, solonetz greyish-brown, grey and meadow soils	136,000	Flatter surface, with a slight slope; good for irrigation; water resources available; present signs of salinity, solonetz, condensation	Complex of meliorative measures, improvement of collector-drainage systems, appropriate regime of irrigation crop rotation	Grain–bean technical cultures and crop rotation of cereals/bean cultures
Stepped soils II_3	Stepped soils Stepped greyish-brown soils	15,000	Unfit for irrigation, surface destroyed; soils developed on carbonate stratum; thickness of fine cultured layer of soils 30–50 cm	Terracing, afforestation and gardening	Forestry, melon growing, viticulture, culture of high crop capacity
Cultured, irrigation-accumulative soils II_4	Cultured, irrigation-accumulative soils Irrigation-accumulative dry steppe and half deserted soils	102,000	Flatter surface, with water resources available; soil developed in agro-irrigation alluvium; has thick cultural layer of soil, structural, fertile	Crop rotation, maintaining watering regime, different norms of organic, mineral and local fertilizers, deepening layer of sowing, resist irrigated erosion	Cereals and technical culture, viticulture, melon growing

Table 7.1 Degree of soil degradation

The indices	Degree of degradation 0	1	2	3	4
Loss of organic matters (humus), weakening of biological activity					
1. Humus AI+AB or thickness of the irrigated layer AI a, sm	>50	41–50	31–40	21–30	<20
2. Decrease in humus supply, in % from norms: A+AB	<10	11–20	21–40	41–60	>60
AI a	<10	11–30	31–50	51–80	>80
3. Humus quantity, in %: AI+AB	5–10	4–5	3–4	2–3	<2
AI a	4–5	3–4	2–3	1–2	<1
4. Cf.a.: Ch.a.AI+AB	0.8–1.0	0.7–0.8	0.6–0.5	0.4–0.5	<0.4
AI a	1.2–1.4	1.0–1.2	0.9–1.0	0.8–0.9	<0.8
5. The quantity of CO_2 in soil air supply, in % of the volume	>0.5	0.4–0.5	0.3–0.4	0.2–0.3	<0.2
6. The activity of invertase, mg/gl in 1 gr soil, 24 h	>35	31–35	26–30	21–25	<20
Physical degradation					
7. Compaction, g/sm^3, in % of norms	1.0–1.2	1.3–1.4	1.4–1.5	1.5–1.6	>1.6
8. General porosity, in %	>60	56–60	51–55	46–50	<45
9. Stoniness, in %	<5	6–10	11–20	21–40	>40
10. Quantity of aggregates (>0.25 mm) stable to moisture, %	>50	41–50	31–40	21–30	<20
11. Ability to aggregate, %	>55	46–55	36–45	26–35	<25
12. Productive moisture, 0–25 cm	>90	81–90	71–80	61–70	<60
13. Water-permeability of soils, mm	>3.0	2.6–3.0	2.1–2.5	1.6–2.0	<1.5
Soil erosion					
14. Thickness of the layer of agro-irrigation, cm, AIi	>80	61–80	41–60	21–40	>20
15. Soil profile decrease (A+B), in % of norms	<5	5–20	20–40	40–80	>80
Salinity and solonetz					
16. Easily soluble salts, in %					
Soda	<0.15	0.16–0.30	0.31–0.50	0.51–0.80	>0.8
Sulphate-chloride	<0.25	0.26–0.50	0.51–1.00	1.10–2.00	>2.0
Chlorine-sulphate	<0.40	0.41–0.80	0.81–1.50	1.60–2.50	>2.5
17. Increase of absorbed Na, in % of absorption capacity	<5	6–10	11–15	16–20	>20
18. Increase of absorbed Mg, in % of absorption capacity	<15	16–25	26–35	36–45	>45
19. Depth of the level of mineralized subsoil waters (>3 g/l), m					
Dry steppe zone >5.5	4.6–5.5	3.6–4.5	2.6–3.5	<2.5	
Half-deserted zone >5.0	4.1–5.0	3.1–4.0	2.1–3.0	<2.0	
20. Rise of the levels of fresh subsoil waters (>1–3 g/l), m					
Dry steppe zone >4	3.1–4.0	2.1–3.0	1.0–2.0	<1.0	
Half-deserted zone >3	2.1–3.0	1.1–2.0	0.5–1.0	<0.5	

The indices	Degree of degradation 0	1	2	3	4
Lack of nutrition					
21. Decrease of microelement quantity, in % of aver. provision.	<10	11–20	21–40	41–80	>80
22. Decrease of the quantity P_2O_5, in % of aver. provision.	<10	11–20	21–30	41–60	>60
23. Decrease of the quantity K_2O_5, in % of aver. provision.	<10	11–20	21–40	41–80	>80
24. Nitrifying ability, mg/kg					
– 15 days	>60	46–60	31–45	16–30	<15
– 20 days	>65	51–65	36–50	21–35	<20
Lack of moisture					
25. Irrigated waters, g/l					
– Mineralized	<1.0	1–4	4–7	7–10	>10
– Quality (carbonate, sodium)	<0.5	0.1–0.2	0.2–0.3	0.3–0.4	0.4–0.5
Chemical and technological pollution					
26. Polluted by oil and oil products, %	<6	6–7	7–8	8–9	>9
27. Polluted by heavy metals	>35	31–35	26–30	21–25	<10
28. The crop capacity, wheat (c/ha)					
– Real	>40	31–40	21–30	11–20	<10
– Potential	>50	41–50	31–40	21–30	<20

Source: M.S. Salayev (1979), Z.R. Movsumov (1978), R.G.Mamedov (1979), G.Z. Azizov (2000), A.B. Jafarov (2000), V.A. Ahmadov (1986) and others.

8 Omayed Biosphere Reserve and its hinterland

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The current paper considers research aimed at developing management strategies for marginal drylands that support the resilience of ecosystems. These are vital for social systems in the western coastal desert of Egypt through their production of goods and services. The western coastal desert of Egypt and its hinterland is renowned for its wealth of natural resources, and has been a point of attraction for development projects due to its richness in natural resources, fine location, good weather and pleasant conditions. Except for the coastal strip, most of the northwestern desert lies in the arid region. Water resources are scarce and variable, and as a result the local community has developed a wide range of strategies for managing water resources in this region. Traditionally, the inhabitants have moved around in search of water, pasture and croplands, with their movements determined by the rainfall pattern. However, the recent sedentary trend has combined with population growth, overuse of water resources, overgrazing and uprooting of indigenous vegetation, climate change, and other political and social forces to exert greater pressure on land resources. This has affected the productivity of the area and the provision of goods and services.

The work described here was carried out by a group of Egyptian researchers for a UNESCO-UNU-ICARDA project named 'Sustainable Management of Marginal Lands' (SUMAMAD). The project is under implementation in eight countries, including the Arab states of Egypt, Jordan and Syria.

The project involved the local inhabitants in identifying, evaluating and promoting the local community resource management system that conserves ecological processes and embraces biodiversity to generate income and cope with changes in social and natural conditions. The outline of the work is an assessment methodology that comprises information gathering and evaluation of the following three elements:

1. *State of existing natural resources*. A detailed description of the current state of existing ecosystem services in terms of its natural resources – water, soil and biodiversity – at the local level, and their relationships at spatial and temporal scales.
2. *Characterization of stresses*. An overall characterization of the typical environmental stresses, including scarcity of water, land degradation, overgrazing, irrational cultivation and reliance on agriculture, social stresses and the deficiencies of social services, and the effects of urbanization dynamics on local traditions and culture.
3. *Description of indigenous, adaptive and innovative approaches*. The strategies of the local communities to adapt to conditions in Omayed Biosphere Reserve (OBR) and its hinterland, and the question of whether such strategies are sustainable in the long-term, were assessed in the field via interviews and observation. Various management approaches and technologies – indigenous, adaptive and innovative – were considered, including water resource management practices, management of rangelands and grazing patterns, soil degradation identification, and use of land suitable for agriculture.

The use of an Environmental Information System based on participatory GIS is recommended to represent the required master database of the project. It is structured to manage all forms of information, spatial (base maps, satellite imagery and the like) and non-spatial (texts, tables, graphs, statistics and so on), from existing literature, previous projects, field observation and data analysis and interpretation. It will facilitate data archiving, analysis and query as well as combining the scientific, administrative and social data obtained on the local inhabitants in one common repository. Implementing this geo-database will enable comparative evaluation of study sites and dissemination of information among the partner institutions.

General description and location

Omayed Biosphere Reserve is located in the western Mediterranean coastal region of Egypt (29°00'–29°18' E and 30°52'–20°38' N). It runs about 30 km along the Mediterranean coast from west El-Hammam to El-Alamein, extending 23.5 km to the south. Its landscape is divided into a northern coastal plain and a southern inland plateau. The coastal plain is characterized by alternating ridges and depressions running parallel to the coast in an east–west direction. This physiographic variation leads to the distinction of several main types of ecosystem. They are arranged in the same sequence from the north (on the Mediterranean coast) to the south.

The major habitats found in the Reserve include five main habitat types:

1. Coastal dunes.
2. Inland ridges.
3. Saline depressions.
4. Non-saline depressions.
5. The inland plateau.

A complete description of these habitats and their major vegetation communities is provided in the section on 'Habitats' later in this paper.

The faunal species found in all five habitats include mammals such as dorcas gazelle (*Gazella dorcas*), a number of gerbils (*Gerbillus spp*.), the east Mediterranean endemic mole-rat (*Spalax leucodon*), the fennec fox (*Vulpes zerda*), red fox (*Vulpes vulpes*), hare (*Lepus capenis*) and North African endemic fat sand rat (*Psammomys obesus*). There are some fifty to seventy bird species, including kestrel (*Falco tinnunculus*) and quail (*Coturnix coturnix*), and between seven and thirteen reptile and amphibian species such as the horned viper (*Cerastes cerastes*) and the tortoise (*Testudo graeca*). Common insects are represented by the families of Terrebrionidae, Scarabaeidae and Carabidae. There are also records of sand roach (*Heterogamia syriaca*), harvester ants (*Messor* spp.) and a localized protozoan, *Acanthamoeba*.

A comparison of meteorological records from two stations, one close to the Mediterranean coast (Burg El-Arab) and the other about 40 km to the south (Dammanhur), demonstrates the north–south climatic gradient in this region (Table 8.1). These records indicate the increase in environmental aridity and thermal continentality from north to south.

The geological formations of the region are essentially quaternary and tertiary. The surface is formed of Miocene strata, about 300 m in thickness, overlain by pink limestone, tentatively assigned to Pliocene. The Holocene formation is formed of beach deposits, sand dune accumulations, wadi fillings, loamy deposits, lagoon deposits and limestone crust. The Pleistocene formation is formed of white limestone in the form of exposed ridges stretching parallel to the coast, and pink limestone of oolitic sand with Pleistocene microfauna.

Moghra Oasis is in the hinterland of the OBR. It is a small uninhabited oasis (latitude 30°14'N, longitude 28°55'E), situated on the northeastern edge of the Qattara depression with a brackish lake at the centre. It has an area of approximately 4 km^2. The lake represents the area of lowest altitude (–38 m). The shallow water table and outward seepage of the lake's water, accompanied by excessive evaporation, create the wet salt marshes (saline flats) that surround the lake. These produce thick surface crusts of salt that may prevent the growth of several plant species. Sand formations dominate on the western and southern sides of Moghra Lake, with deposits in the form of dunes in areas adjacent to the lake and of deep sheets of sand in other places.

Climatic data on Moghra Oasis, extracted from Wadi El-Natrun climatic data (at the same latitude as Moghra), show average temperatures range from 13–30° C in January to 27–60° C in August. Annual rainfall is about 40 mm, with a maximum of 13 mm in November. Relative humidity varies between 44.6 per cent in May and 63.0 per cent in November. Relative wind velocity ranges from 8.1 knots in December to 11.4 knots in April.

The vegetation of Moghra Oasis is diagrammatically represented in Figure 8.1.

State of existing natural resources

Habitats

Biodiversity

RICHNESS OF PLANT SPECIES

A total of 251 species were recorded in Omayed Biosphere Reserve, of which 131 are perennials and 120 are annuals (therophytes). These species belong to 169 genera and 44 families. The composites form the highest proportion of the total flora (15.9 per cent), followed by grasses (13.2 per cent) and legumes (12.8 per cent). Thirty-two species (twenty-two perennials and ten annuals) have wide ecological amplitudes (recorded in at least six out of seven prevailing habitats).

Eighteen species have a national distribution restricted only to the western Mediterranean region, where the Omayed Biosphere Reserve lies: *Asparagus aphyllus, Fagonia cretica, Lotus polyphyllos, Centaurea*

Table 8.1 Annual average (over fifteen years) of some meteorological data at two stations, one near the Mediterranean coast (Burg El-Arab) and the other about 40 km to the south (Dammanhur)

Meteorological factor	North station	South station
Max. air temperature (° C)	24.1	28.4
Min. air temperature (° C)	15.2	15.2
Mean air temperature	19.5	20.4
Rainfall (mm/year)	168.9	90.4
Potential evapotranspiration (mm/year)	994.6	1 033.5
Aridity index	26.9	10.7

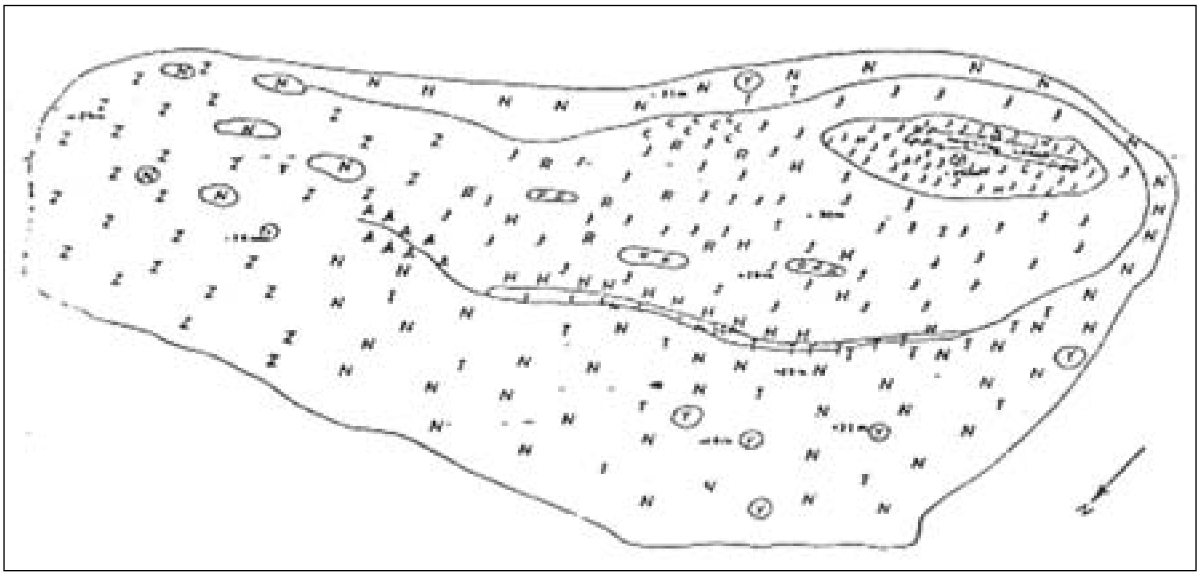

Figure 8.1 Moghra Oasis

J = *Phragmites communis*, t = *Juncus rigidus* , N = *Nitraria retusa*, T= *Tamarix* sp., Y = *Phonix dactylifera*, C = *Cressa cretica*, Z = *Zygophyllum album*, R = *Arthrocnemum macrostachyum* , H = *inula crithmoides*

alexandrina, Helianthemum sphaerocalyx, Prasium majus, Centaurea pumilio, Hyoseris radiata subsp. graeca, Rhodalsine geniculata, Ebenus armetagie, Leontodon tuberosus and *Thymus capitatus* as perennials*;* and *Brachypodium distachyum, Daucus syrticus, Hyoseris scabra, Crucianella aegyptiaca, Hippocrepis cyclocarpa,* and *Matthiola longipetala* subsp. *hirta* as annuals.

ENDEMIC, RARE AND THREATENED SPECIES

There is only one rare endemic species, *Helianthemum sphaerocalyx* (Cistaceae) in the coastal dunes in this region. According to the scheme of rarity forms, 40 rare species were reported in Omayed Biosphere Reserve: 23 perennials and 17 annuals. Moreover, the species uniquely occurring in the coastal sand-dune habitat are considered to be threatened species. This is because the construction of coastal summer resorts is leading to the severe fragmentation and destruction of this habitat.

RANGELANDS

Some of the most common rangeland species in the Mediterranean coastal region are *Anabasis articulata, A. oropediorum, Artemisia monosperma, A. herba-alba, Asphodelus ramosis. Convolvulus lanatus, Carduncellus eriocephalus, Eciochilon fruticosum, Echinops spinosissimus, Gymnocarpos decandrum, Helianthemum lippii, H. kahiricum, Lycium europaeum, Noaea mucronata. Deverra triradiata. Periploca aphylla, Scorzonera alexandrina*, and *Thymelaea hirsuta.* Of these species, 63 per cent are palatable and 42 per cent are considered highly palatable.

Grazing activities take place mainly in three habitats in Omayed Biosphere Reserve and its hinterland: the non-saline depression, the ridge habitat, and the inland plateau habitat. In the early 1990s it was observed that the annual above-ground dry matter production of the rangeland in Omayed Biosphere Reserve in the different habitats (maximum values in different seasons) was about 2,833 kg/ha in the non-saline depression, 1,448 kg/ha in the ridge areas, and 4,416 kg/ha on the inland plateau habitats. In general, preliminary field observations of the behaviour of grazing animals indicated that almost all the forage consumed throughout the year is made up of sixteen perennial species (most common) and annuals. In general the total phytomass of new growth is highest in the habitat of the inland plateau, and lowest in the ridge habitat.

ECOSYSTEM BENEFITS

The benefits offered by the OBR ecosystems are both environmental and economic. Environmental benefits include the following:

- Biodiversity conservation. One of the main benefits of the OBR is its role in conserving biodiversity resources (in terms of habitat and species diversity). This area is efficient in the sense that it encompasses a sequence of interdependent habitats in a relatively small area, including marine waters, sandy beaches, coastal calcareous sand dunes, saline and non-saline depressions, inland ridges, limestone plateau, inland siliceous sand formations (flats, mounds and dunes) and artificial rain-fed farms. These habitats support diverse flora and fauna (about 250 flowering plants, 300 invertebrates, 200 avifauna, 30 herpetofauna and 28 mammals). Some of the biota are endemic and/or threatened.
- Some of the habitats act efficiently for water storage (e.g. coastal sand dunes and the depressions at

the foot of the ridges formed by runoff water in addition to rainfall).

- Many of the plants play an important role in preventing soil erosion, increasing soil deposition and improving drainage of the lowlands. These include the species that form phytogenic mounds (e.g. *Ammophila arenaria*, *Liomoniastrum monopetalum* and *Artemisia monosermum*).
- Maintenance of the rich and colourful traditional cultural heritage of the local inhabitants, which forms an important and integral part of the region's landscape.

Economic benefits include:

- *Grazing*. Domestic and wild animals graze and browse on 94 species growing in this region (72.9 per cent of the total economic species). The highly palatable species in this area are *Echiochilon fruticosum, Plantago albicans, Stipa lagascae, Deverra tortuosa, Helianthemum lippii, Artemisia herba-alba, Althaea ludwigii, Malva parviflora* and *Gymnocarpos decander*.
- *Fuel*. Almost all desert woody perennials are cut for fuel. Local inhabitants usually use the dry parts only, while travellers, workers or other visitor groups cut down green plants when they cannot find dry ones. Most of the shrubs are cut and harvested for fuel, including: *Anabasis articulata, Thymelaea hirsuta, Echiochilon fruticosum, Gymnocarpos decander* and *Lycium europaeum*.
- *Medicinal resources*. There is a lengthy list of medicinal plants in the desert areas. Examples of these plants include: *Artemisia herba-alba,* which is widely used as an anthelmintic in traditional medicine; *Herniaria hirsute*, which is used to prepare a concoction for sore throats; and *Emex spinosa*, whose boiled leaf is used for the relief of dyspepsia, biliousness and as an appetite stimulant. Seeds of *Malva parviflora* are used as a demulcent for coughs and bladder ulcers, and *Sonchus oleraceus* is reported to be useful for liver complaints, jaundice and as a blood purifier. *Salsola kali* is used as an anthelmintic, emmenagogic, diuretic and cathartic.
- *Foodstuffs*. The fruits, flowers or/and vegetative parts of 33 species in this region are eaten by local inhabitants. *Malva parviflora* is a popular pot herb in Egypt. *Deverra tortuosa* and *Sonchus oleraceus* are eaten as salads. *Colchicum ritchii* is used as one of the numerous ingredients added to a beverage prepared from the rhizomes of 'Moghat' (*Glossostemon bruguieri*), usually offered as a tonic at childbirth in Egypt. Mammals such as rats and rabbits, and birds such as quail are eaten by the local population
- *Traditional materials*. Rope is made using *Thymelaea hirsuta*.

Characterization of Stresses

ENCROACHING DEVELOPMENTS

An almost continuous row of tourist facilities stretches along the coastline between Alexandria and El Alamein, and there are plans to develop the rest of the north coast in a similar manner. This has not only led to the complete destruction of the habitats on which the developments are built, but has also led to the degradation of the vast areas of habitat surrounding them. Urban development is taking place along the north coast at a very rapid pace, to the extent that most of the structures found currently along the coasts of the region have been erected over the last five to ten years, and new developments are being established at an accelerated rate.

UNSUSTAINABLE AGRICULTURAL PRACTICES

Traditionally, the native inhabitants of the north coast cultivated small areas of rain-fed winter cereals, olives and figs. Today, with the growth of local populations and the introduction of modern machinery, almost all seemingly cultivable land that receives sufficient rain to grow crops is ploughed, usually to cultivate winter cereals on an annual basis. The areas most intensively cultivated are those that once were prime habitats for biodiversity.

Much of the western Mediterranean coastal area cannot support intensive agriculture, which is leading to degradation of soil, water and rangeland resources. Ploughing using modern machinery is the most destructive recent development for agriculture. Modern machinery indiscriminately and completely removes perennial shrubs, which provide complexity and shelter to wildlife, and flattens the landscape, penetrating through areas previously difficult to cultivate by traditional technology, and probably also killing animals in the process.

OVERGRAZING

Unlike the impact of agriculture, which is very easy to observe even from long distances (as it entails the complete removal of natural vegetation), the impact of grazing is relatively subtle, but is probably as serious. Sheep and goats severely deplete the natural vegetation and compete directly with native wildlife for the same food resources. Close examination of areas that appeared in good condition from a distance reveal that only unpalatable woody perennials remain (such as *Thymelaea hirusta* and *Artemisia monosperma*), while annuals are heavily browsed. Traditional pastoralism in the past was more limited than today. The human population was significantly less and summer grazing opportunities were very limited (thus limiting the possibility of maintaining excessively large herds).

OVER-CUTTING

There is an increasing demand for fuel wood (larger woody perennials) by local Bedouin populations. This leads to a notable degradation of habitats, particularly in areas distant from other sources of energy. The elimination of large woody perennials (which take many years to reach maturity) severely reduces the structural complexity of an already highly exposed environment, and has the effect of rapidly accelerating soil movement and erosion, reducing retention potential and the chances of annuals and smaller plants to germinate and become established. In fact the removal of woody perennials is the first step in a process of complete transformation of the natural landscape. The collection of wild native medicinal plants for commercial trade has no formal or informal regulation. The most serious aspect of this practice is that it usually targets rare and localized flora, increasing the depletion of these vulnerable species.

OVER-HUNTING

Hunting and falconry have had a profound impact on all wildlife in the region. Gazelles and Houbara bustards have been the most severely affected, as they are the main targets for hunters. The use of off-road vehicles by hunters, the military and Bedouins is a major contribution to the degradation of natural habitats in this region.

INTRODUCTION OF ALIEN SPECIES

The introduction of non-indigenous species of plants is a widespread practice in many parts of Egypt, although it is recognized throughout the world as one of the primary factors in the erosion of biodiversity. The Australian *Casuarina spp.* and *Acacia saligna* have been widely introduced throughout the landscape of the north coast, including within the Protected Area, primarily to act as windbreaks and provide wood. Several native alternatives are available. Many other non-indigenous plant and animal species are expected to be found in the area when the Nile waters finally reach the El Nasr Canal. In addition to these main types of stresses, other specific stresses such as quarrying, pollution and waste disposal, and uncontrolled off-road vehicular use, are discussed in detail in the section on the 'Characterization of stresses'.

Existing state of water resources

The existing water resources are:

- *Groundwater*. This is the only significant water source in the northern part of the area (the coastal ridge and second ridge).
- *Runoff water*. This is the main source to the south of Khashm El-Eish and directly on its sloping northern surface.
- *Nile water*. This is provided through extended canals.

Groundwater

Precipitation is the main recharge source for groundwater aquifers in the northwestern Mediterranean coastal zone, and this greatly affects the amount of water stored in such aquifers. The Mediterranean coastal zone of Egypt receives notable amounts of rainfall, especially in winter. The rainy months are between October and February. In summer, no rain is recorded, while in autumn, occasional heavy rain may occur. The rainfall shows a general steady decrease from north to south, ranging from 168.9 mm/year at the coast (Burg El-Arab) to 16.2 mm/year at Siwa Oasis to the south. The Omayed Biosphere Reserve receives most of its rainfall in winter. The total is about 151.8 mm/year, which accounts for 106.26 × 106 m^3 of water. The catchment as a whole would receive about 140.415 × 106 m^3, which contributes to water resources within the catchment. About 98 per cent of this recharges the groundwater aquifer system during heavy storms, and 2 per cent is returned back to the atmosphere via evapotranspiration.

WIND

The prevailing wind is from the northwest and is generally cool. However, variable wind directions were recorded in the different seasons; for example, in spring the area is subjected to the southeast Kamasien wind, which brings severe sand storms and causes visible degradation of the area. The mean monthly value of wind speed may reach 27.75 km/hr.

GROUNDWATER AQUIFERS

The important groundwater aquifers in the Omayed Biosphere Reserve are classified into the following categories: sand-dune accumulations (Holocene); oolitic limestone (Pleistocene); and fissured limestone (Middle Miocene).

GROUNDWATER CONDITIONS

Groundwater in the area is governed chiefly by water-table conditions. The only source of water supporting the main water table in the northwestern coastal zone is localized rainfall directly precipitated on the coastal plain and the southern tableland. The free surface of the main water table has a level at or about the mean sea level up to about 20 km inland. The main freshwater table forms a thin layer floating on the main mass of saline water. The hydrological relation between these two water tables is controlled by the well-known principle of saltwater intrusion into coastal aquifers. Near the sea, the inflow of seawater maintains a dynamic equilibrium, with a comparatively thin layer of freshwater lying on the upper surface of the salt water. Most of the wells along the coastal zone depend on the main water table for their supply.

Runoff water: hydro-physiography and drainage pattern

A great number of drainage lines dissect the elevated table-land that acts as a major watershed area. Rainwater flows to the north, following the regional slope of the table-land surface either towards the low coastal plain or towards the sea. The remaining rainwater infiltrates through joints to feed the lower limestone aquifers. However, the presence of a thin, hard crust accelerates surface runoff to the north, as in the case of Khashm El-Eish. The low coastal plain acts as a collecting basin for the rainfall and runoff water from the southern tableland. The coastal ridges help to conserve soil and surface water, and the elongated depressions act as collecting basins for the runoff water from both the ridges and the table-land. The dominant factors are evaporation and evapotranspiration, surface runoff, and infiltration.

EVAPORATION AND EVAPOTRANSPIRATION

Evaporation is the process by which water is transferred from a liquid to a gaseous state. It includes evaporation from ground surfaces, from open water surfaces, from shallow water tables and plant transpiration. The total mean annual evaporation increases towards the south, where desert conditions prevail. The values of free surface evaporation and potential evapotranspiration increase to the west along the northwestern Mediterranean coast. These values also increase towards the south as the temperature becomes higher and the wind speed becomes less than in the coastal areas.

SURFACE RUNOFF

In the northwestern Mediterranean coastal zone, surface runoff is generally scant due to the low average precipitation. However, some ephemeral streams may occasionally flow through channels of dry wadis that were already engraved in the table-land during the Pleistocene era. Infiltration in the northwestern coastal zone appears to be as follows: a coefficient of 20 per cent in the wadi runoff zone, of 30 per cent in the plane zone, and of 50 per cent in absorbed water reaching the lower strata as groundwater.

The OBR hinterland, 'Moghra Oasis'

The Moghra Formation occupies most of the floor of the Qattara Depression. It is made up of sandy and clayey layers of the Lower Miocene. The maximum thickness of the Moghra aquifer is about 930 meters in the northeastern part. Along the Mediterranean Sea, the aquifer's thickness decreases sharply to zero where it retrogrades into an impervious, clayey facies. The aquifer is recharged from five different sources: (1) direct rainfall on the aquifer's outcrops, (2) groundwater seepage from the overlying Marmarica limestone aquifer, (3) the Mediterranean Sea, (4) the Nile Delta aquifer, and (5) upward leakage from the Nubian artesian aquifer.

The estimated amount of groundwater flow to the depression is 3.2 m^3/s, while the total evaporation from the depression is 7.2 m^3/s. Evaporation leads to an increase in the salinity of the groundwater seepage to the Qattara Depression. The near-surface groundwater ranges in salinity from 3.3 g/l around the Moghra Lake at the east, and 38.4 g/l at the centre, to about 300 g/l in the Sabkha area to the west.

Most of the water samples are of the chloride type ($MgCl_2$ and $CaCl_2$) of marine origin. A few samples are of the $NaHCO_3$ and Na_2SO_4 types of meteoric origin. This indicates either the large influence of original seawater invasion, or the dissolution of salts of the Moghra aquifer water from the host rocks or pre-existing salts. In the eastern part, the near-surface groundwater table has low salinity. During one of the field visits, a groundwater sample was collected and its salinity was found be about 2,400 mg/l, which meant it was useable as livestock drinking water during dry seasons in the Omayed Biosphere Reserve.

Characterization of stresses

In the last few years, the area under investigation has witnessed many stresses on water resources that have led to undesirable consequences related to both quantity and quality. Summer resorts recently established in the coastal area have damaged the important freshwater aquifer (sand-dune accumulation) near the coast. In addition, groundwater pollution caused either by saltwater intrusion or by sewage from septic tanks or landfills (summer resorts) has been observed in some areas.

Groundwater has become an important source of freshwater in coastal areas because of the increased demands placed on potable water supplies. Indiscriminate utilization of groundwater from a coastal aquifer could result in saltwater intrusion that renders the aquifer unsuitable as a source of potable water. As surface and groundwater are integral parts of the same hydrological whole, changes in the salinity of one will most likely affect the salinity of the other. While the objective of a saltwater intrusion control program may be to maintain a zero increase in salinity of freshwater resources, this aim is seldom attainable, especially in areas of high water use. A decrease in the amount of precipitation and number of rainy days (climatic variability) leads to a decrease in the amount of runoff water and to ecosystem degradation. In addition, most of the cisterns become clogged with transported sediments and their feeding channels are destroyed by inappropriate activities that have the effect of decreasing their efficiency in harvesting rainwater.

Description of indigenous, adaptive and innovative approaches

Local inhabitants of the Omayed Biosphere Reserve use various methods for groundwater abstraction and rainwater harvesting. Most of these are traditional methods, some dating back to Roman times. Surface runoff water is collected by applying two principal methods: cisterns (commonly known as Roman wells) and stony dams. In general, the water harvesting system depends on:

- average rainfall
- number of rain storms
- topography
- evapotranspiration
- surface roughness
- land features.

Soils

The arid climate plays a major part in the formation and persistence of soil cover in the Omayed area. The scarcity of water for reactions within the soil, for the leaching of soluble components from the soil itself, restricts the extent of soil formation processes. All soils in the area are considered to be very young and immature, and as such are highly influenced by the geological and geomorphological conditions of their formation.

Soil texture is also controlled by geological and geomorphological factors. Weathering of the omnipresent marine limestone produce soils of medium texture, sandy loam or, less commonly, sandy clay loam, but this tendency can be altered by two main factors. The first is the presence of Aeolian sediments; these are deposited quite close to their source, and are consequently very sandy. The second factor is the sorting of sediments. The sparseness of the vegetation cover and the harsh climate cause extensive soil erosion. There is not enough water enough to carry off most of the eroded material that accumulates in depressions. High-standing surfaces are generally bare, because of the hard parent rock, while soils of medium to high depth are formed by accumulation processes in depressions. Flat areas generally exhibit shallow and often stony soils, whose depth rarely exceeds 30 cm. In depressions, soil depth is proportional to depression level and catchment size, and increases progressively towards the centre of the depression.

Chemical and physical characteristics

In Omayed, soils are characterized by their bright yellowish-brown or orange colours, and sandy and loamy sand textures. The chemical analysis of these soils indicates that they have a generally low salt content. Organic matter and the total nitrogen content are relatively higher in the cultivated (olives and figs) soils than in non-cultivated areas. Calcium carbonate is generally very high in the coastal areas. In general, the physical and chemical characteristics of the soil exhibit a wide range of variation along the topographic gradient (Figure 8.2).

In the case of Omayed Biosphere Reserve, it is necessary to lay stress on the origin of sand deposits, particularly those due to wind action, and on their lime content, in the upper horizons. Accordingly, three categories of soils may be distinguished extremely calcareous soils containing more than 60 per cent carbonates; very calcareous soils containing from 20 per cent to 60 per cent carbonates and calcareous soils with less than 20 per cent carbonate but containing at least some calcareous elements (>2 to 3 per cent).

Characterization of stresses

One of the typical environmental stresses in the OBR is land degradation. The approach adopted in this project is to view land degradation in general and soil degradation in particular as ‘umbrella’ terms, covering the many ways in which the quality and productivity of land and soil may diminish through the activities of land users and of society at large. It therefore includes changes to soil quality and the many other ways in which the overall integrity of land is challenged by inappropriate use. Land degradation also involves many urban and industrial problems, such as pollution, landscape alteration and waste dumping.

Description of indigenous adaptive and innovative approaches

In the OBR, it has been observed that poverty and lack of water, even for drinking, tend to encourage people to focus on immediate needs rather than on benefits may materialize only in the long term. This is not to say that poor land users are necessarily land degraders, while the rich are conservers. Soil conservation is always viewed as being a cost to the land users in additional effort and trouble. The traditional knowledge of the local inhabitants enables them to detect soil moisture and water-holding capacity by very simple methods. They examine the soil’s subsurface consistency due to moisture, and the suitability of this moistness for agriculture, by rolling up a handful of soil and testing its compactness and stability. This traditional method allows an efficient assessment of soil moisture before cultivation, a procedure that enhances soil conservation.

Problems of soil erosion can be halted, and certain practices can lead to soil enhancement and rebuilding. These options include:

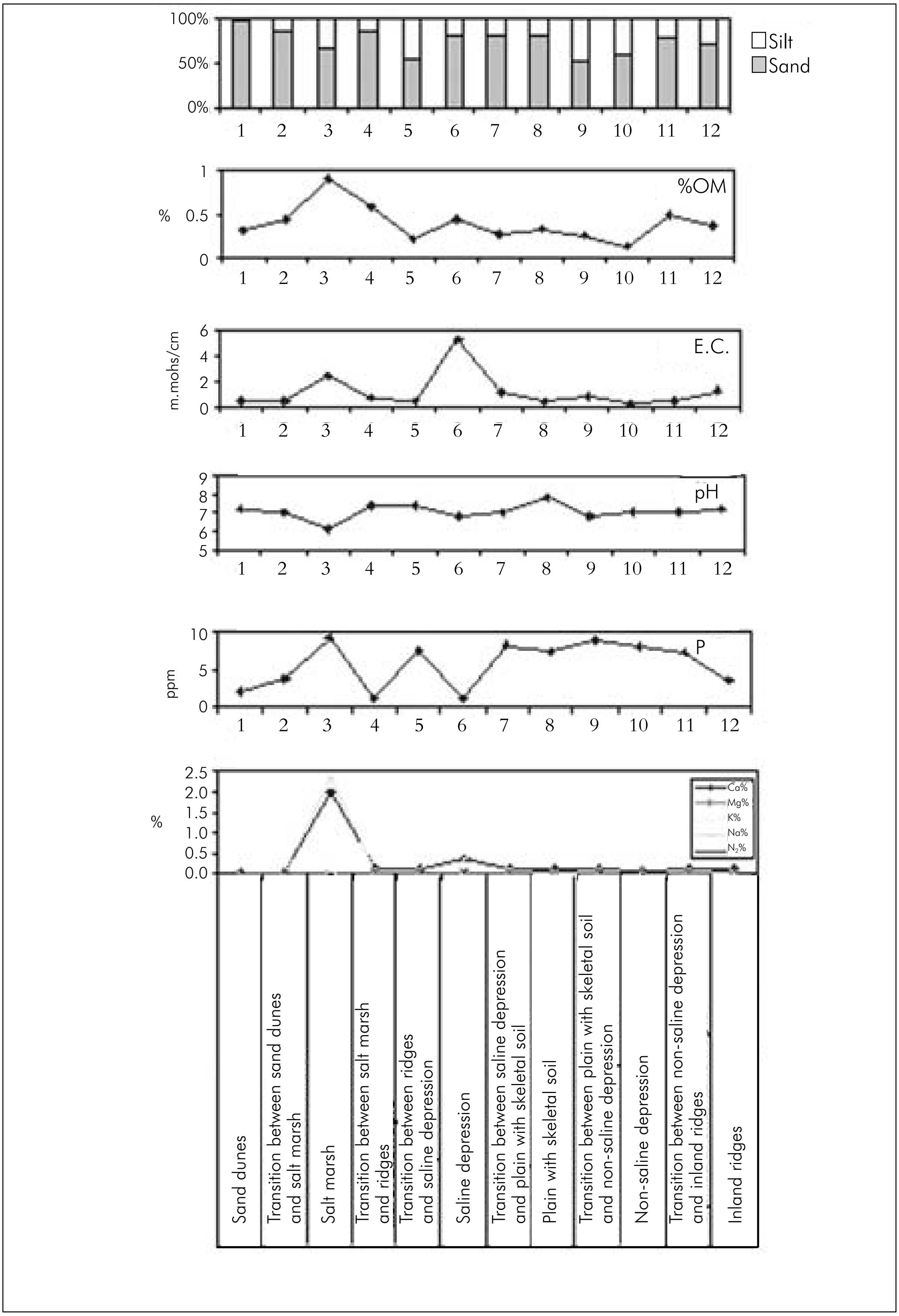

Figure 8.2 The physical and chemical characteristics of the soils along the different physiographic units in the El Omayed Biosphere Reserve

- Stopping the overuses that destroy vegetation.
- Controlling overgrazing by animals, since the trampling and browsing diminish the vegetative cover.
- Enhancing rehabilitation techniques by propagating native species (preferably multipurpose).
- Implement agro-diversity with care, avoiding the creation of monocultures.
- Shelter-belts planted perpendicular to the prevailing wind direction are effective in reducing the wind speed at the soil surface (windbreaks).
- Strip farming involves planting crops in widely spaced rows but filling in the spaces with another crop to ensure complete ground cover. The ground is completely covered, thus retarding water flow so that the moisture soaks into soil, consequently reducing erosion problems.

Description of Bedouin life and traditional knowledge

NUMBER OF HUMAN POPULATION AND FAMILIES

The approximate numbers of people living within the proposed biosphere are as follows:

	permanently	seasonally
Core area(s):	None	None
Buffer zone(s):	600	100
Transition area(s):	5,500	2,000

The OBR comprises parts of four villages; the population numbers and number of families in each is shown in Table 8.2.

In the northwestern coastal desert in general, and particularly in Omayed Biosphere Reserve and its hinterland, the local community is nomadic or semi-nomadic, though there is a trend towards a sedentary lifestyle due to government policy. The local community has always lived in the area, but the shift from a semi-nomadic to a sedentary way of life got under way when the Bedouins began to build stone houses about 30 years ago. However, this does not imply that house dwellers give up grazing. The population of northern Omayed is the most sedentary, a fact that is probably encouraged by registered land holdings. This decreases toward the south, where up to half of the Bedouins are still semi-nomadic. The community can be characterized by their inherited Bedouin traditions and values, which are both tangible (handicrafts, housing configuration, tools, clothing and the like) and intangible (language, poetry, song, dance).

Table 8.2 Village population in the OBR

Village name/ number of families	Population/ (>30 years)
Omayed/195	1 600/(640)
Sahel El Omayed/112	1 280/(490)
Shammamah/68	660/(220)
Awlad Gebreil/60	465/(120)
Total (average)	4 000/(1 470)

In the study area we find that traditional knowledge provides the basis for day-to-day living and for local-level decision making about many fundamental aspects such as:

- agriculture and husbandry
- preparation, conservation and distribution of food
- location, collection and storage of water
- coping with disease and injury
- interpreting meteorological and climatic phenomena
- manufacture of handicrafts and tools
- construction and maintenance of shelter
- orientation and navigation on land for grazing activities
- management of ecological relations between society and nature
- adaptation to environmental/social change.

Women in Bedouin communities have an important role in managing and maintaining the family economy; poverty is alleviated by the raising and selling of animals and by the production of wool handicrafts. However, Bedouin traditions are such that women are prevented from selling the wares they produce. Women are responsible for such daily chores as food preparation and carpet weaving, and occasionally cultivating small patches of vegetables and breeding poultry.

Innovative activities that have recently been developed in the region include:

- running groceries and trading in agricultural products
- selling electrical tools, especially since the introduction of electricity in the region
- transportation by trucks or *kareta*
- employment in the private sector
- brokers of land and houses.

Characterization of stresses in Bedouin life

In general, Bedouin communities experience stress either due to harsh natural environmental conditions, to which their way of life has adapted, or because of the inadequate provision of social services. Stresses may be further classified according to the spatial or temporal context. Communities suffer more during the hot, dry seasons of the year because of water scarcity. They cope with these stresses by, for example, moving their herds to

Moghra Oasis, storing water in cisterns, transporting water by means of water tank trucks and similar strategies. Their houses are also built in a naturally insulated style using palm midribs, with windows directed towards the north. In summer, they use tents installed outside their homes in the direction of the wind.

In terms of geographic distribution of stresses, Bedouin communities living in the coastal region suffer less, thanks to the better environmental conditions and greater rainfall. This enables them to establish productive orchards (particularly figs) and rangelands, and a relatively better quality of life. Even during the dry seasons, communities living in the coastal region cope better with the difficulties posed by environmental conditions because they have access to such amenities as transportation, potable water via water pipelines and electricity.

Integrated methodology

TASK 1

Assessment of the current status of integration between the conservation of natural resources, community development and scientific information (Year 1).

TASK 2

Identification and implementation of practices for sustainable soil and water conservation, aimed at combating environmental degradation by means of a combination of traditional knowledge and modern expertise (Years 2–4).

TASK 3

Training and handling of data collection and inventory techniques, and implementation of proven management technologies (Years 1–3).

TASK 4

Development of income-generating activities based on the sustainable use of dryland natural resources (years 1–4).

TASK 5

Final reporting (year 4).

Conclusions and recommendations

1. The idea behind the SUMAMAD project is a much needed plan that, if fully implemented, would indeed demonstrate a good example of sustainable management in marginal drylands in the sites selected.
2. The western coastal desert of Egypt, which includes Omayed Biosphere Reserve and its hinterland, is a good example of a marginal dryland and would represent a perfect site for SUMAMAD-Egypt.
3. The main purpose of implementing this project in the case of the Egyptian site (the OBR and its hinterland) is to identify the basic elements needed for the sustainable management of a marginal dryland, as a model, and to build on the existing data on the natural resources, rather than re-creating an entire inventory (reinventing the wheel) that was developed between 1972 and 2002.
4. The OBR hinterland, extending to the Moghra oasis on the borders of the Qattarra depression, is a very good case for implementation by SUMAMAD-Egypt due to the following factors:
   - The local community is dependent on a very sparse and fragile natural vegetation cover for grazing activities, and consequently the area is prone to overgrazing and degradation, and therefore needs sound management.
   - There is a potential freshwater resource in Moghra oasis that can support and improve the vegetation cover of rangelands. Grazing capacity can be increased by developing a rangeland development scheme, including the possibility of generating a ‘cultivated rangeland’.
   - The proposed rangeland development scheme would be implemented with the involvement of the local community, with grazing activity carried out on a rotational basis in winter in the OBR hinterland on the basis of carrying-capacity figures. The local community would move to Moghra oasis in summer to benefit from the cultivated rangeland development. The species selected for cultivation should be native and highly palatable.
   - The local community could settle in Moghra for at least five months of the year if sufficient human health, transportation and veterinary services could be provided.
   - In other areas, grazing rotation schemes also could be implemented in order to encourage vegetation regeneration and rehabilitation.
5. With regard to water resources, there is an urgent need for a detailed map of the Roman wells and cisterns, as well as an assessment of water quality and quantity in relation to use. The current project could make an ideal contribution through rehabilitation of selected wells, as well as supporting the construction/reconstruction of water catchments areas for water harvesting.
6. Supporting the quality of life of the local community by developing traditional practices and income-generating activities, by involving women, and by providing essential services such as education, health and transportation would be central to the successful implementation of the project.

Session 2: Traditional knowledge and modern technology in pastoral systems

9 Space imagery processing for land use and rehabilitation of ecosystems in desertified conditions

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Introduction

Remote sensing technology and traditional land use: possible interrelations

Traditional land use in dry regions usually falls into three main categories: pasturing, arable agriculture and irrigation. These lands have extremely high bioclimatic potential due to high solar radiation, and tilling the soil is relatively easy compared with boreal or tropical areas; the only obstacle to development is the shortage of water resources.

These aspects of dry regions have enabled people to use their natural resources throughout history. However, the over-exploitation of drylands – in most cases in the past as well as at present – has exhausted such natural resources as soils, vegetation, surface and ground waters, and biodiversity. The complicated phenomena of resource depletion and land degradation in dry areas, leading to the economic decay we witness today, have become widely known as desertification and are increasingly the focus of global scientific and technological interest.

Remote sensing technologies nowadays are among those advances that provide opportunities unimagined even ten or twenty years ago. The increasing resolution and spectral range of space sensors, together with new methods of processing satellite images, have provided us with a powerful instrument for the regular automatic review and updating of traditional maps and observations. And, moreover, these new methods are much cheaper than traditional field studies or aerial surveys. While they cannot altogether replace traditional scientific research, they can speed processes up and make them more precise (Table 9.1).

Methods and approaches

For our research and for mapping based on satellite-image processing, we use our own TIMAN (Thematic Interpretation and Multi-temporal Analysis) software, which has been designed for thematic decoding of remote sensing data. The algorithms realized in the programs are based on Generative Topographic Mapping (GTM) artificial neural nets which are used for data ordination, classification and thematic decoding.

As tools for classifying multi-dimensional data,

Table 9.1 Can remote sensing technology help in the traditional land use practice?

Previous assumptions	Present trends
Satellite images are less informative than field observations and/or aerial-photos	The level of information required should be judged in terms of its purposes
Remote sensing methods need highly qualified personnel to process and explain them	Automatization and acceleration of expert assessment is facilitating decision making in the field of land use
Satellite images are much more expensive than aerial photos or field studies	For a number of purposes (especially for middle- and small-scale mapping) space imagery is less expensive, and much cheaper in the case of a study of the ecosystems dynamics

GTM neural nets possess important additional features used in most of the algorithms realized in the program.

GTM neural nets make it possible to go beyond the traditional data classification, in which it is very difficult to determine the position of the classes against each other in the features area. Data ordination assumes representation of the classes along the plane that takes topological features into consideration.

The adaptability and self-organization features of GTM neural nets, which do not require pre-calibration of data, and their capacity to retain stability in the face of noise and distortions are valuable features. Because of them, such nets are among the best tools for the ordination of the features area and for assessing its structure.

Another major advantage of GTM neural nets is that the ordination process can be described as ‘thematically directed’. This means that the classes of a neural net can be determined in such a manner that they particularly represent the phenomena of interest in the thematic area. Unlike traditional classification methods, ‘thematic directing’ results in the thickening of the classes in the topological neighbourhood of the features area related to the thematic subject of interest.

The ordination structure shows great stability when dealing with changes of initial values. This is another advantage due to the fact that GTM neural nets create ordination rather than classification. Thus, suppose a neural net is classifying a multi-channel image. If the spectral brightness of all the channels is linearly changed (by multiplication of the constant and addition of arbitrary increments), the repeated training of the neural net will result in the same ordination, even though the centres of the classes created are substantially shifted. Since it is ordination that is used to interpret the thematic data, this unique specificity of neural nets makes them reliable tools for mathematical interpretation. The results of such processing are replicable even if the initial data are changed, as it takes place in the processing of the images obtained in conditions of different brightness or even in different seasons (Figures 9.1 A–D).

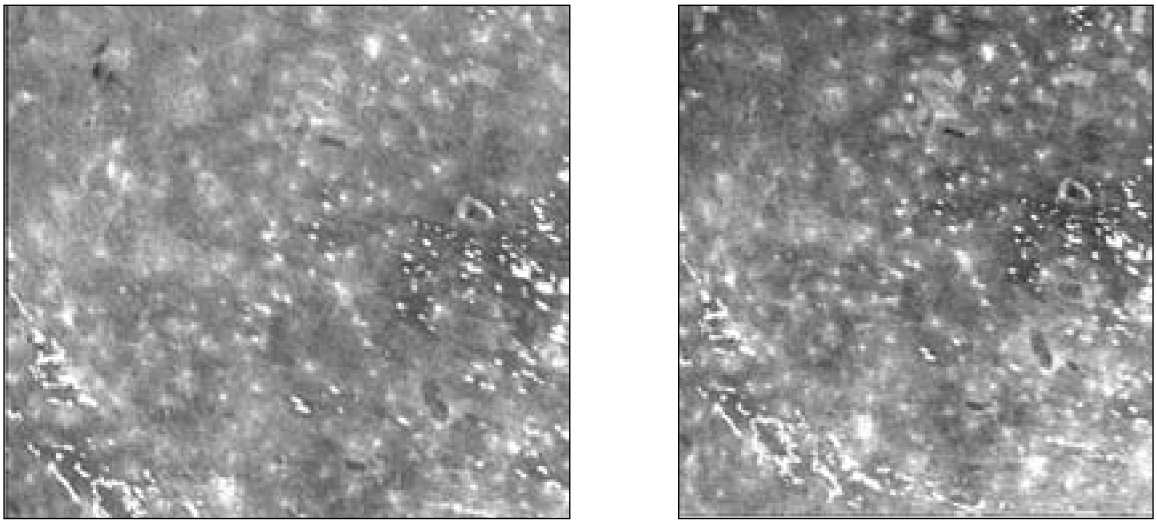


Figure 9.1.A Basic space images (Resource 01 No. 3, 150′150 m) 10.05.00 and 17.05.00 (Kalmykia, Russian Federation)

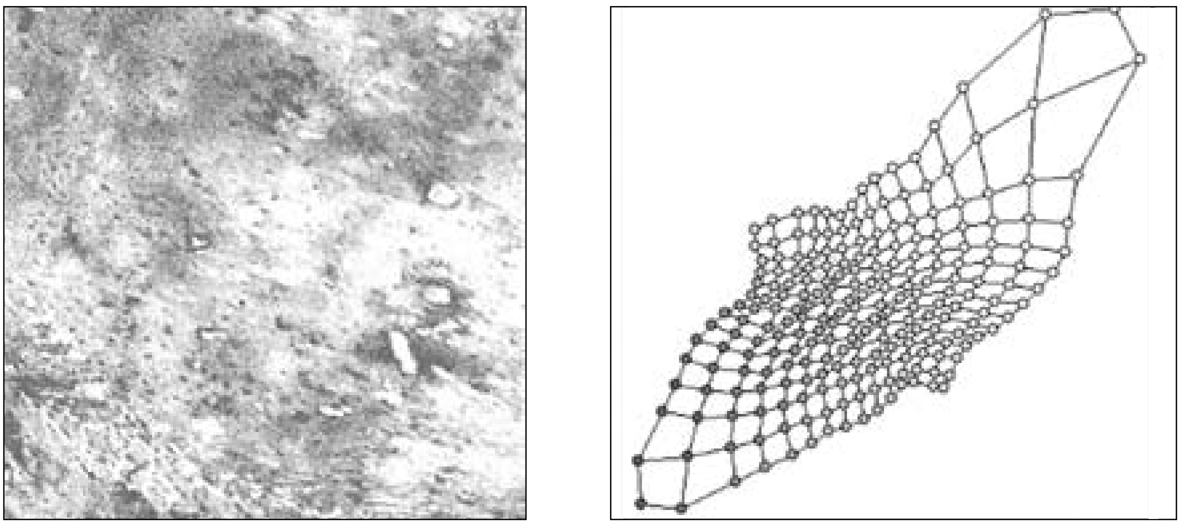


Figure 9.1.B Biomass: neural network revealed by the first image only

All the raster data used in the program can be divided into two large parts: scalar data (continuous values which can be used in arithmetic; for example, the brightness values of the spectral bands) and ordinal data, classified or categorical (for instance, layers with class values).

Initial data are preferably presented in the first format and processing data in the second. The following types of images can be created by the program:

- For scalar (continued) layers:
  - black-and-white single channel images (in grey levels)
  - colour synthesized three-channel images (RGB-synthesis).
- For classified layers:
  - classified images with the palette defined
  - classified images with the palette determined on the neural net ordination of features area.

The visualization of scalar layers is realized by means of standard software tools (channel choice, histogram transformation, gamma-correction). However, there is sufficient specificity in the presentation of classified data. This refers first to the visualization of the results of the neural net's ordination. TIMAN makes possible the creation of thematic pallets based on the neural net's ordination. This method allows visual representation of continued thematic changes in the area. There are few, if any, other methods that can represent continual natural systems on the maps without using artificial boundaries.

The creation of pallets is based on the separation of 'kernels' among the classes of neural nets. These are the classes in the area of features that have a pronounced theme, and are related to the particular colours of the thematic legend. In the next stage, the program assigns intermediate colours to the other classes, using interpolation based on their order in the neural net's ordination. This makes it possible to visualize the spatial transfers of thematic classes from one point to another. The user has freedom in thematic orientation and

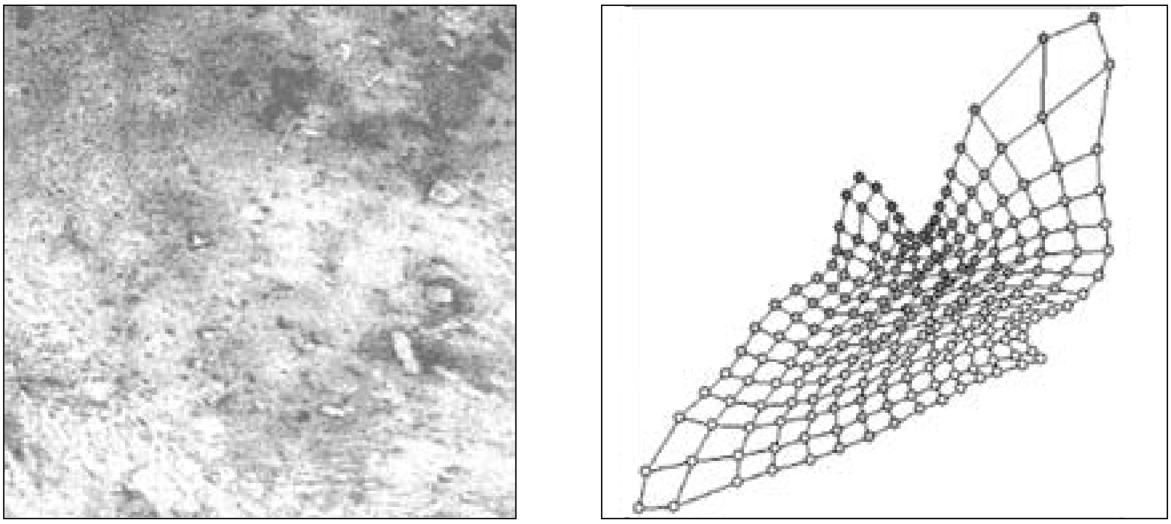


Figure 9.1.C Biomass: neural network revealed by the second image only

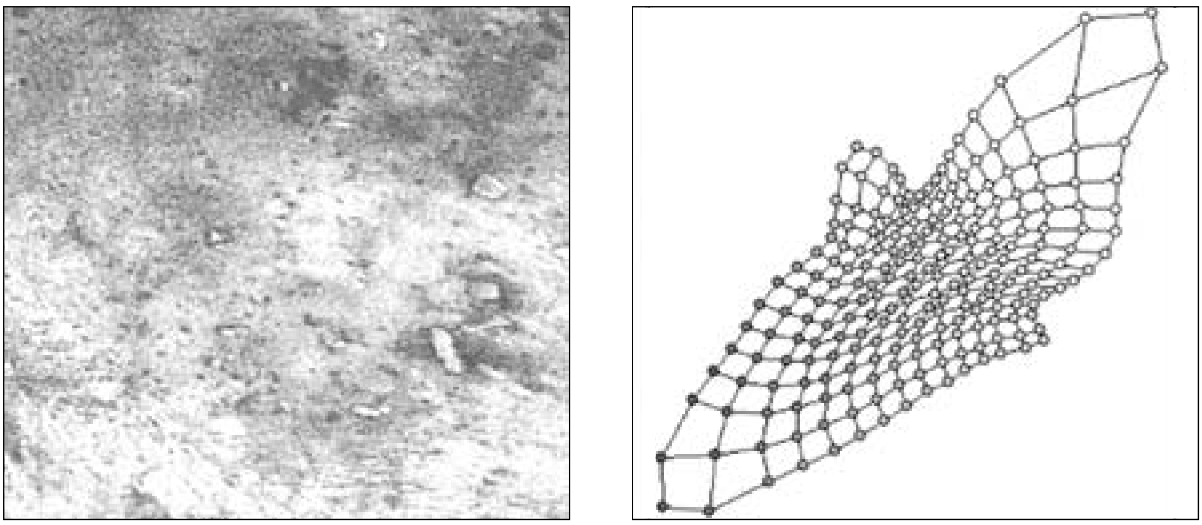


Figure 9.1.D Biomass: neural network revealed by both images

'kernel' choice and is thus given powerful tools to create thematic map models in accordance with his or her expert knowledge and additional data. This method also allows for the use of consecutive approximations to create the cartographic model of the territory that best corresponds to the total available information.

The following procedures can be used to obtain derived layers:

- conversion of vector thematic maps
- calculation of main components for the whole of the scalar layers and their saving as new layers
- filter use for scalar layers
- use of the filters based on wavelet transformation for scalar layers
- calculation of derived layers of local characteristics of scalar layers based on GLCM (grey level contiguity matrix).

The procedure for neural net training includes:

- the selection of the layers used for training
- the selection of the area part and thematic orientation of the neural net
- the selection of the neural net features
- the selection of the parameters for neural net training.

As a result of neural net classification, each image pixel is related to a particular class of the calibrated neural net, so that it is described with the distribution of probabilities of different thematic objects. Thematic decoding is used to determine the boundaries of these classes, so that the classification obtained calls for the following processing (above all, the context (spatial) dependencies of thematic objects should be used for this processing). In TIMAN software the following tools for context re-processing of the classification results are available:

- object creation using random Markov fields
- classification of vector objects (parsell-wide classification)
- re-processing of the classification results using a local window
- generalization of thematic objects created.

A TIMAN programme makes it possible to convert the created thematic objects into vector form for transmission to the GIS. The user can select the objects to be transmitted in accordance with the legend. A subject topology is created (if 'islands' are present in the object, their boundaries are included in the list of object boundaries). The user can specify the size limit of the object to be vectorized. Objects that have a smaller size are not processed and hence not transmitted to the GIS.

The decoding features of land structures can be selected on the basis of the selection of specific changes of brightness related to these structures on the image. They are known as structure units of the image. Boundaries and lines are the main structure units of the images, which do not refer to particular land structures. Boundaries are delimited by the level of brightness. Thus dark objects on a light background and light objects on a dark background both form boundaries. Lines are defined as objects whose section at any point contains a small (not large) number of pixels belonging to the object. The term 'small' or 'not large' reflects the uncertain nature of the definition, because even large linear units with rather large 'sections' can represent linear structures belonging to a smaller scale than the image itself. The scale problem is one of the most important in the selection and identification of the structural image units, and we therefore paid most attention to scale problems when developing the TIMAN software. Besides the boundaries and lines, their prevalent directions should be specified at each image point. Diagrams showing the probability estimate of the relevant direction at each particular image point are used for this purpose. The following procedures can be used for the selection of structure units:

- filter use
- use of wavelet transformation
- use of parametrical transformation.

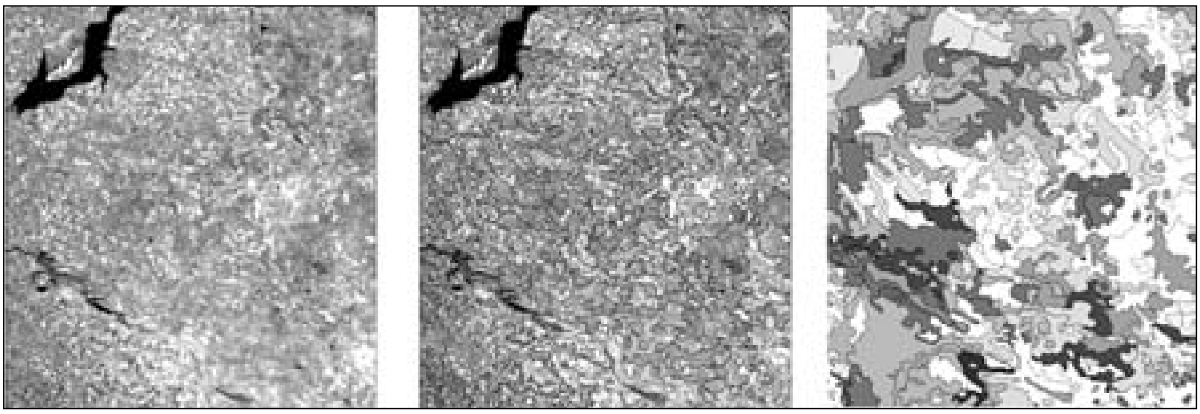


Figure 9.2.A Desertification/land degradation map of Russia (original scale 1:2,500,000), part of Kalmykia: stages of the space imagery processing: initial picture, contour, automatic classification

Results and discussion

Our research on the application of TIMAN remote sensing technology for traditional land-use practice and science has been conducted in various fields:

- desertification assessment, mapping and control
- preparation of basic maps for land-use policy (soils, vegetation, geomorphology, waters)
- up-to-date quality and quantity control
- correction of prognoses of soil and plant dynamics on the basis of present meteorological conditions
- assessment of the interrelations of the ecosystem components and their reflection in the main properties of land use (integral ecological risks and trends, recommendations for the land use policy of the area)
- fire prevention.

A few examples of the usage of the technology are presented below.

Desertification assessment, mapping and control

Figure 9.2 (A–C) shows parts of the desertification/ land degradation map of the southern belt of the Russian Federation, which has been created on the basis of space imagery processing. For this purpose, experts in the state of desertification in different key regions worked closely with specialists in remote sensing and TIMAN technology. Following this cooperation, special algorithms (visualized as the net of classes) for each region were created (Figure 9.3 A–C) and used for automatic mapping procedures.

Preparation of basic maps for the land use policy.

Preparation of some pages of the State Soil map (1:1,000,000) was undertaken with the help of interactive technology. A map that had initially been initially created in the 1970s had to be updated without incurring the high costs of field work. In the first stage of our work, we created a first-step net. After test classification, specialists in neural technology pointed out the most questionable key plots to soil scientists, who carried out special field work on these key areas. On this basis, the neural net algorithm were calibrated more precisely and used for mapping. A few examples in Figure 9.4 show that the revised map showed more detail of the contour base as well as of soil classification.

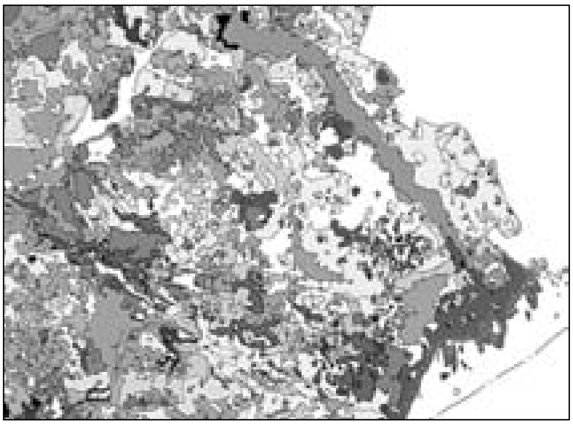


Figure 9.2.B Desertification/land-degradation map of northwest Pre-Caspian Region (original scale 1:2,500,000)

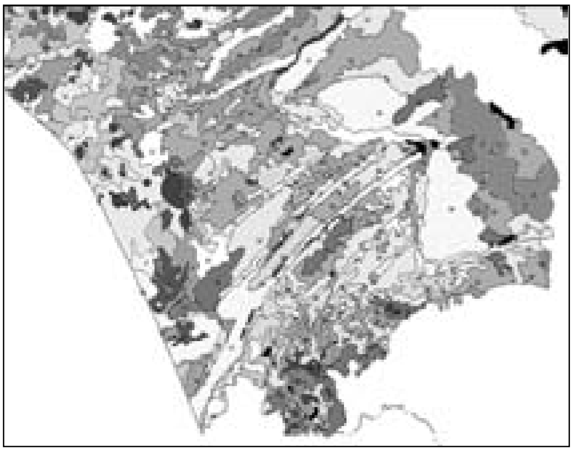


Figure 9.2.C Desertification/land degradation map of south of western Siberia (original scale 1:2,500,000)

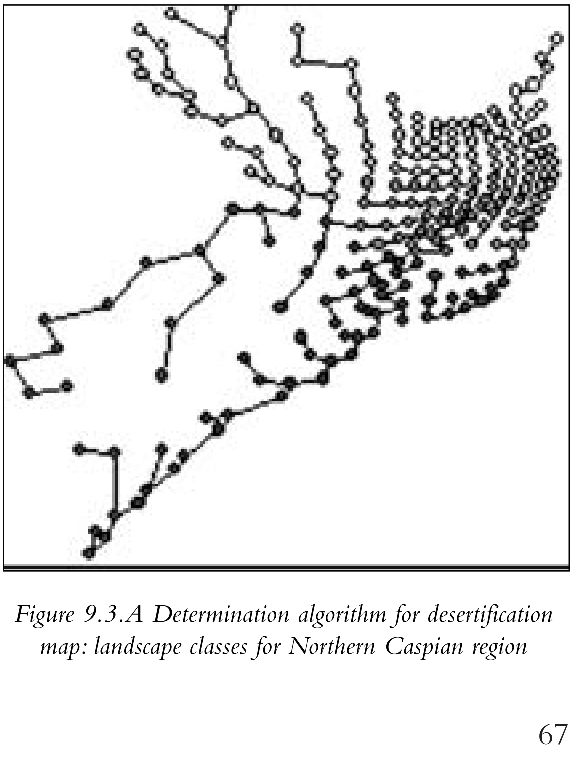


Figure 9.3.A Determination algorithm for desertification map: landscape classes for Northern Caspian region

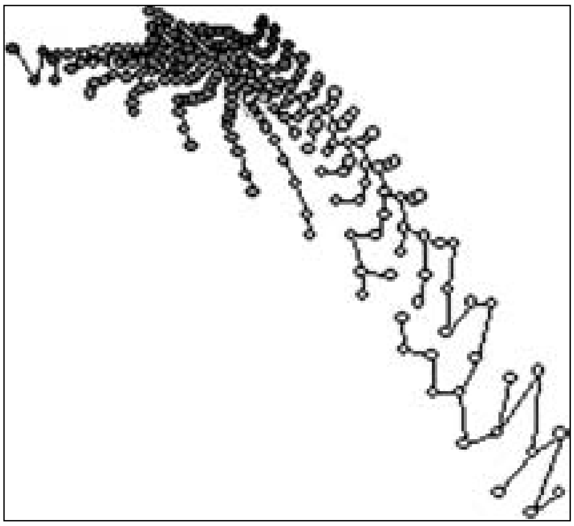


Figure 9.3.B Determination algorithm for desertification map: landscape classes for southern part of western Siberia

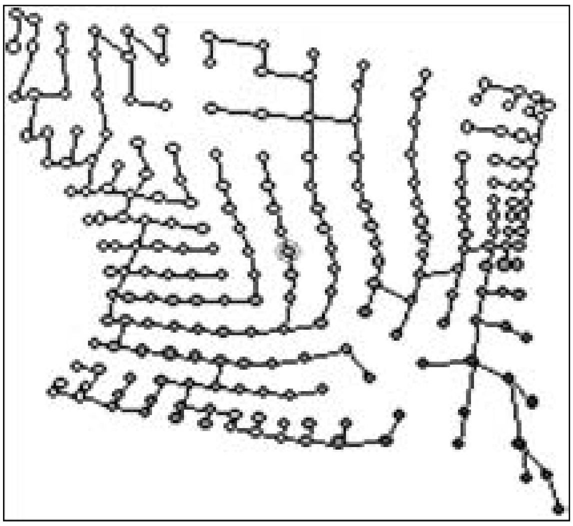


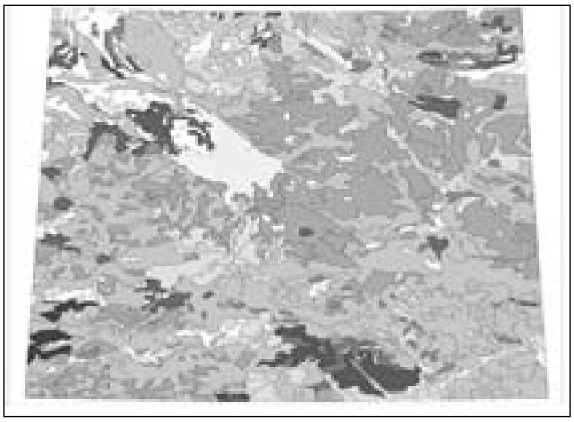
Figure 9.3.C Determination algorithm for desertification map: landscape classes for Baikal region

Conclusion

The technologies that are now available for processing satellite images can be used in various ways to assist land use in arid regions. Special algorithms based on the TIMAN methodology of neural networks, once created, could be used for repeated thematical mapping of the same territory on a regular basis. This makes it possible to effectively monitor natural and anthropogenic ecosystems at different scales and at much lower costs than traditional methods of mapping and assessment.

Note

The colour figures originally prepared for this paper provide more precise information, which is not fully revealed in black and white. However, the figures shown here do provide adequate visualization to demonstrate the utility of processing space images.



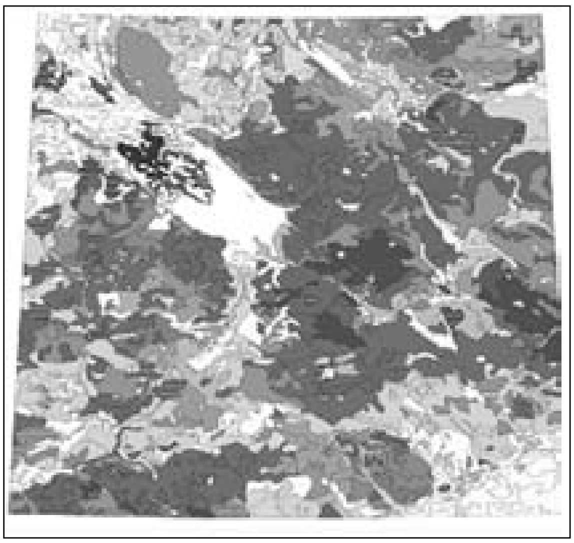


Figure 9.4 Examples of the State Soil Map
(original scale of 1:1,000,000 using 'Resource 01' satellite and interactive technology)
Left: part of a map created using conventional technology, showing twenty-five soil classes.
Right: the same part of the revised map with more a precise and detailed countour base, showing forty-seven classes.

10 Traditional and modern technologies for sustainable development of Turkmenistan

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At the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, and at the World Summit on Sustainable Development in Johannesburg in 2002, action plans for the achievement of sustainable development were adopted.

In 2000 Turkmenistan developed the Support of Agenda 21 Process in Turkmenistan project, with the objective of developing a clearly defined mechanism to realize sustainable development ideals. The project also aimed to assist the government in setting out the basic rules of the programme of the President of Turkmenistan, Saparmurat Turkmenbashi, on the environmental principles of sustainable development in the country.

The concept of sustainable development means the adoption of new approaches to integrate ecological questions in all aspects of regional and branch planning and management; that is, the development of a country through self-organization within a framework for external support that warns of any likely transition into a state of irreversible environmental degradation.

In Turkmenistan there are opportunities for further analyses of socio-economic development, such as identifying what has already been done, what is left to do, and how to move further along a chosen strategic course. In December 1999 a large-scale programme, The Strategy of Socio-economic Reforms in Turkmenistan for the Period to 2010, was adopted. The project is now being extended to 2020, and the strategy for this will be open to national discussion.

In 1995 Turkmenistan ratified the United Nations Convention to Combat Desertification and began work on its National Action Programme on Combating Desertification (NAPCD), which was completed in 1996–7. This programme lays down important scientific, theoretical and practical principles not only to overcome the country's pending ecological crisis but also to convert the degraded lands into biologically enriched ones.

The parties to the Convention undertake to encourage and use traditional technologies, knowledge and know-how, to seek to adapt them for wider use, and to integrate them with modern technology, thus providing an opportunity for local populations to receive direct benefits from any commercial use in the fight against desertification. Projects that were carried out between 1998 and 2002 can serve as examples of the measures incorporated in the national programme. These projects were carried out by the National Institute of Deserts, Flora and Fauna (NIDFF) of the Ministry of Nature Protection of Turkmenistan, with support from the Secretariat of the UNCCD, UNDP/UNSO, GTZ and the Regional Environment Centre of Central Asia (RECCA). The given projects are important examples of the realization of Agenda 21, as well as programmes to combat desertification in the Aral Sea basin.

In the course of developing these programmes for participatory project planning and management techniques at the NIDFF, a pilot project was conceived that has since evolved into an independent community-based resource management project in three pilot areas in Turkmenistan. For the first time ever in Turkmenistan, participatory forms of project planning and implementation are being tested in partnership with people in rural areas – under the extremely difficult conditions prevailing in a society that had been shaped by a planned economy for many decades.

Since the start of the project it has already become possible to plan and implement, together with the stakeholders, concrete measures to control desertification (such as dune stabilization, improvement of pastureland, use of solar energy in shepherds' houses and the establishment of small gardens for vegetables and medical plants).

In Bahardok valley, where 500 km of railway and the Ashgabat–Dashoguz motorway cross the Karakum desert from north to south, pilot projects are being carried out on the stabilizing and reforestation of mobile sand dunes on an 8 ha area. Also, thirty solar generating plants have been installed to provide power to raise water from wells and to light shepherds' houses in the remote deserted pastures. The basic aims of the projects were:

- to make possible the adoption of independent solutions for sustainable development by communities and groups of cattle-breeders
- to improve production systems so as to increase productivity in accordance with complex approaches to the development of rural regions
- to provide alternative means of livelihood in order to reduce the stress on land resources.

The current means of earning a living and of using resources cannot provide a reasonable livelihood for populations in regions that are suffering desertification and droughts. The principal means of livelihood is based on agricultural production, and does not provide a suitable basis for sustainable use. Poverty is one of the basic consequences of desertification. Therefore, measures are needed to restore and improve agricultural systems to allow sustainable and rational use of rangelands as well as small oasis agriculture and alternative systems for the well-being of both people and the environment.

There are pasture massifs throughout the Karakum deserts. Arborous shrub and grassy vegetation extend over almost all the desert areas and are used for pastures. Where there are no fresh underground water sources, cattle breeders and shepherds make the best use of surface runoff by means of collection and storage. Accumulated water is used not only for sheep and camels but for drinking purposes and to satisfy the economic and everyday needs of the population. Where there is no system of collection but where the soil is saturated by means of precipitation, melons are grown.

New technologies that improve living conditions are available, most notably solar energy units, but they are not yet readily affordable. For instance, the installation of solar units for a small house in a remote desert region will cost at least US$10,000. At the same time, however, traditional means of supplying electricity to small and remote desert settlements also demand large investments. Technological development is gradually moving towards a solution to this problem. Wind farms are also proving their value and are being established in many states. According to the American Wind Energy Association, the production cost per kWh of electrical energy by a wind station is 3.3–6.0 cents. The same energy obtained through biomass costs 5.8–11.6 cents. This is relatively expensive compared with the production of electrical energy by burning natural gas (3.9–4.4 cents), oil (4.0–5.0 cents) or coal (4.8–5.5 cents). A hydroelectric power station costs 5.1–11.3 cents per kWh, while for solar batteries the average cost is 12.0 cents.

In other words, the cost of electrical energy produced by alternative methods is already beginning to come down to the cost of generation by hydrocarbon fuel. The lack of infrastructure is the principal constraint on the development of new and alternative energies. A new industry clearly needs to be created.

Solutions for the further development of agriculture in Turkmenistan include the wider use of deserted pastures, collection and storage of atmospheric precipitation for the watering of cattle, and the application of renewable sources of energy in agriculture.

Analysis of the land-tenure structure in Turkmenistan shows that 90 per cent of the territory is characterized by desert landscape, serving as ranges for sheep and camels all year round. About 2 million ha fall within the category of irrigated lands, which are concentrated in oases. Nationally, the range economy is the most profitable and least labour-intensive economic activity. Across a considerable area, however, the rangelands have experienced desertification and now have low fodder capacity. Thus, of 39.5 million ha of ranges, 69 per cent are degraded, 37 per cent are not irrigated and 5 per cent have been transformed into bare, moving sands. About 10 million sheep currently graze on the rangelands; it is possible to increase the crop capacity two or threefold and considerably increase sheep population while conducting appropriate ameliorative techniques.

Problems of water supply and irrigation are key issues in the sustainable development of settlements in the deserts of Turkmenistan. Annual precipitation generally varies between 100 and 150 mm, mainly as rain, but evaporation exceeds precipitation by about 20 times. Turkmenistan thus has a great deficiency of fresh water. Rivers have unstable runoff and they do not by any means satisfy the country's needs. Hence, the search for additional sources of water supply to develop the country's economy is particularly urgent.

In Turkmenistan, the decisive role in climate-forming is played by solar radiation and climatic circulation. The basic climatic features – the country has the greatest extremes in the CIS region in terms of air and soil temperatures, extreme air dryness in the summer period and also great weather contrasts in the cold and even in the warm period – are defined by these factors. Because of the clear skies over the country, the influx of radiation in summer is so great that atmospheric circulation is entirely secondary to the primary climate-forming factor – radiation – which defines the characteristics of its geographical location.

The duration of sunlight in the east of the country averages 2,800–3,100 hours a year, decreasing in littoral regions. In all, radiation generates around 145–163 kcal/cm^2 of heat a year. Of this total, 65–70 per cent is the result of direct radiation. In many years the average air temperatures in July reach 28-32 °C, with an absolute maximum of 50 °C and an absolute minimum of –33 °C.

Active participation by the local population in carrying through the National Action Programme on Combating Desertification in Turkmenistan is a key factor in nature protection. About 10,000 people live on 'Erbent' livestock farm, in Central Karakum. The socio-economic conditions there are directly related to desert ecosystems. The population have experience of desertification processes and therefore, from our perspective, their ecological understanding has a great role to play in the conservation and integrity of the environment.

For several years the Institute of Deserts, together with the German Agency on Technical Cooperation (GTZ), has been holding consultations and seminars on desertification problems. The Institute's staff have led a number of seminars in order to extend the consultative service of the Institute, both in Turkmenistan and in foreign countries. New trends of research using GIS technology have been discovered and special attention has been paid to the socio-economic aspects of desertification in Turkmenistan using PRA (participatory rapid/rural/relaxed appraisal) methods.

When Turkmenistan gained independence, a new administrative post was created that combined the functions of the leader/headman of a peasant group and of an elected local administrator. The same person is also the leader of the *gengeshi*, a council of active and respected people elected by a village population to tackle issues of rural life.

The *etrap* (administrative area) of Rukhabat in Turkmenistan's Akhal *velayat* (province) has been designated as a centre for solar power generation, specially created to achieve optimum ways of sustainable development in the rural setting, making use of current achievements in science and technology.

For example, one of the mine wells has been equipped with a solar-powered water pump. This is intended to help raise water from small debit wells and underground sources of fresh water with a depth of up to 30 m. It is driven by an electric motor with a constant supply – 36 or 110V. The pump is notable for the simplicity of its construction and operation. It is not seriously affected by water salinization or the presence of sand in the water.

The solar water pump installation consists of a photoelectric unit with a power of 360 W, a water-pump device with a rate of 1.0 m^3/h and a storage battery with a capacity of 125 ampere-hour.

The photoelectric unit has an assembly module construction that includes twelve modules of the type 'START-BS-5-01', with a frame and support. The assembling and dismantling of such a construction creates jobs. The support frame has hinge joints with props, set over a concrete base. The photo panels are oriented southwards, and the hinge joint makes it possible to make seasonal corrections of the inclined angle of the plane of the panels (zenith orientation). The photoelectric unit only requires one technician to carry out maintenance and correction of the inclined angle. The photoelectric unit outlet provides two outputs of 12V and 36V (or 110V) to charge the battery and the pump. The pump provides ecological protection of the well as it prevents flows and merging of the fresh and salt water in the well. More fresh water can be collected from the water-receiving part of the well, which is provided by a special watershed device.

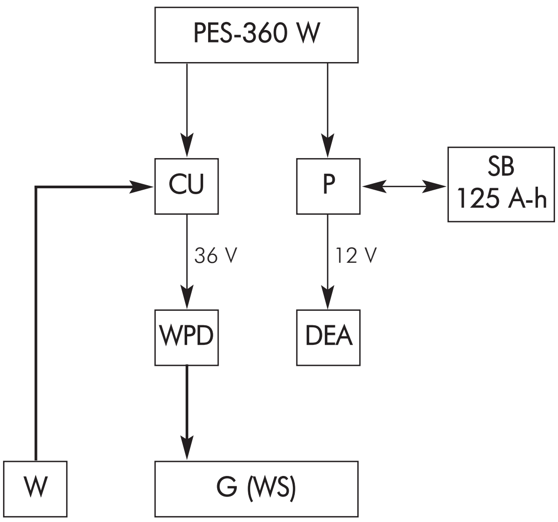

Figure 10.1 Block scheme of solar water-pump device

PES = photoelectric station; CU = control unit of WPD; WPD = water-pump device; P= protector for SB; DEA = domestic electrical appliances (TV set,refrigerator etc.); SB = storage battery; G = gaudan (WS-water storage); W = well.

Where photoelectric units and storage batteries are used they can be connected to domestic electrical equipment such as televisions, refrigerators, radios, lights and so on. Solar installations are therefore of critical importance for shepherds' farms and for the sustainable development of small settlements in the desert. They are guaranteed to have a long working life (more than fifteen years) and energy can be accumulated in batteries for use at night. These advantages, as well as the ecological benefits of solar power, confer an incontestable advantage to these installations in remote desert regions. The project implemented with funds provided by a grant from the Regional Environment Centre of Central Asia (RECCA) for the provision of electric energy from alternative energy sources in remote desert settlements will create jobs for the local population in the restoration of degraded pastures.

Increasing the fodder yield from pastures is one of a series of measures directed at the intensification of desert cattle-breeding. The efficiency of phytomeliorative action lies not only in the higher fodder yield, which has increased up to 1.2–2.0 t/ha, but also in additional profits. The net profit obtained from 100 ha of improved pastures is three to five times greater than can be obtained from untreated ranges. To repay the cost of creating pastures that will last for decades will take around four or five years. The long-term pastures created will continue to preserve high productivity and generate higher profits for twenty or twenty-five years after the costs have been paid off.

Interviews with local inhabitants of the remote desert settlements reveal how interested they are in participating in activities to improve pastures as well as other measures to combat desertification, such as providing a power supply to their settlements. The women are particularly keen to lighten the burden of household chores. As projects were carried out, the local inhabitants of the remote settlements located 120 km north of Ashgabat were convinced of the opportunity of improving their socio-economic conditions. The NIDFF of Turkmenistan has received the go-ahead for further measures within the framework of the UN

Convention to Combat Desertification. The Aarhus Convention also evokes public participation in decision making concerning the further development of cattle breeding industries in desert communities as well as environmental protection.

A number of priority projects to combat desertification in the Aral Sea Basin have been developed and submitted for consideration to the International Fund of the Aral Sea (IFAS) jointly with western donors, including the Global Ecological Fund and the World Bank. To extend the consultative service of the NIDFF, an English version of a book on the main trends of its activities, with recommendations on the rational use of desert territories for industrial consumers has been published (*Desert Problems and Desertification in Central Asia*, Springer, 1999).

On the basis of the recorded results of the project, RECCA has prepared a brochure entitled 'Sustainable development of the remote settlements in deserts'; this is issued in Turkmen, Russian and English-language editions, and may be of interest to all countries suffering from desertification.

In Turkmenistan in 1999 a **c**ompany called Gek gushak ('Green belt') was established and has developed wide-ranging activities for the creation of a protective forested zone around the capital of Ashgabat and other cities and centres of the *etrap*. These forests are soundly established and capable of protecting small settlements against hot and dusty winds in desert conditions. They also create a favourable microclimate and adorn the landscape. Within the last few years more than 50 million coniferous, deciduous, fruit and other trees have been planted.

Other effective measures in the field of nature protection and sustainable development have been carried out in Turkmenistan. One of them was to supply gas to all the small settlements around the country. This has considerably decreased anthropogenic pressure; the number of bushes cut down for fuel has fallen sharply, while the processes of natural forestation and the accelerated restoration of natural pastures are producing improved ecological conditions in the country.

The President of Turkmenistan has approved the decision for a new state development project in Central Karakum and the creation of Lake Turkmen, which is part of the huge programme of development in the country for the twenty-first century. The lake will have a surface area of 3,460 km^2 and a capacity of 132 km^3. Initial estimates indicate that the project will cost approximately US$5 billion over the projected twenty years of its implementation.

The Karakum desert curves around from south and east of the Karakum river and from the north by Amudarya. From the deserted areas in the south, numerous large and small drainage/collection systems such as Main Murgap, Jar, Tedjen, Ashgabat and Gekdepe water an area of 450,000 ha of pastures in Karakum.

The two main systems for the collection of drainage waters will be built in the first stage of the construction project. Their combined reach will be equal to more than 1,080 km. Water will accumulate in Karashor in Central Karakum, where there is currently a huge natural depression whose base is 25 m below sea level. Its length exceeds 100 km with a width in places of 12 km, and it can thus store up to 140 km^3. This will minimize the cost of reservoir construction.

Expert calculations indicate that there will be an improvement in the quality of water in lower Amudarya and a melioration in the condition of land areas in Dashoguz *velayat*, resulting in an overall rise of 25 per cent in crop production and an improved water supply for the population. The projects described above will have enormous value for further agricultural development in the country, for the substantial growth of water reserves and their secondary use to meet the economic needs of an Aral zone facing ecological crisis.

Lake Turkmen will be provided with up to 10 km^3 of water per year, which will drastically improve and meliorate the status of irrigated grounds throughout virtually all the country. Currently 1,800,000 hectares of land are irrigated and the creation of the lake will increase the irrigated area to 2,250,000 hectare in the long-term. Lake Turkmen will provide a powerful impetus to the development of fishing facilities in the country. It will also have an effect on the climate and will certainly become an important factor in the improvement of the ecological system, not only nationally but throughout the region.

This international seminar takes into account the issues evoked by the sustainable development of arid ecosystems combined with the use of modern technologies. This workshop is taking place in Russia, which has a certain experience in the development of methods to produce rain artificially, including experiments to use artificial atmospheric precipitation for watering purposes.

Transforming clouds into rain is big business, the demand for which is growing all over the world. This artificial rain maintains field fertility and provides areas with water. For Turkmenistan such artificial rains could solve irrigation problems and allow the planting of green trees in the Kopetdag foothills. Once there have been successful experiments on the use of artificial rain in the foothills, this experience can be expanded for sustainable development of dry agriculture in Turkmenistan and in other Central Asian countries.

In order to raise awareness among the population of the issues associated with combating desertification, the NIDFF is creating a versatile Natural Museum of Turkmenistan Deserts in Karakum. The purpose of the museum is to function as an original nature-study laboratory of the wild desert, combining the functions of a natural park for ecological purposes and for tourism and recreation. The museum will display the traditional methods that have been in use for centuries in the development of desert resources, and that were practised in ancient times by the Turkmen people. It is an original way of depicting the way of life of desert peoples in the past and present, and the extent of the combat against desertification will also be demonstrated.

Such experience in educational work on protecting nature in deserts and arid ecosystems in Turkmenistan has been conducted over many years. The Museum of Nature was created in 1948 in Repetek State Biosphere Reserve, and is now part of the World Network of Biosphere Reserves (WNBR). The museum houses and displays collections of many kinds of the butterflies, insects, poisonous arachnids and snakes found in the reserve, and of reptiles, birds and mammals that live there. The sandy landscapes of Repetek have no equivalent in the world and thus, quite rightly, the museum enjoys international status.

The Scientific Information Centre of the Interstate Sustainable Development Commission of countries in the Aral Sea Basin (SIC ISDC), based in Ashgabat with branches in all countries concerned, has an important role to play in decisions about regional and interstate ecological problems, especially in Central Asian countries. The need for integrated processes to agree on decisions in the environment and development field on the basis of economically effective, socially fair and sustainably responsible use of the environment is recognized.

The ministers for nature protection in the Central Asian countries initiated the coordinating role of the SIC ISDC as a regional system to support decisions for sustainable development. Since reliable information is a necessary prerequisite for coming to valid, consistent decisions, the SIC has been given a mandate to create and maintain an extensive database of ecological, economic and social data at the national and regional levels.

Today the SIC ISDC is the regional centre for developing the Central Asian system of support for reaching consensus on decisions in the field of environmental protection and sustainable development. The work will be carried out with support from UNEP, UNDP and the Asian Bank of Development.

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11 Integration of traditional knowledge and modern technologies for the sustainability of dryland ecosystems in Mongolia

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Arid and semi-arid regions make up 48.8 million km^2, 34 per cent of the world's terrestrial surface.The drylands are located between 15° and 45° in the northern hemisphere, and 13° and 22° in the southern hemisphere. Intensification of the desertification process is extreme in some areas. Conservation, adequate use and restoration of natural resources are important issues affecting all zones and regions, from the tundra to the tropics.

A quarter of the planet, or 38 million km^2, is subject to desertification, and more than a hundred countries (with 17 per cent of the world's population) are deeply concerned about this problem. Significant activities of international importance are being organized in order to identify and conserve dry land ecosystems, and to make better and more appropriate use of their resources within the framework of national and international agreements.

The dryland ecosystem is the main concern of global ecology in Mongolia, and its conservation has become an important planetary issue. More than 90 per cent of this landlocked country has a sharply continental climate and comprises arid and semi-arid areas with water deficits. The dryland ecosystem of Mongolia must therefore provide extraordinary scope for conservation (Figure 11.1).

The Mongolian drylands extend for 400 km in width and about 2,000 km in length, and occupy 41.3 per cent or 647 km^2 of the republic's territory, of which 19.5 per cent is in the Gobi desert and 21.5 per cent is in semi-desert (Sarantuya, 1995). Desertification processes in the Gobi desert move predominately from north to south, and are notably manifest in a sparsely populated, extra-arid tract along the frontier. Drought in the Gobi desert tends to occur annually .

Human-induced land degradation and desertification is relatively intensive in half of the northern arid

Figure 11.1 Mongolia

areas. Oases in desert areas are very sensitive ecosystems. Urbanization and agricultural development threaten the oases' ecosystem with a decreasing groundwater table, intensified land erosion and emerging salinized area, with the negative impacts of water and wind adding to the process. In Ekhiin gol, Bayan tooroi and Khurshuud, which suffer the same problem, large areas are seriously affected by desertification (Dash, 2000).

Recent surveys reveal that 76 per cent of drylands show initial signs of desertification: 20 per cent are at a medium level, 3 per cent at an intensive level and 1 per cent at a very intensive level of desertification. In Mongolia, 42,200 km^2 of the land area has sandy cover, of which 3,800 km^2 has appeared since 1940. A total of 96.5 per cent (42,175 km^2) of the sand area is in Gobi, while 3.5 per cent (1,527.5 km^2) is in the north; the Khangai landscape and sanded area is equal to 2.79 per cent of the territory of Mongolia. Illegal logging of saxaul trees in 125,000 hectares of forest has resulted in the degradation of 38,000 hectares of land. The deterioration of 4.8 per cent of sanded areas, originally caused by wind erosion, is mainly due to frequent drought and inappropriate human activity such as bad pastureland management and fuelwood collection.

Over the last seventy years, livestock numbers in Mongolia have increased by 44 per cent, while the area of pastureland has decreased by a fifth. Between 1970 and 2000, the biodiversity of flora in the dryland pastures declined from 33 to 18, and the yield from 1 ha of land dropped from 320 to 230 kg. During the last decade, the increase of livestock was recorded as 7.7 million or 28.9 per cent, while the area of pastureland decreased by 5–6 million hectares. In the last quarter century, yield production dropped to between 19 and 44 per cent, and 77.8 per cent of the entire land has been degraded by inappropriate farming that opened the land to water and wind erosion, and by the importation of damaging technologies and herd species. Around 46.5 per cent of the state's rotational land has been affected by soil erosion. More specifically, it has become commonplace to leave uncultivated the land that becomes unusable for producing crops; this amounts to 28.5 per cent of the total. Almost 70 per cent of this land suffers from heavy soil erosion and is not subject to crop rotation.

There are many roads that criss-cross the mountains and steppes and have ravaged more than 800,000 hectares of pastureland. Thus, pastureland with a potential feeding resource of 1.9 million tones is destroyed due to the presence of roads. The length of derivative land is 200,000 km. A further large area of land, 5 million m^3, suffers degradation due to the extraction of minerals for geological research, where mines and excavations are not restored when production ends. Since 1960, chemicals such as HCH phosphoric zinc powder, NaCl, butyl ether and granozane have been extensively used to fight rodents and weeds in pastureland.

The meteorological data of the last sixty years indicate that the driest weather was observed in the mid-1940s and 1980s. Drought in Gobi seems to occur once every three years. During the period 1960–90, the Gobi region was characterized by a decreased amount of precipitation.

Erosion of soil in dry areas is caused by wind and water erosion, with dust storms in the Mongolian dryland lasting for thirty to sixty days. The longest

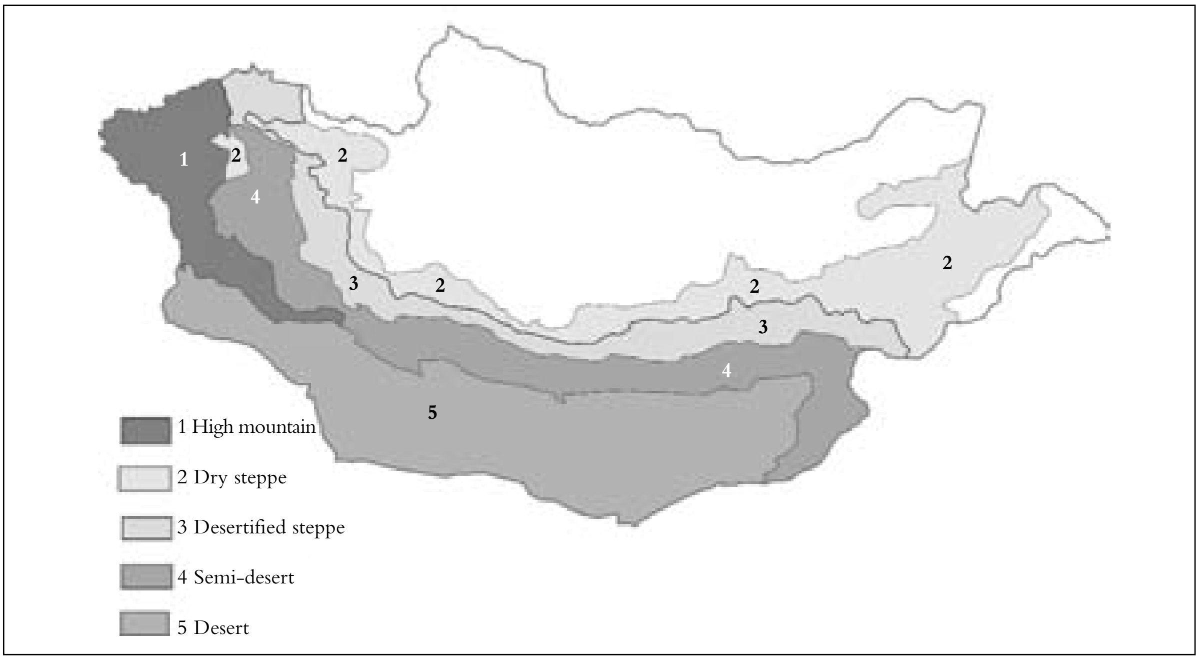

Figure 11.2 Dryland ecosystems of Mongolia

sandstorms occur in the Great Lakes depression, and may last for 120 days. Since 1960 the number of days with sandstorms has tripled, which is evidence of intensified land degradation. Therefore, ensuring the sustainable management of dry ecosystems is a crucial issue for Mongolia.

Not only is there a failure to invest in new methods or know-how for pastureland management, but there is also a disregard for methods that use traditional knowledge, and this despite the fact that the principles of nature protection and development – the conservation, restoration and use of natural resources – are deeply rooted in the local knowledge of people of every nation, including the Mongolians. Mongolians have a long tradition of natural resources management and rotational utilization of pastureland. The latter prevents the erosion of grazing lands, as it keeps the springs clean and allows the animals to survive while maintaining their strength. The Mongolian tradition of nature conservation can be divided into the strands discussed below.

- *The reforestation tradition*. The Mongolian people have inherited a strong, ancient tradition of nature and pastureland protection, and the know-how to plant trees and bushes to create gardens. This experience is now of great importance. However gardening has become more difficult and complicated because of the dry climate and fragile soil. Over the last twenty years, we have achieved some success in regions where the climate is very dry. For instance, a strip of forest was planted with saxaul, wild olive, tamarisk, elm, silver aspen and karagana bush to protect against sand movements in the Khukh-Morit *soum* of Gobi-Altai province and Zamiin-Uud *soum* of East-Gobi province. Experience has shown the effectiveness in combating land degradation of planting indigenous trees and vegetation that are used to the local climate.
- *The nature conservation tradition*. Mongolians have an ancient tradition of protecting and preserving the beautiful nature and landscape. The ancient legal manuscript called *Khalkh Juram* ordered the protection and preservation of fourteen mountains, including Bogd khaan, Khan-Khentii, Khugnu-Khaan and Zorgol-Khairkhan Mountains. In 1778, the Bogd khaan Mountain was designated a reserve and strictly protected area (it and its surrounding area are now included in the World Network of Biosphere Reserves). Today, 13.4 per cent of the country's territory (in fifty-four areas covering 15.6 million hectares) has official protected area status. National parks with a typically dry climate include the Great Gobi and the Small Gobi Strictly Protected Areas (SPA), Lake Uvs basin SPA, Lake Khan-Us, Lake Khan-Khukhii and Lake Khyargas National Parks, the Bulgan River, Sharga-Mankhaa, Zagiin-Us, Ergeliin reserve, Ikh-Nart, Toson-Khustai, Yakhi-Lake, Suikhent National Parks. The Great Gobi and the Lake Uvs SPAs have been included in the World Network of Biosphere Reserves (Figure 11.3).
- *Traditions related to religion and religious beliefs*. The Mongolian tradition of nature protection is linked to Buddhist practices as well as to the fact that Mongolians sanctify and worship their motherland. For instance, it was specifically prohibited to dig up the land, kill animals or cut down vegetation on sacred land. The Mongolians believed that if this unwritten law rule was violated, nature would

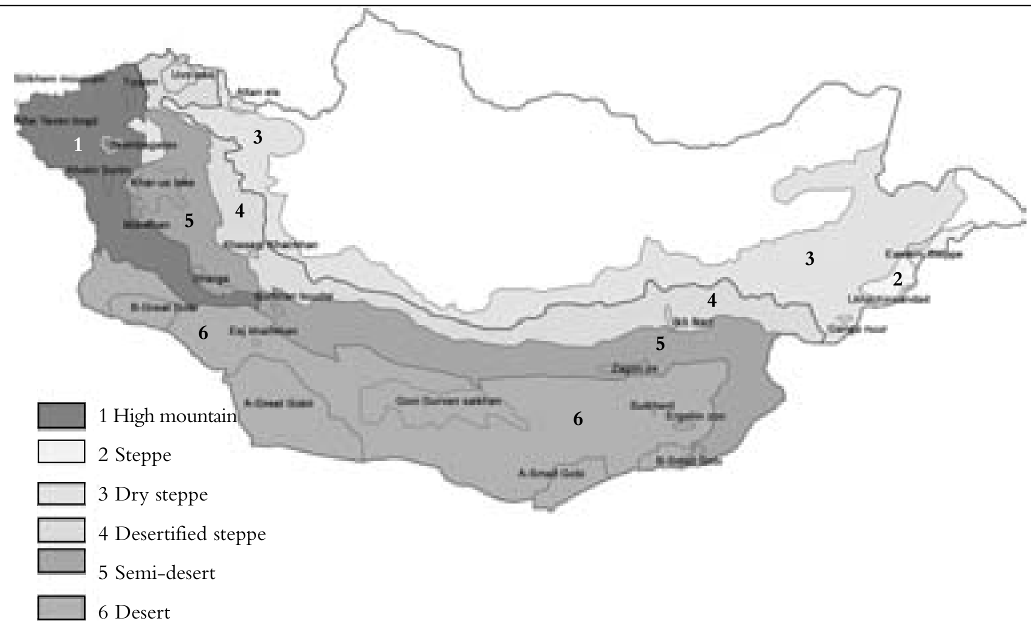

Figure 11.3 Protected areas in dryland ecosystems of Mongolia

unleash drought, flood and fire to punish the culprits.

- *Traditions connected with everyday life and customs*. Cattle breeders have a surprising ability to predict the weather. They are able to forecast tomorrow's weather for the day-to-day management of the pasture and also predict it over a longer period. Thus they are used to resolving many everyday problems, and these traditions are still being used.
- *Pasture management practices*. The proper use of pastureland is one method of protecting the dryland ecosystem. The main characteristic of this traditional method is the change of pastureland over the four seasons, which is widely practised by cattle breeders. The pasture management of the cattle breeders, used in summer and autumn is called the *otor* method, and the grazing grounds are changed twice, in winter and spring. The administration, distribution and use of pastureland was very important among the Mongolians. Throughout the history of Mongolia, livestock breeding was the basis of economic life, and it was heavily dependant on precipitation and the growth of vegetation on the pastureland.

The main purpose of state policy for the protection of the dry climate regional zone is to protect its natural wealth and fertility, which are the basis for the sustainable development of the country, to halt the damage that threatens the ecosystem and to remove the causes of desertification. The ultimate aim is to improve the environment and the living standards of the local people.

The policy for sustainable protection of dryland ecosystems will be implemented within a concrete legal, social, economic, environmental and geographical framework. It is necessary that this should follow the principles for ecological sustainability and help develop an economy that supports the ecosystem and is appropriate for the current condition of the environment in the transition period. The dryland ecosystem is being damaged by the harmful effects of inappropriate human activity, and biological diversity has been reduced by the declining economic potential of the region; all these factors contribute strongly to desertification.

The tradition of nature protection needs to be skilfully combined with modern scientific and technical knowledge, producing the most rational approach to protecting the dryland ecosystem. Distance education and teaching methods will be widely used, along with communication and public awareness campaigns and other educational initiatives in order to bring tangible results, combating desertification by psychologically preparing the local population to change.

Having studied the difficulties associated with land utilization, and the reasons for desertification of a region with a dry climate, it is now important to improve pasture management. Relevant measures include the formulation of recommendations to combat sand movements, the planning and carrying out of practical measures for protecting the dry climate region, complex analyses of the social and economic conditions in the region, and defining concrete measures for further steps.

It is also important to work out scientific grounds for protecting the dry climate region, to organize mechanical protection against sand movements, to plant trees and bushes, to irrigate pastures, to avoid use of pastures during certain periods, to modernize land management and to introduce new progressive technology into land management.

Nowadays, the world's main strategy for the conservation of dryland ecosystems is to establish green zones by planting trees and bushes. Sustainable development of dryland areas in Mongolia, in view of the points mentioned above, should involve the following policy implementation and actions:

- To prevent pasture degradation, it is necessary to create forest shelter belts or massifs and regulate livestock numbers.
- Saxaul forest should be reforested.
- Plantation should be undertaken on sand dunes to prevent sand movement.
- Green zones are needed to prevent sand movement in settled urban areas.
- Shelters and forest plantation should be built to protect livestock, herders, wintering camps and fences, as well as shelters from direct sunlight, dust storms and sand movement.
- Gardens should be introduced in cities and settlement centres.
- Tree belts are needed to protect railways and roads from sand movement.
- Arid ecosystems should be given protective status, and enlisted into the world network of international biosphere reserves.

Due to the climatic and natural characterisitics of Mongolia, especially during the spring season when the wind speeds and sandstorm frequencies increase in the drylands, sand movements and sand dunes are likely to occur, causing a disturbance in household activities. There are various ways to prevent sand movement. These include biological or biotic action, which involves planting vegetation, and mechanical or abiotic action, using chemical substances. In the specific conditions of the Mongolian climate, the biotic method is commonly practised, along with abiotic action in urban areas, water units and mineral mines.

Conclusion

The landlocked nature and sharply continental climate of Mongolia explains why more than 90 per cent of the land comprises arid and semi-arid areas with scant

Table 11.1 Potential measures for dryland conservation and restoration

Principal directions of measures	Measures to be implemented
1. To improve pasture management	release pasture from use for certain periods reduce the grazing period of livestock re-use the less-utilized pasture rotate lands used for pasture appropriately irrigate the pastureland
2. To combat wind erosion	prohibit the grazing of livestock on land exposed to severe sand movements set up forest belts fix the sand movement prohibit the use of trees and bushes as firewood
3. To combat water erosion	create terraces on slopes exposed to erosion exclude open streams of water from irrigation systems dig protective dykes and trenches create water accumulation reservoirs
4. To combat salinization	protect the pasture around land and salt marsh from over-erosion reduce amount of salt in soil strictly observe the norms for irrigation of land under cultivation
5. Forest protection	prohibit the use of bushes, trees and elms river as firewood or timber supply the population with wind and solar generators
6. To improve water supply	find new irrigation sources provide research opportunities establish wells for mining and normal wells restore damaged wells, protect them from sand pressing invest in rainwater-collecting technology
7. To improve land use management	include land with fragile and specific ecosystems in the state and local special protection improve specially protected areas develop ecotourism plant appropriate vegetation with provision for irrigation
8. To restore and utilize land	cover up mine shafts, and restore exploited land reduce transportation problems by establishing straight, hard-surfaced roads restore and improve overgrazed land around wells and springs restore and use abandoned crop land

humidity. Consequently the drylands of Mongolia have an extraordinary interest for conservation.

The folk tradition of nature protection, its constraints and experience, should be skilfully combined with modern scientific and technical knowledge. Distance education, organized communication and public awareness campaigns will bring tangible results for combating desertification by psychologically preparing the people for change.

Having focused on the difficulties associated with land utilization while analysing the reasons for desertification in the dryland areas, this paper has indicated ways to improve pasture management. Among the relevant measures are: to formulate recommendations for combating sand movements, to plan and carry out practical measures for protecting the dry climate region, to make complex analyses of social and economic conditions in the region and to define concrete measures for further steps. It is also important to work out the scientific principles for protecting the dryland region, and to organize mechanical protection against sand movements by planting trees and bushes. Other actions include the irrigation of the pasture, releasing pasture from use over a certain period, modernizing land management methods and introducing new progressive technology into land management.

12 Traditional knowledge in Moroccan drylands

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Drylands are areas that are permanently deficient in useful natural resources as well as being the theatre of extreme conditions. We could therefore define the sustainable management of such ecosystems as a way of maintaining these impoverished environments so that they continue to provide essential needs on the basis of causing minimum disturbance to the natural heritage with, as far as possible, a process of auto-regulation that achieves an acceptable natural and socio-economic balance.

For the inhabitants of the oases, the sedentary part of the desert population, this definition essentially means the production of food and services and the maintenance of a habitat that has been rigorously shaped by the oasis and is concentrated in an extremely small area. This obviously implies shrewd water management requiring unique ingenuity both to achieve an optimal organic and diversified production and to maintain the solid social cohesion needed for major undertakings to safeguard the community and, even more important, build and maintain its infrastructure. Apart from basic production, income is provided by subsidiary activities such as handicrafts, small-scale mining and, most of all, commerce. Trans-Saharan commerce has long been essential and lucrative because of its almost global scope, and crossing the desert required expertise and protection that were practised in masterly fashion by nomads. A powerful sociocultural structure assured the general cohesion of sedentary and nomadic groups, assigning roles and inculcating appropriate attitudes.

Today, this pattern, which was for the most part well balanced and structured, has largely been consigned to history. Economic and cultural expansion, as required by colonial globalization models as well as the subsequent portrayal by the media in the twentieth century, has profoundly disrupted this way of life. It is actually impossible to find traditional knowledge models in sovereign existence anywhere. Instead the general rule was to scorn traditional ways.

The pre-Saharan zone of Morocco typifies this situation. The zone is in fact well endowed by nature and has a great and splendid cultural heritage. However, due to its close position to temperate Europe, it has endured all the processes of acculturation perpetrated in the twentieth century. Yet it has the precious advantage of having preserved much of both worlds in so much as it retains the local structures relating to the rational management of aridity as well as the invasive models and powerful technologies that are excessively predatory. Over the past century, the two forms of management of space and society have been incompatible and mutually disrupting. The result is a complex montage of the two civilizations where it is nonetheless possible to recognize the distinctive traits of each.

From the beginning, it was imperative for the population of the oases to cover the absolute needs of the community from the available arable land; these constituted only the areas capable of forming an oasis and were always of very limited size. The pre-Saharan Moroccan zone, which is well endowed by nature, receives its water – and therefore its existence – from the neighbouring Atlas mountains, which border it to the north. The populations, who have lived here for thousands of years, have always believed that the only usable areas are the banks of the water courses from the mountain, a small strip of land whose soil is provided only by the fine sediment brought from the High Atlas, served by the replenished surface water, with the inhabitants excluding all use of fossil water.

In terms of the shrewd management of scarce resources in such conditions, three principles for the best possible approach that will produce the greatest benefit are outlined below.

- *The extreme intensity and diversity of agricultural exploitation* is seen in the elaboration of the '*staggered*' oasis. Just below the upper canopy of date palms can be found a second level of Mediterranean fruit trees, and below them are cereals, fodder, vegetables and cash crops such as roses, henna, and *gombo* or saffron. There is also extremely effective cattle farming in the oases, typically using cowsheds. Most of the agrodiversity, animal as well as plant, is endemic and highly specialized. There is a whole drylands culture that covers the entire spectrum from the valuable Demmane ewes and Saharan bees to the multitude of date varieties. This should be carefully studied, in terms of local expressions and ecological knowledge, so as to finally find its place in the register of official science.
- *A pattern of ownership that is specific to the Sahara* is well designed to overcome the handicaps due to the lack of space. It gives the community the right to be involved in 'oasian' affairs and even to enjoy a certain flexibility in the application of Muslim law in order to prevent loss of land. The very limited area that can be handed down from generation to

generation has rendered the notion of ownership essential, and thus dependent on a common solidarity. Moreover, in the same way as there are staggered layers of agricultural exploitation, we find a multiplicity of ownership levels superimposed at the same levels. It is thus possible to distinguish a property that is marked by a tree on one side or water on the other, as well as by the usual system of land distribution. Inheritance rights are also decided by consensus so as to prevent the exchange of agricultural land outside the oases, as happens for example in the case of marriage. In the Djemaa oasis, responsibility is vested in a group of heads of families, thus preventing outside authorities from interfering in local affairs.

- The *ksar* is a *medina* that is specific to the Sahara. It consists of a fortified urban unit that benefits from at least three optimal spatial qualities and proven sustainability, a formidable challenge in such a sparse environment of extreme conditions. The Saharan *ksar* takes advantage of the synergies between an extreme concentration of inhabited space, a functional distribution of local elements, and a systematic adoption of collective services. Furthermore, the art of building the earthen *ksars* goes well with the defensive architecture that characterizes them to produce aesthetic masterpieces. The working space of the oases is so arranged that the urban districts never encroach on the arable lands, which are entirely reserved for organic production and which are given priority in terms of choice in land planning.

In short, the oases centres and the arid and hyper-arid area of the steppes that surround them have always been linked by a sort of socio-economic pact. There are two reasons behind this solidarity. The mainly sedentary and agricultural oasis populations perfectly compliment the steppe dwellers with their pastoral economy and nomadic transhumant activities. The people of the oasis are known for the mild way in which they work the soil, while the nomads, once fierce warriors, are important itinerant cattle herders who cover huge areas, marking out their tribal territory as they migrate with their cattle, and totally disregarding modern-day national boundaries.

For these reasons, the social structures were inextricably entwined, and were expressed in their intelligence with regard to the use of the environment, territorial planning, resource exploration and human settlements.

The drylands of the Mahgreb, and particularly of Morocco are, directly dependent on the Atlas mountains, which exert two major controlling effects on them:

- *The mountain range is the principal supplier of strategic natural resources, water and fine sediment to the desert.* Due to this geographic configuration, the Moroccan pre-Saharan zone relies on running water originating from the mountains and the population has always followed the agricultural calendar on tangible and renewable hydrological and nival resources. This makes it possible to follow a sustainable water policy, whose consequences are easily foreseeable. The majority of oases are thus fluvial in origin and for the most part do not rely on underground water. More than 90 per cent of the production of dates in Morocco, for example, is secured by fluvial oases. Only a mountain that is massive and elevated enough (more than 4,000 m in the case of the High Atlas) is capable of providing this margin of security in the Saharan latitudes. Moreover, the water originates in the Atlas within national boundaries, thereby removing any dependence from neighbouring countries.
- *The Atlas chain isolates the Moroccan pre-Sahara of the Mediterranean zone*. Communication was historically more common with other regions of the Sahara such as Egypt and Mesopotamia than with northern Mediterranean countries. During more humid periods of varying lengths, this circulation of ideas, knowledge, practices and lifestyles became even more easy and intense. Conversely, the same humid periods, which brought more snow and even glaciers on the mountains, only accentuated the region's isolation from the North. Ancient trade routes can be reconstituted from Egypt across dry arid stretches to Chad, Niger, Hoggar and Tassili. Traces can still be seen of the corresponding rivers crossing the Sahara from their origins right up in the high massifs and the dividing watershed in the heart of the Atlas mountains. Concurrently, a sort of cultural continuum existed from archaeological times right up to the nineteenth century, and through great historical events at a regional or even global scale.

Throughout the twentieth century, lifestyles seen as modern and universal have systematically drained the vitality of traditional society, considered underdeveloped because it is less productive in terms of output. European-style cities, mechanized agriculture, high-output mineral exploitation, successful industries and services with a reputation for quality, notably in luxury tourism, and the prevalence of modern mass media have more or less completely marginalized the *ksars*. Their small-scale domestic agriculture, traditional irrigation techniques, functional handicraft wares, in fact all their activities are seen as laborious with low output.

Indeed, in view of the power of technology and technological outputs, the survival of traditional models, with their techniques, equipment, lifestyles and convictions, raises wonder. It proves beyond doubt that the ancient arid civilisations possess a heritage of adaptation and self-assurance that makes them an ongoing reference point for the world.

It is evident, however, that despite the vigorous resistance that has safeguarded Saharan traditions, losses do seem irreversible, not least because the principal driving forces behind traditional attitudes have essentially disappeared. Security has of course become a national affair. There is no longer a need to reinforce urban settlements nor is there a sense of tribal solidarity. Moreover, inequalities among the population occur with the introduction of large-scale infrastructural developments. At the same time, the easy accessibility of services from such projects threatens to nullify all traditional forms of solidarity developed through working together to meet the community's needs.

There are numerous signs of the emergence of this seriously imbalanced situation. Among others:

- *The abandonment of the ksars is becoming commonplace.* The traditional Saharan urban structures are deteriorating and their residual population is becoming poorer, in a way that is comparable to the fate of the Moroccan *medinas*. We are in fact witnessing the disintegration of the *ksars*. This is accompanied by the extra-mural construction of interminable rows of concrete buildings, constructed on Western lines, which multiplies never-ending needs for resources and sophisticated 'city' commodities, and above all for water.
- *The development of the modern oasis* is generally seen as an investment in quality, bringing in a constant flow of capital using scientific agronomic practices. However, that involves recent additions, which provide a certain leverage compared to traditional oasian systems of a fluvial nature. Secure in terms of financial and technical means, people could open up new grounds and use of underground water. But, in so doing, they ignore the fundamental precept of traditional life, which essentially uses water from the surface network, well aware that the exploitation of underground reserves diverts the hydrological supply and constitutes a threat to the general system of distribution.
- Finally, a massive urban system appears, itself structured around the traditional centres but detached from them and able to offer and manage modern administrative, technical, socio-economic, industrial, commercial and security services. Modern cities are the most recent phenomenon in the Saharan environment, but have nonetheless become inevitable. Their institutions have even managed to take control of the irrigation systems, through the powerful regional offices for agricultural affairs that manage the irrigation networks of dams constructed in the early 1970s. The cities are also home to some of the most sumptuous hotels and palaces in the country, for tourism has come to be considered the principal development activity in the Saharan regions. It is obvious that these structures and activities drive up the demand for natural resources, particularly water. The limits on resources are disregarded as there is no general assessment for the regional potential as a whole. Bearing these aspects in mind, the new consumerist society in these towns clearly appears as inappropriate and ruinous. This is the more starkly evident since it exists alongside an oasis agriculture that is extremely respectful of environmental concerns and cautious in its approach to water usage, especially as the region is confronted with persistent droughts that manifest as severe shortages, endangering palms and increasing soil salinity.

The reactions to the imbalance occurring in the natural environment are complex and have been expressed throughout this period of changing attitudes. There are many examples of the renewed onslaught of desertification processes.

The deforestation of *Acacia raddiana* on the structured steppes is essentially a recent phenomenon that has completely denuded the interfluves bordering the oasian valleys. Due to wind circulation in increasingly exposed areas, the sandy dunes have encroached dangerously near to the human settlements. Artificial structures that fix the dunes are appearing closer to the villages along roads, and need to be increasingly heavy. In some cases irrigation structures have been buried.

The mountain valleys, whose lower portions extend into the desert, have few landslides but have become dangerously exposed. These valleys contain extraordinary humid landscapes of rich biodiversity, which is associated with localized flows of water from wadi underflows. Today, they too have been obliterated by sand that renders them completely sterile. A notable case is the vast abiotic desolation of the Draa lower valley. The evidence of its once-luxuriant past is shown by the abundance of surrounding archaeological sites that are rich in cave paintings. Some decades ago the landscape was an attractive and advantageous site for an important nesting colony of pink flamingos. There are even sites that have recently been inscribed as national sites of biological and ecological interest (SIBE or *sites d'intérêt biologique et écologique*). The coincidence in timing between such environmental degradation and the construction of the Mansour Eddahbi dam (1972) close to Ouarzazate on Draa, more than 200 km upstream, is disconcerting and teaches us a valuable lesson.

The principal lesson learnt is that water from the High Atlas after having formed a veritable pre-Saharan fringe with a powerful oasis structure of about 800 km in length by 100 to 200 km in N-S width and thanks to an original network of perennial surface flows, continues its work in naturally combating desertification by engaging itself further into the desert in the form of underflows. This water (in an underground manner or locally in fairly wide flows) manages to supply the steppe biotopes and the Acacia bush that is capable of elaborating a slope of solidly rooted living matter and with proven efficiency to stop sand encroachment. Only traditional 'oasian' know-how, carefully adapted and fine-tuned over the centuries, is capable of both maintaining life in the pre-Saharan zone and to keep the wind rushes of the African Sahara at bay. A few decades of short-sighted and totally ill-adapted behaviour is enough to reduce a significant portion of the entire zone of specialised civilisation, the only type capable of creating an intricate and elaborate life model learnedly inscribed within an historical dimension in these latitudes of extreme shortages.

To conclude, the delicate survival of the pre-Saharan zone depends on a vast operation of successful rehabilitation, moreover, it has a planetary role. In the case of the Maghreb pre-Saharan zone, it is situated on the Saharan front and is a living buttress providing a genuine obstacle in the combat against desertification that directly benefits the entire Northern hemisphere and probably the whole of humanity.

It has been proven that its function is essentially of a cultural origin, as beneficial modifications of the extremely precarious bioclimatic conditions. It is evident and logical that the culture has developed in contact with nature over a very long period of time and is thus best adapted to the point of producing a genuine arid civilisation. Such a civilisation relies heavily on all landscape components, as much in the dense and complex structure of the oasis as in the dull boundless horizons of the steppes.

The collapse of the pre-Saharan zone that occurred during the twentieth century is too abrupt to be attributed to some form of natural bioclimatic change but can also be linked to the introduction of an imposed and discordant culture, that of a dominant world economy. Furthermore, it emerged as being totally ill-equipped resulting in a definite retreat and growth of the pre-Saharan zone. For the first time in the natural history of the planet, we are subjected to an unfavourable climate of entirely cultural origin.

Cultural rehabilitations are for most realist researchers an impossible task. Attempts have nevertheless been made particularly in Morocco to rehabilitate specific separated elements: those that are decisively the most effective or the most attractive.

The 'khettaras', a Moroccan name for a system of irrigation composed of a network of underground collect tanks, are known to be the best approach to capture and distribute water that has ever been developed in the arid environment. Its effectiveness, which has never been rivalled, explains its return to service following a period of partial abandonment. Improved models have been proposed. They attempt to maintain performance while reducing the difficulty in construction and maintenance.

A number of *ksars*, before their designation as UNESCO World Heritage sites, showed that they could become an appreciable resource for tourism. Particular attention has been given to those that are most aesthetic or the most representative. The Centre of Study and Research of Ksars and Saharan Casbahs (*Centre d'Etudes et de Recherches sur les Ksars et Casbahs Sahariens* or CERCAS) was created under the auspices of the Moroccan Minister for Culture to defend the cause in a rational way and capital was raised for the physical restoration of the monuments.

In every case, success was moderate. It appears to be very difficult to restructure a single element when the spirit of togetherness is lost.

The rehabilitation of the pre-Saharan zone is an incredibly difficult process involving oasis and steppes and quite simply implies the fate of the whole world. It is obvious that continuing with the actual destruction is completely suicidal; however it is not conceivable to attempt a return to the original condition. The future most certainly lies along a third path that takes into consideration the richness and technicity of the present in combination with tradition that remains intelligent and alive and that seeks a harmonious balance between society and its environment.

When the stakes are this important it takes courage to go towards difficulty and to create the school of cultural rehabilitation in a conceptual sense, where all forms of rehabilitation, including biotic and abiotic, organize themselves to serve the diversity of civilizations.

Session 3: Traditional knowledge and modern technology for wildlife management systems

13 Indigenous knowledge of plant uses in arid land: Wadi Allaqi case study

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Abstract

The livelihood of nomads and pastoralists depends on the limited resources of arid lands. The more severe the aridity, the fewer the available resources. In the extreme arid desert where Wadi Allaqi Biosphere Reserve (WABR) is located, nomadic and semi-nomadic people use almost every one of the 130 plants growing in the area. For the management of resources they use the *hema* system, a traditional land use developed in the Arab lands and enforced by nomadic pastoralists. Only deep knowledge of the uses of these plants, combined with knowledge about the management of limited resources, enables people to survive in such a hostile environment. Traditional knowledge of plant uses is widely recognized by scientists worldwide. However, local knowledge about resources management where the conservation strategy is the key element in land use is not significantly acknowledged by developers

The management programme for the protection of biodiversity in WABR is based on the knowledge of local people about the uses of these plants together with scientific knowledge of plant ecology, and the application of new technology in the habitat restoration programme.

A scheme for assessing the economic and conservation value of plants found in the Allaqi region was developed on the base of indigenous knowledge, with the help and participation of indigenous people. Using a simple scoring system, an importance value for various uses was calculated. The system was based on the actual and potential uses of different species. It allowed for differentiation between those species of high actual and potential economic value, and those with some but a lesser degree of utility. This study of economic use value has formed a component in the establishment of overall conservation priority for particular plant species. Species that were both relatively rare and had a high use score have the highest conservation priority. Examples of such species include *Balanites aegyptiaca*, all *Acacia* species found in the area, *Ziziphus spina-christi* and plants of significance for medicinal and grazing purposes.

Restoration of habitats by the development of plantations as an alternative to the exploitation of wild stocks has been proposed for fuelwood, building materials and medicinal plants. Modern and appropriate low-cost technology was used to establish plantations in ecologically favourable habitats.

Introduction

Water deficit is the main constraint of the drylands, which cover about 41 per cent of the earth's surface. About a third of the human population lives in the drylands, which provide them with all goods and facilities. With increasing aridity, biological productivity has declined and provides fewer services to humans. Most of the land resources of arid countries in North Africa and the Middle East are, at best, only suited to pastoral livestock keeping. The traditional system was, and in some areas still is, essentially nomadic or transhumant, with seasonal movement of flocks in search of water and grazing (Upton, 1995).

This article focuses on resource use by Bedouins, who make up the main population of the vast desert areas of Egypt.

About 96 per cent of Egypt is desert land, with annual rainfall varying from about 100 mm on the Mediterranean coast to almost nothing in the southern part of the Nubian Desert. In spite of the temporal and spatial variations of rainfall, the Mediterranean lands provide almost permanent pasture for Bedouin livestock, which is intensively used. The more severe the aridity, the fewer the resources that are available. In the extreme dry conditions prevailing in the southern part of the Eastern Desert, plant life is confirmed to wadi drainage systems. In rainy years wadis are covered by dense plant carpets, comprising mainly annual plants that provide excellent pastures. However, such rainy years may happen only once in many years, and the rest of the time only a few deeply rooted perennials survive the severe dry conditions.

Despite such harsh conditions scattered nomadic populations still inhabit these areas. Some of them are truly pastoral nomads (for example, the Khushmaan clan of the Ma'aza tribe) who raise animals (sheep, goats and camels) and move them across the Eastern Desert between the Nile and Red Sea hills following the rain, which provides the livestock with ephemeral pasture. 'They have no fixed dwellings: home is a mobile woollen tent or a temporary windscreen of dead plants' (Hobbs, 1989).

Others (like the Bishari tribe in Gebel Elba and the Eastern Desert bordering Sudan) are more closely attached to certain areas where water is available and where they dig wells and build wooden shelters, and from where they move to temporal pastures, returning to the water source during the rainless period. The livelihood of this nomadic population is based on the resource characteristics of the system of wadis. The main components of their economic system are livestock transhumance, charcoal production and collection of medicinal plants (Briggs et al., 1993).

Only deep knowledge of the uses of these resources in combination with knowledge about the management of limited resources enables people to survive in hostile environments.

Traditional knowledge

Knowledge of the use of plants in Egypt goes back to ancient times and has been well-documented since the Pharaonic era (from around 3000 BC). It has come down to modern society by being well presented as drawings and paintings on the walls of ancient tombs and temples, descriptions on papyrus, and even dried plants and plant parts such as fruits in the tombs of the Pharaohs. In Bedouin society, traditional knowledge has been orally transmitted from one generation to another over thousands of years. This knowledge is very dynamic and pragmatic, varying in time and space. There is still a well-defined bridge between ancient Egyptian and present Bedouin knowledge about the uses of desert trees. Fruits of *Balanites aegyptiaca*, *Hyphaene thebaica* and *Ziziphus spina-christi* have been found in baskets and pots in Pharaonic tombs (Hepper, 1990); these trees still grow in the Eastern Desert and their fruits are widely used by Bedouins and collected for sale in the local markets.

A quite astonishing phenomenon was recently observed in the Eastern Desert. Bedouins, who had recently moved from the remote desert areas and semi-settled on the shores of Lake Nasser, attracted by the water available, have tamed the wild Egyptian goose which was one of the domestic species for the ancient Egyptians (Houlihan, 1995)

Testimony comes from the past on the behaviour of Egyptian goose in a text dating from the New Kingdom Ramesside period:

> It (the Egyptian goose) spends the summer in destroying the dates, and the winter in destroying the emmer. It spends its free time of the year pursuing the cultivators, and allows not the seed to be thrown to the ground before it has got wind of it.
>
> (Houlihan, 1995, p. 112)

This warning did not reach developers who in the 1990s sowed seeds of fodder plants from the plain to be grown on the shore of Lake Nasser. Not surprisingly all the seeds were eaten by birds, mainly by geese. Cultivation on the lakeshore suffered the same fate.

Indigenous (local, traditional) knowledge is the chain of knowledge of different resources: animals, plants, soil, landforms and energy sources. All are linked to each other in maintaining the traditional livelihood that often is called traditional ecological knowledge (TEK) (Watson et al., 2003).

> According to Pierotti and Wildcat (1997), TEK promotes 1) respect for nonhuman entities as individuals, 2) recognition of bonds between humans and nonhumans, including incorporation of nonhumans into ethical codes of behaviour, 3) appreciation of the importance of local places, and 4) recognition of humans as part of the ecological system, rather than as separate from and defining the existence of that system.
>
> (Watson et al., 2003)

'As a result of these connections with the nonhuman world, native peoples do not think of nature as wilderness but as home' (Pierotti and Wildcat 2000).

TEK is excellently described by Hobbs who studied the life of the Ma'aza tribe and travelled many hundreds on miles on foot with nomads of the Khushmaan clan living in the Eastern Desert: 'The Khushmaan know a great deal not only about interrelations of plants and animals but about the life-cycles, habits, habitats, and other details of particular animals and plants' (1989). The ecological value of *Acacia* and *Balanites* trees growing in Wadi Allaqi is well known to the Bedouins inhabiting this wadi. Both trees are drought resistant and capable of growing on poor-quality soils, and do not attract snakes and scorpions (Briggs et al., 1999).

Traditional knowledge of plant uses is widely recognized by scientists worldwide. However, the local knowledge of management of resources where conservation strategy is the key element in land use is not significantly acknowledged by developers.

Example of the hema system

The *hema* system is an example of traditional land use that was developed in the Arab lands and enforced by nomadic pastoralists.

From early times, land-use rights to particular areas of rangelands were ascribed to particular tribes under various systems of communal tenure. A particular form of communal tenure developed in the Arab heartland is *hema*. Certain areas belonging to Bedouin tribes were declared as *hema*, meaning protected and off-limits, and access to them or using them in specified ways was restricted by inter-tribal agreements or by force.

Draz (1969) enumerates the following forms of *hema* management:

- grazing prohibited, grass cutting permissible by controlled licence during specified periods and droughts
- grazing and grass cutting permitted in certain seasons
- grazing allowed the year round, but the number of animals controlled
- reserved for bee keeping
- tree reserves, with tree cutting prohibited.

Under the national land-reform policies of the 1950s and 1960s, *hema* was banned along with all traditional communal land-use systems in most states. The desert regions were declared state-owned and open to unrestricted use by all citizens.

To some extent, land management similar to the *hema* system is still practised by local Bedouins inhabiting Wadi Allaqi Biosphere Reserve.

Intensive work on the social, economic and natural life of the nomadic and semi-nomadic populations inhabiting Wadi Allaqi Biosphere Reserve has been conducted during the last twenty years.

Wadi Allaqi Biosphere Reserve (WABR)

Wadi Allaqi is an extensive drainage system that collects and contains runoff water, when available on the rare occasions of cloudbursts and spells of rain. Its catchment area stretches across the southern part of Egypt from the Red Sea coastal mountains to the principal wadi debauching into the River Nile (now Lake Nasser). The Red Sea Mountains of the Elba group form the divide, with eastward drainage contained in the Wadi Allaqi system up to the Nile (see Figure 13.1).

Wadi Allaqi is characterized as a 'hyperarid environment' with an aridity index of less than 0.05. Annual rainfall in this area rarely exceeds 5 mm and is highly variable in both time and space. Inundation from the lake, forming inlets or bays named 'khores' has penetrated into the wadis deep in the Eastern Desert, a previously waterless, hyper-arid environment. Fluctuation in the water level of the lake has led, as it recedes, to temporary exposure of about 40 km of the once-inundated area of Wadi Allaqi, where a new ecosystem has been established. This ecosystem, generally known as an ecotone, represents a transitional zone between aquatic and desert land.

Wadi Allaqi as a system spans three ecological formations:

- The Elba mountain group at the upstream end represents a 'coastal mist oasis' that receives orographic precipitation and provides habitat for a rich biodiversity.
- The main reach of the Wadi extends over part of the 'rainless desert' of Nubia, where occasional rain (or run-off flow) causes rich plant (and other biota) growth.
- The ecotone habitat at the deltaic part of Wadi Allaqi, where water flow and ebb cause dense plant growth including tamarix woodland.

The Wadi Allaqi system has provided a subsistence habitat for its nomadic inhabitants for millennia. Before the High Dam development (in the 1960s) and the establishment of a paved road that made the town of Aswan accessible, these inhabitants subsisted on the natural resources of the wadi. This has created a culture of intimate relations between humans and available biota.

At present, downstream Wadi Allaqi is inhabited by the Ababda tribe and the upstream part by the Bishari tribe. The middle part is very dry and supports no permanent human habitation.

Research in Wadi Allaqi has focused on the indigenous inhabitants (Bedouins) as the essential component of the ecosystem. A team of both local and overseas researchers has studied different aspects of the livelihood of indigenous communities. Indigenous knowledge is the focal point in such studies (Briggs, 1989; Briggs et al., 1993; Solway, 1995; Belal et al., 1998; Briggs et al., 1998; Solway and Mekki, 1999; Springuel et al., 2001; Hamed et al., 2002.)

Examples of plant uses and economic value

Plant uses

In our study of the floristic diversity of the Wadi Allaqi Biosphere Reserve as well as other desert areas we always refer to the knowledge of the local inhabitants,

Figure 13.1 Topography of Wadi Allaqi

who usually guide us in the remote desert areas. The local names of the plants, their morphological characteristics, autecology, habitat characteristics and main uses are well known to the local people, and they seldom hesitate to share this knowledge with us.

A scheme for assessing the economic and conservation value of plants found in the Allaqi region has been developed (Springuel, 1991) on the base of indigenous knowledge with the help and participation of indigenous people. Using a simple scoring system, an importance value for various uses was calculated. A fragment of this system is presented in Table 13.1. The scoring system was based on the actual and potential uses of different species. Actual uses are by the local population of Bedouins living in Wadi Allaqi, while potential uses are those obtained from different sources (Bedouins from other locations, literature, research). The flora of the area comprises 127 species, and the uses of all but 32 have been recorded.

The scoring system allows differentiation between those species of high actual and potential economic value, and those with some but a lesser degree of utility. This study of economic use value has formed a component in the establishment of overall conservation priority for particular plant species. Species that were both relatively rare and had a high use score have the highest conservation priority. Examples of such species include *Balanites aegyptiaca*, all *Acacia* species found in the area, *Ziziphus spina-christi*, and plants of significance for medicinal and grazing purposes, *Cymbopogon proximus* and *Solenostemma arghel*.

Economic value of acacia trees

Another example where indigenous knowledge played a key role was the research assessing the economic value of acacia trees in Wadi Allaqi Biosphere Reserve (Springuel and Mekki, 1994). The research was conducted to throw light on the continuous disappearance of trees in the desert, particularly those close to large settlements. Many people living in the Nile Valley, including some Egyptian researchers, believed that the Bedouins' activities caused deforestation by cutting trees for charcoal production, and hence the biodiversity of the desert lands declined. In the research, by comparing uses of acacia trees for charcoal production (dead trees) and as fodder for livestock (living trees), we found that the latter brings a higher household income as well as providing drought-reserve fodder, which is only fed to stock at times when other food is very scarce. This is why

Table 13.1 Example of a few economically important plants in Wadi Allaqi Conservation Area, Egypt

	Species Uses							
	M	T	G	H	F	C	O	TIV (%)
Acacia nilotica	6	6	6	–	6	6	6	64
Acacia ehrenbergiana	–	–	8	–	6	6	–	35
Acacia raddiana	7	8	8	–	8	8	6	80
Acacia tortilis	7	7	8	–	8	8	6	78
Aerva javanica	5	–	5	–	–	–	–	18
Astragalus vogelii	–	–	6	–	–	–	–	11
Balanites aegyptiaca	8	8	7	8	8	6	8	94
Calotropis procera	7	–	–	–	7	–	7	37
Capparis decidua	7	–	–	5	6	–	–	32
Cassia senna	8	–	–	–	6	–	–	25
Cleome droserifolia	8							14
Cymbopogon proximus	7	–	6	7	–	–	–	36
Cynodon dactylon	6	–	6	–	–	–	–	21
Fagonia indica	–	–	6	–	–	–	–	11
Heliotropium supinum	4	–	–	–	–	–	–	7
Hyoscyamus muticus	8	–	–	–	–	–	–	14
Hyphaene thebaica	6	7	–	7	–	–	7	48
Indigofera argentea	–	–	6	–	–	–	–	11
Solenostemma arghel	8	–	–	–	–	–	–	14
Tamarix nilotica	7	–	7	–	8	–	7	51
Ziziphus spina–christi	6	6	6	6	6	–	6	64

Explanation of estimation TIV of plants, following Belal and Springuel (1996). An Importance Value (IV) has been ascribed for each of the seven use categories of each species presented in the table. A score of 4 suggest the minimal important value and 8 the maximum important value for each use. No value is indicated by (–). For each plant the Total Importance Value (TIV) is given in the last column, which is the sum of the importance values for each uses, expresses as the relative percentage of the maximum possible score which is 56.

Importance values as follows:

M = Medicinal use
T = Timber
G = Grazing
H = Human food
F = Fuelwood
C = Charcoal
O = Other uses
TIV(%) = Total Importance Value (%)

Source: Springuel, 1991.

resource conservation (*acacia* trees) is a concept inherent in the Bedouin livelihood and value system. A similar observation was made by Hobbs (1989) of the behaviour of nomads inhabiting the Eastern Desert of Egypt.

Palatability

An example of the combination of indigenous and scientific knowledge is the study of palatability of plants.

Grazing is the one of the main activities of pastoral nomads living in WABR. For this reason, many studies have been directed to this particular topic. Indigenous knowledge of the grazing value in Wadi Allaqi is well documented (Springuel, 1991; White, 1995; Briggs et al., 1999; Belal et al., 1998). Springuel (unpublished) has reported that the majority of the plants in Wadi Allaqi have two main uses: grazing (65 per cent) and medicinal (45 per cent). Animals, both domestic and wild, can graze and browse on eighty-three of the species growing in Wadi Allaqi. Among the most palatable plants are Leguminosaea (*Acacia* spp, *Astragulus fogelii*), followed by Gramineae, amongst which *Panicum turgidum* is of particular importance.

Selective use of plants by animals provides an example of resource portioning among grazing stock. The camels' diet is of a wider variety than other domestic animals. In addition to the highly palatable species, camels can graze on twenty-three species that are usually avoided by other grazers. There are also a few examples of selective use of different parts of the plants. Small branches of *Tamarix nilotica* are apparently good for camels and goats, but sheep can only eat the flowers. Sheep and goats can eat the dry seed of *Lupinus varius* when other food is not available. Bedouins believe that the dry flowers of *Aerva javanica* and pods of *Acacia raddiana* are good for sheep during the lactation period.

Observations and interviews in Wadi Allaqi indicate a considerable seasonal variation in grazing. Ephemerals provide the main forage in wintertime, and in dry periods phanerophytes (mainly *Acacia* spp.) are the main browsing plant. In this context, it might be noted that *Tamarix* has a better palatability in winter than in summer, because the high salt content in its foliage makes animals thirsty. Subsequent high water consumption can be harmful under hot conditions.

Even among the Bedouins living in Wadi Allaqi, local knowledge varies, according to their locations (upstream or downstream part of the wadi), to where they take their animals, gender issues and the time when they resettled on the lakeshores. Because of new resources available on the lakeshores, the local knowledge is modified to be adapted to new conditions. *Najas* spp. growing in shallow water becomes an important grazing source collected by Bedouin women, but only when this plant is dry. This is one example of a new knowledge developed (Briggs et al., 2003).

From Table 13.2, with forage analyses of dominant plants from the downstream part of Wadi Allaqi, it may be noted that most plants have reasonably high palatability in terms of their crude protein content and *in vitro* dry matter digestibility. This is scientific knowledge obtained through plant analyses. In reality however, as is well known to local inhabitants, species such as *Aerva javanica*, *Pulicaria crispa*, *Glinus lotoides* and *Najas* spp. have low palatability, but this can be improved if they are dried prior to being fed to animals (Briggs et al., 2003). On the other hand both *Senna alexandrina* and *Hyoscyamus muticus* are very well known as medicinal plants and could be poisonous for animals. This indicates that in real life scientific knowledge should not be used in isolation from local understanding.

Application of knowledge

On the basis of knowledge obtained of the economic and livelihood system of the Bedouins living in Wadi Allaqi Biosphere Reserve, traditional ecological knowledge and a combination of scientific and indigenous knowledge, a management programme for the restoration of habitats has been established. It is based on sustainable use, and recovery and enhancement of economically important plants that have become rare or may be threatened by overexploitation.

According to the criteria developed, the most important plants for the Bedouins' economy and for the ecosystem were selected for reintroduction into the downstream part of the wadi in ecologically favourable habitats. (We consider habitats to be favourable for rehabilitation where sufficient water is available for plant growth.) Despite a good understanding of the physical properties of soil, soil fertility, and other soil characteristics among local inhabitants (Briggs et al., 1998), there was only a minor contribution by local Bedouins to the selection of habitats for the restoration of and planting of indigenous plants. At first, we took into consideration the water level fluctuation of the lake for establishing a farm that was based on monitoring data and results of the soil survey carried in this area. However, we subsequently accepted the knowledge of Bedouins on wadi topography and followed their advice in planting trees at the lower levels of the wadi topography, where more water collected and was stored in wadi deposits.

The selection of plants for rehabilitation in the downstream part of the wadi was based on ecological and sociological criteria. The ecological criteria relate to the keystone species of the natural Wadi Allaqi ecosystem and their ability to tolerate the extreme conditions (drought and flood) that characterize the ecotonal system. The plants successfully growing in both the Nile Valley and favourable desert habitats fulfil the criteria of ecologically suitable plants. The sociological aspect related to the value of plants in relation to their uses by humans, and was based on the indigenous knowledge of nomads living in the Eastern Desert.

Although modern irrigation technology has been

Table 13.2 Forage analyses of ten pasture species from the downstream part of Wadi Allaqi

Plant species	DMD	OMD	CP	CF	EE	Ash
Acacia raddiana	29–40	26–37	6–10	30–56	3.4–4.2	7.3–8.9
A. ehrenbergianna	37–41	33–39	5–12	27–51	2.7–3.2	17–18
Tamarix nilotica	37–43	33–38	8–13	26–36	2.5–3.1	14–15
Senna alexandrina	35–41	31–37	8–13	27–37	3.6–4.2	17–25
Aerva javanica	31–40	26–36	4–13	41–57	3.4–4.6	8.2–9.8
Pulicaria crispa	31–38	28–32	7–13	33–39	2.7–2.4	14–16
Hyoscyamus muticus	38–42	32–40	9–16	35–48	2.8–3.3	8.9–9.9
Astragalus vogelii	35–40	31–36	10–15	39–45	3.4–3.8	10–11
Glinus lotoides	35–42	34–38	7–13	31–39	2.6–3.2	7.0–9.1
Najas spp.	31–38	28–34	7.9–10	49–61	2.4–3.1	15–17

DMD: % in vitro dry matter digestibility
OMD: % in vitro organic matter digestibility
CP: % crude protein
CF: % crude fibre
EE: % ether extract
Ash: %.

Source: Springuel et al., 2003.

used to establish plantations in ecologically favourable habitats, it does not provide for success in the growth of desert plants. Drip irrigation caused an increase of soil salinity and the development of shallow roots. Running water in irrigation tubes attracted rodents from the surrounding desert which destroyed this system in no time at all. More successful was the subsurface irrigation system (Springuel et al., 2000), whose design was based on knowledge of the ecology of desert plants. The percolation of water downward through the sandy soil facilitated the elongation of the roots. As soon as the roots reach the underground water, the irrigation can be stopped. At the same time this method of irrigation conserves water and prevents salinization of the soil.

PVC tubes (10 cm diameter), open at the top and the bottom, were installed vertically in the ground to the depth of one metre, while half a metre of the tube remained above the surface (see Figure 5.1.2). Three- to four-month-old seedlings of *Balanites* or *Acacia* were planted close to the tubes. At the beginning of growth, surface irrigation was applied to allow the seedlings to establish themselves in the soil and to enlarge the root system. When new foliage appeared, after about two or three months, water was added directly to the tube, bringing water close to the roots of the trees. Water was added to tubes to fill them up to the top twice a week. The tubes had a 10 cm diameter and 150 cm length ($V = \pi r^2 l$, where V is the volume, r=radius of tube and l=length of tube), and each tree received about 12 litres of water, that is, about 96 litres per month. In all, 200 trees planted in one acre would receive 19 m^3 water monthly.

Bedouins help in planting and watering the plants. The farm will be transferred on a continuous basis to the local community to support its members' livelihood, as an alternative to collecting plants in the wild.

Conclusion

First, it could be concluded from the example of Wadi Allaqi that indigenous knowledge of ecology and management of natural resources can offer a powerful tool for sustainable development of the Wadi Allaqi Biosphere Reserve. However, researchers have warned that indigenous knowledge in isolation should be not seen as ideal. For development to be sustainable there should be a good balance between scientific and indigenous knowledge.

Second, we would like to highlight the analogy between TEK 'which represents a constantly evolving way of thinking about home' (Watson et al., 2003) and the 'Ecotechnie' concept which was proposed by Captain Jacques-Yves Cousteau from the Greek words *oikos*, which means 'home', and *tekne*, meaning 'art of doing'. Both terms complement each other. TEK is an application for understanding and maintaining the relationship among the full community of human and

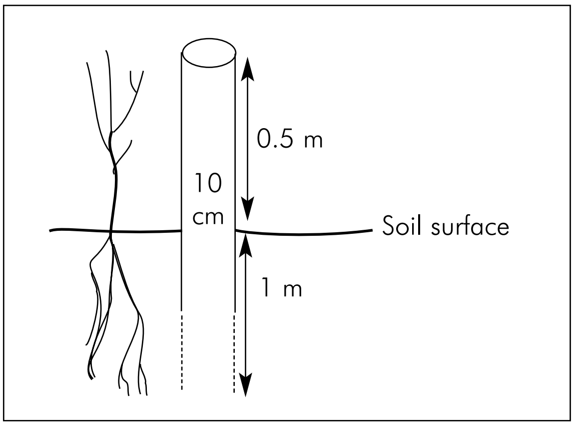

Figure 13.2 Subsurface irrigation design

nonhuman entities found in nature (Watson et al., 2003). Ecotechnie aims holistically to consider ecology, economics, the social sciences and technology in order to understand the long-term consequences of management and development decisions (UCEP, 2002).

Universities in many countries have been setting up an Ecotechnie network to promote partnerships and capacity building through multidisciplinary education and research that combine theoretical problems with specific cases.

The UNESCO Ecotechnie Chair at South Valley University is a Founding Member and the Co-ordinator of the Arab Region Ecotechnie Network (AREN) uniting eight universities: the University of Bahrain, Bahrain; the University of South Valley, Egypt; the University of Jordan, Jordan; the University of Mohamed V, Morocco; the University of Khartoum, Sudan; the University of Damascus, Syria; the University of Sana'a, Yemen; and the University of Balamand, Lebanon.

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14 Traditional knowledge and practical techniques for combating desertification in Jordan

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Abstract

Jordan is a Middle Eastern country situated between the arid Arabian Desert and the semi-arid Mediterranean climatic zone. Peoples of the region have practised agriculture and livestock husbandry for the past 7,000 years. During that time, much knowledge has been gleaned and is employed to sustain the agricultural and pastoral resource bases. Moreover, much of the social structure is built around sustaining these resource bases. For example, the *Himma* and *wajihat el Asahirieh* (tribal lands) systems are designed to maintain the lands by empowering certain families to be responsible for them. Another example is the use of water harvesting for domestic and agricultural use. Water collected in cisterns and desert catchments (*hafair*) amount to 1.4 million cubic metres a year. Desert dams and pools (such as those at Jawa and Burqu) have been used for thousands of years.

Conservation of genetic resources has also been practised for a long time. Suitable animal species for meat, milk and wool production were specifically maintained. The world-renowned Arabian horse was bred and preserved in this region. As for plant species, wheat is a good example of the selection, refinement and preservation of a species that is now planted around the world, which began in the area 7,000 years ago. For many generations, medicinal plants have been harvested and conserved and soil reclamation has been practised. This is especially evident in the widespread use of terracing to preserve soil in the highlands. Other practical techniques have long been used to combat desertification and maintain the sustainability of the land. These will be discussed in this chapter.

Introduction

Generally, Jordan is divided into three distinct physiographic and climatic regions: the Jordan Valley (*Ghor*), Wadi Araba and Gulf of Aqaba area; the highlands (*Shafa*); and the eastern and southern deserts (*badia*). The Jordan Valley is a segment of the great African rift system that extends through eastern Africa, the Red Sea, through the Jordan Valley and into Lebanon, ultimately fading out into the north. The elevation of the valley ranges from sea level at the shores of the Gulf of Aqaba to about 150 m above sea level in central Wadi Araba, then down to about 410 m below sea level at the Dead Sea, and ultimately reaches about 200 m below sea level in the northern Jordan Valley. The valley tends to receive modest amounts of rain due to orographic effects. Average rainfall ranges from about 25 mm at Aqaba to around 300 mm in the northern Jordan Valley (Salameh and Bannayan, 1993). Despite low rainfall levels, the Jordan Valley is a rich agricultural area in the segment extending north of the Dead Sea and in small areas on the southern shores of the Dead Sea. This is because of the availability of water from runoff originating in the adjacent highlands that feed the Jordan River and its tributaries.

The highlands region is a mountainous strip which bounds the eastern flank of the rift valley, with elevations reaching over 1,000 m above sea level in the northwestern mountains of Belqa and Ajlun. This region contains the largest proportion of the Jordanian population. Here, the average rainfall ranges from about 350 mm in the south (Karak) to over 600 mm in the Ajlun Mountains (Salameh and Bannayan, 1993). A mixture of pastoral, agricultural and urban usage characterizes this area, which also contains some natural and planted forests. This region ranges in width from 30 to 50 km, and merges into the eastern and southern plateau deserts (Salameh and Bannayan, 1993).

The largest area of the country is covered by the eastern and southern desert, which receives less than 200 mm of rainfall per year, and usually less than 150 mm. The change between the highlands and the desert is more perceptible from the sharp drop in rainfall and change in plant cover than from any change in physiography. In general, this land is used for sheep herding with minor agriculture. Agriculture is concentrated near the major oasis of Azraq, which derives its waters from adjacent aquifers, and in areas where groundwater is extracted through wells.

Thus, it is fair to conclude that the entire country relies on the water resources which fall on the western highlands, along with groundwater which is partially fossil water, and thus non-renewable (Bajjali and Abu-Jaber, 2001). This places the country in a precarious position. For while the boundary between the western highlands and the rift valley is defined by geological features, the boundary between the *shafa* and the *badia* is defined by rainfall patterns, which vary from year to year, and may be affected by changes in the climate of the earth. Stakeholders in water resources include farmers (70 per cent of the available water), domestic users (25 per cent) and industry (5 per cent). Future pressures on this resource may lead to mining existing resources, causing irreparable long-term damage.

Jordan is part of the Middle Eastern area, which has a long history of agriculture development and understanding of desert life. The Jordanians, as part of the Arab peoples, have developed and accumulated alongside a range of productive practices, traditional knowledge, local techniques and adaptable experiences for combating desertification. These include irrigating agricultural land in times of water scarcity, controlling salinization and rehabilitating rangeland, revegetating eroded hilly areas and managing watersheds, developing irrigation systems, and protecting the oases (such as Azraq Oasis) by utilizing groundwater in highly developed irrigation systems. There are many universities and research institutions doing a substantial amount of work on developing methods to reduce desertification.

Jordan is one of the poorest countries in the world in terms of water and natural resources, and is therefore facing a serious problem of desertification. The affected lands are mainly in the eastern parts of the country, extending to the Mediterranean region. Jordan covers about 90,000 km², and 80 per cent of the total area is affected by land degradation.

Desertification in Jordan is mainly caused by climate change and human activities. The human factors can be summarized as follows:

- population growth as a result of immigration, which leads to societal damage
- heavy grazing
- misuse of arable lands
- use of agricultural water industrialization and urbanization
- loss of floral and faunal biodiversity in every ecosystem in Jordan
- irrational exploitation of fuelwood, desert shrubs and vegetation cover
- deforestation and shifting cultivation
- salinization
- a lack of awareness about issues of ecological protection.

All of these have destroyed the vegetation coverage and accelerated the uncontrolled spread of desertification.

The issue of climate change in marginal environments is of prime importance for understanding the susceptibility of these regions to environmental stress. Development plans for such regions will be seriously disadvantaged if policy makers and planners do not take into account the environmental history of the area under investigation and understand how this area will respond to either global climate fluctuations or the stresses that may occur with large-scale development.

The Jordanian government and people attach great importance to combating desertification and improving the ecosystem and the environment, and have incorporated, as a basic state policy, environmental protection and resistance to desertification into the national economic and social development plans.

Existing traditional knowledge for combating desertification and rehabilitating degraded land

Water harvesting

This involves the following aspects:

- providing water to isolated areas and for the cultivation of foliage plant species and animals
- recharging underground water
- improving the local environment and reducing the effect of drought
- reducing runoff damage on human and agricultural activities
- reducing the pressure on drinking water net systems.

The most important traditional methods used in harvesting water are summarized below.

Desert mud flats (gaa) and depressions

A *gaa* is a natural or artificial depression in the desert that collects rainwater in winter and retains it until spring and early summer. There are a about twenty-six artificial pools with a full capacity of about 1.4 million cubic metres (Table 14.1).

Desert dams

Some desert dams are historical and some are newly established. Both types are used to collect rainwater and fluids. There are eighteen dams, with a combined full capacity of about 28.56 million cubic metres (Table 14.2). The water in these dams is used for animals and agricultural purposes. The Roushed northern dam is the largest, with a capacity of around 10.7 million cubic metres.

Desert pools

The pools are made of concrete and rocks and are found all over the country. They are used to collect rainwater for drinking, and for animals and small-scale

Table 14.1 Desert mudflats and depressions

Serial no.	Pool name	Location	Capacity (1,000 m^3)
1	Alroushed	Alroushed, Mafraq	225
2	Umelmanghy	Alroushed, Mafraq	100
3	Umtarfah	Alroushed, Mafraq	50
4	Albustaneh	Alroushed, Mafraq	50
5	Admetheh	Alroushed, Mafraq	37
6	Anqa	Alroushed, Mafraq	50
7	Khabreh asraeal	Alroushed, Mafraq	50
8	Algraa	Alroushed, Mafraq	50
9	Aldubadeb	Alroushed, Mafraq	50
10	Qaa algatareh	Alroushed, Mafraq	50
11	Reshet Alnajelly	Alroushed, Mafraq	50
12	Almasahlye	Alroushed, Mafraq	50
13	Albowehy	Alroushed, Mafraq	50
14	Algaseeb	Alroushed, Mafraq	50
15	Alsateeh	Alroushed, Mafraq	50
16	Alzeharey	Alroushed, Mafraq	50
17	Abu elhussen	Alroushed, Mafraq	37
18	Alghssen	Alroushed, Mafraq	50
19	Alnajelly	Alroushed, Mafraq	50
20	Addehneyeh	Alroushed, Mafraq	50
21	Alseeb	Alroushed, Mafraq	30
22	Marab souad	Alsafawi, Mafraq	25
23	Hassa I	Tafeleh	25
24	Hassa II	Tafeleh	20
25	karak	Karak	20
26	Alrabeh	Karak	8
	Total		1 402

Source: Ministry of Water and Irrigation, Water Authority Jordan Valley authority, *Annual Report 1999*.

Table 14.2 Desert dams

Serial no.	Dam name	Province	Dam height (m)	Type	Capacity (million m^3)
1	Alaageb/Khaledyeh	Almafraq	15	soil	1.1
2	Alghader alabyedh	Almafraq	13	concrete	0.7
3	Sama alserhan	Almafraq	8	soil ,rock	1.7
4	Dair Alkaheef	Almafraq	5	soil,rock	0.05
5	Burqa	Almafraq	5	soil	1.5
6	Alboudha	Irbid	9.5	concrete	0.07
7	Algatraneh	Karak	12	soil, rock	2.1
8	Alsultani	Karak	13	soil, rock	sedimentation
9	Allahfi	AlZarqa	8	soil	0.7
10	Wadi Rajel	AlZarqa	9	soil	3.1
11	Aljalat	Amman	10	rock	0.09
12	Swageh	Amman	19	soil	2.5
13	AlJardan	Maan	15	soil	2.3
14	Almauqar	Amman	10	soil	0.1
15	Alshaalan	Almafraq	3	soil	1
16	Roushed Alshamali	Almafraq	7	soil	10.7
17	Aluntha	Almafraq	3	soil	1.0
Total					28.86

agricultural irrigation. The total number of desert pools is sixty-six, with a water capacity of 363,950 thousand cubic metres (see Table 14.3.).

Rainwater collection wells

Located just below groundwater reserves dug out from rocks (especially calcareous rocks), these wells are used to collect rainwater mainly to drink and for animals. The wells are mostly archaeological remnants from the Roman and Islamic periods. Today, the government and Ministry of Agriculture help local people with funding to build such wells to reduce the pressure on the drinking water system.

Roman pools

These are water reservoirs built during Roman times to collect surface water for drinking purposes and for animals. In Jordan there are a number of historical pools like Jarash, Zezya, Jawa and Gabla.

Springs

These are small water resources that have appeared naturally, although some of them were dug out in the foothills or at the bottom of the wadis to collect water in a special cavity (examples include Ain Almansoura and Ain Zoubia).

Water canals

These are simply narrow canals that were built into rocks, or constructed of rock and concrete, to transfer water to farms. Historically, most of these canals were built by Nebatians in Petra and in Jarsh. In Wadi Elyabis Orjan they were built during the Roman and Islamic period. These canals are still used by local people and have always enjoyed protection by the government and NGO associations.

Table 14.3 Desert pools

Province	No. of pools	Capacity (1 000 m^3)
Mafraq	43	117 700
Karak	9	79 100
Amman	3	126 500
Ajloun	2	4 750
Irbid	3	5 200
Balqa	2	7 000
Madaba	2	10 000
Maan	1	1 700
Jarash	1	12 000
Total	66	363 950

Rangeland management and practical techniques for protection and rehabilitation

Since prehistory, during the Roman and Islamic periods, the Jordanian people have managed their rangelands according to tribal understandings, by recognizing specific areas of rangeland to be used by different tribes for grazing their animals at specific times in order to prevent excessive grazing by animals from other tribes.

Al-Hemma

This is an old system of creating range reserves that were used under the control of a tribal leader or governor during drought years. In this system the Bedouin used this reserved area during the winter on two trips to graze their animals in the eastern part of the country, while during the spring the local people grazed their animals in the hilly western rangeland. The government establishes range reserves to protect them from grazing for several years and to rehabilitate and enrich the vegetation cover by planting the reserve with drought-resistant plant species. Jordan has established more than twenty range reserves such as Sirra, Alkhnasreh, Dhabah, Aljarba and Rajib, which are used by farmers with official permission from the Ministry of Agriculture.

Wajihat el Asahirieh

This system has existed in Jordan for a long time, and provides the tribes with a piece of land for grazing their animals, which is managed by the tribal leader. The system allows the tribe to graze their animals during a particular season and over a certain period of the year.

Forestry and traditional knowledge

Jordanian forests have been degraded by such human activities as cutting down trees to fuel trains during the First World War and for fuel over the past 100 years. This practice led to the removal of thousands of hectares of trees from the northern and southern part of Jordan. The Forest Department has consequently begun an afforestation programme to plant trees in hilly areas like the Ajloun and Salt mountains to prevent soil erosion and water loss.

The traditional method is to build terraces on private land before cutting the trees, keeping the vegetation on the terraces undamaged. The government and the local people intend to plant native trees such as *Pinus halepensis* and *Ceratonia siliqua* with exotic drought-tolerant tree species such as *Pinus brutia, Acacia cyanophylla* and *Tamarix aphylla*. Religious beliefs play an important role in conserving the forest and preventing some forest species from disappearing from the Jordanian environment. Holy forests and trees such as *Celtis australis, Quercus ithaburansis* and *Pistacia atlantica* are protected and planted for religious reasons.

The local people use forest tree products for fuel by collecting dead trees and trees that have been removed during road construction. In Jordan there is no periodical utilization of the forest; the bylaws do not allow local people to cut down trees for any reason. However, the private forest is used with special permission from the Forestry Department. In any case, the Jordanian forest is not a productive source of timber but is valuable for protecting the soil against erosion and for recreation. The local people also use forest products for food, collecting the fruits of species such as *Pyrus syrica, Crategeaus azarrolus, Arbuts andrachne, Ceratonia siliqua, Pinus halepensis, Quercus ithaburansis, Pistacia atlantica, Pistacia palestina* and *Rhus coriaria*. Products like the fruit of *Quecus ithaburansis* and *Quercus calliprinos* are used for animal fodder, while others are used for dying leather and clothes, and some are used in handicrafts.

Terraces and contour lines

Terraces and contour lines constructed for farming and for planting trees are normally set in hilly areas to prevent soil erosion. These methods have been in use since Roman times and are still used by local people. Nowadays the government and the Ministry of Agriculture give financial support to encourage the local people to employ this method. In Jordan there are several major projects to build terraces, such as the Sad Elmalik Talal Dam project and the Yarmouk river project in the northern part of Jordan.

Agriculture

Crop rotation

Jordan like any other Middle Eastern country has developed its agricultural system over thousands of years of practice. Patterns of crop rotation include:

- planting wheat one year and barley the next
- planting chickpeas in summer and wheat in winter
- planting wheat one year and legumes the next.

Soil treatment

- *Surface tillage*. The soil is normally tilled two to three times consecutively in opposite directions. Animals (*faddan*) and traditional *almehrath* (a woody tool for tillage) are used for this. Surface tillage is undertaken to maintain soil fertility, employing a traditional tool (*mehrath baladi*) and animal manure to produce two crops a year. Legumes are planted in the first year and vegetables in the second (followed by grazing for one year and lying fallow for another).
- *Minimizing soil erosion*. There are various practices for this, such as: digging drainage rows in the ground for water drainage; making tillage strips and allowing animal grazing in the summer; planting flat areas and leaving the rocky slopes for animal grazing.
- *Improving soil moisture*. Ways of improving soil moisture include: surface tillage to open the soil surface to receive the first winter rainfall showers; summer surface tillage to close the soil to prevent water loss and keep the soil moist; planting the land with winter crops and leaving the land fallow in the second year; surface tillage to improve soil texture and harvest runoff while preventing soil erosion.

Traditional knowledge and cultivated wild species

Various cultivated plant species originated in Jordan, as did wild wheat and viches (*Vicia spp*.), and the local people still plant some of these. They include *Triticum* spp. *Hordeum*, *Aegilops, Allium* spp., *Vicia peregrena, Lathyrus* spp., *Medicago* spp., and other fruit and wild trees such as *Pyrus syriaca, Amygdalus communis, Olea europea, Prunus* spp., *Pistacia atlantica* and *Lens* spp. It should be noted that most of these plants are threatened species and are cultivated by farmers in isolated villages.

Medicinal plants

Traditional medicine in Jordan can be divided into two types: preventive and curative. Preventive medicine, used to avoid illness, includes practices such as hanging amulets on the body, writing verses from the Koran, taking vows, visiting the tombs of saints, outwitting the evil eye, and observing rules of behaviour, religion and hygiene.

Curative medicine on the other hand is used when either physical or mental illness has already struck. It normally relies on medicinal plants.

The flora of Jordan is made up of about 2,500 vascular plant species (Al Esawi, 1998), of which around 25 per cent are considered to have medicinal properties (around 485 species of medicinal plants are recorded).

Medicinal plants are mostly managed by women who deal with the whole procedure, including planting, collecting and processing. There are special routines for collecting specimens as collection depends on timing (plants wither in the early morning or late afternoon), and drying and processing also require special methods. The women working with medicinal plants know these methods and practices.

Animal husbandry (traditional practices)

Animal husbandry is widely practised in the eastern part of Jordan. The local people (*Bedu*) may be nomadic or sedentary and remain in the *badia*, and make up only about 4.7 per cent of the total population of 4.15 million (Ministry of Planning, 1989). In the *badia*, the *Bedu* settlements are tribal based, with all members living on land given to the tribe by the government as a way of encouraging them to settle. As these settlement are far from urban centres, the *Bedu* have been better able to keep their cultural values and traditions than other populations, and their economy is still dependent on livestock and livestock products (Al-Oun, 1998).

Animals play a central role in the social and economic life of the *Bedu* and are well adapted to the harsh environmental conditions of the desert. These animals are raised in an extensive nomadic system where they graze throughout the year, travelling several kilometres in search of scarce food and water. Very often the owners travel with their animals from one region to another, crossing national frontiers to secure food and water. The animals depend mainly on grazing, and are very rarely provided with straw, particularly during the winter. The mating season is July and August. Milking is performed manually, mainly by women. The kids and lambs remain with their mothers for two to three months in order to receive the necessary amount of milk before the owners sell their animals in the market on Mondays and Thursdays, using the *Rouz* method. Little professional animal health care is provided; treatment chiefly depends on the acquired experience of the shepherd and elders, whose traditional approach includes such methods as oil drinks and flame (cauterization). Sheep are sheared at the beginning of the summer hot season and the fleeces are sold by the *jizeh* (the amount of wool from one animal). The *Bedu* use traditional practices to rear animals, selecting certain strains of camels, sheep and goats that are resistant to diseases and thrive on natural vegetation. At the same time, they produce milk and meat (for instance, *awasi* sheep). The *Bedu* rear Arabian horses as symbols of strength and dignity.

Extensive grazing and increased numbers of animals per unit of land, as well as policies and regional politics, have affected the zone of desertification in the region, which requires an immediate strategy and policy for correction and intervention.

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15 Natural resource management in the Great Gobi Strictly Protected Area

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Introduction

The Great Gobi Strictly Protected Area (GGSPA), is one of the biggest protected areas in Mongolia and was designated as a UNESCO biosphere reserve in 1991. Habitat loss of globally significant fauna and flora of the park (including the buffer zone), land degradation and loss of ecosystems are a result of the mismanagement of the limited resources.

The main aim of the Great Gobi Conservation Project is to ensure the long-term conservation of the Great Gobi ecosystem and its umbrella species by consolidating the park management authority, improving participation of local communities in making decisions about the SPA, and supporting research and environmental monitoring activities through the development of a model conservation programme, using the wild Bactrian camel. Geographic information systems (GIS) and remote sensing techniques may assist in determining and analysing the potential habitat of the fauna, as well as land cover changes, in order to help dwellers and authorities understand the current situation and to predict the future of the area.

The use of existing indigenous knowledge/practices of the Mongols, such as nomadic pastoralism, and of modern technologies in sustainable use of the natural resources in dry areas of Great Gobi is presented for discussion.

Great Gobi Strictly Protected Area

The Great Gobi Strictly Protected Area is one of the most significant protected areas in the world in terms both of size and of the biodiversity it supports. The need for its continued protection was recognized and prioritized by the Mongolian Biodiversity Action Plan. Its globally significant biodiversity was also identified in the National Action Plan Against Desertification.

Figure 15.1 Great Gobi Strictly Protected Area (A)

Mongolia's Great Gobi reserve (Figure 15.1) protects largely undisturbed parts of the vast Gobi desert, and provides a last refuge for representatives of the ancient terrestrial fauna of Central Asia. The GGSPA (Figure 15.2) was established in 1975, and in 1990, UNESCO designated the Great Gobi as a Biosphere Reserve, the fourth largest Biosphere Reserve in the world, and the largest in Asia.

The protected area is divided into two ecologically distinct parts, the Southern Altai Gobi (Gobi A) and the Dzungarian Gobi (Gobi B), separated by 300 km. Gobi A comprises the Altai, Tsogt and Erdene *soums* (sub-provinces) of Gobi Altai *aimag* (province), and the Bayan Ondor and Shinejinst *soums* of Bayanhongor *aimag*. It covers a geographical area of 4.42 million hectares, and lies between 42°30'N, 95°30'E and 44°20'N, 99°10'E.

The terrain features small mountain ranges and massifs broken by wide valleys and hummocks. Despite what many people imagine, very little of the area is covered by sand. The Atas Mountain, at 2,695 m asl, is the highest point in the GGSPA, and the lowest point is 586 m asl.

The area exhibits flora and fauna typical of the deserts of central Asia. Scientists have identified 410 species of plants, forty-nine species of mammals, fifteen reptiles and amphibians and over 150 bird species in the protected area. The Southern Altai Gobi is uninhabited except for park staff and border guards. Desert steppe species are primarily found at higher elevations, with saxaul forests occurring on mountain slopes. Southwards, the climate becomes increasingly arid, and low elevations of the Southern Altai Gobi are characterized by stone-covered super-arid desert.

Unique flora and fauna include such wildlife species as the wild Bactrian camel (*Camelus bactrianus ferus*) and the Gobi bear (*Ursus arctos gobiensis*). Reptiles found that are endemic to Central Asia include the Gobi gecko (*Cyrtapdion elongates*) and Tatar sand boa (*Eryx tatarica*).

Water sources in the area are critical for large mammals and many other desert animals. Springs are particularly scarce, and are concentrated in mountainous massifs and low hills.

The internal zoning of the strictly protected area (SPA) plays a significant role in its management. SPA territories are classified into three protection zones (see Figure 15.2): the core, buffer and transition zones. Out of a total of 4.42 million ha of GGSPA, 27.8 per cent is in the core or pristine zone, 57.5 per cent is in the conservation zone and 14.7 per cent is in the limited zone (under the system for internal zoning of strictly protected areas of Mongolia).

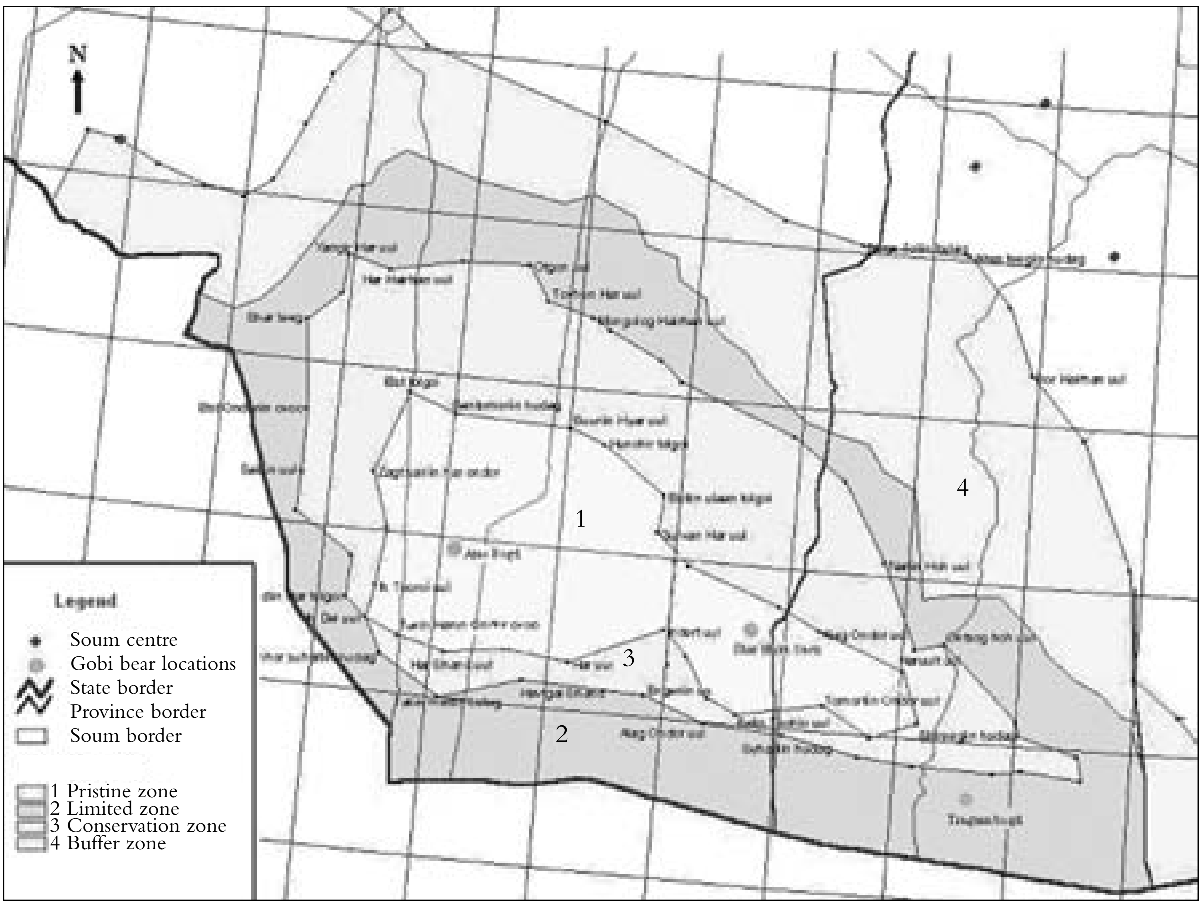

Figure 15.2 Zones of the Great Gobi Strictly Protected Area (A)

Description of buffer zone (Mongolian SPA internal zoning)

The GGSPA buffer zone covers an area of about 1.8 million hectares and includes the areas of five surrounding *soums* belonging to two *aimags*: Gobi-Altai and Bayanhongor.

About 12,000 people reside in these *soums*; the Tsogt *soum* of Gobi-Altai *aimag* has the highest population, with 4,500 inhabitants. All five *soums* are characterized by the extensive use of the saxaul tree for fuelwood (see Table 15.1). The reason for this high consumption is the enormous amount of livestock that died during the consecutive harsh winters of 2000–2. Nearly 250,000 head of livestock (mainly cows and horses) died. This caused a scarcity of animal dung, which was used for fuel, and as a result poverty increased. At the same time poaching was taking place. Some herders sold belongings such as motorcycles to buy livestock. Tsogt *soum* uses saxaul specifically for heating in schools and hospitals. Altai *soum* has the highest saxaul consumption for its half-yearly usage.

The northern border of the GGSPA is Edryn ridge, the only wintering shelter for the local herders. It extends over 200 km from west to east, and 20 km from north to south. There is quite significant competition among locals to secure sites for the winter. In order to develop adequate pasture management planning, the project conducted field surveys on biophysical and socio-economic data about the area for further analyses. The survey revealed that most households' livestock had been hit by the consecutive drought and *zud* of 2000–2, and that wolves are another threatening factor. Household income is generated mostly from cashmere; there is very little income from livestock raw material or value-added milk products as they are not worth very much. Households do not cooperate with each other in terms of labour, objectives or activities due to their lack of knowledge about cooperation and sharing experiences. The *ail* (neighbourhood) of Khot is not included in Edryn ridge, possibly because of the shortage of pasture and water. The poor quality of water means that it is not used for drinking purposes; instead, water from snow and ice is used during winter. (Livestock are given water once every three days.) Some families crossbreed wild camels with domestic breeds, as they believe that crossbred camels are faster and have finer wool.

Households in the transition zone often see grazing wildlife (ibex, argali), which suggests a conflict in the habitat and at water points between livestock and wildlife.

Some activities have taken place in Edryn ridge to restore the springs. The park staff made a small pond (1 m^2) to collect running water through a 10 m metal tube, and the spring water collected in this way was sufficient to meet the needs of wildlife. This approach was singled out as the best option for wildlife.

Existing constraints

The GGSPA is under increasing threat from habitat loss and degradation along its northern border and throughout its buffer zone as a result of mismanagement of the limited water resources. There is a danger of loss of ecosystem integrity and depletion of species abundance and diversity, with species such as the wild Bactrian camel at risk.

Overgrazing and range deterioration

Most of the core Great Gobi SPA is in pristine or near-pristine condition as there is low human (and consequently livestock) intervention. However, human incursions lead to habitat degradation along the northern border of the park and in the immediate buffer zone. Both overgrazing and over-collection of trees and shrubs have tangible impacts on biodiversity, affecting for example the Argali sheep, ibex, goitered gazelle, Asiatic wild ass and snow leopard.

Local grazing patterns and rights are complex, and there is increased transhumance movement along the northern border of the park that is caused by:

Table 15.1 Saxaul use and livestock numbers in GGSPA buffer zone

Buffer zone soums	Saxaul use (ton)	Wells			No. of livestock
		Deep	Manual	In disrepair	
Altai	280.0	6	19	4	9 044
Tsogt	258.0	16	29	4	19 894
Erdene	75.0	8	44	5	11 175
Bayanondor	125.0	5	48	16	16 978
Shinejinst	104.5	25	71	16	24 000
Total	842.5	60	211	45	81 091

Source: Dashzeveg, 2003.

- family-based groups appearing as a result of de-collectivization in the early 1990s
- reversion to traditional grazing areas and seasons, especially wintering camps along the northern border of the park's Edryn ridge
- abandonment of past collective grazing areas
- increasing herd size
- new markets for cashmere wool, leading to a greater proportion of goats, which are known for causing compaction of fragile soil systems and for being indiscriminate foragers
- less nomadic movement
- longer periods spent in wintering areas bordering the park where reliable water sources are available, due in part to the disrepair of wells in the buffer zone
- poverty.

Under exceptionally harsh winter circumstances, people are allowed to bring their livestock into the buffer zone of the park. The GGSPA management authority controls permission, but illegal incursions occur and some herds may venture into the pristine zone.

Over-collection of dung, saxaul bushes and downy poplars for fuel

People have traditionally relied on animal dung, saxaul bushes and downy poplars for fuel. Due to over-harvesting, mismanagement and lack of regeneration, the quantity of saxaul and downy poplar has decreased around traditional grazing areas and settlements. There is increasing pressure on more pristine areas and within the park itself. In some cases illegal incursions and large-scale 'stripping' of saxaul and other shrubs has been reported. The latter may lead to direct and lasting impacts on the desert ecosystem where slow growth of perennial ecosystem is the norm.

There is too little understanding of biological requirements for sustainable management, and harvesting occurs without taking biological needs into account. Most saxaul is culled and the harvest impacts on the ecology of the area, since the removal of dead matter causes wind erosion and loss of the nutrient compaction of topsoil. At present, the use of dead saxaul is restricted.

The situation is worsened by the lack of stewardship by local communities who are excluded from the resource use decision-making process. Lack of formal access and use rights serves as a disincentive for communities to control resource access. As people have few opportunities to make a living in areas further outside the *bag* (administrative unit of sub-province) centre limits, they come under pressure to collect from areas within the park. This in turn creates greater pressure on the already stretched policing and enforcement capabilities of the park management staff.

Decline of water resources

Water resources and management are a key factor in the Gobi because all humans, livestock and wildlife depend on a safe and reliable water supply. In recent years there has been a decline in the availability and quality of water resources across the great Gobi SPA. In particular, the numbers of functioning springs or oases in the core and protected zone are decreasing. Desert oases in pristine, near-pristine and protected zones have decreased by 60 per cent in the last few decades, and this is likely to have a direct impact on wildlife movements, mortality and fitness. The decline in water resources is due to:

- increased use of the natural springs (in other words, competition for water by livestock and wildlife along the northern border of the park, or 'capping' of springs to prevent access by wildlife)
- collapse in the maintenance and operation of the deep wells in the buffer zone, leading to more reliance and pressure on natural springs and park border areas
- little rehabilitation or management of water sources due to a lack of funds, leading to a dependence on the natural springs along the northern border
- erosion, sedimentation, a drop in the water table and climate change.

Water resources for wildlife such as the Bactrian camel and Gobi bear are becoming scarce; this may lead to a habitat shift. Erosion may also contribute to the habitat shift of wild animals. Also, the probable effect of global warming on local water supply is not fully understood. The Mongolian water agency indicates that the permanent water table (above 5 m) has changed little over the past twenty-five years. However, in the core area of the park there are oases where the water table has dropped and standing water no longer exists. It has been surmised that as some springs dry up, there is excessive pressure on the remaining ones. In some sites this has resulted in physical degradation of the oases brought on by extensive wildlife use, with consequent trampling, sedimentation and loss of resources.

Depletion of species abundance and richness

There is a general consensus that the populations of rare species such as the wild Bactrian camel, Gobi bear and Argali sheep are at a critically low level. The Gobi bear is endangered by the effects of inbreeding depression.

The genetic pool of the wild Bactrian camel is weakening because of interbreeding with domestic camels. Argali sheep are easily disturbed by human presence and suffer from substantial poaching and grazing competition by domestic stock.

Though the actual causes of species decline are not yet defined, a number of factors are hypothesized as causes, including:

- wolf predation of wildlife young
- wildlife migration to China
- cross-breeding of wild camels with domestic strains
- disease transmission
- limited water and forage
- poaching.

Recent studies suggest there is competition for food and water between the domestic camel and other wildlife roaming inside the park. Moreover, large intermixed herds of domestic and wild camels have been reported at oases in the SPA's western part. This leads to concern about interbreeding and the genetic erosion of wild camels. Apart from the interbreeding threat, vector-borne diseases are transmitted to wild camels through contacts with domestic camel herds belonging to the military outposts.

The values of biodiversity and conservation are still not seen as sufficiently important among local communities, the military or the government. Targeted training in more modern techniques of ecosystem management is urgently needed. Management actions must be based on the sound evaluation and monitoring of potential causal factors and results. For example, the revitalization of water resources may be a useful management action, but its efficacy needs to be properly tested.

Common problems characterizing the territory of the GGSPA buffer (transition) zone include:

- poor quality of drinking water that threatens local health
- land degradation caused by overgrazing and gold mining
- scarcity of water sources/water shortage
- herder families moving into wildlife habitat areas due to shortage of water sources
- shortage of winter and spring camps
- overlapping of wildlife and livestock habitat
- desertification, sand movements
- deforestation of oases.

Application of modern technology and traditional knowledge

In order to combat species decline and prevent further land degradation the government of Mongolia aims to launch a package of conservation and human development initiatives. In particular, government funds will be used to support sustainable livelihood options for nomadic communities and assist in basic water supply and management schemes. Both modern technology and traditional knowledge may have considerable value in retrieving, analysing, and storing and managing natural resources.

RS/GIS applications

Every resource survey involves ground sampling, and this can be speeded up by new satellite technologies that can provide ground navigation. Particularly in remote areas without good base maps, roads or reference points, determining geographic location is a major task. Satellite-based global positioning systems (GPS) can identify positions for ground sample points quickly, inexpensively and very accurately.

A geographic information system (GIS) permits the capture, storage, manipulation, analysis and display of spatial data. These may be in the form of maps (e.g. land use), images (e.g. satellite), point data (e.g. rainfall) or tabular data associated with geographic areas (e.g. census data). A GIS is capable of storing, processing and displaying all these types of information.

A GIS can be considered in terms of more general roles (Wadson and Treweek, 1999), including:

- visualization and communication that help people to understand what is known about the distribution of particular species
- audit and inventory that help understand and measure how much of a resource is present and how it might be changing
- analyses, predictions, modelling and decision making that help people to understand the significance of information and to make better-informed decisions.

Remote sensing (RS) includes instrumentation, techniques and methods to observe the earth's surface at a distance and to interpret the images or numerical values obtained in order to acquire meaningful information of particular objects (Janssen, 2000).

The use of remote sensing, combined with a GPS-navigated ground sampling strategy, yields a more accurate and credible product (in the form of estimates or maps) than can easily be produced through ground sampling alone. It is impossible to generate resource estimates (for example, range production and animal census) or produce maps quickly, inexpensively and accurately using ground samples alone. Remote sensing and statistical methods are critical for balancing the improvement of information accuracy (that is, more sampling) against the added cost of that improvement.

The use of GIS and remote sensing techniques supported by statistics has great value in sustainable management of natural resources (Skidmore et al., 1997). Warren and Hatchinson (1984) have produced significant findings through monitoring rangeland change with the aid of remote sensing data, and have identified causal factors. Toxopeus (1996) and Aligula et al. (1997) demonstrated successful spatio-temporal modelling for sustainable management of semi-arid rangelands, as well as geo-information use for sustainable rangeland management of a park in Kenya, taking biophysical and socio-economic data into account. NOAA data for drought monitoring has been extensively used in Mongolia, and over ten years time-series data reveal drastic vegetation cover degradation in the study area (Oyun, 2004). Many other findings and research can be referred to. Socio-economic and biophysical data collected by the project personnel will be used to produce comprehensive visual output specifically designed for end users such as communities and higher authorities. These may include digital elevation models (3D) and pasture or land cover/use maps with data on winter campsites; some analyses are to be done specifically on a land-use suitability map.

The following outputs can be produced with RS for further sustainable land use management:

- wildlife distribution and potential habitat mapping (Lamperierre et al., 1980), for example of the wild camel, Gobi bear and Argali sheep
- species richness and diversity of both flora and fauna (Narantuya, 2001)
- interaction between wildlife and livestock
- land cover change detection (Westinga and Thalen, 1996)
- degree and scale of patchiness (Rietkerk et al., 1998)
- vegetation regeneration possibility detection (Milton and Dean, 1995)
- pastureland maps showing degradation level and pasture availability (Rasmussen et al., 1990)
- land suitability for certain uses such as silvo-culture or grazing
- assessing suitability of areas for safaris or ecotourism
- effects of climatic disasters on livestock and wildlife population (Ottichillo et al, 2000; Kay, 1997)
- many other products taking different factors into consideration.

Such information can successfully be used for monitoring, evaluation and management, and can be scaled up to the regional and even global scale taking slightly different factors into consideration. Such applications, supported by traditional practice of Mongols, will produce beneficial results.

The government of Mongolia has emphasized the need to promote the application of traditional knowledge for purposes of nature conservation. The Mongolian national security concept (Law on Environmental Protection) fully supports and respects the traditional practices of local communities for the utilization of biological resources (Convention on Biological Diversity, 2002).

Indigenous knowledge embodies local values and management systems as well as awareness of the relationships among other resources, for example soil–vegetation associations.

Mongolia has a long history of good practice in conservation and sustainable use of natural resources. From ancient times the Mongolian people have relied directly on natural resources for food and materials, and have accumulated a wealth of traditional knowledge over thousands of years of nomadic animal husbandry culture. For example, Marco Polo noted that the Mongols had a closed season for hunting or disturbing wildlife as they respect mating and birthing seasons. In 1709, the Khalkh Juram Law set aside sixteen mountains where hunting, cultivation and timber felling were prohibited. Those who wanted to hunt for food had to first appeal to the Spirits of Sky, Mountains and Land to forgive them for the sin that was to be done. Moreover, water was actively protected, mainly by means of prohibiting tree felling, earth digging, rock moving and pollution of water sources.

Local knowledge is the starting point for work directed towards animal health, livestock production and environmental conservation, and provides the basis of more socially oriented strategies for coping with drought, resolving conflicts and sharing common property.

A recently established NGO in Mongolia is using ancient scripts to restore and rehabilitate indigenous knowledge. Its work will make a significant contribution in training and applying traditional knowledge for nature conservation purposes.

Suggested applications of traditional knowledge/practice

Pasture management

Traditional practices developed by the Mongols over many centuries to manage pastureland (which provides the forage for their livestock) have implications not only in the management of over and under-utilized grazing land but also in combating desertification. Nomads change their pasture from season to season to make rotational use of pastureland. The grazing land management methods of the Mongols can be divided into two kinds. One is *otor*: a transhumance type of pasturing practised in late summer and autumn when herders take advantage of the seasonal growth of vegetation by moving their animals from place to place, following good grassland in order to avoid trampling and overgrazing and thus land degradation.

Another management method is used in winter and spring, when pasture productivity is low. In this case, pastureland is divided into basic resources for horse and milked cows. Use is first made of the furthest pasture, when livestock is still fattened and able to move distances. As the conditions become harsher, livestock is herded in closer pasturelands to prevent any loss.

This practice is being improved through pasture management training and encouragement of local participation. In this context, herders are made to comprehend the value of having higher-quality livestock, rather than a greater number of animals with disease and parasites. Pasture utilization practice, assisted by GIS and remote sensing products such as 3D digital terrain maps and pastureland degradation-stage maps of the area enable locals to visualize the existing condition and location of their own and their neighbours' camps. In this way, the carrying capacity and plant regeneration status of the area will be determined. Meanwhile, a participatory rural appraisal tool has been applied among the herders to identify the problems confronted by the community itself, and to assist and mobilize them in forming herder groups.

The remoteness and isolation from the market of the Gobi region makes training on market determination necessary. Many of the relatively less-educated herders are still not convinced that high productivity livestock is better than huge but less productive herds.

Forestry to combat desertification

Afforestation, natural vegetation management and agroforestry systems can be used to control and combat desertification. The reforestation tradition of the Mongols is documented in legal documents and books from as early as the thirteenth century (for example, Chapter 58 of the legal code of 1294 indicates the necessity of reforestation and gardening). That these laws were effective and obeyed is confirmed by Marco Polo's note on Mongol tree-planting practices along the roads and trails that enabled strangers to travel without difficulty and not lose their way. There are very early documents containing information about fruit-tree gardening practices in the Gobi oases and river valleys. In the seventeenth century, in order to ensure a clean environment, it was prohibited to fell trees, to cull wildlife or pollute the environment near the capital city. Those who disobeyed the law were punished by seizure of their equipment.

The above practices of reforestation can be applied to the successful re-establishment of saxaul trees. It is suggested that every saxaul that is cut down should be replaced with three to five replants.

Water resource management

In order to restore wells and water supplies in the buffer zone, and to reduce impacts due to the overuse of natural spring water along the park border, it is wise to use historical, local knowledge as well as lessons learnt from previous projects on water rehabilitation and management.

Local people in the Gobi region can detect water sources by the distribution of saxaul, karagana, poplar and *budargana*. They have a rich knowledge of botany, invasive flora, disaster signals and so on. For example, they are aware that collection of shrubs and feather grass will result in water table decline. Application of such knowledge in practice will simplify any existing problem. Using their knowledge and capacity to visualize the effects of changes that will take place in time, dwellers understand and become involved in taking action towards the sustainable use of natural resources.

Wildlife conservation

Restrictions on hunting were adopted in the thirteenth century to prevent disturbance of wildlife in the mating and birthing seasons. These were enforced by strict punishment in order to prevent the loss of wildlife species, including their possible migration from the territory of Mongolia.

To ensure that local dwellers recognize the effect a decrease of wildlife inhabitants would have, they need to be taught that conserving wildlife will generate income, at least in long run. Community-based wildlife conservation will become a good technique for family income generation, supported by domestic tourism and photo safaris.

Weather forecasting

Mongols have a great tradition of using their knowledge to predict the weather using flora, animal, stars, the moon and so on in relation with each other. For example, if *Stipa* grass dominates in the summer pasture, this indicates a harsh winter (*zhud*). If the sun is surrounded by a halo, it is a sign of imminent rain; and if the moon is surrounded by a halo, it will become colder. If marmots hibernate earlier and roe deer occur in large numbers, this indicates *zhud*. If the colour of the rainbow is bright or salt becomes moist, bad weather is on the way.

Local predictions of weather and seasons from the behaviour of wild or domesticated animals are widespread in the region, varying from area to area. Typical examples are:

- If a cuckoo sings early in the spring, summer will be short and autumn longer.
- If birds fly low, expect a rainy year.
- If a ruminant makes a sound while breathing in, it is a portent of a dust storm.

Recommendations

The natural resources of these fragile environments can be better managed through the integrated application of long-practised traditional knowledge together with remote sensing and GIS supported by spatial modelling. The best indigenous practices such as *otor* pasture management, which prevents over and under-utilization of grazing land, should be adopted and used.

Community participation at all levels of management should be encouraged: communities themselves should define the problems and realize the need for rational utilization of natural resources, and will thus take part in and support management and planning.

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16 The biodiversity of agroforest landscapes of Kalmykia

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The character of forest vegetation is influenced by many factors (climatic, edaphic, biotic, historical and others). But of all the factors affecting forest vegetation of Kalmykia, two are most important for the growth and state of arboreal/shrub plants: the dry climate, which provides little moisture for the soil; and soil diversity, which influences the growth, condition and pattern of species.

There are about 160,000 ha of protected forests in Kalmykia today. If managed appropriately, they would become an active regulator of the ecological and biological equilibrium in meliorative areas, thus forming a new type of anthropogenic landscape – the agroforest.

The growth, health and longevity of trees and shrubs depend heavily on the pattern of afforestation and the cultivability of the soil. It is for this reason that the choice of tree species should be carefully related to the soil type and the characteristics of its salt regime and salinization. Long experience of afforestation in Kalmykia makes possible a clear understanding of how the arboreal/shrub group depends on the soil–climatic conditions of natural–economic zones of Kalmykia.

On chernozem and dark-chestnut soils in the western zone, more than thirty tree and shrub species are grown. Here the following tree species are found: *Quercus robur* L., *Robinia pseudoacacia* L., *Gleditschia triacanthos* L., *Ulmus pumila* L., *Ulmus laevis* Pall., *Ulmus foliacea* Gilit, *Fraxinus lanceolata* Borkh., *Acer negundo* L., *Ailanthus glandulosus* Dest., *Populus alba* L., *Pinus Pallasiana* Lamb., *Pinus silvestris* L.. Shrub species include: *Ribes aureum* Pursh, *Caragana arborescens* L., *Amorpha fruticosa* L., *Rosa canina* L., *Crataegus* L. Fruit tree species include: *Juglans nigra* L. and *Armeniaca vulgaris* Lam.

On dark-coloured soils of the central zone, the same groups of plants can be found. On light-chestnut soil with different salt content and salinization, however, the arboreal/shrub assortment is more limited. Among the group of tree species the following demonstrate stability: *Ulmus pumila* L., *Fraxinus lanceolata* Borkh., *Robinia pseudoacacia* L., *Gleditschia traicanthos* L., *Elaeagnus angustifolia* L. Shrub species include: *Ribes aureum* Pursh., *Cotinus coggygria* Scop., *Caragana arborescens* L., *Lonicera tatarica* L., *Tamarix*. These shrub species can also be found on solonetzs.

The eastern zone of Kalmykia is in an area of brown soils. In the northern part (Sarpinskaya lowland) brown loamy soils and solonetzs predominate, while to the south (the 'black lands', or in Russian *Tchernye zemly*) soil types change from loamy to loamy-sand. Frequent sand masses are found here, whose quantity increases towards the seaside–delta belt. The main shrub species found here include *Calligonum aphyllum* Gurke., *Eurotia cratoides* L. and various kinds of *Tamarix*.

The resilience of species in specific types of soils is the principal consideration for selecting plants for forest cultivation. When planning cultivation of arboreal/shrub plants on a territory, they should be classified according to the type of forest-cultivable conditions of certain soils. Furthermore, specific species should be matched to particular types of soils, taking into account their ecological growth characteristics. Taking ecological aspects into consideration is one of the main guarantees of the survival and longevity of plants. It provides an opportunity for the efficient usage of species, within an assortment of different types of forest planting conditions.

Protected forests have high meliorative, agronomical and economical effectiveness and can be regarded as the determining factor in the organization of high levels of land use. Improvements in land-use culture, agricultural and industrial employment, and the general living conditions of the inhabitants in woodless regions of Kalmykia require a system of planning and the concept of protected forests to ensure close and beneficial interaction between the different types of agroforest landscapes in the republic.

Session 4: Poster presentations

17 The ecological traditions of the Kalmyks

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The establishment of moral, legal and social norms by the Kalmyks also included a code of conduct or attitude towards animals. The herder–nomad lived in complete harmony with the surrounding world, and in order to preserve this harmony lived according to a whole system of prohibitions and symbolism, which was taught from an early age. According to the Kalmyks, it was inconceivable to cut a lone-standing tree, or whistle pointlessly near the herd (which could provoke a strong wind). To kill a frog would cause rain, and to kill a crane would, the Kalmyks believed, bring a curse on the offender.

The Kalmyks were prohibited from shooting game birds, especially eagles, swans and cranes. They believed that animals, game and fish understood the worlds connected to them, and that any disrespectful hunting would bring misfortune; it was believed that animals would keep away from the offender, who consequently would be left without a catch. Part of the fish catch was released back into the sea as a sacrifice to the owner of water: to the khan of *luses*.

According to the Kalmyks, the White Old Man was the owner of the district and they believed that he could wander with the herd of *saigas*, preserving them. Echoes of the hunting cult are still marked today in the Kalmyk language, and is expressed in the forbidden names of animals: Thus, people say '*teepn*' instead of '*noha*', '*chushka*' instead of '*gaha*', '*bor*' – the wolf – instead of '*chon*'. The particle '*jumn*' is attached to the names of animals and various things: for example, '*ovrte jumn*' meaning 'the cow of letter *ju*' (horned), or '*turuta jumn*' for hoofed cattle; '*ondg jumn*' is a horse that can be saddled, '*saadg jumn*' a cow that can be milked; '*meeldg jumn*' are bleating goats.

The cattle-breeding tradition of the Kalmyks was reflected in their prohibitions and taboos:

- If the cow had calved, it was forbidden to remove the milk from the house within three days.
- The birth of twins by cows was considered a bad omen and one of them had to be given to relatives.
- During cattle migration it was forbidden to pick up droppings, dust and other objects from the ground.

Another moral rule involved the cutting down of trees, which was only allowed in the case of an emergency. The Kalmyks believed that trees understood human speech, and strictly upheld the cult of the lonely tree as a symbol of the district. Such trees were considered sacred objects of worship.

In the Kalmyk territory today one can see many lonely trees. There is a legend about one that grows in the north of Kalmykia and is called 'Tree of Heechi'. Heechi was an old man who lived with an old woman and their only son, Chotny. The woman became incurably ill and died. Having buried her, the old man later understood her illness and himself became ill. He called three old men and forced them to migrate to another district and not to come back for three years. Meanwhile, he remained alone and began planting trees along the border of the lake. When three years had passed, Buddhist priests from the Dundu Temple read prayers, and after this ritual the old men decided to return to the area. There they discovered one sprawling apple tree in which, the temple attendant told them, the soul of the old man, Heechi, was embodied. Thus, he brought happiness to the people who lived in the settlement. Since that time the 'tree of Heechi' has been a subject of worship for adults and children, and its leaves and fruits became '*arshan*', a magic medicine. People who were unwell would walk or be carried around the tree forty-nine times as part of their treatment (Zyltrhn, 1976).

The meadow-sweet was another tree that was highly valued by the Kalmyks. In Kalmyk fairy tales, *bogatyrs* carried whips made of meadow-sweet grafts. In fairy tales, the whip took the role of the soothsayer's omen. One fairy tale hero called Zorigte left his whip to his brother after thrusting it to the ground and saying: 'If oil drips from the cutting of this whip, it means I am alive; if blood, I am dead.' The whip thus takes on all the magical, protective functions of the meadow-sweet tree.

In the epic *Djangar*, the description of the *bogatyr*'s whip is one of the transitive formulas of the heroic tale. This is typical of the repertoire of such storytellers as Eljan Ovla and Mukebjun Basangov. The distinctive feature of the whip's handle is that it is made from a tree that grows alone (*tnchn*, *jarsa modn*) (Burikin, 2002). A lone tree (which could be of various types) was a subject of worship because the spirit of the owner of the district was said to be embedded in it. It was forbidden to cut down a lone tree, but if a powerful weapon was made from it by the masters (*yrchud* – sacred persons who were able to work with it), then their magical properties were transmitted to the weapon. The *bogatyr* fought against his enemies with the help of his whip; one whipped his horse so fervently that 'drops of blood, about the size of a bowl flew from the whiplash'.

The careful attitude of the Kalmyks to their district is reflected in the ceremony of the burial of nails. (The Oirats from Western Mongolia also practised this ceremony.) The burial of nails was a special ceremony involving the pronouncing of a charm, consisting of eleven strophes. This charm represents a dialogue between the participant in the burial of nails, together with the owner of the ground (*sazrin ezn*), and the nails. At the ceremony a piece of land is requested from the owner, and the participants of the ceremony then sacrifice a gold and a silver coin. The text of the charm concludes with wishing the nails to become 'a white transparent rock' (*had bolh*). This expression is connected to the ancient custom that people were usually buried on a rock, close to a dry mountain slope; after death the person becomes one with the mountain and departs up the hill, merging with it. The couplet '*Bi zal byyrl sahlta, zasan gvgn bolnav*' ('I shall become a white old man with a beard') makes tangible the invisible ceremony of the owner of the ground: the White Old Man.

In the folklore tradition of the Kalmyks, there were a number of myths concerning pets (cats or dogs). In accordance with the national beliefs of the Kalmyks, the souls of ancestors were reincarnated in dogs. The first thing the Kalmyks did upon seeing a hungry dog was to feed it, and they believed that it should carry out only sentry functions and help its owner in hunting. Keeping a dog indoors in the house, however, was considered a sin.

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18 An ecological aspect of Buddhist iconography

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The Mongolian folk art of Central Asia is unique. It developed at the time when a canon of Buddhist fine art evolved under the influence of folklore. Old Kalmyk art in the historical-cultural context represents an organic stewardship of artistic traditions and the wholeness of the nation's traditional culture. Indigenous representations were incorporated into the complex philosophical system of Buddhism, as it was perceived in Central Asia by the Oirats, the ancestors of the Kalmyks. Buddhist iconography is syncretic in interpreting Mongolian nomadism: it represents a further development of the ancient Buddhist cultural traditions of India and Tibet.

The content of traditional graphic art informs us about the Mongolian mytho-poetic consciousness. It is strictly mythological, representing the traditional culture's universal complex of symbols. Culture is not only moulded by the influence of the environment but has also an internal dynamic, expressed in ethnic artistic traditions. Among the Mongols, the sources of these traditions are in the spiritual sphere of the categories and symbols of traditional nomadic culture, representing the 'unique cultural world of the Mongolian peoples'. It is an interconnected system of views on the harmony of Nature, the person and society.

The generic structure of society is seen as fundamental to the whole of Creation in its traditional relationship between people and Nature. Nature is predominant, but the phenomena of spiritual nomadic culture are deeply social. The memory of ancestors is a genetic mechanism hidden in the depths of the psyche and consciousness of the ethnic community. This is the original collective world perception. It comes from the depths of the past, existing as a primary layer in the consciousness of humankind. C.G. Jung called it the 'archetype': a substantive characteristic of the prototype, fixed in graphic art. 'Archetype' is a term that indicates fundamental, original schemes of representations that are the basis of artistic structures of the consciousness.

In the iconography of Northern Buddhism, there is a specific regeneration of archetypal structures of the collective memory. The phenomenon of the traditional culture is born in the form of the cult of particular signs, phenomena and subjects embedded in the graphic memory of ancestors. The history of art is a journey from the 'language of signs to the language of a semantically saturated culture'. In traditional art, the patterned space of the depicted scene alludes to the ancient cosmogony of ancestors. It represents an archetypal building block, revealing the attitude of the person to Nature. Its personified, canonized image can often be found in Buddhist iconography, and even more so in the depiction of characters of pre-Buddhist folk beliefs.

Art is a projection of an artistic reflection of reality. Ethnic consciousness designs the mytho-poetic, syncretic model of the Universe. The unique wholeness of the folk worldview was denominated in ancient animistic beliefs, animating Sun, Sky and Land. Nomadism implies the organic unity of Nature and people, which never conflict with one another. It finds an expression in the spiritual culture of the people in religion: the traditional way of seeing the world, defining the relative positions of the person, Nature and society. There the archetypal structures have their being, realizing primary connections between the phenomena of world perception and world reflection. The archetype as an element of the structure of the primitive generic consciousness is transformed in the process of myth creation into images of the external world.

The patterns of graphic art represent the ideal organized system, a model of Being in the mytho-poetic vision of the 'epoch of the world tree'. Graphic art is the single authoritative source of mythological information, as it creates conditions for its visual reconstruction. The traditional culture of the Mongolian nation, which is its distinguishing ethnic feature, is represented in the anthropomorphous image of Nature. It is a distinctive reconstruction of the Buddhist graphic canon; the central character of the animistic outlook is *Delkyan Tsagan Ovgon* (in Kalmyk): the White Old Man of the Universe. His sources lie in the ancient culture of the matriarchal epoch. In Buddhist paintings, he is depicted in ways that vary in the different regions of the Mongols, Buryats and Kalmyks. The Kalmyk variant most brightly and deeply expresses the ecological balance of Nature and the individual in the nomadic folk culture. The specific ethnic variations in the iconography of this image are a characteristic element of Kalmyk traditional culture.

In the foreground, the White Old Man grows from the ground in the Buddhist icon. In this image, Sky, Sun, Land and the Person are equal. Their unity is naturally represented by the person, who emulates the condition of the surrounding world. This image is an ecological representation of the invigorating power of Nature. One could hardly find a more all-embracing formulation of the ecological balance of life, understood as a harmonious alliance of Nature, the individual and society.

In the composition, the iconography of the image represents a mythological world tree, with the roots deeply embedded in the ground and with the crown rising skyward, connecting land and sky. This is the main idea of the scene. The archetypical worldview designs the mytho-poetic space. The person is not the omnipotent conqueror of Nature, but is an equivalent, harmonious part. Such is the traditional world attitude of the people, confirming the harmony of life. In the Buddhist paintings of the Kalmyks, Nature is the first and fundamental home of humanity.

This unusual image of the Universe was born in the prehistoric epoch of the matriarchal life of the people. It is the artistic foundation of the epic folk heritage, a profoundly distinctive concept of being. The iconography postulates the ecological balance of Nature and person. In the worldview of ancestors, which is the basis of traditional culture, lies the concept of the spirituality of Nature in the image of the person. Animism, nurturing the non-rational world attitude, offers humankind a resolution to the global ecological problems faced by modernity. This takes the form of a cultural dialogue, eschewing conflict between Nature, the individual and society.

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19 Nature-preserving aspects of ethnic culture

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In the course of centuries of life in the steppes, the Kalmyks, steppe nomads, have developed a well-adjusted system to regulate the norms of humankind's behaviour and attitude to nature, taking into account the ecological fragility of the steppe landscape. In a modern civilization, where the problem of environmental protection is particularly acute, it is advisable to study and use traditional knowledge and ethno-ecological culture. With this and the historical past in mind, it appears indispensable to make use of traditional knowledge of the people in the effort to adjust the ethnic culture of the Kalmyks to the modern industrial urban civilization.

In 2003, the Centre of Ethnic-Social Research at the Kalmyk Research Institute for the Humanities (Russian Academy of Sciences) conducted preliminary research with the aim of defining the public attitude towards ecological issues and testing its specially worked-out methodological procedure. The research questionnaire consisted of several blocks of questions, which were to formulated to:

- determine the public attitude to ecological problems in Kalmykia
- evaluate measures taken by the authorities and society to tackle these ecological issues
- explore attitudes towards the nature-preserving traditions of the Kalmyks
- identify the characteristics of ecological training at home and in schools.

Those taking part in the questionnaire numbered 289, a rather small sample due to lack of funds to conduct a larger survey. Town dwellers made up 75.4 per cent of those questioned; the remaining 24.6 per cent were rural dwellers. Male respondents made up 44.3 per cent, and female respondents 55.7 per cent. As for the ethnic affiliation of those questioned, 62.3 per cent were Kalmyks, 29.1 per cent were Russian, and 8.6 per cent were representatives of other ethnic groups.

This paper is intended to provide a tentative analysis of some results of the survey.

Attitudes to nature-preserving traditions

The Kalmyks possess a unique ecological culture that provides the population with all its needs while caring for the sustainable preservation of the ecological and cultural environment. Nowadays it is urgent to study the invaluable knowledge that makes up the treasure trove of the ethnic culture, to ensure it is preserved and, if possible, recover what has been forgotten.

One in ten of the respondents (10.4 per cent) believe that many of the nature-preserving traditions should be reviewed. 7.6 per cent of the participants think that the traditions, which in their opinion are relics of the past, must also change. Fortunately, a greater number of the respondents think differently: 41.5 per cent of those questioned think that nature-preserving traditions should be revived and reintroduced into everyday practice, and 35.3 per cent emphasize the importance of traditional knowledge in modern life.

The answers we received to the open question '*What do you know about the attitude of our ancestors to their land?*' give us an opportunity to understand what the contemporary inhabitants of Kalmykia know about the nature-preserving traditions of the Kalmyk people. Some 17.2 per cent of the Kalmyk respondents (group 1) and 11.9 per cent of the non-Kalmyks (group 2) simply have no idea. Among the responses, we found unexpected and even utterly misleading accounts, whereby the respondents saw no correlation between livestock breeding, the traditional economic activity of the Kalmyks, and the land itself. Some 3.3 per cent of the respondents from the first group remarked that their ancestors were cattle-breeders and had no relation to land farming.

The following answers characterize the positive attitude of the ancestors to the land:

- Took good care of the land: 29.4 per cent (group 1); 17 per cent (group 2).
- Respected, valued and cared for it: 22 per cent (group 2).
- Respected it as the main supplier of their needs: 5 per cent (group 1).
- Were more responsive to the land than we are now: 3 per cent (group 1).
- Were in harmony with nature; wanted to pass it on to the next generation.

Another category of answers gives a more distinct picture of the human–land relationship; 11.1 per cent of the first group and 3.7 per cent of the second group believe that the Kalmyks as nomads rotated their pastures, allowing the land to rest and so preserving the grass cover. Some 2.2 per cent of the people questioned from group 1 and 1.5 per cent of group 2 remarked that the Kalmyks reared a special breed of flat-hoofed sheep, which do not trample the grass and land. Only a few in both groups noticed that the wise forefathers did not raise more cattle than was necessary. Some 2.8 per cent of the Kalmyk respondents mentioned that the ancestors made use of the water springs and also took care of them.

In some questionnaires we find descriptions of various rites: for example, it was forbidden to dig the land thoughtlessly, to walk on one's heels, to whip the land or perform various other acts, in order to avoid unnecessary loosening of the soil. For the same reason, the Kalmyks used to wear turned-up footwear. They worshipped the land as the most sacred of all things, begged its pardon for treading on it, and offered it lavish sacrifices. One of the tasks of our research was to define what aspects of ritual activities involved ecological elements: the presence or absence of ecologically oriented forms of conduct.

The responses given to the question '*Do you take part in traditional folk rites of passage?*' indicate that the people in our sample do not generally take part in such rites. Negative answers were given by 46 per cent of the respondents. The rest of the respondents take part in the following rites:

- Festive occasions (both Kalmyk and Russian): 23 per cent.
- Natal events: 2.2 per cent.
- Weddings: 4.4 per cent.
- Life-prolongation: 3.3 per cent.
- Land, water consecration: 6.1 per cent.

It should be noted that most of the respondents (75 per cent) were from urban areas, and according to the Kalmyk ethnographists, they are less aware of the ritual culture than the rural population. This is definitely reflected in the results of our research.

In spite of the fact that ethnic traditions are being revived in the republic, few people are actively involved in the process, or particularly aware of that facet of the ethnic culture. This can be confirmed by the results of the survey. Some 27.2 per cent of the respondents do not have any idea of the reasons underlying those traditional rites. Among the answers to a question on that topic, there are many widespread, stereotyped, mass-media clichés that show that the respondents had made no effort to find the true reasons for such rites. Among the main motives mentioned were:

- Preservation of folk traditions: 18 per cent.
- Preservation of the ancestral memory: 2 per cent.
- Succession of generations: 2.5 per cent.
- Striving for general well-being: 5.6 per cent.
- To improve the ecological situation: 4.2 per cent.
- To foster patriotism: 2.1 per cent.
- Rebirth of the national culture: 2.5 per cent.

There is no nation without tradition. Traditions unite and strengthen the nation. Neglect of folk traditions, and blind adoption of technical and cultural innovations, result in the extinction of nature awareness, of traditional nature-friendly economic activities and of sustainable land-use, cumulatively aggravating the ecological situation in the republic.

The development of ecological culture among the public

The west European experience in the field of ecological activity shows that the environmental situation can only be radically improved if all social strata are actively involved. In turn, the degree of public activity in resolving ecological problems depends on the level of ecological awareness and public consciousness, and on the distribution of information about the environmental situation. A question designed to assess the degree of public involvement in nature-preserving activities, was answered in the following way: 31.1 per cent of the respondents said that no such activity had been organized or ever taken place, 33.2 per cent agreed that if there were good leaders and organizers they would follow them, while 28.7 per cent were sceptical and observed that public passiveness hampers the organization of such events.

One of the questions was intended to evaluate the efforts made by the local authorities to preserve nature. Only 21.1 per cent of respondents are satisfied with such efforts. The overwhelming majority (73.7%) do not find the measures taken by the authorities sufficient to resolve the present ecological problems in the republic, and 33.9 per cent think the ecological situation is deteriorating.

There is huge public interest in the issues of social ecology (contemporary environment-friendly aspects of social economic development of the region). The vast majority (82.7 per cent) of the respondents are concerned about the ecological problems facing the republic, and only 5.8 per cent of the respondents claimed that these issues are of no concern to them. Some 26.6 per cent of the respondents are determined that the issues of nature preservation should be urgently addressed, otherwise it will be too late to change anything.

The questionnaire data enabled us to rate the ecological problems on the territory of Kalmykia in the following order of priority:

1. Low quality of drinking water: 86.2 per cent.
2. Desertification: 56.4 per cent.

3. Extinction of rare animal species: 34.6 per cent.
4. Air pollution: 31.8 per cent.

Numerous tests on drinking water show that it does not meet the normative sanitary, chemical and microbiological standards. The issue of water supply in the republic is therefore of vital importance. Which solution will best help to protect health and improve living conditions?

According to scientific data, 80 per cent of the territory of Kalmykia is subject to desertification; soil degradation has reached critical proportions and is aggravating the ecological situation everywhere in the republic. That is why the issues related to desertification processes are given top priority in our rating.

The ecological awareness and behaviour of the Kalmyks has been realized in the form of steady traditional stereotypes, which have been passed from one generation to the next over many centuries: that is, they were of successive character. In this transfer of experience, knowledge and traditions, the role of experts in folklore and ritual culture is crucial. Some 6.2 per cent of the respondents note that in the place where they live there are many people who have preserved the ancestral traditions and handed down their knowledge to the younger generation. In some questionnaires we could even find references to the names of such people. However, more than half of our sample (51.6 per cent) think that there are very few such knowledgeable people, although these do pass on their knowledge. Another 28 per cent of the respondents think there are no such people left. There is no doubt that this fact complicates the ecological socialization of the general public.

One question was aimed at finding out how families pass on environmentally friendly and appropriate attitudes. Half of the respondents (50.5 per cent) admit that their parents would seldom instruct them in this regard, but that those useful instructions stayed with them for life. Some 14.9 per cent report that it was their grandparents who took care of their ecological upbringing; 19.7 per cent feel that their parents did not pay enough attention to raising their children's ecological awareness due to lack of time; and 12.1 per cent believed they learned a lot about nature from Kalmyk stories and the works of Kalmyk writers. Thus, more than two-thirds of the respondents stated that they were taught within their families to treat nature respectfully.

The next question aimed to find out if the respondents' relatives knew and were able to construct their relationships with nature. A total of 39.1 per cent replied that their close relatives could not treat the environment correctly because they were anxious about their daily needs (such as managing to support their families). Some 8 per cent of the respondents are not interested in environmental issues at all, and are quite unconcerned about it. In contrast to this group, a quarter of the respondents are concerned about the environmental situation, and are aware that the future of their children depends on their attitude towards the environment now. Indeed, 9.3 per cent admit that priority must be given to ecological issues, which are vital for human life and activity.

Ecological education and nature-consciousness are indispensable elements in sustainable nature use and environmental protection. They form the ecological culture, ethics and morality that regulate people's conduct and enable them to make correct decisions in ecological practice. In this regard, the role of both educational institutions and families as the main agents for ecological socialization is very important.

The results shown in Table 19.1 show that 39.1 per cent of the respondents think the ecological curriculum of educational institutions is satisfactory. However, the majority of the respondents (56 per cent) disagree. They think that schools either approach ecological education in a merely nominal, formal way or do nothing at all in this field, and that the existing curricula need to be revised. Incidentally, it should be noted that effective

Table 19.1 Survey of parents' views of the quality of ecological education in schools

Responses	% of total number
Yes, I am fully satisfied, my children go to nursery school where ecological education is given a lot of attention.	6.6
Yes, my children get a lot of information in the field of ecology. Then they teach elder members of the family.	8.6
Yes, school does a lot to form ecological consciousness in our children.	23.9
No, school does practically nothing in this regard	15.9
No, this issue is approached formally, leaving no impression in either the minds or the souls of the children.	30.4
No, this part of school curriculum must be reviewed.	9.7

ecological education can only be achieved through systematic training of skills and paying attention to the children themselves and nature as a whole.

The problems brought to light in the course of this survey require insightful analysis. In this connection it is necessary to conduct sociological surveys to study the ecological consciousness of the general public. The concern of the public about the worsening environmental situation is increasing year by year. The main thing is that every person should be aware of his or her individual participation in and responsibility toward nature. There is truth in the statement that, of all the world's ecosystems, the fate of the steppe is the most dramatic, and the main protagonist in the final acts of this drama is humankind.

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20 Folk knowledge in the life-support system of the Kalmyk ethnos

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The Mongolian peoples, and notably the Kalmyks, still hold the ancient belief that all things and entities in the world and in their environment have a spirit lord: mountains and rivers, trees and lakes, sky and earth, fire and water, places and even dwellings have their own soul. Many elements of traditional knowledge have been preserved through the cults and rituals that have been practised in this region and remain a living tradition today. Traditional rites and customs concerning the life circle of every person (birth, marriage, death) and calendar (holidays) are still prevalent among the present-day Mongols in general, and among the Kalmyks in particular.

In recent years, several books and articles on this subject have been published (Bakaeva, 1993, 2003; Omakaeva, 1995, 2003). These works have enriched our knowledge in this field, which had previously been known to us through the work of U.E. Erdniev (1980).

The main aim of this paper is to identify and analyse the characteristics of the Kalmyk system of traditional knowledge on the basis of information taken from field studies and Kalmyk old-script documents (manuscripts). Most of the published manuscripts have been out of print for decades, and thus beyond the reach of scholars.

The system of folk knowledge is an important part of the spiritual culture of ethnos and is closely connected with its economic activity and world outlook.

Calendar knowledge

The system of calendar representations of the different peoples, including the traditional Kalmyk calendar, is of great interest for investigating many aspects connected with problems of ethnic and cultural genesis, traditional ceremonial rites and the outlook of the peoples. The calendar contains information about base categories of the worldview such as time (Omakaeva, 1999). The calendar stores the image of our ancestors' life; it is a representation of the earth order and appears as one of the approaches for mastering the special knowledge of mythology through the consciousness of natural appearances (Braginskaya, 1997). The different natural and climatic conditions, as well as the varying life-support systems, of the different peoples can be observed in the ethnic and local specificity of Kalmyk calendar knowledge.

The centuries-old experience of contact with nature is reflected in the cattle-breeding calendar of the Kalmyks. The recurrence of seasonal natural phenomena actually led to the first representations of the temporal cycles. The seasonal marking of time was carried out on the basis of phenological features (for example, planting trees and gardens, grass). According to the Kalmyks' world outlook, the year was divided into four seasons of three months. The first season lasts from the middle of the first winter month to the middle of the first month of spring (*tsagan ul'rl,* 'the white season'); the second season begins on the fifteenth day of the first spring month and ends in the middle of the first month of summer (*devyan ul'rl,* 'the grassy season'); the third season runs from the middle of the first summer month until the middle of the first autumn month (*nogan ul'rl,* 'the green season'); the fourth season begins on the fifteenth day of the first month of autumn and continues until the middle of the first winter month (*kiryu ul'rl*, 'the season of hoarfrost') (Korsunkiev, 1977). The beginning of the year is supposed to take place during the winter solstice (21–3 December). The old month-names of the seasonal calendar represent the ancient occupations of the Oirats (ancestors of the Kalmyks), taking the names of birds or constellations.

The month was divided into three decades: *sarin shin* first, then *sarin dund*, and third *sarin khuuchn*. The Kalmyks identify four phases of the Moon: the first quarter, *sarin ekn*; the full moon, *arvn tavna sar*; the second quarter, *khuuchn sar*; and the new moon, *dald sar*.

The Kalmyk year was divided into two parts: the winter and summer half-years. Winter and summer solstices served to mark the division, and were determined in accordance with the length of a temple's shadow and its movement during the longest and shortest days of the summer and winter (Korsunkiev, 1987). The division of the year into two halves was connected with the important natural and climatic rhythms of economic activities: pasturing cattle from early summer, and bringing them back when the cold arrives. Such archaic forms of calendar are typical of cattle breeding nations.

Although the Kalmyks now use the Gregorian calendar, traditional holidays are celebrated in accordance with the Kalmyk lunisolar calendar. This is the very point that defines the approach to Kalmyk holidays: to uphold the traditional ceremonies and to keep a vow of one-day post-*macak*. Every year of the Kalmyk lunisolar calendar, as well as each day, is named after one of twelve animals, its own element (*makhmud*), its own sign (*menge*), its place, its planet, its constellation (*odn*).

The twelve-year animal cycle is familiar to many Central Asian nations, including the Oirats. It was adopted by the Mongolian peoples in the thirteenth century and is still very popular with them today.

This twelve–year cycle commonly starts with the Mouse-year, but a distinctive feature of the Kalmyk calendar is that the cycle begins with the Tiger-year. A New Year begins with the first Tiger-month, which starts between the twentieth days of November and December. In this way, the Kalmyks always begin the following year of the animal cycle two months earlier than other Mongolian nations.

The twelve years of a cycle, as well as the twelve months, are divided into 'male' and 'female'. Numbering the days of the month depends directly on the Kalmyk national calendar. The 'male' months (Tiger, Dragon, Horse, Monkey, Dog and Mouse) always begin from the Tiger-day. The 'female' months (Hare, Snake, Sheep, Hen, Pig and Cow) begin from the Monkey-day; the Monkey is thought to be the antipode (*kharsh dzil*) to the Tiger. In this connection, it is very important to study the gender aspect of the traditional culture: the different roles of men and women (regarding rites, taboos and the like) and their different relations with nature and the environment (Omakaeva, 2003).

Each day of the month, as previously mentioned, is also connected with one of the twelve animals. If there are skipped (*tasrkha*) or doubled (*davkhr*) days in the month, then the animal character is also skipped or repeated accordingly.

The astronomical and phenological knowledge of the Kalmyks

The Kalmyks know the main celestial luminaries very well. Observing the movements of the planets and stars, the people gained experience in meteorology, which was passed on from generation to generation. The Kalmyks had the cult of celestial luminaries: the Sun, Moon, the planets of stars and constellations (Omakaeva, 1993). In addition to these, other planets such as Mars (*Ulan nyudn*, 'Red eye'), Mercury (*Ulemdzi*), Jupiter (*Pyurvya*), Venus (*Tsolvng*) and Saturn (*Bembya*) were known to the Kalmyks. The Kalmyks distinguished the Morning and Evening Stars. The Morning Star signalled the start of a new working day. The Evening Venus was called *Zal'gdg emgn* by the Kalmyks ('the swallowing old woman').

The Kalmyks made a cult of the Ursa Major constellation (*Dolan burkhn*, 'Seven deities'), considered to be a measure of happy life. In the Kalmyk calendar there are special days set aside for lighting icon-lamps to honour Ursa Major. Each of the seven stars that make up the constellation is thought to have a deity which is connected to one of the energy channels of humanity. The polar star was represented to the Kalmyks as a sentinel (*Altn gasn*, Golden picket). People call it *Bat odn* or 'Fixed star'.

The Pleiades, an accumulation of seven small stars, were reliable signs to orient oneself in time. Their appearance in the sky was connected with the onset of winter, and their disappearance with the approach of warm weather. Several times a year the Pleiades come close to the Moon. The Kalmyk weather tellers paid special attention to the position of the Moon and the Pleiades during such periods. On this basis they would predict future meteorological conditions. People used to call the Pleiades 'cold stars', and it was proverbial that: 'If the Pleiades shine brightly, there will be frost.' The Kalmyks connected various superstitions with the stars.

Countable and metrological knowledge

On specific days, the Kalmyks predicted the character of the forthcoming winter. One such day was the fifteenth of the middle winter month. If the weather was fine and sunny on that day, there would be blizzards and lack of food. If the weather was cloudy and rainy, late winter and spring would be warm. The Kalmyks also made forecasts with the help of a thread. They would hang a weight on it, and before sleeping they would hang it from a column or a pole in their yurt (traditional nomadic dwelling). If in the morning the thread was twined round the pole in a clockwise direction, under the influence of the wind, it was considered a good meteorological sign. If it was in a counter-clockwise position, then a cold winter was to be expected.

Numbers were also well known to the Kalmyks from childhood, going up to a billion and higher. They had a system for keeping count on their fingers. Our ancestors were well familiar with geometrical concepts such as *togrog* (circle), *gurvldzn* (delta circuit), *dorvldzn* (quadrate) and so on.

The national system of measurements was widely used in the everyday life of the Kalmyks. Their linear measurements were made with various parts of the human body: *tokha* (elbow), *ald* (*sazhen*), *delm* (half-*sazhen*), *toe* (span) and others. Containers of different sizes served as the liquid measures: *tsogts* (a sacrificial cup, 100 g), *shaazng* (drinking bowl, 400 g), *borv* (a leather flask, 3-7 π), *bortkh* (flask, 4 π), *suulg 'karka'* (7 π), *arkhd* (a leather bucket, 30 π). Dry measures were *alchur* (a shawl parcel), *uut* (leather sack) and *tulm* (leather bag).

Geographical knowledge

According to Kalmyk belief, there is a mountain called Sumeru at the centre of the Universe (*somr uul*). Situated around it are seven gold mountains, between which there are seven oceans. Mount Sumeru has four sides, each of which has a particular colour: the east side is white (made of silver), the south side dark blue (lazurite), the west side red (ruby) and the north side yellow (gold). The Universe consists of 4 major continents.

Veterinary knowledge

The Kalmyks knew animal anatomy very well, as well as how to cut up an animal. The knowledge of anatomy helped in the treatment of their cattle. Treatments include cauterization and exorcism. They used a so-called 'dragon's arrow' or 'devil's claw' to cure a cow with a tumour on its udder, affixing it to the udder while saying: 'Let poison be taken by the arrow'. Usually this was applied three times. Each time the negative energy would diminish after the 'dragon's arrow' was laid down on the ground. Other charms included the fang of a mole, claw of a black bird and the nail of a woman who had given birth to twins (Bordzhanova, 1999)

Knowledge of botany and zoology

The nomadic life of the people taught them about flora and fauna. Plants played a great role in the life of the Kalmyks. Some served as raw material for the production of embrocations. *Shagan budg*, for example, was 'an embrocation for an *alchik'* (an ankle-bone). They were also used in dressing hide, pharmacology and cooking national dishes.

Medical knowledge

The Kalmyks have their own traditional medicine (Omakaeva, 1997, 2000, 2002). This is determined by a number of factors: local natural and climatic conditions, economic and cultural activities, and people's ethnic and cultural contacts. The contacts made by the ancestral Kalmyk with eastern nations, which had a variety of medical systems, were very important in the development of medical knowledge. The roots of Kalmyk medicine are found in Iranian, ancient Indian, Chinese and Tibetan medical schools. The latter approach was widely used by the Kalmyks due to the spread of Buddhism. In the Buddhist monasteries, the doctors (*emchi*) were particularly masterful, and the patron of Buddhist medicine is Manla Buddha. The spread of the Tibetan medicine among the Kalmyks is connected with Sangadzi-Aravg, a founder of 'Emchin temple' ('*emchi*' means 'a doctor'). Kalmyk doctors, including many well-known monks (Dordzi Setenov, Dambo Uljanov, H. Baburkaev, O. Dordziev and N. Kichikov), received their education in Tibetan monasteries.

Kalmyk doctors were given different names depending on their form of treatment: *emchi* (treating with medicines and herbs), *otchi* (bone-setters), *bo, udgn, medlgchi* (shamans and masters). As experts in medicinal magic, the shamans and masters provided treatment with the aid of charms and spells.

Kalmyk national medicine had two main forms of treatment: medicinal and non-medicinal. Medicinal remedies were divided into those of vegetable, animal and mineral origin. It is thought that the Kalmyk *emchi* knew up to three thousand medicines.

Curative broths and powders were made from vegetable raw materials. These were gathered in the steppes or bought at chemist shops, where the medicines were supplied from Tibet and China; plants such as the sage-brush and milfoil, among many others, were widely used. Medicinal grass and tonic tea from curative grasses were mentioned in the Kalmyk epic, 'Djangar'.

Bile, raw meat and milk products were also used. Among milk products, *koumiss* (fermented mare's milk) should be noted. Drinking *koumiss* was considered to be the best way to gain strength and health. It was prescribed in cases of exhaustion, tuberculosis, anemia and struma.

Animal fat, particularly badger's fat, was considered especially effective for curing tuberculosis, and has been used for treating many diseases. The badger's meat was considered a useful medicine for stomach pain. There is a legend about this:

> Once upon a time an old man lived with his son. The son came down with a stomach ache and he soon died. To understand the cause of his death, the old man performed a dissection and found something hard, like a horn, in the stomach of his dead son. The old man used this horn to make a handle for a knife, which melted once the old man had eaten badger's meat.

Children were treated for scrofula by placing a sheep's heart to the aching ears. The sheep was picked out from the herd without letting its 'owner' – *nachtsnr* (the maternal relatives) – know. In the case of appendicitis, the patient was prescribed fresh mutton broth. The boiled water mixed with oil was often used as a good remedy. Meat roasted in gopher's oil was widely used for whooping cough.

Poultices and wrappings, made from cloths and sheepskin, were widely used for physiotherapeutic procedures. This form of treatment is described in the well-known medical manuscript *Kok khutsin nom* ('The book of the dark-blue ram'). Baths, compresses and cupping-glasses were used in physiotherapy.

Natural resources such as mineral water, silver, sand, salt, clay, ashes and so on were of great importance in Kalmyk traditional medicine. Metal treatment was also widespread, particularly the use of copper for fractures. Hydrargyrum, camphora and tar were also used. Glues and mountain resins were included in the collection of medicines.

Non-medicinal forms of treatment included massage, gymnastics, water treatment and acupuncture. In the seventeenth century, a treatise on acupuncture and cauterization was translated from Chinese into the Oirat language.

The Kalmyk *emchi* thought that the human organism consisted of five elements: earth, water, fire, wood and iron. Upsetting the balance of the five elements, or of the three regulative systems or the two types of energy, was thought to bring about illness. The treatment depended on which elements were lacking in the organism at that time. The predominance or shortage of one or another element in the organism depends on the season. For example, the element 'iron' is weak in the first seventy-two days of autumn; this translates as the time of the lung. The first seventy-two days of winter are linked with water: this is the time of the bud. The first seventy-two days of spring are linked to the tree: this is the time of the liver. The first seventy-two days of summer are linked with fire, and this is the time of fire. The remaining eighteen days of each season are associated with the element 'earth'. Thus, everything is based on the mutual relationships between the elements.

In Tibetan medicine, the laws managing the mutual relation of elements were symbolically termed 'mother', 'son', 'enemy', 'friend'. These laws were of great importance in explaining the state of energies in the human body, which in the West are called biorhythms. As this is the purpose of the horoscope, it can be said that Tibetan medicine was closely connected to astrology.

Illness is often linked to nutrition: rich and fatty foods cause illness that is associated with bile; too much starchy food is also deleterious, and a calorie-poor diet is associated with wind. In all, Kalmyk medicine distinguished 404 common illnesses and 360 diseases linked to the nervous system. The 404 common illnesses were divided into four groups, depending on the cause of the illness and the method of treatment. The first three groups were caused by three fundamental morbid factors, and illnesses of the fourth group by evil spirits. There were two methods of treatment: doctors cured certain forms of illness, while the other kinds were treated with charms and magic. One class of illness was treated with special rituals (the shamanist ritual *ga gargkh* or the Buddhist ritual *gurm*) and the last group comprised illness that did not require any treatment.

The Kalmyk doctors could diagnose (by studying the pulse, urine and so on) and treat a number of illnesses, including typhoid fever. They distinguished eighteen forms of typhoid, six forms of illness linked to consumption, five forms of stomach catarrh and nine forms of smallpox. Black smallpox was considered the most dangerous form of these, and the mildest was chickenpox.

The ritual 'ransom of life' was the most radical way of recovery. This ritual calls for a religious service that is performed in front of the patient. A figure of the patient was made with dough and spells were read to it. In this way, the illness was 'driven' into the figure, which was then thrown onto the crossing of three roads or taken out on the steppes. The figure was thrown into a hole face downwards and covered by earth (Smirnov, 1881). In the more distant past, a real person might replace the dough figure. The person would wear fine clothes and be placed on the patient's favourite horse to be expelled forever from the native nomad camp. The reading of spells was said to expel the spirits of illness from the patient by transferring them into the 'double/substitute'. If a person felt in low spirits, apathetic or flaccid, then it was believed that the soul had left the body. It was necessary to perform a ritual 'calling the soul' so that the person would not die.

According to our records, two people could perform this ritual: the Buddhist priest (*gelung*) together with his assistant whose horoscope had to be in harmony with the patient's. A tent was set up on the steppes with the patient lying inside it, and food was placed in a basin outside. The priest and his assistant placed a cap belonging to the patient on the big shinbone of a sheep's right leg. Twice a day during sunrise and sunset, the *gelung* called out to the soul, calling it by the patient's name. If the soul returned, the patient's cap became heavier than the sheep's shinbone. The assistant would then grasp the cap and place it on the patient.

The *sumsn* (the soul) was of great importance in national medical treatment. The Kalmyks considered it to be the vital power that circulated in a person's body over a monthly cycle. According to the Kalmyk calendar, the soul was considered to be present in the big toe on the first day of the month; during the second day, it was said to be contained in the malleolus or sexual organs; on the third day, in the muscles; on the fourth, in the loin or elbow; on the fifth, in the knee joint; on the sixth, in the femoral muscle; on the seventh, in the side; on the eighth, in the kidneys; on the ninth, in the edge; on the tenth, in the brachia or blade; on the eleventh, in the arm (hand) and fingers; on the twelfth, in the palm; on the thirteenth, in the throat or neck; on the fourteenth, in the chin or cheekbone; on the fifteenth, in the whole body; on the sixteenth, in the ear, chin or jaw; on the seventeenth, in the neck; on the eighteenth, in the palm; on the nineteenth, in the wrist muscles; on the twentieth, in the blade or brachia; on the twenty-first, in the edge; on the twenty-second, in the kidneys; on the twenty-third, inside; on the twenty-fourth, in the femur; in the twenty-fifth, in the knee joint; on the twenty-sixth, in the elbow; on the twenty-seventh, in the muscles; on the twenty-eighth, in the malleolus or sexual organs; on the twenty ninth, in the anticnemion; on the thirtieth, the whole body.

In addition to the 'daily' soul cycle there were annual, seasonal and hourly soul cycles. The annual cycle was a twelve-year cycle, the seasonal cycle trimensual, and the hourly cycle was a twelve-hour cycle (the Kalmyk hour usually equalled two of our modern hours). The Kalmyks thus believed that the soul travelled as a material substance within the body and was capable of leaving it under certain conditions. The *emchi* therefore tried to avoid influencing the human heart at the particular times when it housed the soul, as otherwise the soul could leave the body. A sick person who was left with his soul and did not die would lose the vital power of the whole body. This vital power the Kalmyks called *amin sumsn* (biotic energy, or 'external soul', as opposed to the 'internal soul' (soul consciousness), which lived continually in the heart of the person from birth and left at the moment of death. The internal soul 'supplied and fed' the person's brain and was responsible for mental activity. It is no surprise, then, that the Kalmyks believed that the brain was not in a head but in the chest (where the heart is).

If a child became inert, it meant that the child had been struck 'with the black tongue'. To execute the healing ritual, two threads were used, one white and one black, a metre in length. These threads were interwoven, the patient holding one end while the person conducting the ritual held the other end and cut the thread into sections, performing the spell of 'the black tongue'. Then the pieces of thread were put together. The pieces were then spat three times and thrown outside the house. To restrain evil spirits, special amulets and rituals (such as those for 'extension of life', 'correction of menge', 'correction of a place', 'restraining the baby's spirit') were widely used. The 'extension of life' ritual could be performed with or without the help of holy persons. In the first case people would cut a collar from their clothes and place it on their body, together with old socks that had been buried in the steppe. The man would wear knitted white socks with black toes. If a holy person performed the ritual, then special prayers were read. There were several variations on the specific rituals for the 'extension of life'.

People turned to charms when treating many diseases, not least mental illnesses. For example, shingles was treated by placing a fire charm above the patient's sick bed. From the Kalmyk perspective all dermal and venereal illnesses and smallpox were treated as external illnesses, which were caused by microbes, bacteria and viruses. The Kalmyks called such illnesses *khorkha gem* ('endless screw illness'). They were treated with the help of special charms (*khorkha tarni*). Any wound might become *khorkha gem*, if it wasn't treated in time (within five or six months). To avoid this happening, the Kalmyks burnt the bones of a dead dog, and the ashes were rubbed into the wound for two or three days.

Smallpox was considered the most dreadful disease. The early Kalmyks did not treat patients for smallpox as they did not know any effective remedies against the illness. The patient was simply kept on a special diet: goat's meat and warm gruel.

Another type of illnesses that was treated with the help of charms was named *zedkr gem* or *ad gem* ('evil spirit illness'). A special charm (*ad tarni*) weakened the influence of evil spirits. The illnesses referred to were caused by accidents and mental disease.

Internal ailments ('*dotr gem*') caused by fever were treated with medicine. This group of illnesses included typhoid, colds and inflammation.

The disease named 'chicken blindness' was treated with the help of a black goat's fresh liver. This had to be cut into small pieces and boiled in vegetable oil; the mixture would be drunk on an empty stomach in the morning for three days. Eye illness was treated by using horses' and bears' blood. Good eyesight was of great importance for hunters and cattle-breeders and was tested on the starry sky. If someone could make out a small star near the sixth star of the Ursa Major, it meant that person had good eyesight. It was a sign of worsening vision if someone ceased to be able to see that star.

Tarantula bites were treated with the help of sheep wool and broth. The patient was covered by a sheepskin that contained fat, and was given fresh broth. The swollen bite area was rubbed with oil in which two tarantulas had previously been soaked, and the patient was given warm, melted mutton lard to drink (P. Smirnov, 1881).

Generally in the case of accidents the ritual *gar kurgkh* was performed before the arrival of the doctor with the help of *domchi*. In the case of a dog bite, the ritual involved wool that was set on fire, ashes that were scattered on the bite, and a grandmother's thimble turned and pressed down on it three times.

Gargling with a child's urine was another remedy, and so was chewing of dried-up wolf bile. The well-known doctor, *gelung* Dordzhi Setenov, treated some ailments with the help of hare's bile. Almost all the hare's organs were considered curative, because the Kalmyks believed that a hare ate seventy-two sorts of grass at night. A hare's heart was used in the case of heart disease (the illness *кі*). For illnesses of the kidneys or for constipation, wolf's bile was applied. To stop bleeding, a piece of felt or cotton was burned and placed on the cut.

Illness could also be qualified as a disorder in the three governing systems: wind, phlegm and bile. The position and amount of wind, phlegm or bile depended on climate, season and day, and on the patient's age and temperament: phlegm predominated during childhood, bile in youth, and wind in old age.

Minor ailments were not considered to require treatment. It was sufficient to follow a healthy diet and lifestyle. Broth was prescribed for mild diseases, and pills for more serious ones.

Illness was also said to be caused by disruption of the harmony of the five units due to either internal or external factors. The balance of units could also be upset by age. Thus it was believed that senility was caused by a lack of fire. This could be compensated for by means of warming procedures (heaters and so on), and also by the application of vegetable-based therapy (grass growing on the solar side) and appropriate diet (products in which fire predominated). Metal imbalance was said to cause struma, curvature of the legs, weakness and breakdown.

It is important to distinguish three aspects of traditional Kalmyk medical knowledge. The first is folk medicine, a process of healing rooted in the national experience and based on oral tradition (transmitted from generation to generation). The second is the written corpus of Tibetan medical practice. And third, there is professional, scientific medicine.

The ethnic roots of Kalmyk traditional knowledge lay in the geographical environment associated with climatic features. The medicine of the earliest period was characterized by syncretism, combining rational and non-rational ways of thought as well as religion. Treatment was therefore the main occupation associated with religious–magic activity: shamans, charms and the like. The source of medical knowledge was certainly bound up with the national experience, but it is impossible to deny that charm-workers and shamans also had access to particular knowledge, which was transmitted and anchored by family traditions.

If 404 common diseases were identified many years ago, many new illnesses have since appeared which are caused by disturbances in the environment, radiation and new chemical products, as well as by the corruption of ethical standards. The local population has carefully accumulated knowledge of the medicinal properties of plants. Today we are beginning to revert to the experience of our ancestors, and not without a certain sense of urgency. The rather negative attitude towards traditional medicine of the last eighty years has changed with increasing national self-awareness and the failure of conventional medicine to treat some illnesses.

To conclude, I hope that the research work on traditional knowledge I have previously carried out, and to which I refer in this article, will be useful for further investigation in the role and importance of traditional knowledge in the sustainable development of the dryland ecosystems and for combating desertification in Kalmykia.

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21 Traditional knowledge in the Kalmyk Republic as a basis for the development of ethno-economics

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The south of Russia contains thirteen republics of the Russian Federation, which are characterized by different cultures, traditions, lifestyles, customs and rites. The ethno-economic space of the south of Russia is represented by a combination of 'state economies', 'market economies' and 'ethno-economies'. One of the major characteristics of Kalmykia is the territorial, localized pattern of economics historically based on a household ethnos, characterized by traditional, mainly agricultural forms of activity, and the production of natural commodities by a predominantly manual labour force.

The republic's territory mainly consists of arid ecosystems, which for centuries were used rationally by applying local traditional knowledge. The traditions of the Kalmyk people helped a great number of families survive periods of crises, as well as defining the Kalmyks as a nation. Many modern ecological, social and economic problems in Kalmyk Republic have arisen because the unwritten laws of the steppe had been forgotten and/or broken. The violation of the interconnected laws of ethnic harmony with the environment harmed the social and economic development of the nation. Neglect of the life-enhancing ethnic culture undermined the basis of its existence, which was the essence of the traditional method of economic life. The abandonment of the ancient ethno-economic lifestyle led to decreasing productivity or outright destruction of arid ecosystems, and consequently a fall in the biological potential of the territory.

To restore ecosystem productivity in the Kalmyk Republic it is necessary to return to the use of traditional knowledge that understands the potential for restoration through pastoral stock raising, which has traditionally been the basis for the use of nature in arid ecosystems in southern Russia. The local population acquired unique experience in the organization and utilization of pasturelands and the selection of local domestic cattle. The distinguishing characteristic of traditional pasture stock raising is the year-round maintenance of cattle on natural pastures. The technology looks to the rational use of pasturelands with the aim of restoring and preserving their productivity for future generations.

The writings of N.N. Palmov, I.A. Zhitetskyi, N.P. Barbot De Marny and others contain invaluable information about the Kalmyk ethnos, mode of life, culture and household structure. Long-established adaptation to the dry climate and limited vegetative resources underpinned an ethnic understanding that defined the appropriate economic strategy, in the form of nomadic cattle-breeding, which was well developed by the Nogaii, Kazakh and Kalmyk people. The area over which Kalmyk cattle roamed was enormous and varied with the almost constantly changing routes. The nomadic lands were strictly distributed and protected within a framework of community legal norms. The roving system was based on the seasonal use of pasturelands and the need for a systematic search for new pastures. The observance of a cycle of migrations was the precondition for achieving stability in nature use by the Kalmyks. The constant movement of herds eliminated the danger that they might totally uproot and trample the vegetation, and so helped to preserve the landscape. The migration routes were strictly determined in chosen directions.

Information about the land and its uses, as well as seasonal preferences in terms of migration, was conveyed from generation to generation. On the whole, the marshlands and all the territory making up the arid and sub-arid area in southern Russia (with the exception of riverbanks and lakeshores) contributed to meeting the demands for summer pastures. During winter the herders used those lands where there was the least amount of snow, and thus in Kalmykia the area that was called *Khaar Gazr*, or the 'Black Lands'.

It can be seen that the Kalmyks' seasonal system of migrations is deeply ecological and tightly bound up with the landscape structure. The Kalmyks evolved a highly developed nomadic society with a profound knowledge of the ecological and economic niches of the steppe area. The pattern of their movements can be seen as optimal, and corresponds to modern ecological demands and norms.

The grazing technology of nomadic stock raising, which can also be used nowadays, comprised various distinctive elements. During very snowy winters the horses were the first to graze, and their hooves cleared the land of snow; the cattle would then eat the upper parts of dried grass, and then sheep and goats would eat the twigs. If the snow was not too deep on pasturelands for stock raising and sheep were able to reach these twigs, then the shepherds drove off the horses and allowed the cows and sheep onto the pasture. It was well known that different stock breeds preferred different fodder types, which is why their influence on the vegetation condition varies. This therefore determined both the optimal correlation of stock breeds and numbers in the herds, in conjunction with the seasonal cycle of grazing that aimed at preserving the pastures and their productivity, and at maintaining the multitude of grass species.

To conclude, the Kalmyk economic life style, with its traditional knowledge and experience of housekeeping under the conditions of arid ecosystems, is an important subject for study, preservation and practical application. Traditional technologies have huge unrealized possibilities for the improvement and preservation of unique arid ecosystems in the south of Russia and offer great potential for ethno-economic development.

22 Ecological restoration and increase of productivity of degraded arable lands

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A new approach to the theory and practice of agriculture is being realized to experimentally recultivate degraded arable lands in the arid Caspian lowland in Kalmykia. The approach is aimed at increasing agro-ecosystem productivity by means of stable protein balances, unchangeable acids and major macro- and micro-elements, and creating a highly productive fodder agrocenosis capable of partial self-regulation. For that purpose, once all relevant conditions had been taken into consideration (Nastinova, 1989, 1992, 1994, 1998), complex multilateral ecological research was undertaken to work out effective, resource-rich, environment-protecting systems of land tilling and agrocenosis exploitation of economically valuable new C4 crops: sorgo and amaranth.

One of the main goals of rational agriculture in the pursuit of food security in the region is the creation of an adaptive, highly productive, fodder agro-ecosystem, following the principle of using, in the 'plants–abiotic environment' system, the various plants that have by evolution adapted to the arid conditions. The concept is based on the ability of agricultural crops (sorgo, amaranth) to use C4-type photosynthesis to realize their adaptive potential and productive optimum. This capacity is due to their genotype and phenotype reaction to the available elements in the abiotic environment of the arid Caspian area, including the Republic of Kalmykia.

The main aim of the research

The main aim of the research is to restore and increase the productivity of degraded arable lands, to obtain stable fodder of biologically high value and to introduce the economically valuable C4 crops sorgo and amaranth in Kalmykia.

Research materials and methods

The main object of the research focused on the types and hybrids of sorgo (*Sorghum mellitum Snowd*) and amaranth (*Amaranthus paniculatus, A. caudatus, A. hipohondriacus)* from the world collection VIR (Russia) and from the NPO Don, VNII sorgo, and Rodal Institute (USA) collections.

The tasks involved laboratory and field experiments along with observation of changes in meteorological conditions and a theoretical summary of the received data. Methods used include geographical sowing, increased frequency of sowing, parallel or conjugated field observation, mathematical statistics, and mathematical modelling. To fulfil all the requirements, ten experiments were made on the experimental plot of the Kalmyk State University and on the experimental farm of the republic. The plots were arranged in blocks with an area not less than 50–100 m^2, or in some specific cases 10–50 m^2. More than 100 plants and soil samples were taken and analysed for laboratory research. A vast range of well-known instrumental methods was used to study the metabolic parameters, chemical composition and nutritive value of plants (Yermakov, 1972; Nastinova, 1994; Udovenko and Alexeyev, 1972; Rubin and Gavrilenko, 1977; Photosynthesis and productivity: definition methods, 1989) and physical and chemical analyses of soils (Kaurichev et al., 1982; Nastinova 1994; 1996).

Experimental data analysis – the definition of the interconnection between various indices of agrocenoses on the basis of regressional analysis – was carried out by means of a special program of computer applied statistics called 'Stadia'. The authenticity of average calculations from 4–6 time recurrences of 3–4 laboratory and field experiments done for two years were defined at the level of $p=0.05$ (Strelkov, 1966).

The main results of the research

The natural conditions and abiotic factors (climatic, edaphic) in the zones of the republic were assessed. The Republic of Kalmykia is situated in the southeastern part of the Russian Federation and has three natural zones: steppe, semi-desert and desert. The territory of the republic occupies most of the arid lands of the northwest Caspian area (79.4 per cent), minor parts of the Astrakhan region and the south of the Volgograd region (20.69 per cent).

Kalmykia is the most arid region in the European part of the Russian Federation, and has a range of soils. There are various dynamic combinations of solonetz–solonchak soil complexes with specific dry and salt-resistant vegetation. At present a critical situation has been reached on the agricultural lands, where very acute degradation processes can be seen and there is a decrease of humus content (dehumification). In Kalmykia, the decrease in humus content has been noted at 0.1–1.4% or at 4–48% of the initial content. In addition, irrational economic activity has resulted in the widespread water and wind erosion on the Kalmykia soils. As a result of the inappropriate irrigation of agricultural plots, the rate of secondary salinization processes has increased. According to B.V. Vinogradov (1993) more than 100,000 hectares have been destroyed because of secondary salinization and sinking.

The results of the research determined the response reactions to extreme conditions of the crops – sorgo and amaranth – in accordance with organogenesis periods and defined critical periods in the republic.

The significant characteristics of the species forming mixed agrocenoses establish the place of each species (sort, hybrid) in the mixed agrocenoses, and determine its ecological niche. Identifying these characteristics involves estimating and compiling the indices of tropic compatibility of objects in two and three component agrocenoses of fodder crops: the rate and form of plant growth, the peculiarities of leaf formation, their use of environmental resources and their productivity.

The dynamics and agrocenoses that produce a cycle favourable to high productivity and stability have been studied. The behaviour of species and composition of component types influence the ways that components should be arranged and sown. The optimal density of sowing and the interrelations between components have been defined. In the sowing of amaranth with other crops (maize, sorgo), the relationship is complementary and the crops influence one another (mutualism). This is clearly seen in the uneven rate of growth, not only during the early phases but also during the whole growth period. Thus, sorgo and amaranth are characterized by differences in the height and rate of growth in mixed sowings.

The time of the onset of germination plays a decisive role in the growth and development of plants. Germination occurs three to five days later in amaranth than in sorgo. Because of this, sorgo plants precede amaranth in development and overground biomass growth. The higher competitive capacity of sorgo plants at the beginning of vegetation is explained by their biomorphological characteristics. During this period the amaranth root system develops intensively. Circadian growth of amaranth plants increases sharply during the period of bud formation, when it reaches 3–4 cm; during the first days of vegetation it is 1.5–2 times less than in sorgo. A high rate of growth is observed in amaranth until the end of the growth period. In mixed sowings, even during the early stages of growth, the relationship between components that are competing for light corresponds to the principle of inter addition: at the beginning of the vegetation period sorgo plants are dominant, while amaranth becomes dominant in the later growth period.

The species studied suffer to a varying degree from soil and atmospheric drought. It is noted that environmental water resources are absorbed and utilized more fully in mixed than in single-species sowings. This is due to the wider spread and depth of penetration of roots in the area (see Table 22.1). The significant capacity of the amaranth plant is its ability to form new leaves during the whole vegetative period and to retain more leaves than sorgo. At the beginning of the growth period (the phase of panicles for sorgo and bud formation for amaranth) sorgo has higher values, and amaranth during the second half of the growth period.

The nutritive and economic value of the crops and their overall quality have been studied. It was found that, due to the chemical composition of amaranth, it significantly exceeds sorgo and maize in content of ash, calcium, protein and nitrogen-free extractive substances (NES) contents (see Table 22.2).

The study of species diversity in amaranth showed that green amaranth mass is rich in protein and can become a valuable fodder crop and nutrition additive. The nutritive value of amaranth protein (established by aminogram analysis and compared with 'ideal protein FAO') is very high, and attains 97% (according to the unchangeable amino acids sum).

The results of species, sort test and production experiments in different geographic regions of the Caspian, along with data on the agrobiological and economic value of amaranth, clearly demonstrate the importance of its widespread introduction.

This, along with the widening of agrocenoses of highly productive crops (sorgo, amaranth) and the significant increase of fodder value, accounts for the considerable increase in fodder production. It has led to a

Table 22.1 Productive moisture supply in the soil before harvest of single-species and mixed agrocenoses (mm)

Horizon (cm)	Sorgo	Amaranth	Maize	Sorgo + amaranth	Maize + amaranth
0–20	5.9	6.5	5.4	13.7	12.5
0–50	15.4	20.2	14.2	22.2	21.4
0–100	25.5	39.0	24.8	39.1	39.7

Table 22.2 Chemical composition and nutritive value of experimental plants

Object and material for analysis	Chemical composition and nutritive value (% of dry matter) Ash	Ca	P	Protein	Fat	Cellulose	NES	Carotin (mg/kg of dry matter)
A.paniculatus	11.2	1.1	0.2	13.7	1.8	22.2	51.4	68.0
A.caudatus	13.2	1.3	0.1	14.2	2.5	17.5	53.5	72.5
A.hypohongriacus	19.4	1.7	0.1	15.2	2.4	18.5	54.5	78.7
Sugar Sorgo 32	7.0	0.5	0.1	10.4	2.3	27.8	52.8	93.8
Maize hybrid Moldavian 320	9.4	0.4	0.2	9.7	2.3	30.7	47.8	92.8

diversification of agrophytocenoses to include two or three or more crops, allowing considerable increases in fodder quality and providing a stable quantity of fodder in the arid Caspian area. Continuing research will include a more detailed investigation of polycrop (amaranth mixed with sorgo and maize). Protection technology for productivity increases on degraded arable lands will be developed.

Conclusions

The research demonstrated:

- the results of circadian and seasonal adaptive reactions and dynamics of experimental plants to arid conditions
- the ability of experimental plants to decrease salinity, and the conditions for recultivation in saline soils in the field
- the principles for geographical selection of economically valuable fodder crops
- the advantages and value of amaranth and sorgo fodder in comparison with maize, and of one-species compared with mixed cenoses

A preliminary model of adaptive highly productive mixed agrocenoses for arid conditions in the Caspian area has been developed.

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23 Phytomelioration of saline lands in Kalmykia

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Due to its geography, Kalmykia is characterized by a number of extreme ecological factors, including severe aridity, poor soil fertility, abnormal isolation and dry winds. In this context, stable agricultural production and development is only possible with the aid of complex melioration techniques. Irrigation can promote an effective rise in soil fertility by improving water, saline and flood conditions. However, where schemes fail to use scientifically proven technologies, irrigation can often lead to a series of harmful effects such as a rise in subsoil water levels, secondary salinity and alkalinization, floods and the creation of vast bogs.

The main causes of these negative phenomena are the rich reserves of salt in the aeration zone, the limited flow in the upper part of the territory, the complexity of the soil cover, mistakes occurring outside the drainage network, the low level of irrigating systems, and failure to adequately implement special meliorative measures (melioration of solonetz, washed conditions of irrigation, chemical and biological meliorations).

To maintain a stable level of effective fertility in the irrigated lands and to create stable irrigated agricultural landscapes, we must be able to predict the possible dynamics of meliorative conditions.

The main considerations in arid conditions are water availability and salinity. One of the principal means of regulating, improving and reconstituting the natural surroundings, as well as raising the biological potential of degraded lands, is biological melioration based on adaptive strategies, which involves optimizing the use we make of the various functions of plants with different ecological specialization.

Crop cultivation technologies are now in place for the phytomelioration of saline lands in Kalmykia. They have high agronomical salt stability and a good meliorating effect. These techniques are able to remove considerable amounts of unhealthy salts from the soil through the biological mass above ground, while simultaneously enriching it with organic matter comprising roots and tufts. In addition to the loosening effect of root systems, the plants improve the porosity of arable and sub-arable soils, and water permeability therefore improves. Furthermore, plant roots release organic acids into soil during growth. This increases the solubility of calcium carbonate, and absorbed sodium removes itself from the exchange complex. Plants above the soil create shade and diminish solar radiation, thereby averting salt accumulation on the surface.

Irrigated lands in arid regions are characterized by unfavourable agrochemical and agrophysical features in the main root-inhabited zone (0–0.4 m). They are low in humus content (0.8-1.9 per cent) and easily accessible nutrients, have a high content (up to 0.5 per cent) of toxic salts (NaCl, $NaSO_4$, $MgCl_2$), substantial soil density (1.41–1.58 kg/m^3) and bad aeration.

With a view to using crop meliorants more effectively in the Kalmyk branch of VNIIGiM on the secondary saline lands in the desert zone of the republic, agronomic ecological tests of the most promising species, *Agropiron tenerum (Vasey)* and *Medicago sativa (L.)* are being carried out.

For these tests, *Agropiron tenerum* was sown in early spring using the dense drill method (Figure 23.1). The standard quantity of seed sown was between 23 and 25 kg per ha. The irrigation conditions maintained the water content level at 75–80 per cent of ultimate field water capacity. The application of nitrogen-phosphorus fertilizers (in dose $N_{110–130}P_{60–90}$) improved the nutritive conditions of the saline soil.

Research findings revealed an inverse correlation of the plants' standing density and salt content in the soil (the correlation coefficient is 0.96). Thus, a salt increase of 0.1 per cent reduces the plants' standing density by 7–12 per cent. The mass of harvest is closely connected to the linear growth of plants. Correlation analysis showed that the plants' height, which varied from 18 to 65 cm, depended on the degree of salinity. A rise in salinity from 0.673 to 1.760 per cent caused plant numbers to decrease by 40 to 43 per cent. The hay crop varied from 6.3 to 38.5 t/ha.

We observed the soil profile for the saline content of brown semi-desert, and found that the content of toxic salts in the soil varied from 0.590 per cent to 1.206 per cent. The distribution of cations and anions in soil profile takes place under the influence of irrigation and saline couch-grass cultivation, which helped to reduce toxic salt content by between 46 and 67 per cent.

Analysis of couch-tolerance in the same soil under the same climatic conditions showed that plants of *Agropiron tenerum* (Vasey) of the variety 'Solonchakovy' could normally grow where the salinity level of the soil metric stratum was between 0.605 and 1.306 per cent. A rise in salinity from 1.306 to 1.566 per cent has a negative effect on couch-grass productivity (reducing the biological mass crop by 1.5).

Figure 23.1 Agropiron tenerum Vasey (variety 'Solonchakovy')

The most widely distributed phytomeliorant of the complex brown semi-desert and light-chestnut soils is *Medicago sativa (L.)*. The possible water-soluble salt content in the soil metric stratum is equal to 0.560 per cent (when agrocenose productivity is at 70 to 80 per cent of the ultimate field water capacity). When the salt content rises from 0.560 to 0.723 per cent, we observe that the *Medicago sativa (L.)* crop is reduced by 2.2 to 2.5 times. Our research shows that in a given culture of soil there are 220 to 460 kg/ha of toxic salts (including: sodium 26–75, magnesium 50–80, chlorine 80–150, iron sulphate 65–160 kg). This was observed on saline lands under irrigation and with 11–15 t/ha of absolute dry crop matter.

After three years of alfalfa cultivation the humus content in the main root-inhabited zone (0.0 to 0.4 m) of brown semi-desert middle-loam soil rose by 0.32 per cent, and in the first stratum by 0.14 per cent. Humus accumulation led to the increase of soil aggregates, water-firmness and an improvement in soil permeability in the root-inhabited zone. *Medicago sativa (L.)*, with its powerful root system, intercepts capillary water and thus tends to lower the groundwater level by 20 to 50 cm in one year.

Non-traditional varieties of salt-stable plants are used in the recultivation of saline lands. They combine high salt-tolerance with good economic indicators. Agro-ecological research to select crops for development in saline irrigated lands was carried out in the Kalmyk branch of VNIIGiM under collection hatchery conditions. Nineteen non-traditional Kalmyk crops were chosen for the tests. They were: *Mentha piperita (L.), Ocimum basilicum (L.), Nepeta cataria (L.), Nicandra physaloides (L.), Lactuca sativa (L.), Rumex confertus (Willd.), Helianthus tuberosus (L.), Trigonella foentum-graecum (L.)* and *Amaranthus paniculatus (L.)*.

Tests were carried out on the light zone of chestnut, middle-loam solonetz soils with a chloride-sulphate type of salinity and easily soluble salt content in strata between 0.0 and 0.7 m of 0.20 to 0.80 per cent. Test schemes studied variants selected according to factors that influenced seeding productivity (dates, seeding rate, seeding methods). Irrigation conditions for all crops were based on maintaining a water content of 70 to 75 per cent of ultimate field water capacity in the stratum from the surface to a depth of 0.7 m. Watering was carried out by surface irrigation. On the basis of these tests, the following highly productive plants with a multi-purpose orientation, from stable to extreme conditions, were selected.

- *Rumex confertus Willd* is a plant of the buckwheat order. Its roots are used as raw material for tanning (19 to 21 per cent of tanning materials), and its overground mass can be used for green forage and silage for pigs and poultry. This crop is able to grow on highly saline soils (up to 0.80 per cent), though its growth is reduced by 10–15 per cent in comparison with seeding on non-saline lands. This phenomenon is observed on strongly saline soils provided with sufficient moisture. The plant turned out to be adaptable to temperature regimes. The most effective period of seeding during the first year of growth was found to be autumn. The plant begins to grow in early spring, when the temperature is above 0 °C, and reaches hay-harvest ripeness by the end of May (with a plant height of 60 to 65 cm). The average green mass crop for two hay harvests was 38.5 t/ha in the research years. The root system is powerfully developed, with thickened rootstalks and thin lateral suckers in its upper part. The roots of the crop can amount to 25.6 t/ha on average.
- *Nicandra physaloides (L.) Gaertn* is a non-capricious plant of the solanaceae family. It has a well-ramified root system that penetrates to a depth up to 0.6 or 0.7 m even with substantial soil density (1.45 to

1.60 g/cm^3). Green mass crop in 1998–2001 amounted to 19.5 t/ha and the seeds to 0.40 t/ha. This crop may be recommended for forage production for cattle. The green mass is used for silage production, while the seeds increase the vitality and vigour of animals, notably horses.

- *Lactuca sativa (L.)* or lettuce 'Seasons parago' is a non-capricious annual vegetable plant of the compositae family. It forms a considerable green mass during its short period of vegetation (45–50 days). It may be cultivated by itself in Kalmykia, producing two crops during the vegetation period, or as an accompanying culture in crop rotation to diversify an assortment of vegetable crops, which has considerable benefits for human health. We studied different planting schemes on averagely saline soils (0.25 to 0.41 per cent) and came to the conclusion that the best crop is produced through square-cluster planting (45 × 45 cm). The weight of one plant was 360 to 420 g and the leaves of the whole crop amounted to 21.6 to 25.2 t/ha. The seeding method has a particular advantage over four-lined tape seeding, and is beneficial in severely arid years. The green mass crop did better in 1999; square-cluster planting was 24 per cent more productive than four-lined tape seeding, and in the arid year this rose to 37 per cent.
- *Trigonella foenum-graecum (L.)* is a culture of the legume type that can serve various purposes. It is a headily aromatic fodder that produces green manures (leys). Its valuable biological peculiarity is that it has a short period of vegetation (56 to 70 days). This means that not only can it produce an additional quantity of feed but it can also be used as a green fertilizer to improve soil fertility. Furthermore, the plant is characterized by rapid and steady shoots, which grow irrespective of the seeding date.

Meteorological yearly conditions exert a significant influence on the productive process, which is why the seeding date is important for crops. Plants grew faster (38 to 42 cm) during the spring seeding period (due to the optimal temperature regime in the period of shoot growth, which is called branching); the minimum height (16 to 17 cm) was observed during summer seeding in 1998. This year was memorable as having the hottest summer months since meteorological observations began. During this time the crop mass increased from 7.0 to 12.5 t/ha and crop seeds increased from 0.3 to 0.9 t/ha.

Amaranthus paniculatus (L.) has a high food value: the absolute dry matter of plants contains from 10.1 per cent to 18 per cent of raw protein. Seeding was carried out in two periods during testing (April 5 and April 20) using a 60 × 15 cm scheme. The first shoots appeared between the tenth and twelfth days and between the seventh and tenth days.

Amaranthus paniculatus (L). is very sensitive to water regimes because the salt in the soil impedes water entry into the dry seeds and thus reduces the degree of humidity in their tissues. As a result, saline conditions seriously restrict the intensity of growth and dry seed germination. The germination of shoots is delayed when the levels of moisture are insufficient; when this is the case, plants grow slowly and the delay in growth and accumulation of mass above the ground cannot later be compensated for, even if the water regime improves in the later periods of growth.

The green mass of *Amaranthus* is determined by the sowing date (an early seeding date increases productivity by 34 per cent compared with a late one) as well as water-solute content in the root-inhabited stratum of soil (the determination factor is 0.89).

A shortage of water, even in conditions of comparatively low salinity, leads to a rapid change in the period from the shooting of seeds to the development of generative organs and the formation of small crops. Thus, the plants, having only used moisture from natural stocks, were blooming within 45 days, reaching a height of 15 to 18 cm and 6 to 15 cm, forming crops with a density of 0.08–0.11 and 0.13–0.15 kg/m^2. At that time, the salt content in the main root-inhabited zone (0.0–0.4m) was 0.22–0.26 and 0.48–0.54 per cent. Furthermore, amaranths are sensitive to soil fertility: there may be a reduction in crops of up to 80 per cent where there is a low humus content and poor access of nutritious macro elements.

Helianthus tuberosus (L). is a tuberous insulin-containing plant of the compositae family. It has high ecological stability, being resistant to heat, illness, drought and winter conditions. It is grown as a food, fodder, technical and official crop. Field tests were carried out in the zone of light-chestnut solonetz soils of chloride-sulphate salinity; the easily soluble salt content in the root-inhabited zone varied from 0.20 to 0.65 per cent (Figure 23.2). Subsoil chloride-sodium waters with total mineralization of 2.3 to 3.8 h are deposited at a depth of 1.5 to 2.0 m. The tubers were transplanted according to the 70 × 30 cm scheme, at a depth of 8.0 to 10.0 cm. The irrigation regime was differentiated (maintenance of soil humidity before watering in growth periods with an appearance of four to five pairs of leaves in a soil stratum of 0.0 to 0.4 m and in periods with five to ten pairs of leaves in a soil stratum of 0.0 to 0.7 m with a level of 70 to 75 per cent of ultimate field water capacity in a growth period of twelve to twenty pairs of leaves – 60 to 65 per cent of the ultimate field water capacity. Watering was carried out by surface irrigation.

Research results showed that the green mass crop and *Helianthus tuberosus* tuber crop were in inverse proportion to the degree of soil salinity; they varied from 31.1 to 88.8 t/ha for green mass and from 28.6 to 65.1 t/ha for tubers. It was found that salinity has almost no negative influence on the growth and development of *Helianthus tuberosus* in the first period (up to the appearance of two or three pairs of leaves). Salinity is marked by a fairly high content of nutritive matter and water in available form in the tubers. Plants begin to suffer when this is combined with a high concentration of soil solution at the time when vegetation growth and active consumption of matter take place. When the salt content increases from 0.20 to 0.65 per cent, plants stop growing upwards (and their height is 28 to 36 per cent lower), and the lateral shoots, leaves and leaf plate areas are reduced by 15–22 per cent. This leads to a reduction of leaf area of 35–42 per cent and as a result it was found that in average test years the green mass crop declined by 57 per cent.

Soil humidity before watering 'α min' is maintained at a level of 70 to 75 per cent of ultimate field water capacity. With the help of irrigation, there is a considerable reduction in the toxic action of highly concentrated salts. With increased humidity, this decreases further to 60 to 65 per cent of the ultimate field water capacity at the period when the plant would have already developed a powerful root system, and begins to gain nutrition from subsoil waters (total mineralization is 2.2 to 3.8 g/l), which favours the diminution of soil solution concentration and a consistent supply of plants with capillary-accessible moisture.

Helianthus tuberosus (L). influences the agronomical–chemical and agronomical–physical characteristics of the soil. Root-inhabited zone desalination takes place owing to the unhealthy washing of ions (Cl 40 per cent – Na 18 per cent) and some enrichment by calcium (by 6 per cent). Irrigation during one growing period also exerts an influence on salinity. When *Helianthus tuberosus* is cultivated for one year, 5.2 to 9.0 t/ha of organic matter with hay harvest and root mass remained in the soils. These contain nutritive elements: nitrogen (42 to 72 kg), P_2O_5 (11 to19 kg) and K_2O (53 to 91 kg). Main and inter-row cultivation of *Helianthus tuberosus* assists soil loosening. As a result the density in the arable stratum is reduced from 1.42 to 1.29 g/cm^3, and porosity increased from 44 per cent to 48 per cent. The economic technology (irrigation water's economy makes up 30 per cent) of *Helianthus tuberosus*' cultivation on saline lands with a high subsoil water level (1.5 to 2.0 m) allows us to obtain up to 59.6 t/ha of green mass and 25.1 t/ha with a total yield of fodder units of 19.5 t/ha. Such a method provides a meliorative effect.

It is necessary to form a functional collector-drainage network that provides ecological meliorative balance by reducing subsoil water level and drainage water. It must prevent waterlogging processes, secondary salinity and solonetz on rice systems of the republic. In the case of rice paddies in an unfavourable, unmeliorated condition, the overall water processes have to be measured. This entails accurate mapping of the surface of the paddies (with a probable error ±3 to 5 cm from average mark), the pegging out of the area (depending on the soil's water-penetration and the slope of the terrain) in micro-paddies measuring 0.05–0.25 ha, divided by barriers with a height of 30 to 40 cm, and feeding in freshwater at a rate that will produce a depth of 5 to 10 cm in the paddies for 507 days (with the air temperature below 16 °C for ten to fifteen days). Once the micro-paddies have absorbed those amounts, we fill them again with fresh water up to the given norm. Usually they require 2,500 to 3,000 m^3/ha.

The system for cultivating wasted soil includes autumn ploughing, sub-soiling, and ploughing without a mould-board. Rice seeding and rice crop rotation are conducted at the earliest time possible. The best measure for intercepting and reducing the subsoil water level is to use compartment drainage equipment in the channel zone. This will have a depth of 0.8 to 1.2 m along big irrigation channels.

Problems with growing rice in solonetz can be tackled with chemical melioration methods: on solonetz soils (up to 20 per cent absorbed sodium) and solonetz (more than 20 per cent of absorbed sodium), they are applied at rates of 8 to 10 and 10 to15 t/ha, respectively.

Tests on the main crop-forming factors were carried out from 1999 on rice fields of SUE, VNIIGiM's experimental production farm ('Kharada') Oktyabrsky region, Republic of Kalmykia. The tests also studied high-profit accompanying multi-purpose crops. One of these cultures is Sareptskaya mustard. We conducted tests on residual matter after rice production moisture (280 to 300 mm) and application of doses of mineral fertilizers. A heavy crop of oil seeds was obtained by using between 1.56 and 1.80 t/ha of nitrogenous-phosphorus fertilizers in a dose $N_{180}P_{120}$ with spaces between rows of a width of 30 cm.

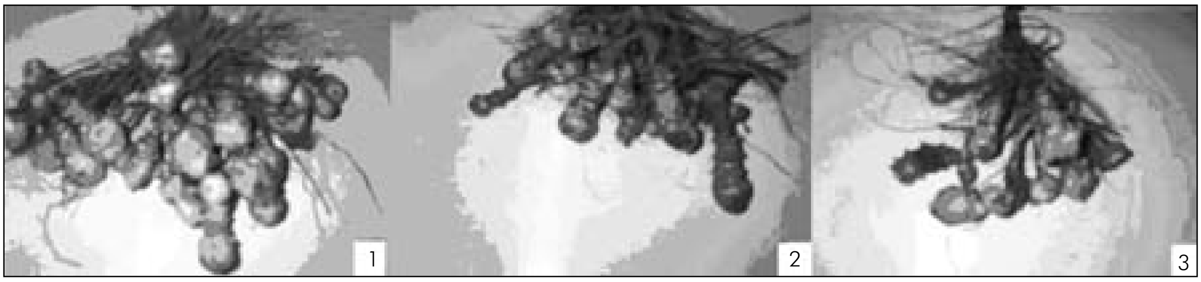

Figure 23.2 Helianthus tuberosus grown with different levels of salt content in soil (stratum 0-0.7 m): 1 – 0.32 %; 2 – 0.44 %; 3 – 0.61 %

The role of Sareptskaya mustard was observed in terms of its character and the degree of obstruction of the sowing area under observation. This showed that weed shoots (*Echinochloa crus-galli, Echinochloa phyllopogon, Bolboshoenus compactus, Poligonum aviculare*) on test variants with widths between rows of 30 cm were suppressed; the area was practically free of weeds. Agronomical and chemical analysis of soil samples confirms that after Sareptskaya mustard cultivation the content of an accessible form of phosphorus rises in the main root-inhabited zone (0.0 to 40 cm) by 10.3 to 15.1 per cent, and exchange potassium by 25 to 30 per cent. It is most probable that the mustard's root system, penetrating deep into the soil (1.5 to 2.0 m), acts like a pump that raises and washes from the depth phosphorus, potassium and other micro and macro-elements from the lower arable soil strata. By improving phosphoric and potassium soil regimes, in its role of biological meliorator, Sareptskaya mustard's roots and tufts improve the biological activity of soil, which makes the main elements of nutrition more available to rice plants while ameliorating conditions for their absorption. It accumulates between 3.9 and 4.5 t/ha of overground dry matter and 2.2 to 3.0 t/ha of root biological mass in semi-desert conditions in Kalmykia. Thus Sareptskaya mustard is a good predecessor for rice, raising its productivity by 20 to 22 per cent.

The meliorating effect of plants (phytomeliorants) should be examined from the perspective of zone crop rotation using culture-phytomeliorants. These help to improve the ecological condition and soil fertility while maintaining water resources and minimizing waste of irrigation water for food production.

24 Oasis-type hydro-meliorative systems under Kalmyk conditions

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Broad experience of irrigated agricultural development in our country and abroad has shown that the most efficient irrigation systems for arid zones are of the hotbed (oasis) type. The exploitation of very large irrigational systems does not meet ecologically safe meliorative standards and can lead to the destruction of fragile traditional ecosystems. This can be clearly seen in the case of the Kalmyk Republic, in the southeast European part of the Russian Federation, more than 50 per cent of whose territory is made up of semi-desert and desert zones.

The hydrographic network on the territory of the republic is poorly developed. The main volume of local overland flow is formed on the slopes of Ergeninskay and Stavropolskay highlands, and fluctuates between 90 and 300 million m^3 a year (averaging around 120–130 million m^3) depending on the level of atmospheric precipitation. The flow is controlled and regulated by many ponds and reservoirs, but there is no logic in the way it is used. The so-called 'economic' systems of regular irrigation ('small-scale' irrigation) with an area of between 20 to 240 hectares function on this basis. Currently, their total area does not exceed 3,500 hectares (Rudneva et al., 1999a, 1999b).

The main areas of irrigated lands in the republic (more than 120,000 ha) are situated on the five large hydro-meliorative systems (HMS) – Chernozemelskay, Sarpinskay, Kalmyk-Astrahanskay, Kaspiskay and Pravo-Egorlykskay – which feed the water sources from the basins of the Volga, the Kuban, the Kuma and the Terek onto the contiguous territories. Built between the mid-1960s and the 1980s, these systems are technically imperfect (very wide beds in the canal network causing water loss through filtration; structural incompleteness; inefficient techniques of watering and so on), and the level of their exploitation is also very low. These flaws have combined to produce a mass of negative consequences through so-called 'irrigational desertification' (secondary salinity and soil alkalinity, flooding and waterlogging), as a result of which more than 70 per cent of the area is now in a poor condition (Rudneva et al., 1999a).

A similar situation can be seen in almost all the irrigated agricultural regions in Russia. This has recently motivated a trend towards creating a new generation of HMS with multiple functions and closed water cycles, based on sophisticated principles for melioration and landscape adaptation (Shumakov et al., 1997).

One of the new generation of HMS that is adapted to arid zone conditions is the fine-outline oasis type of HMS (the 'fine-outline irrigation' system), which is designed with the aid of recent scientific and technical research to ensure the creation of stable and highly productive agricultural ecosystems on the basis of existing natural-territorial complexes and the preservation, modernization and improvement of natural cycles and material and energy cycles.

The essential requirements of such HMS types are: the ability to perform complex water regulation and to improve the saline, food, air and thermal conditions of soil and plants on the basis of adaptive-landscape, resource-efficient and ecologically safe technologies; multi-purpose capabilities and usage of different constructions, methods of watering and types of melioration (irrigation, chemical, biological and anti-erosion measures, agro-forest growth and so on) and their combinations; a closed cycle of water rotation, that makes it possible to make secondary use of drainage waters; economic efficiency (improving the return on material, labour and finance by 15–20 per cent, and the production per unit of water used by 30–40 per cent or more).

Generalizations of the oasis irrigation experience and trends towards new-generation HMS development (Balbekov and Borodychev, 2003; Guber and Sazanov, 2003; Shumakov et al., 1997; Shumakov, 1999; *Guiding principles*, 2000; Sazanov et al., 2002) allow us to suggest the following classification of fine-outline, oasis-type HMS according to four indices:

- *Area.* Micro-till: 4 ha; mini: 1–20 ha; midi: 20–100 ha; macro: 100–200 ha; maxi: 200–500 ha.
- *Fundamental power.* Multi-functional: ensuring the work of different systems on the water rotational principle.
- *Type of water source.* Classifying on the basis of surface flow, underground or seawater, irrigation canal systems, pipelines, water pipe lines.
- *Method of watering used.* Surface, sprinkling irrigation, infra-ground, micro-irrigation.

In general fine-outline oasis types of HMS will comprise: the source of irrigation, both surface (lakes, ponds, reservoirs, canals, local flow) and underground (head and non-head underground water); the intake (mechanical inflow); transport routes (canal, flume, pipeline or others); the engineered area of irrigation with different net constructions and watering techniques; the header line drainage network; junctions of purification and demineralization of drainage and irrigation water; the system for artificial replenishment of underground water reserves (ARUW); the system for automatic management of irrigation processes, feeding plants with mineral elements and combating pests and disease; the system for controlling environmental conditions; system of forest- and field-protection stands; roads; energy supply systems, communications, industrial premises and lodgings.

On the Kalmyk territory various types of fine-outline multi-function and specialized oasis types of HMS can be created, using: (a) local surface flow; (b) canals for water supply and irrigation systems; (c) head underground water (artesian); (d) lenses of non-head underground water using ARUW technology; (e) sea-water; (f) group and local pipelines.

The most suitable irrigation techniques are as follows: when cultivating cereals, fodder, vegetables and melons, *sprinkling irrigation* with the use of small, low-head machines and equipment is effective, watering at rates of 20–70 mm; under conditions of air drought and hot dry winds, regulation of the micro- and phyto-climate with *fine-dispersion (aerosol) sprinkling* (generally with one watering of 0.08 mm every ninety minutes) should be used on the sown area.

It is efficient to use most of the fodder on systems of limanous (lagoon) irrigation, as this makes it possible to create more natural conditions when depressions in the local relief (liman) are periodically inundated in high-flood conditions. The basins are naturally low and are filled by water from the local flow (mainly during the period of spring flash floods) or from canals of the irrigation systems. In order to spread the water evenly and to ensure optimal flooding conditions, the liman area is divided into 100 ha sections with the help of land dikes and bores. The standard depth of flooding is between 250 and 400 mm, and the water takes 30–60 days to settle. This ensures formation of a considerable biomass of natural cereals (*Agropyron repents* – couch grass, *Poa pratensis,* etc.) of up to 8 t/ha of hay at a cost four or five times less than conventional irrigation systems. The general area of basin depressions in the territory of the republic comprises 150,000 ha, of which only 43,000 ha are being intensively used at the present time.

On soils of medium and heavy granular-metric composition, it is possible to use *surface irrigation* methods (furrow and border irrigation, flow-based irrigation, check-plots of land and micro-checks). With a discrete-impulse water supply, the watering standards are 60–170 mm. Surface irrigation is most efficient on salinized soil where a sluice regime is required.

A recent development is the *dropping method of irrigation (micro-irrigation)* (Figure 24.1), which provides local and constant moisture to the root-inhabited soil layer, regulating the water supply and nutrients according to the actual needs of the plants at different stages of their development. Compared with spray and overhead methods of irrigation, this achieves considerable savings of irrigation water (up to 30–60 per cent) and of mineral fertilizers. It incorporates automation of irrigation processes and is very reliable; it is also ecologically safe (contributing to soil/plant fertility) and economically efficient.

Consistently high yields of agricultural crops can be achieved by establishing the optimum irrigation regime for each stage of plant development at the level of 70–90 per cent of ultimate field water capacity (irrigating in small quantities of 5–25 mm) in combination with adequate doses of fertilizer. Such regimes using the dropping method can produce 60–80 t/ha of tomatoes, 80–120 t/ha of cabbage, 100–140 t/ha of cucumbers, and 10–15 t/ha grapes. The net profit from such production is between 100,000 and 260,000 roubles/ha, with a profitability level of 250 per cent. This will repay the costs of construction (around 120,000–150,000 roubles/ha) over a period of one or two years (Balbekov and Borodychev, 2003).

In Figure 24.2 we see a schematic map of the regionalization of the Kalmyk territory according to the prevailing oasis types and the methods of irrigation used. It shows the borders of natural–agricultural zones (steppe, dry steppe, semi-desert and desert), and the borders of zones of influence served by large water supplies and irrigation systems as well as zones of distribution of definite kinds of fine-outline oasis type HMS. The predominant kind of treatment can be seen to be fine-outline HMS in combinations of different types (for example, B and A) .

- The A-type systems are mainly distributed on the slopes of the Ergeninskaya and Stavropolskaya highlands and in the zone adjacent to them.

Figure 24.1 The dropping irrigation system

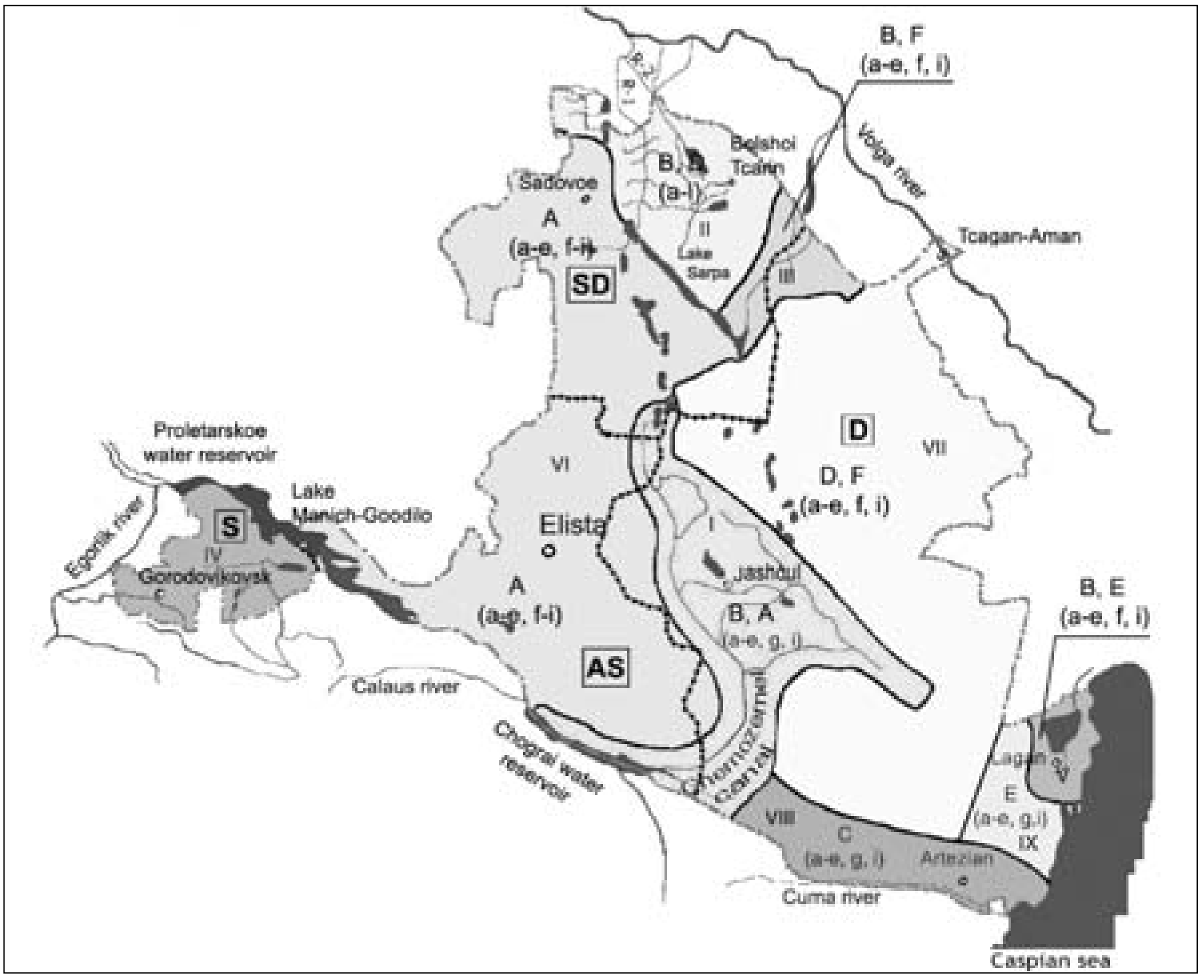

Figure 24.2 Regionalization of the Kalmyk territory to the kinds of multi-functional hydromeliorative systems of oasis type

Natural-agricultural zones:
S: Steppe AS: Arid steppe SD: Semi-desert D: Desert

Large water-supply and irrigation system (WIS) and irrigation regions of oasis type:
I - Chernozemelskay WIS; II - Carpinskya WIS; III - Kalmyk - Astrahanskya WIS;
IV - Pravo - Egorlycskya WIS;V - Caspinskya WIS;VI - Region of local surface water recourses;
VII - Desert region;VIII - Region of head underground waters; IX - Region of seawater
H - MS of oasis type for water - springs:
A - local surface water recourses; B - canals of WIS; C - head underground waters;
D - un-head underground waters; E - seawater; F - waterpipes

Irrigation methods:
a - sprinkling irrigation (standard methods); b - aerosol irrigation; c - synchronous impulse irrigation;
d - furrow irrigation; e - border irrigation; f - flooding basin irrigation; g - limanous (lagoon) irrigation ;
h - intraground irrigation; i - micro irrigation

National frontier
Irrigation canals
Water basin (pond, reservoir)
Community
Irrigation systems of oasis-type frontier
Natural-agricultural zones frontier

- B-type systems are developed in the territory with large WIS, in the form both of new constructions and remodelling of old irrigation systems and plots.
- C-type systems work well in the south of the republic, where there is a large basin of artesian waters.
- D-type systems are used in the eastern and south-eastern parts of the republic in the desert zone of the Precaspian lowland, where there is no hydrographical network, the surface water is only accessible in the form of salty lakes, and underground water (fresh and saline) is concentrated in separate lenses

formed under the natural depressions of the area and in the hollows produced by wind action. Lens reserves are not substantial and the reserves are easily exhausted when exploited, which is why they need to be filled up regularly.

- E-type systems are situated on the shore of the northwestern part of the Caspian Sea, where the seawater is freshened by the flow of the Volga and Ural rivers (mineralization does not exceed 1.5 g/l). This area thus has almost unlimited water reserves that can be used for irrigation and other needs.
- F-type systems can be used in the same areas as the E-type systems (Precaspian lowland), drawing from the existing northern group of water pipelines (intake from the Volga) or from newly constructed pipelines (preferably local) with an intake from the Volga, the canals of the Chernozemelskaya WIS or the wells of head underground waters.

In order to define the areas with potential for fine-outline HMS on the Kalmyk territory, work has been undertaken to define and classify the main parameters in the suitability of water sources (lakes, reservoirs, ponds) for the water systems. These were divided into four categories: large, with a functional volume of more than 1 million m^3; medium, with a volume of 0.5–1.0 million m^3; small, with a volume of 0.2–0.5 million m^3; and micro-reservoirs, with a volume of less than 0.2 million m^3. In addition to the volumes of water, the interval of water-mineralization is measured in each reservoir; since this depends on the amount of flood runoff and the weather conditions (precipitation and air temperature), the saline composition can change significantly depending on the year and the season. On this basis it has been established that the estimated areas of plots suitable for fine-outline irrigation (FOI) on the territory of Kalmykia make up between 47,000 and 54,000 hectares, which is comparable to the area of available regular irrigation lands (53,100 ha). It is suggested that most FOI plots should be situated on the available irrigation systems because of the ecological reconstruction of the landscape associated with their use. Using the available local flow, it is possible to create about 12,000 ha of fine-outline HMS, replenishing the underground water through a system of water rotation.

In our research, we defined typical technological operational regulations for fine-outline hydromeliorative systems of the oasis type, according to time of holding and length. The basic scheme that we used was of a multi-purpose fine-outline HMS on the local overhead flow (Figures 24.3 and 24.4).

To clarify the functional operations process, the technological order of the oasis type of systems is represented in the form of a network chart (Figure 24.5), the main elements of which are the events and the work. The term 'event' refers to the beginning or end of a definite stage of HMS functioning or technological operation. The 'work' involves the interaction of events, expressed in the

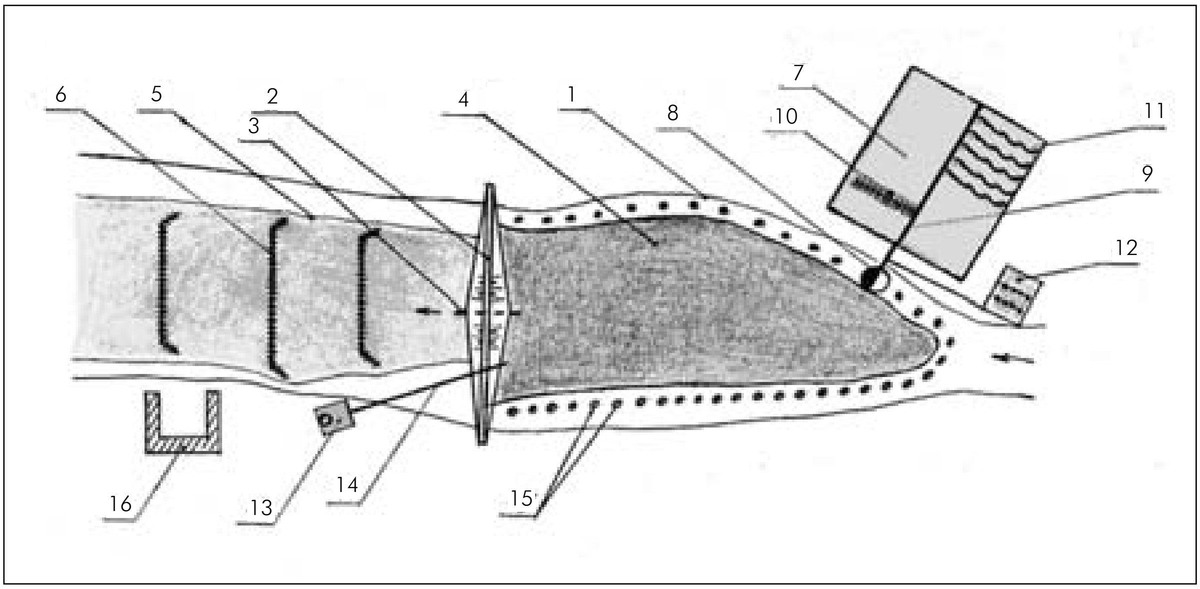

Figure 24.3 Scheme of oasis type multi-function hydromeliorative system based on local surface water recourses

1. Frontier narrow bed.
2. Earth dam.
3. Bottomed water outlet.
4. Pond.
5. Frontier of limanous irrigation system.
6. Dykes of liman stages.
7. Region of regulate irrigation system.
8. Pumping station.
9. Head pipeline.
10. Overhead machine.
11. Section of surface irrigation (furrow, border and others).
12. Trickle irrigation system.
13. Synthetic beating up underground water system (filtration platform and miscellaneous wells).
14. Pipeline of synthetic beating up underground water system.
15. Tree and brushwood plantations.
16. Industrial-dwelling rooms of farm.

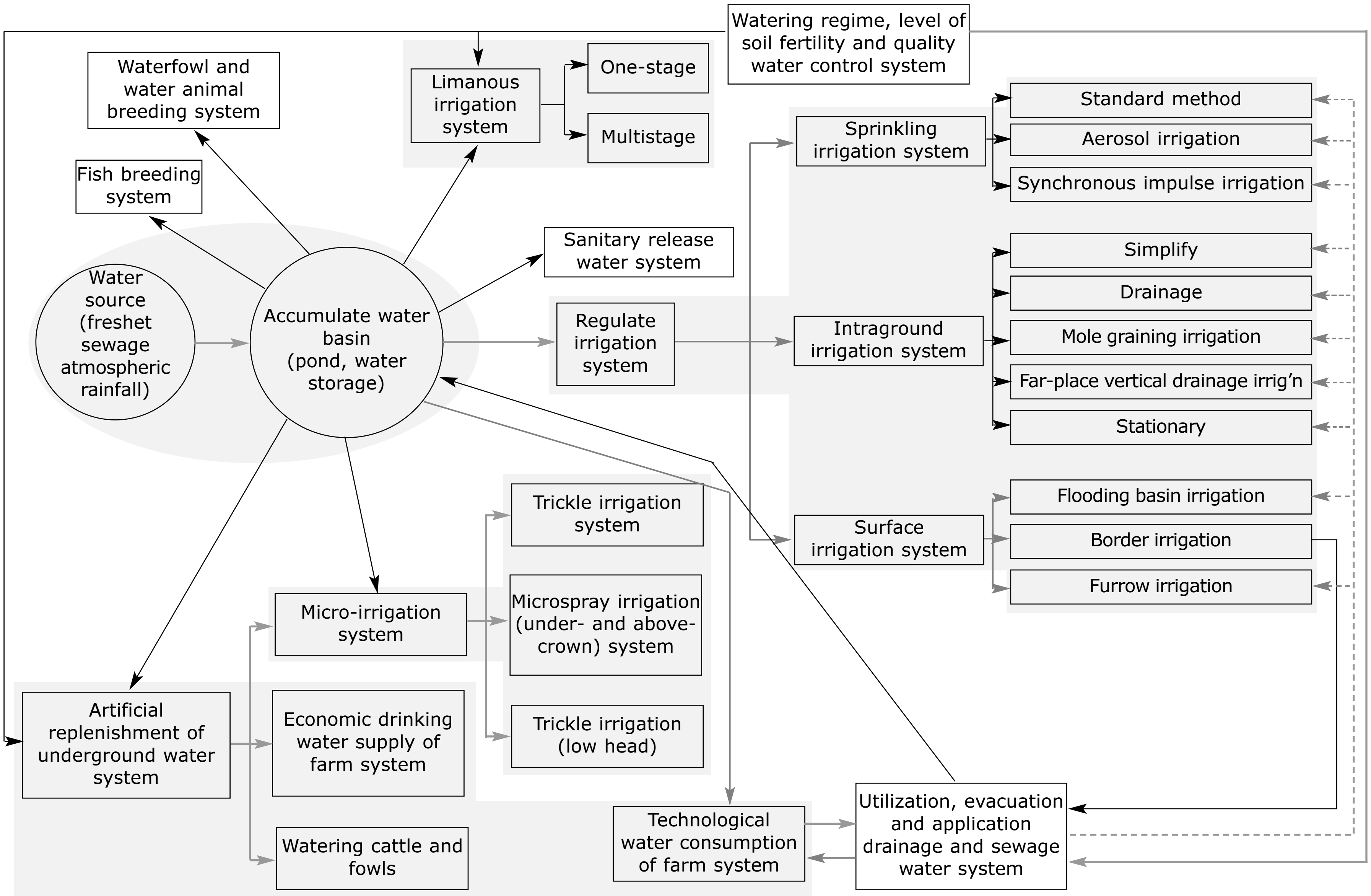

Figure 24.4 Structure of multi-function hydromeliorative system of oasis type from local surface water resources

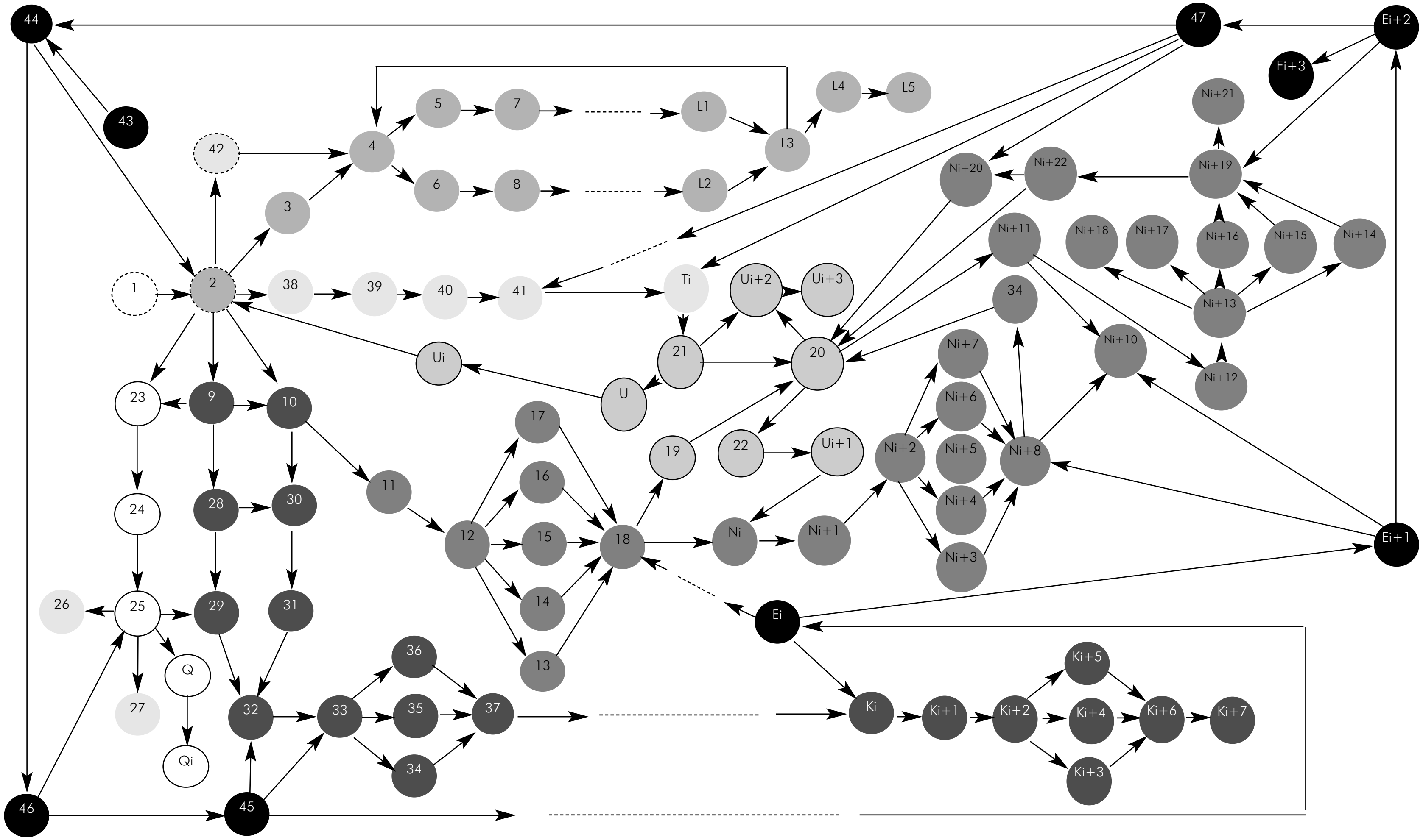

Figure 24.5 Setting graphic work of multi-function hydro-meliorative system of oasis type from local surface water resources

time spent in transition from one event to another as well as their logical sequence.

In Figure 24.5 the events are represented by circles while the works are represented by arrows. The direction of the arrows indicates the sequence of separate events. The names of the events (the technological operations of HMS work) are shown in Table 24.1. They are divided into corresponding elements (general preparation work, lens irrigation and so on).

The first stage of technological regulation is *the general preparatory work* (Operations 1–2 in Table 24.1). This section relates to the carrying out of repair, reconstruction and precautionary work.

Limanous (lagoon) irrigation (Operations 3–L_5) is one of the main constituent parts of the multi-purpose fine-outline oasis type HMS, as this method of overhead irrigation is the nearest under arid zone conditions in Russia to natural conditions.

Regular irrigation (Operations 9–(N_1+21)), in the fine-outline oasis-type HMS, can be performed by all methods of irrigation: surface (along furrows, borders, checks and micro-checks); sprinkling irrigation (usual, small-dispersed and synchronous impulse irrigation); and intra-ground methods.

The micro-irrigation element (Operations 9, 28–(K_1+7)) is the most progressive because it ensures that a stable, high yield of crops is obtained from the significant (50–90 per cent) water resources economy.

The element of *artificial replenishment of underground water reserves* (Operations 9, 23–Q_1) within the framework of HMS activities allows the lens of underground water to form, ensuring a constant regime of water resources following the principles of water rotation.

The *control element* in the watering regime of the soil moisture and the degree of soil fertility and water quality (Operations 43–(E_1+3)) must be equipped with modern automated systems based on computer technology; an efficient supply of information and analysis of managerial decisions is needed.

The element of *water usage for the technological needs of farms* (Operations 38–T_1) stipulates an intake from accumulating agricultural complexes: farms, fodder kitchens, washers and so on.

The element of *fishing systems and breeding of water fowl and animals* may be either the natural process of ichtyo-fauna development in the accumulating reservoir (pond) – the appearance of fish, crayfish and wild fowl – or an intensive industrial-type system, which involves artificial breeding of fish, water-fowl (ducks, geese) and animals (coypus, muskrats and others).

The element of *sanitary flood flush water* (Operations 42) relates to preserving the water balance throughout the territory of the watershed.

The technological work order of specialized systems of fine-outline irrigation (FOI) on the local flow will be analogous to the corresponding section type presented in the table. The scheme and technological work of fine-outline oasis-type HMS with nutrition from canals of IIS does not differ from that seen above; only the type of intake and water supply is changed.

The structure and organization of fine-outline systems using underground water can have various functions: that is either of a complex character or specialized (for example, agricultural water supply (AWS), irrigation or other individual functions). The technological order of such HMS functioning will not be significantly different from the typological order. Among these systems, the ones that can operate as water sources are: artesian wells (or groups of wells) equipped with regulating armatures (slide-valves or valves) or accumulating reservoirs of daily or more regulation, recharged by self-filling wells; lenses of non-head underground water, where quite different schemes of intakes are used from mine-wells; and artificially replenished underground water reserves (ARUW) equipped with water hoists of various types (loading electric pumps; airlifts, band, wind and sun installations).

For multi-function fine-outline HMS using seawater, the following schemes can be used: a water supply that flows along the canals by itself, due to the natural global process of rising sea levels and wind events (*moryana*); flow along water pipes (either self-propelled or under pressure); and canal flows that combine self-flowing with a mechanical water lift. The construction of irrigation systems can be quite varied: there may be no system of ARUW, in which case the system of AWS must make provision for purification and water-quality improvement with the help of various installations. Water rotation of drainage wastewater and sewage water (after purification) can be achieved by using the water for secondary usage to irrigate plots or for other technological needs of farms.

Summary

The effective creation and application of a new generation of hydro-meliorative systems must take into account the diversity of landscapes and natural climatic characteristics of desert and semi-desert zones, and thereby improve their ecological safety. The interrelated and ecologically grounded functioning of the varying elements of multi-function, fine-outline, oasis-type HMS ensures their efficient use in conditions of water-resources deficiency. These systems are designed to safeguard the general water balance within the drainage area in arid territory with stable and highly productive agro landscapes, the basic elements of which are micro-agroanthropogenic ecosystems: farmlands with all their necessary infrastructure.

The strategy of hydro-meliorative construction on the territory of Kalmykia should be carried through in the near future. This strategy allows the creation of more perfect technological systems, which are progressively adapted to the natural landscapes and the cycles of matter and energy.

Table 24.1 Technological operation of multi-functional hydromeliorative system of oasis type from local surface water resources

No of events	Nomenclature of events	No of events	Nomenclature of events
1	2	3	4
	Block of general preparatory work		
1	Canal cleaning; repair earth banks, dykes and hydraulic structures (HS)	2	Filling the accumulator - water reservoir of spring flood waters
	Limanous irrigation system		
3	Organization of temporary dam from synthetic materials	L_1	Discharging water flow to final (lower) stage
4	Opening main HS, water supply on first (highest) stage	L_2	Water layer regulation on final (lowest) stage
5	Water layer regulation	L_3	Closing the main HS and turning off water supply
6	Discharge of superfluous water across the outlet works	L_4	Discharge of water leavings from lower stage on discharging
7	Opening main HS at dykes and issuing water to second stage	L_5	Disassembling temporary dam
8	Discharge of superfluous water on third stage		
	Regular irrigation system		
9	Preparation of irrigating techniques and equipment for season	N_i+2	Water transfer from head pipeline to irrigating section
10	Including the pumping station and with-drawal of water from reservoir	N_i+3 – N_i+7	Watering by one of the methods (repeat the events 13-17)
11	Mineral fertilizers and herbicides from irri-gation water assistance	N_i+8	Ending the final seasonal irrigation
12	Water transfer from head pipeline to irri-gating section	N_i+9	Drainage water transfer to utilization and evacuation system
13	Sprinkling irrigation	N_i+10	Including the pumping station and withdrawal of water for winter irrigation
14	Furrow irrigation	N_ii+11	Clarified drainage water transfer for winter irrigation
15	Border irrigation	N_i+12	Mineral fertilizers and herbicides from irrigation water assistance
16	Flooding-basin irrigation	N_i+13	Water transfer from head pipeline to irrigation section
17	Intraground irrigation	N_i+14 - Ni+18	Winter irrigation (repeat events 13-17)
18	End of first watering	N_i+19	End of winter irrigation
N_i	Including the pumping station and with-drawal of water from seasonal irrigation	N_i+20	Drainage water transfer to utilization and evacuation system
N_i+1	Mineral fertilizers and herbicides from irrigation water assistance	N_i+21	Technical servicing of equipment and structures, to prepare them for winter
	Utilization, evacuation and application drainage and sewage water system		
19	Drainage water test from regular irrigating section	22	Clarified drainage and sewage waters transfer to regular irrigation section for first irrigation
20	Drainage water clarification, and regulation of its quality	U_i+1	Clarified drainage and sewage water transfer to irrigation section for the final irrigation
21	Sewage waters utilization and clarification	U_i+2	End of work of the clarification system
U	Sewage waters test in accumulator-water reservoir	U_i+3	Technical servicing of equipment and structures, to prepare them for winter
U_i	Repeat the rounds of sewage water clarification in water reservoir in past year		

System of artificial replenishment of underground water (ARUW system)			
9	Preparation of system for season, systematic technical servicing	27	Withdrawal of underground water from watering place of cattle and birds
23	Withdrawal of water from accumulator reservoir	29	Withdrawal of underground water for necessary micro-irrigation
24	Water transfer to pipeline for filtration landing place	Q	Regular technical servicing of the equipment of ARUW (every change)
25	Water filtration process in the underground reservoir over filtration landing place. Filling up the lens water stock	Q_i	Systematic and periodical technical servicing of the equipment of ARUW system
26	Withdrawal of underground water from filtration well of ARUW system for economical watering that is necessary for farm		
Micro-irrigation system			
9	Preparation of system for season, systematic technical servicing	34	Trickle irrigation
28	Setting up programming arrangement and including the apparatus of moisture, air temperature, control of soil fertility level	35	Micro sprinkling irrigation (under-crown and above-crown)
29	Withdrawal of water from SRGW system	36	Trickle irrigation (low head)
10	Withdrawal of water from accumulator reservoir	37	End of first irrigation
30	Water clarification via special filter	Ki	Water transfer to final irrigation
31	Water transfer via pipeline to irrigation section	K_i+1	Mineral fertilizers and herbicides from irrigation water assistance
32	Mineral fertilizers and herbicides from irrigation water assistance	K_i+2 – K_i+6	Repeat of events 33-37
33	Water transfer to irrigation system and first irrigation to convey	K_i+7	End of work of the system
38	Preparation of system equipment for season, withdrawal of water from reservoir on technological necessity of farm	41	Sewage water test from utilization and clarification system
39	Water use for technological needs of agricultural enterprise	T_i	Repeat of events 38-41 (throughout the year)
40	Sewage water test from the farm		
Sanitary release water system			
42	Withdrawal of water from the reservoir through the bottom water system outlet of pond		
Water regime, level of soil fertility and quality water system			
43	Preparation of system equipment for season, systematic technical service	E_i	Control of water quality on regular and micro-irrigation systems, drainage waters, level of soil fertility (the end of first irrigation – final season irrigation beginning)
44	Control of water quality in accumulator-reservoir	E_i+1	Control of water quality after final season irrigation; drainage water, which is withdrawn for winter irrigation; irrigated and clarified drainage water; level of soil fertility
45	Control of water quality in ARUW system	E_i+2	Level of soil fertility control, quality control of drainage water, when season is over
46	Control of water quality in micro-irrigation systems, level of soil fertility, watering soil. Giving the signal, when the first irrigation begins.	E_i+3	Ending the work of the control system
47	The control of utilization and clarification drainage and sewage water		

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25 The effects of constructing linear structures on pasture ecosystems

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Any engineering structure must be constructed with consideration for the environment so that its construction and subsequent use do not cause harmful effects. We have monitored the construction and use of linear structures (highways, gas-pipes, oil-pipes) in the area of brown soil distribution of light granulometric composition in Kalmykia.

The area under investigation is situated in the Afro-Asian desert region (Gribova et al., 1980). During the last three decades, annual precipitation in the region has fluctuated between 72 and 342 mm, with an annual average of 211 mm (Bakinova et al., 2002). The dry season lasts for eight months. The main ecosystems of the region under research are pastures, traditionally used for rearing sheep, cattle, and horses. The modern ecological situation is influenced by both natural factors and economic developments.

Plant associations prevail on brown semi-desert with various rates of saline soils of light granulometric composition in the structure of vegetation cover. The dominant vegetation is *Stipa capillata, St.sareptana, Agropyron fragile* and *Artemisia lerchiana* (Bakinova et al., 2002). Halophytic vegetation such as *Halocnemum strobilaceum, Petrosimonia brachiata* and *Anabasis salsa* is well developed on solonchaks in the depressions of the relief. The Psammofile vegetation of the overgrown sands component consists mostly of *Artemisia tschenieviana, Calligonum aphyllum* and *Calamagrostis epigeios*.

The development of a market economy in the republic has led to the intensive construction of linear structures such as gas-pipes, oil-pipes and metalled highways, and the area traditionally used as pasture is suffering from overload. Studies of the condition of vegetation cover and observations made in the construction zone of the influence of the linear structures constructed during 1999–2001 provided the following data:

- A particular problem is caused by land that is used temporarily in connection with engineering projects. The intention is generally to return these to agricultural use once construction comes to an end. In reality, however, they suffer severe ecological degradation that affects not only the area actually used in connection with the projects, but also much adjoining land. As a result of wind erosion of this adjoining area, vegetation up to a distance of 5 m from the plot border can be destroyed, and some damage to the vegetation occurs up to a distance of 10 m.
- Sand drifts reach heights of 18 to 20 cm. The vegetation and soil cover is entirely broken up on the pastures adjoining land that is used temporarily in connection with engineering projects such as new roads, car parks, quarry development and the laying of foundations. The destruction of the vegetation cover in the pasture area is increased by wind erosion, and the affected area has trebled in two years. A pattern of native vegetation in which perennials prevailed has been replaced by secondary vegetation dominated by annual species: *Ceratocarpus arenarius, Salsola australis, Atriplex tatarica* and *Anisantha tectorumi*.
- In the zone affected by oil-pipelines, pollution by oil spills has resulted in the destruction of vegetation cover. The area of oil pollution increased twelvefold between 1999 and 2001.

In desert and semi-desert conditions where vegetation associations consist of small numbers of species, successional changes are connected with the age spectrum of dominant species populations. The presence of species with varied ages, with a population dominated by generative species, is considered a normal and stable phase of phytocenoses. Analysis of age spectrum dynamics in the vegetation associations in the areas influenced by linear structures shows that technogenic stress results in the aging of the dominant population, *Artemisia lerchiana* (Table 25.1).

The stability of vegetation associations decreases with regeneration, aging and the absence of cenopopulations. The absence of *Artemisia lerchiana* regeneration is due to sand drifts at the time of germination, an unfavourable

Table 25.1 Artemisia lerchiana age spectrum (in %)

Year	Age condition		
	Virgin	Generative	Old
1999	5.1	89.8	5.1
2000	–	79.6	20.4
2001	–	68.3	31.7

water regime and soil pollution by oil products. Thus, technogenic stress caused by the construction of linear structures affects pasture ecosystems in the zone of brown semi-desert soils of light granulometric composition. As a result, the vegetation cover is unable fulfil its preservation function in protecting the soil, and is unable to provide fodder for animals.

In order to restore these functions it is necessary to employ phytomelioration techniques on the degraded lands. For this purpose, technological schemes and experience of biological recultivation of arid pastures are available in the republic. To decrease the negative impacts on pasture ecosystems during the construction of engineering structures, it is necessary to consider increasing the biological recultivation area. Monitoring the condition of pasture vegetation cover in the zone of influence of linear structures should be mandatory during the entire construction and exploitation period.

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26 Halophytes of natural flora and their use for breeding and phytomelioration of degraded pasture ecosystems

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Introduction

The landlocked location of southern regions of Russia, far removed from any ocean, is a precondition for the formation of dry-steppe, semi-desert and desert climates characterized by low precipitation (Kovda, 1946). Here an upward water movement always prevails in the soil, leading to salt accumulation in the topsoil layer. Similar natural conditions are typical of the semi-desert zones in the Caspian, Urals, and west and east Siberian provinces of the dry steppe zone in Russia. Among these conditions are an overall water deficit and climate aridity, and soil salinity is thus one of the more serious constraints. In such extreme environmental arid conditions the prospects for cultivating agricultural subsistence crops are limited, or even non-existent. It is necessary to develop varieties of forage crops that feature stable year-to-year productivity, particularly in unfavourable years, as well as high-quality forage that is non-shedding of the most nutritive parts (leaves, seeds, assimilation sprouts), tolerant to a grazing regime, and resistant to droughts and saline soils.

The requirements of high environmental stability and economic value are met by halophytes: a group of natural plants with environmental, physiological and biochemical characteristics that facilitate their successful growth and production in conditions of high soil salinity and/or irrigation with saline waters. In this context, populations of halophytes from natural flora are the basic source of initial material for selecting and developing environmentally differentiated kinds of forage crops for use in adaptive systems of phyto-reclamation of degraded pastures.

The world's genofund of halophytes includes some 2,000–2,500 species (Aronson, 1989), with 700 species in Central Asia (Akjigitova, 1982) and 512 species in the Russian Federation (Shamsutdinov et al., 2001). Halophytes and xerophytes can be used for the development of such environmental niches as saline and solonetz soils, coastal saline sands and dry takyr-like soils, where traditional plants cannot normally grow (Shamsutdinov, 1970, 1988, 1996; Shamsutdinov et al., 2001).

An analysis of world experience of halophyte growth, and our experience in arid regions of Central Asia and Russia, show that halophytes and xerophytes not only display a wide range of environmental and biological characteristics but also offer a wide spectrum of possibilities for their economic utilization. Genetic resources of halophytes are of interest as decorative plants and as a source of fodder, oil, medicine, energy and biological ameliorants (Shamsutdinov et al., 2001).

Our book *Halophytes of Russia: their environmental assessment and use* (Shamsutdinov et al., 2001) analyses work conducted by research institutions in Central Asia, Kazakhstan and southern Russia on the cultivation of forage plants in arid zones. Three hundred species of cultivated plants, representing twenty-nine botanical families, were selected for the trials. Most of these belong to the *Poaceae* family (75 species), *Chenopodiaceae* (40), *Fabaceae* (29), *Crassulaceae* (25), *Asteraceae* (17), *Polygonaceae* (13) and *Apiaceae* (10), with only fifty species belonging to the other twenty-two families.

The following species of forage halophytes and xerophytes are most promising for cultivation and selection improvement: *Haloxylon ammodendron* (C.A. Mey.) Bunge; *Haloxylon persicum* Bunge ex Boiss. and Buhse; *Salsola paletzkiana* Litv., *S.; richteri* (Moq.) Kar. ex Litv.; *S. orientalis* S.G. Gmel.; *S. gemascens* Pall.; *Halothamnus subaphyllus* (C.A. Mey.) Botsch.; *Eurotia ceratoides* (L.) C.A. Mey; *C. pungens* (M. Pop.) Czer.; *Kochia prostrata* (L.) Shrad.; *K. scoparia* (L.) Shrad.; *Camphorosma lessingii* Litv.; *Climacoptera lanata* (Bieb.) Botsch.; *Suaeda arcuata* Bunge.; *S. acuminata* (C.A. Mey.) Moq.; *Suaeda altissima* (L.) Pall.; *Artemisia lerchiana* Web.; *A. terrae-albae* Krasch.; *A. diffusa* Krasch. ex Poljak.; *A. halophila* Krasch.; *Psathyrostachys juncea* (Fisch.) Nevski; and *Elytrigia elongata* (Host) Nevski.

Materials and methods

A genofund of forage halophytes has been produced, using collected germ plasma of the natural flora in arid regions of Russia and Central Asian countries (Kazakhstan, Turkmenistan, Uzbekistan). The halophyte genofund includes more than fifty species and 1,200 specimens, including twenty-five species of forage halophytes, which provided interesting initial material for selection. As a result of integrated ecological studies, the following species were selected on the basis of an assessment that their forage properties presented the best perspectives for selection: *Eurotia ceratoides* (L.) C.A.

Mey, *Camphorosma lessingii* Litv., *Suaeda altissima* (L.) Pall. and *Glycyrrhiza glabra* L.

The selection process included three sets of studies: first, an analysis of the various initial material; second, the selection and study of candidate halophytes; third, formation and appraisal of selection material (Anon, 1985). Studies of ecotypes were carried out in collection and selection nurseries by appraising and selecting highly productive, salt-tolerant species. Types of forage semi-shrubs were selected by applying the individual-mass selection with appraisal of the behaviour of selected plants (populations) in saline and arid conditions. Comparative testing of the types was carried out using the methodology of the state approach to testing (Anon, 1985).

Results and discussion

Selection of forage halophytes

Selection of Eurotia ceratoides (L.) C.A. Mey

To assess and select the most promising species, a collection nursery of *Eurotia ceratoides* was set up in 1995 on a trial field that is part of the Caspian Research Institute on Arid Farming. Twenty-four species of *Eurotia ceratoides* were collected both in the Astrakhan Region and Kalmykia and used in the comparative assessment.

Eurotia ceratoides starts growing in early April, and its blossoming phase lasts from mid-July through the third month of August; a fruit formation stage begins in late August and lasts until early October; ripening occurs in October and early November, and fruits are shed until the third week of November; the vegetation period ends in late November or early December. Thus, the vegetation period lasts for between 215 and 225 days.

Eurotia ceratoides is a monoecious plant; flowers are of different sex, with a binary perianth and four stamens forming at the ends of branches, with short spike-shaped compact flower clusters without bracts. Female flowers have no perianth, and are hidden in two adnate over-the-middle bracts located in axils of leaves under the male clusters. The pistil has two filament stigmas, and is characterized by cross-pollination.

From all the species that met a productivity criterion, specimens were gathered on the margins of the Baskunchak Lake, at the Bogdinsky (Experimental) Station in the Privolzhsky area, in the Astrakhan Region and in the Promyslovka settlement of the Limansky District of the Astrakhan Region. The yield of their dry forage mass in the second year was 1.47–2.01 t/ha, in the third year it was 2.57–2.38 t/ha and in the fourth year it was 2.51–2.73 t/ha.

A comparative analysis and assessment of prospective varieties of *Eurotia ceratoides* species, grown in a nursery for strain testing comparison with a standard control sample, indicated that a specimen from the Narimanovsky District of the Astrakhan Region showed the greatest forage productivity over the four years; we called this specimen 'Favorit'. It gave yields of 0.52, 0.98, 1.66 and 2.9 t/ha in each year, which significantly exceeded the standard figures (Ugtinsky local) by 0.24, 0.42, 0.46 and 0.40 t/ha, respectively (Table 26.1).

Analysis of the structure of forage mass yield (Table 26.2) showed that the 'Favorit' specimen has the greatest number of generative shoots, and is equal to the standard control sample in terms of the proportion of the most edible part of the forage (leaves and seeds) that it contains.

The 'Favorit' variety of *Eurotia ceratoides* is referred to as a hay-cutting type because of its characteristic great height, with many upward generative shoots, a good leaf formation (54.5 per cent) and good seed productivity.

Table 26.1 Yield of dry forage mass of Eurotia ceratoides in a comparative test in 1995

Samples	Year 1 (1996)			Year 2 (1997)			Year 3 (1998)			Year 4 (1999)		
	Yield (t/ha)	Diff'ce from standard	LSD	Yield (t/ha)	Diff'ce from standard	LSD	Yield (t/ha)	Diff'ce from standard	LSD	Yield (t/ha)	Diff'ce from standard	LSD
Uttinskiy mestnyi	0.28	–	–	0.56	–	–	1.20	-	–	2.50	–	–
From Astrakhan Nariman district (Favorit)	0.52	0.24	0.47	0.98	0.42	1.78	1.66	0.46	0.57	2.90	0.40	0.57
From Kalmykia Sarpinskiy district (Standard)	0.32	0.04	–	0.75	0.29	–	1.43	0.23	–	2.40	0.10	–

In the second test cycle the 'Favorit' also showed significantly greater yield than the standard local Utginsky. The difference from the standard was 0.26, 0.27 and 0.35 t/ha in dry forage mass, and 0.025, 0.13 and 0.025 t/ha in seeds.

Selection of Camphorosma lessingii Litv.

In 1995, we identified two specimens in a collection nursery: one from the Ikryansky District of the Astrakhan Region and one from the Tselinnyi Region of Kalmykia. These specimens gave higher yields of dry forage mass (2.54 to 2.86 t/ha) than other specimens.

Analysis of the structure of the forage mass yield of the most promising specimens of *Camphorosma lessingii* in the 1995 collection shows that these specimens have the highest portion of leaves and seeds (53 per cent).

The nursery for preliminary strain testing of *Camphorosma lessingii* has three plots measuring 10 × 2.8 m, with wide rows and a row spacing of 70 cm; the seed sowing rate is 3 kg/ha, and seed is embedded to a depth of 0.5–1.0 cm. Of all the specimens tested, the *Camphorosma lessingii* specimens from the Privolzhsky District (Nachalo settlement) of the Astrakhan Region gave the best results of forage mass yield. They greatly exceeded the specimens from the Ikryansky District in terms of dry mass (0.30, 0.28, 0.41 and 0.5 t/ha) and of seed yield (0.013, 0.022, 0.018, 0.015 and 0.020 t/ha).

In 1997 a comparison strain test with a four-fold duplication was started for winter (November). The results for yields of dry forage mass and seeds are presented in Table 26.3.

The study of the collected material of *Camphorosma lessingii* made it possible to select the initial material from which, by means of multiple selections, a new variety of *Camphorosma lessingii* was obtained, labelled 'Alsu'. Its features include high yields (1.73 t/ha of dry forage mass, on average), long life and stability with respect to grazing and cutting.

Table 26.2 Structure of forage mass of Eurotia ceratoides specimens in a test comparison in 1995

Samples	Number		Green mass			Dry mass		
	Generative	Vegetative	Sample	Leaves	Stems & seeds	Sample	Leaves	Stems & seeds
From Astrakhan Nariman district (Favorit)	36	11	100/ 200	55.5/ 98.8	44.5/ 101.2	100/ 51.3	54.5/ 25.1	45.5/ 26.2
From Kalmykia Sarpinskiy district (Standard)	33	14	100/ 200	49.4/ 103.5	50.6/ 96.5	100/ 52.0	49.0/ 27.0	51.0/ 25.0
Uttinskiy mestnyi	31	11	100	51.7	48.3	100	52.0	48.0

Table 26.3 Yields of dry mass and seeds of Camphorosma lessingii test comparison with 1997 base

Samples	Year 1 (1998)			Year 2 (1999)			Year 3 (2000)		
	Yield (t/ha)	Diff'ce from standard	LSD	Yield (t/ha)	Diff'ce from standard	LSD	Yield (t/ha)	Diff'ce from standard	LSD
Fodder mass (t/ha)									
Ikryanskiy district Astrakhan province	0.59	0.27	0.12	1.13	0.10	1.6	1.78	0.40	1.2
Privolzskiy district Astrakhan province	0.86	–	–	1.23	–	–	2.18	–	–
Seeds (t/ha)									
Ikryanskiy district Astrakhan province	0.053	0.022	0.002	0.075	0.06	0.00	0.087	0.021	0.05
Privolzskiy district Astrakhan province	0.075	–	–	0.081	–	–	0.108	–	–

Selection of Suaeda altissima (L.) Pall.

In November 2000 the Caspian Research Institute on Arid Farming established a collection nursery of *Suaeda altissima* where nineteen specimens of this plant (collected from various ecological-geographical regions of Russia and Central Asia) were sown.

The first shoots of tall *Suaeda altissima* appear in late March or April. In late April, it starts to branch (sprout) intensely. Budding begins in late May or early June and lasts for thirty days. A blossoming phase begins in early or mid-July and lasts until late September. Fruits of *Suaeda altissima* are formed from mid-September until mid-October. The first ripe fruits appear in the middle of October, and mass ripening of fruits is observed in late October. Cultivated under irrigation, *Suaeda altissima* grows quite quickly, and by the end of the first year can reach a height of 100 to 110 cm.

Of all the specimens tested in the collection nursery, the tallest was K-227 from the Privolzhsky District of the Astrakhan Region.

The *Suaeda altissima* natural population collected in the Chernoyarsky District of the Astrakhan Region (Solenoye Zaimische settlement) was sown as a control sample.

Cultivated in the semi-desert conditions of Russia, *Suaeda altissima* is a fast-growing plant that reaches a height of 120 to 130 cm by the end of the vegetation period.

In 2001 specimens of *Suaeda altissima* were grown in a nursery; they were selected from the best populations of prospective species sown in a collection nursery in 2000 (Table 26.4).

Considering the dry conditions prevalent in 1996–8, these specimens gave quite satisfactory yields of forage mass and seeds. The highest yields were from K-69, K-216, K-225, K-227 and K-223, which produced 10.3–14.4 t/ha of dry forage mass. These specimens were differentiated by greater height, a long vegetation period (205 to 210 days) and high seeding productivity (0.45–0.77 t/ha). After repeated sorting-out, specimens K-69, K-216, K-225 and K-227 were moved to the next stage of the selection process – to nurseries of strain test comparison. The results of the comparison are presented in Table 26.5.

Table 26.5 shows that over all five years in both test cycles, a specimen from the Privolzhsky District of the Astrakhan Region labelled 'Zemfira' showed the greatest forage productivity. It produced up to 12.5 t/ha of dry forage mass, surpassing the standard control sample by 3.5 to 3.9 t/ha. This variety of *Suaeda altissima* grows to a great height with many lateral shoots, good leaf formation (51.5 per cent) and higher seed productivity. Due to its high drought and salt resistance, the 'Zemfira' variety gave high yields of seeds (Table 26.6) even in the dry years of 1998 and 1999. In fact, in all three years of tests 'Zemfira' produced the greatest yields of seeds, exceeding by far the standard control sample (a natural population) by 0.18, 0.26 and 0.29 t/ha.

Use of halophytes for phyto-reclamation of degraded pasture ecosystems

Effective methods for phyto-reclamation of degraded pastures were developed on the basis of selected prospective species as well as developed varieties of forage halophytes.

Phyto-reclamation by sowing a mix of zonally specific dominant varieties and life forms of halophytes

During phyto-reclamation of degraded lands it is possible to construct various types of pastures that have optimal productivity, structural-functional organization, and stability. This is achieved by a

Table 26.4 Yield of dry forage mass of Suaeda altissima specimens in a selection nursery sown in 2001–3

Samples	Year 1 (2001) Height (cm)	Dry yield mass (t/ha)	Seeds yield (t/ha)	Year 2 (202) Height (cm)	Dry yield mass (t/ha)	Seeds yield (t/ha)	Year 3 (2003) Height (cm)	Dry yield mass (t/ha)	Seeds yield (t/ha)
K-58	17	10.0	0.35	109	8.9	0.35	107	8.7	0.33
K-61	110	9.1	0.38	111	8.6	0.34	112	8.5	0.29
K-69	121	11.5	0.45	119	10.3	0.48	124	9.8	0.45
K-215	111	7.9	0.37	113	8.6	0.35	111	8.6	0.37
K-216 St	115	10.3	0.48	113	9.8	0.50	115	10.0	0.48
K-219	110	8.5	0.38	111	9.7	0.38	112	8.7	0.31
K-221	98	8.9	0.36	101	9.1	0.36	109	9.1	0.35
K-222	100	10.1	0.30	104	8.7	0.29	107	9.0	0.29
K-223	114	9.8	0.31	114	9.8	0.31	116	10.1	0.33
K-227	129	14.3	0.77	132	13.2	0.75	131	14.1	0.78
K-225	119	10.3	0.54	116	10.5	0.56	115	9.7	0.58

Table 26.5 Yield of dry forage mass of Suaeda altissima 'Zemfira' in test comparison of 2001–3

Samples	Year 1 (1998) Yield (t/ha)	Diff'ce from standard	LSD	Year 2 (1999) Yield (t/ha)	Diff'ce from standard	LSD	Year 3 (2000) Yield (t/ha)	Diff'ce from standard	LSD
Standard (native population)	8.9	–	–	7.0	–	–	7.6	–	–
Zemphira	12.4	3.5	0.42	11.3	4.3	0.97	12.6	5.0	0.11
from Turkmenistan	9.3	0.4	–	7.5	0.5	–	8.1	0.5	–
from Kalmykia	9.9	1.0	–	7.2	0.2	–	7.5	–0.1	–

Table 26.6 Seed yield of Suaeda altissima 'Zemfira' in the first cycle of test comparison

Samples	Year 1 (1998) Yield (t/ha)	Diff'ce from standard	LSD	Year 2 (1999) Yield (t/ha)	Diff'ce from standard	LSD	Year 3 (2000) Yield (t/ha)	Diff'ce from standard	LSD
Standard (native population)	0.51	–	–	0.52	–	–	0.48	–	–
Zemphira	0.69	0.18	0.19	0.78	0.26	0.17	0.77	0.29	0.23
from Turkmenistan	0.48	–0.03	–	0.54	0.02	–	0.51	0.03	–
from Kalmykia	0.51	0	–	0.56	0.04	–	0.54	0.06	–

combination of various zonally specific dominant varieties and life forms of forage halophytes that are suitable for various types of adaptive strategy. The structures of such pasture ecosystems comprise poly-dominant communities consisting of violent and patient shrubs, semi-shrubs, xerophytic perennial grasses and explerent annual grasses (from a seed bank).

- *Creation of long-life pasture ecosystems for spring–summer use.* Such pasture ecosystems are created in regions where the natural grazing lands are characterized by low productivity during the summertime. Used here are:
  - shrubs*:* *Calligonum arborescens* and *C. aphyllum*
  - semishrubs: *Kochia prostrata, Camphorosma lessingii* and *Eurotia ceratoides*
  - xerophytic perennial grasses: *Agropyron sibiricum* and *A. desertorum, Elymus sibiricus, Festuca valesiaca* and *Stipa lessingiana*.

  The ratio of these basic life forms is 20:60:20. The average yield of spring–summer pastures is 1–1.5 t/ha of dry forage mass (in unfavourable years it drops to less than 0.6–0.8 t/ha), whereas the yields of natural pastures (control) are 0.15–0.30 t/ha.
- *Creation of autumn–winter pasture ecosystems.* For their formation the following are used:
  - xerohalophyte and halophyte semishrubs: *Kochia prostrata, Camphorosma lessingii, Artemisia halophila, Artemisia lerchiana, Eurotia ceratoides*
  - xerophytic perennial grasses: *Agropyron sibiricum* and *A. desertorum, Elymus sibiricus, Festuca valesiaca, Stipa lessingiana*
  - annual grasses.

  The ratio of these components is 25:70:5. Autumn–winter pastures are characterized by a consistently high productivity. In regions with total annual precipitation of 170 to 250 mm, the yield of dry forage mass is 1–1.2 t/ha, and in regions with total precipitation of 250 to 350 mm a year it is 1.5–2 t/ha.
- *Creation of long-term, year-round pasture ecosystems.* It is feasible to create such pastures in semi-deserts and dry steppes. They are composed of halophyte and xerophyte forage shrubs (20 per cent), semishrubs (65 per cent) and grasses (15 per cent) and are grazed by sheep in different seasons. Such pastures may be used throughout the year; they yield 1.2–2.6 t/ha of dry forage mass. Basic technological operations applied here are as follows. On zonally-specific, brown semi-shrub, chestnut, and dark-chestnut soils, in early spring, soil strips 12 to 50 m wide and 16 to 18 cm deep are usually dug across the direction of dominating winds. Then in May–June, to take care of weed overgrowth and compaction of the ground surface, the ground is dug over to a depth of 6 to 8 cm. In autumn (November) and winter (December to February) a mixture of forage plant seeds of various kinds is sown, composed of semi-shrubs and annual and perennial grasses.

Methods of phyto-reclamation of secondary saline irrigated soils using halophytes

Halophytes can be successfully used in the phyto-reclamation of saline lands, restoring their productivity by creating highly productive forage biocenoses, putting the lands to agricultural use, improving the conditions for reclamation and increasing soil fertility.

For this purpose the following halophytes can be used: *Suaeda arcuata* and *S. altissima, Atriplex, Climacoptera crassa, Chenopodium album, Bassia hyssopifolia, Kochia scoparia, Glycyrrhiza glabra* and *G. uralensis, Artemisia halophila* and others. The selected species of halophytes form 10 to 12 tons of dry forage mass, 1 to 1.5 tons of seeds (fruits) and can produce up to 1.5 tons of protein under irrigation with saline waters.

Studies have shown the time required for soil desalinization by means of a reclaimed crop rotation that includes various ecological groups of halophytes. For a moderate level of salinity level this takes four to five years; for heavy salinization six or seven years is necessary. The desalinizing effect of halophytes can be seen in these statistics:

- Within a 1-m layer of heavily saline, medium loamy soils of semi-deserts, the salt content is equal to 48 t/ha.
- With an overland phytomass of 18–20 t/ha, halophytes remove 8 to10 tons of salts a year from each hectare.
- The shading provided by the soil halophytes prevents evaporation and related movement of salts to the topsoil horizons.
- The effect of green mulch is equal to 2.5 t/ha of salts. As a result, in an area where halophytes grow, salt removal from the soil reaches 10 to 12.5 tons a year.

Soil desalination with halophytes is the only way to remove from the soil the salts that are so harmful to agricultural plants. The use of improved drainage and the leaching regime of irrigation will merely redistribute salts in the soil profile, not remove them from the biological cycle.

The most promising biological ameliorant for the efficient development of saline irrigated lands is *Glycyrrhiza glabra*, which is also a valuable medicine and forage crop. In the Lower Povolzhie on saline irrigated lands with high occurrence of ground waters, liquorice gives 6–8 t/ha of hay and 8–10 t/ha of liquorice root, which is a valuable raw material for the pharmaceutical and food industries.

Conclusion

The natural flora of Russia and Central Asian countries comprises a great number of environmentally specific plant varieties, mainly halophytes, that are of great importance as forage plants for agricultural development. Using halophyte seeds collected during expeditions, a genofund has been established that contains fifty species and more than 1,200 specimens of these plants. This genofund has made possible the development of three varieties of forage halophytes: *Eurotia ceratoides* 'Alsu', *Camphorosma lessingii* 'Favorit' and *Suaeda altissima* 'Zemfira', which are being used in the phyto-reclamation of degraded pastures in arid regions of Russia and the Central Asian countries (Uzbekistan).

The use of halophytes for agricultural development in the arid zones of Russia and Central Asia has enormous value and is extremely promising, as more than half of the arid pastures are degraded and require phyto-reclamation.

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27 Chernyje Zemli Biosphere Reserve and its role in the conservation of biodiversity in dryland ecosystems

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Chernyje Zemli Biosphere Reserve, established by UNESCO's Man and the Biosphere programme in 1993, is situated in the Pre-Caspian lowland with its main territory bordering the Ramsar site of Lake Manych-Gudilo. The reserve occupies two separate areas in the Republic of Kalmykia. The larger portion (91,000 ha) lies in the administrative regions of Komsomolskoye and Yashkule, protecting the semi-desert plains of the near-Caspian lowlands. A buffer zone of 56,000 ha surrounds this portion of the reserve, lying at an elevation of 24 m below sea level, as this region was once at the bottom of the Caspian Sea. Chernyje Zemli, meaning 'black lands' in Russian, gets its name from the fact that strong winter winds blow away most of the snow cover, and the lands look black and barren. While winters are cold and harsh, with temperatures dropping as low as –30 °C, snow cover is moderate to sparse. Summers, on the other hand, are hot and dry. Temperatures soar above 40 °C throughout the summer, and hot winds drive over the endless plain. Rain is scarce, and even the rangers have to transport their drinking water into the reserve.

The second, smaller section (30,900 ha) of the Chernyje Zemli Reserve is located in the very northwest corner of the Kalmykia Republic on Lake Manych-Gudilo, locally known as the Proletarskoye Reservoir. Water from the reservoir flows into the Don River, which then leads to the Azov Sea. The lake is long and narrow, covering an area of 344 km^2, with an average depth of only half a metre. Its southeastern shore is protected in the Chernyje Zemli Biosphere Reserve by a buffer zone of 34,000 ha. This section is markedly different from the dry plain in the protected territory in the centre of Kalmykia. Water is abundant everywhere, but the lake is so saline from runoff and the lack of freshwater inlets that hardly any fish can survive. The numerous small islands near the shore are safe places for bird colonies, although the birds have to fly to freshwater bodies to feed. Rolling hills line the lakeshore, sloping off gradually into the shallow, silty waters of the reservoir.

The fauna of the Chernyje Zemli Biosphere Reserve comprise twenty-two species of fish, three species of amphibians, thirteen species of reptiles, 219 species of birds and thirty-one species of mammals. The reserve was created primarily to conserve important breeding and calving grounds of the unique saiga (*Saiga tatarica*). This small antelope with a rather squarish body on thin legs can run over the plain at speeds of up to 80 km an hour. It has a odd looking hump on its long, soft nose, which filters out dust as it runs across the dry steppe. The antelope has large black eyes that protrude slightly from its head. The males have short spiky horns, yellowish in colour, with black rings near the base.

Hunted for their meat and horns, which are used in stomach remedies in oriental medicine, saiga have declined dramatically in number during the latter part of the twentieth century. Some experts say that the main reason for the decline is the inordinate number of wolves (*Canis lupus*) in the region, which prey on young and sick animals. Habitat loss due to the cultivation of steppe lands has also taken its toll. As a result, the saiga is now listed in CITES Appendix II, and hunting in Kalmykia has been halted. Surveys of saiga have been conducted, and conservation measures and public awareness activities in the Republic of Kalmykia have received support from organizations such as the Darwin Initiative 'Using saiga antelope conservation to improve rural livelihoods', the People's Trust for Endangered Species, Large Herbivore Foundation, Denver Zoological Society and Chicago Zoological Society.

The European hare (*Lepus europaeus*) and eared hedgehog (*Erinaceus auritus*) are smaller mammals found in the protected steppe of Chernyje Zemli Nature Reserve. The long-legged corsac fox (*Vulpes corsac*) trots across the level plain in search of rodents, sometimes catching the equally long-legged jerboas. Three species of jerboas are found here: the great, small five-toed and Northern three-toed jerboa (*Allactaga major, A. Elater, Dipus sagitta*).

The territorial range of the endangered marbled polecat (*Vormela peregusna*) has been shrinking over the past 200 years due to grazing and cultivation of prairies. The Caspian Sea and Caucasus region, where the Chernyje Zemli Biosphere Reserve is located, is one of only two areas where the marbled polecat is still found in Russia; the other is in the Altai foothills in Western Siberia. The rather large polecat, with a long bushy tail and light-coloured mask on its face, has an effective way of defending itself from foxes and wolves. It stands up on its hind legs, throws its furry tail up in the air, displays its vicious set of fangs and growls like a dog. This display and the foul odour emanating from the polecat's glands are often enough to deter any would-be predators. A filling meal for the marbled polecat consists of hamsters (*Cricetulus* spp.), voles (*Microtus* spp.) or pygmy ground squirrels – also called sousliks (*Spermophilus pygmaeus*). The sandy-coloured ground squirrels dig elaborate dens in the steppe, where colonies of several families live together. Ground squirrels feed on seeds and grasses while keeping watch for predators. When it senses danger, a ground squirrel stands up on its hind legs and gives out a long whistle, sending all the others underground within seconds.

Ground squirrels are also the favoured prey of many hunting birds in the Kalmykian steppe. Twelve species of raptors are found in the reserve, including rare steppe eagles (*Aquila nipalensis*) and imperial eagles (*A. heliaca*). Long-legged buzzards (*Buteo rufinus*) build their nests on mounds of earth left from old settlements and burial grounds, often bringing pieces of saiga fur into the nest for bedding. White-tailed sea eagles (*Haliaëetus albicilla*) soar above the steppe, hundreds of miles from the sea. Four kinds of harriers (*Circus* spp.) frequent the reserve, flying low over the plain in search of prey. Egyptian vultures (*Neophron percnopterus*), cinereous vultures (*Aegypius monachus*), and Eurasian griffons (*Gyps fulvus*) flock to the saiga birthing grounds to feed on helpless saiga calves, minutes after they are born. Endangered worldwide, the demoiselle crane (*Anthropoides virgo*) is oddly one of the most visible birds in the steppe. Smaller than the common crane, this rare bird is one of the most beautiful of the crane species. Its body is dove-grey in colour, with long black feathers on its chest, wings, and tail. Brilliant white wisps of feathers stream off the back of its slender black head like a ponytail. Beady red eyes are set a little above the base of its bright yellow beak. The birds, which mate for life, stay near their nest in spring, a bare indentation in the earth with two large, greenish eggs with reddish-brown spots.

The other section of the Chernyje Zemli Reserve, along the edge of the saline Manych-Gudilo Reservoir in northeastern Kalmykia, is a haven for nesting shorebirds. The rare Eurasian spoonbill (*Platalea leucorodia*), with a rounded shovel-like tip at the end of its long, reddish bill, feeds on insects and molluscs in silty soils near the shore. Rare Eastern white pelicans (*Pelecanus crispus*), listed in the *Russian Red Book*, nest in colonies of up to 400 pairs. Dalmatian pelicans (*P. Onocrotalus*) are much less numerous; only five pairs nested in the reserve in 1997. Great cormorants (*Phalacrocorax carbo*) also nest in large colonies on islands of Lake Manych-Gudilo. Great and little egrets (*Egretta alba, E. garzetta*) build their nests up with dead reeds on islands, flying to bodies of freshwater to feed on small fish, frogs and insects. Herring gulls (*Larus argentatus*) make their nests alongside the egrets, often preying on their helpless chicks. Whooper swans (*Cygnus cygnus*), mute swans (*Cygnus olor*), ruddy shelducks (*Tadorna ferruginea*) and others are among the 202 species of birds found in Chernyje Zemli Reserve. Amphibians and reptiles in the reserve include the toad-headed and spotted toad agama (*Phrynocephalus mystaceus, P. Guttatus*), rapid fringed-toed lizard and steppe runner (*Ememias velox, E. arguta*), sand boa (*Eryx jaculus*), Montpellier snake (*Malpolon monphlessianus*) and Renard's viper (*Vipera ursini*).

According to the inventory, the flora in the Biosphere Reserve consists of 245 species of vascular plants. The endlessly flat and unbroken plain – or steppe – stretches to the horizon in every direction. Not a single tree breaks up the wide-open space. In spring, the brownish steppe is transformed into a carpet of greenish-grey grasses. The red, white and yellow flowers of rare tulips (*Tulipa biebersteiniana, T. biflora, T. schrenkii*) bring a sprinkling of colour to the unvaried plain. White tufts of feathergrass (*Stipa capillata, S. lessingiana, S. zalesskii*) sway in the summer breeze. Bulbous bluegrass (*Poa bulbosa*) grows beneath the dangling pennants of downy chess (*Bromus tectorum*) and rare Japanese brome (*Bromus japonicus*). The sweet smell of wormwood (*Artemisia tschernieviana, A. austriaca, A. pauciflora, A. salina, A. lerchiana*) wafts over the open plain in spring and summer. Ground squirrels eagerly tear open the green tops of oriental eremopyrum (*Eremopyrum orientale*) to get at the tender seeds inside. These species, along with sword-flag (*Iris pumila*), mullein (*Verbascum austriacum*), and groundsel (*Senecio noemus*) are some of the 179 types of plants found in the reserve.

Before the biosphere reserve was created, the dry steppe lands were under constant grazing pressure from sheep, cows and horses. Some 4 million sheep once grazed on the open plain. As a result of overgrazing, many lands were stripped bare of vegetation and began to turn into deserts. Blowing sand piled up in long mounds, which moved over time. Although protection and re-cultivation of the steppe has allowed vegetation to regenerate gradually on some lands, 25,000 ha, or nearly a third of this section of the reserve, is still covered with bare soils and sand dunes.

The conservation of necessary habitat for the saiga antelope is perhaps the most important function of the Chernyje Zemli Reserve. However, saiga roam over large areas, and can cover several hundred kilometres a day. Once the herds leave the reserve, poachers pursue the herds on motorcycles and by car, sometimes shooting dozens of animals in one night. A national body – the Department for Conservation, Monitoring, and Management of Game Resources of the Republic of Kalmykia – is responsible for protecting the species outside of the reserve, but its rangers cannot always be in the right place at the right time. During breeding and calving seasons, the saigas generally return to the reserve, where they are granted protection from poachers.

However, wolves are also protected there; these numerous predators inflict considerable harm on saiga populations, especially by preying on the young immediately following their birth.

About 1,400 people live within the buffer and transition zones of the biosphere reserve and their income comes mainly from cattle breeding and irrigated cultivation of different crops, vegetables and melons. Constant long-term monitoring of the steppe ecosystems carried out by the biosphere reserve now provides information on the remarkable rehabilitation of the previously degraded vegetation cover within the reserve. The biosphere reserve staff undertake measures to help local people in alternative income generation and in speeding up the rehabilitation of used pastures, and in general attempt to alleviate poverty.

28 Problems of conservation and monitoring of biodiversity in dry steppe areas around Lake Manych-Gudilo

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The south of Russia, and in particular the areas of Rostov and Stavropol, and the Republics of Dagestan and Kalmykia, are characterized by a semi-arid and arid climate, shortage of water resources and ecologically unstable soil conditions, vegetative cover and fauna. The Manych-Chograj water system stretches for almost 1,000 km across these regions. It includes artificial reservoirs that were built as part of the USSR's hydraulic engineering programmes. The development of a system of artificial water basins and regional fresh water reserves has resulted in drastic changes in biological diversity. The last decades have seen a catastrophic decline in fish and bird diversities as a result of the deteriorating conditions of the artificial reservoirs and infrastructure, and a lack of freshwater ones, resulting in an increase in salinity in some reservoirs. The environmental problems arising towards the end of the twentieth century drew public and scientific attention.

One unique example of a saline lake system is the relict Lake Manych-Gudilo, a favoured nesting place for rare bird species. Lake Manych-Gudilo is a very interesting area that provides a reserve for rare species of plants and animals. It is located in the territory of the Rostov area, in the Kalmyk Republic and Stavropol territory. Since September 1994, the relict lake, together with the Proletarsk water basin that connects it to a network of reservoirs, has been included in the Ramsar list of *Wetlands of International Importance* under a decision taken by the Government of the Russian Federation, and these lakes are protected by the state.

Within the vicinity of Lake Manych-Gudilo there are plenty of rare and disappearing plants, many of them protected species. The lake's avifauna is one of the richest in the south European part of Russia in terms of species diversity and aggregate number of individuals (only the Volga delta is comparable in terms of bird diversity). It is the largest migratory route for birds in Eurasia, connecting Western Siberia and Kazakhstan with the Black Sea basin, the Near and Middle East, and Northern and East Africa. It is also one of the largest areas of longstop migrating Anceriformes and waterfowl within the limits of Russia. During migration, numerous and diverse individuals of many kinds – Anceriformes, Charadriiformes, Ciconiiformes, ibises and Pelicaniformes birds – pause here to rest and feed. In the autumn of most years, a majority of Anceriformes fly on to other destinations, but in years of late ice formation they winter on the reservoir. In the spring, up to 1.5 million ducks and 400,000 geese can be seen, including not less than 8,000 of the red-breasted goose *Rufibrenta ruficollis*. In the autumn there are up to 3 million ducks and 500,000 geese, including from 8,000 to 20,000 of the red-breasted goose. Every year on Lake Manych-Gudilo there are approximately 50 to 200 different kinds of large marked white-headed duck, *Oxyura leucocephala*, with a total of up to 1,000 individuals (Krivenko et al., 1998; Linkov, 1984). Furthermore, practically the entire world's population of red-breasted geese and a majority of all white-headed ducks migrate over the valley of the Manych River.

In the water basin of Manych-Chograj, unique marked avifauna can be found that nest in various habitats in both terrestrial and water ecosystems, or stop to rest and feed during migrations. Other steppe birds worth mentioning are the tawny eagle *Aquila rapax*, the Demoiselle crane *Anthropoides virgo*, the great bustard *Otis tarda*, the little bustard *Tetrax tetrax*, and among those birds preferring lakes, bogs, water basins and the rivers are the spoonbill *Platalea leucorodia*, herons (*Egretta garzetta, Ardea cinerea, A. purpurea*), gulls (*Larus melanocephalus, L. minutus, L. ridibundus*), the mute swan *Cygnus olor*, the Dalmatian pelican *Pelecanus crispus* and the white pelican *P. onocrotalus*, the grey lag goose *Anser anser*, and ducks (*Anas strepera, A. acuta, A. clypeata*). Many species rest for a specified period of time, often in the salty lake of a confluence of rivers. Bird diversity increases during spring and autumn migrations when the whooper swan *Cygnus cygnus*, bean goose *Anser fabalis*, red-breasted goose, European wigeon *Anas penelope*, white-winged scoter *Melanitta fusca* and many other species of birds rest at the Manych-Chograj water system.

It is evident that the avifauna of these lakes is one of the most numerous and varied in the south of the European part of Russia. In the vicinity of Lake Manych-Gudilo and the entire Proletarsk water basin, 208 species of birds can be found, of which 122 species are breeding. The lake is a site for the mass nesting of many colonial waterfowl birds. Around Lake Manych-Gudilo itself, many rare and endangered birds, which are in the *Red Book of the Russian Federation* and the IUCN, can be found (for example, the Dalmatian and white pelicans, the spoonbill, the glossy ibis *Plegadis falcinellus*, the great black-headed gull *Larus ichtyaetus*, the Demoiselle crane, the little bustard and the tawny eagle. According to V.G. Krivenko et al. (1998), on islands of Lake Manych-Gudilo there nest more than 100 pairs of Dalmatian pelican and about 300 pairs of white pelican, from 400 to 900 pairs of spoonbill, and about 1,000 pairs of great black-headed gull. Native steppe species breed in steppes near the lakes: the Imperial eagle *Aquila heliaca*, the golden eagle *Aquila chrysaetos*, the white-tailed eagle *Haliaeetus albicilla*, the Egyptian vulture *Neophron percnopterus*, the black vulture *Aegypius monachus*, the great bustard and the little bustard, whose numbers have decreased owing to anthropogenous influences on the environment.

From our data, numerous sandy island colonies of rare and endangered species of birds can be identified: the spoonbill, the Dalmatian pelican and the white pelican (see Figure 28.1).

Numerous fish-eating birds accompany nesting rare species: *Larus cachinnans*, the cormorant *Phalacrocorax carbo*, the grey heron *Ardea cinerea* (Figure 28.2), the little egret *Egretta garzetta*, the great egret *E.alba* and other species. The grey lag goose, the mallard *Anas platyrhinchos*, the mute swan and others assemble on the islands. In May 2004, for instance, we found 464 *Larus cachinnans* nests, 159 white pelican nests, 29 Dalmatian pelican nests, 445 cormorant nests, 29 grey heron nests, 2 mallard nests, 1 grey lag goose, 1 mute swan nest and 31 spoonbill nests (Figure 28.3). Pelicans fly from their nesting place to feed on the Dunda River (a distance of 10 km from the colony) and the Egorlyk River (which is further from it).

Rare species identified in the *Red Book* of a different rank nest here: the gull-billed tern *Gelochelodon nilotica*, the least tern *Sterna albifrons*, the black tern *Chlidonias niger*, the Caspian tern *Hydroprogne caspia*, the black-winged stilt *Himantopus himantopus*, the pied avocet *Recurvirostra avocetta*, the great black-headed gull and the slender-billed gull *Larus genei*. Numerous sheld duck *Tadorna tadorna*, roody sheld duck *T. ferruginea*, spoonbill and glossy ibis can be seen in adjoining wetlands and on small salty lakes. The black-winged pratincole *Glareola nordmanni*, the little bustard *Tetrax tetrax*, the booted eagle *Hieraaetus pennatus* nest in adjoining steppes; the Demoiselle crane, the rose-coloured starling *Sturnus roseus* and other species are common here.

The islands are not easily accessible, but are regularly visited by hunters who disturb the birds during reproduction. This affects breeding and influences bird population numbers. Although two reserves –

Figure 28.1 Dalmatian and white pelicans in a multispecific colony of birds on an island in Lake Manych-Gudilo

Figure 28.2 Hatching of grey heron nestlings in a multispecific colony on an island in Lake Manych-Gudilo

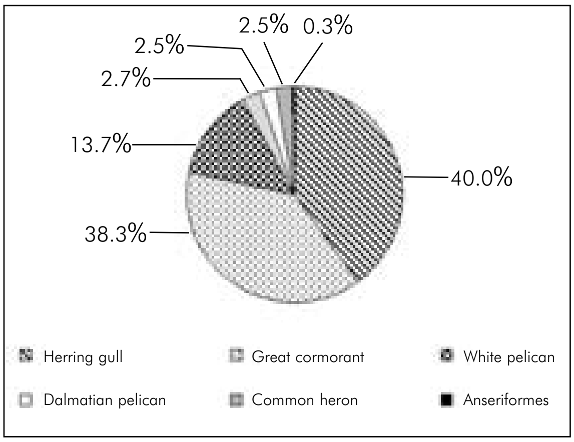

Figure 28.3 Structure of a multispecific colony on one of islands in Lake Manych-Gudilo in 2004

Rostovsky Reserve and Chernyje Zemli Biosphere Reserve – have responsibility for the Manych-Gudilo islands, they do not have the resources to tackle this problem and the protection they offer is clearly insufficient. Some of the adjoining territories and water bodies need to provide the protected status necessary for the preservation of key areas in order to maintain the birds' biological diversity.

The adverse consequences of modern anthropogenous influences on ecosystem lakes such as Manych-Gudilo and adjoining steppes have not been properly investigated. It is therefore necessary to carry out research to analyse and evaluate the processes that are occurring in order to develop measures for the optimal management, conservation and protection of the area's biological diversity.

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29 The saiga antelope in the drylands of Russia and how to ensure its sustainable future

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During the Quaternary, when most of the Northern Hemisphere was covered by tundra-steppe, immense herds of saiga antelope, together with woolly mammoths, used the available plant resources of a far more extensive territory than the saiga's present range. Fossil bones, not so different from the modern species, have been found in deposits scattered from the British Isles all the way to Alaska, and from the northwest territories of Canada to the New Siberian Islands to the north and the Pre-Caucasus region to the south. Two subspecies of the saiga are currently recognized: *Saiga tatarica mongolica*, which inhabits the small steppe area in Mongolia, and *Saiga tatarica tatarica*, which occupies the vast plains of Central Asia and the Pre-Caspian region. Their massive seasonal migrations have been described, particularly those of *Saiga tatarica tatarica*.

The nominative subspecies of saiga antelope is a unique form of nomadic ungulate that once regularly migrated over hundreds of kilometres of grassland habitat. In the course of its evolution this subspecies became very well adapted to the harsh and unpredictable conditions of an extreme environment. Despite its rather sheep-like body, the saiga antelope is one of the fastest terrestrial vertebrates, capable of reaching speeds of up to 80 km per hour. The saiga's most notable external feature is the presence of a curved, trunk-like nose, which apparently evolved for air filtering and thermoregulation during hot, dusty summers and ice-cold winters. Individual saigas have a short life span, and the adults have high reproductive rates, with adaptations that allow for rapid demographic recovery following particularly severe climatic episodes. The males are crowned with a pair of waxy, light yellow horns, which they use as effective weapons. Unfortunately, however, these horns are a valued commodity in the Chinese traditional medicine market; records of exports that passed through the customs office of Kjakhta (Transbaikalia) indicate that 3.95 million horns were exported to China during the 1800s alone.

By the 1920s, over-harvesting had almost completely eliminated the saiga from most of their range. Intensive hunting and the development of steppe lands in the late nineteenth and early twentieth centuries reduced global saiga populations to only a few hundred. For seventy years, the Soviet Union's closed borders supported the antelope population by cutting off international trade routes. Saiga hunting was banned from 1919 until the 1950s, allowing numbers to recover to nearly 2 million, and bringing the antelope from a position of near extinction to the most numerous ungulate in the Soviet Union. This amazing recovery was in part due to the animal's high fecundity: saiga females begin breeding in the first year of life and give birth to their first calf in the second year. Older females are capable of producing two and even three calves per year.

Three populations of *S. t. tatarica* are known in Central Asia: the Ural, the Ust'-Urt and the Betpakdala populations, in addition to one European population in the Pre-Caspian region. It is possible that some herds from Ust'-Urt in Kazakhstan also migrate to adjacent territories of Uzbekistan and Turkmenistan. Saiga herds of the European population may migrate from Kalmykia to Daghestan and other adjacent territories in Russia. In the particularly harsh winter of 1998–9, a herd of 80,000 migrated into Daghestan in search of food. A few weeks later, only a few small groups returned. Witnesses in Daghestan reported that the snow was red with blood from the slaughter of saiga by poachers.

Between 1980 and 1994, total saiga numbers fluctuated between 670,000 and 1,251,000 individuals. In the same period, single population estimates were as follows: European population, 142,000 to 430,000; Ural population, 40,000 to 298,000; Ust'-Urt population, 140,000 to 265,000; and Betpakdala population, 250,000 to 510,000 individuals. All four *S. t. tatarica* populations experienced severe population declines after 1998. The annual rate of population decline during 1998–9 was roughly 35 per cent, reaching a dramatic 56 per cent drop during 1999–2000. The 2004 census revealed the numbers as 15,000 European, 15,000 Ust'Urt, 8,800 Ural and 6,900 Betpakdala saiga (A. Bekenov, personal communication).

Saiga aggregations vary in size throughout the year. Larger herds are recorded during the reproductive season, but can also be observed in other periods of the year. During the winter, large herds are better able to break through the superficial layer of snow and reach the forage they need. During the summer, large herds may offer individuals temporary relief from massive attacks by blood-sucking insects. Most importantly, large herds offer better protection and early warning against predators, particularly the wolves that are common in many regions of the Eurasian steppes.

Since the early 1980s, saiga populations have suffered from illegal poaching and trade, and from habitat degradation and other forms of environmental disturbance. The demographic effects of periodic summer droughts, occasional severe winters, the spread of some diseases and pressure of predators have been magnified by large-scale hunting with dramatic results for the majority of herds. Hunting, and particularly poaching, are connected with a demand for saiga horns for the Chinese traditional medicine market. Such trade through 'open' frontiers was a source of hard currency for a number of people involved in this illegal business. More recently in Russia, against the background of a drastic decline in livestock farming, saigas have been targeted for meat consumption, and this has added to the overall pressure on wild populations.

Now, at the beginning of the twenty-first century, the saiga's range within the northwest Pre-Caspian region has shrunk considerably. Not so long ago many thousands of herds of this unique animal moved freely across grassland habitats in the territory of the Republic of Kalmykia and the Astrakhan oblast, and they could sometimes be found in the Rostov and Volgograd oblasts. In the cold and persistent snowy winters of the mid-1980s, they were seen within 10 or 15 km of Astrakhan city. Today it is very rare to see saiga even in the remotest parts of the steppe, and thus there is a general lack of information about their migrations. The reasons for the decline are numerous, but the development of agriculture, particularly the construction of irrigation channels, had a major impact on saiga numbers and nomadic behaviour.

On the eve of the Great October Revolution, sheep comprised about two-thirds of the entire livestock population in the northwest Pre-Caspian region, followed by cattle (c. 20 per cent) and horses (c. 13 per cent). During the 1920s, the proportion of sheep grew to 74 per cent, while those of cattle and horses dropped to 16 per cent and 7.5 per cent respectively. The collectivization drive of the 1930s furthered this tendency a little, by pushing sheep numbers up, and horses down, a few per cent more. But it was during the 1960s that Kalmykia was subjected to the most dramatic changes in the structure of its livestock population since the advent of Soviet power: in just one decade, the proportion of sheep reached 85 per cent or more, while the horses sank below 1 per cent.

The unprecedented explosion of sheep in the area (a rise in the 1960s to 2 million head, over twice the population in the 1950s) soon led to forage deficits, which provoked haphazard attempts to 'improve' natural pastures by turning them into fields to cultivate more fodder. During the 1960s, Kalmykia saw over 150,000 hectares of its pastureland ploughed up in pursuit of this goal; by the early 1970s, every bit of this land had been destroyed by wind erosion, to the point of having no vegetation whatsoever. Of course, this resulted in the fragmentation of the saiga range, competition for forage with livestock and the isolation of some sub-populations.

For example, Sarpa Depression with its many lakes was a preferred site for the saiga, especially in the spring when lush ephemeral plants would grow, and was where female saiga preferred to give birth. In the early 1960s the construction of the Sarpa Irrigation Facilities largely cut them off from the area. In 1981–2, the Sarpinskaya and Chernozemelskaya irrigation systems were brought into operation. The total length of the systems is about 500 km and the area of irrigated lands amounts to about 62,000 hectares. As a result the saiga range decreased to 20,000–23,000 km^2 and the number of animals counted at that time was about 160,000–200,000 (in 1977–8 there had been 600,000–700,000).

The boom in economic reconstruction in the region was growing at a frenetic pace. In the late 1970s, the Sarpa Depression saw the launch of a new irrigation project, the Kalmyk–Astrakhan Facilities, intended to transform the area into a rice-growing region. While this huge development was rapidly devouring what was left of the saiga's favourite spring pastures, the remaining steppe tracts in the western parts of Kalmykia and adjacent provinces were turned into a uniform mass of ploughed fields, interrupted only by newly-built canals and roads. As a result, the usual summer retreats of the saiga in areas such as the Ergeni Heights and the Kuma-Manych Interfluve were practically eliminated.

Construction of the Volga–Chograi Canal, 80 km of which was 20 m deep, began in the second half of the 1980s, and also brought changes in patterns of migration routes and in saiga numbers. The impact of this huge canal, if it had been completed, would have further decreased the range and numbers of saiga. Fortunately, the construction of the canal was stopped and only the very steep slopes of the 80-km canal portion remind us of this pointless project.

The development of irrigated agriculture in these regions, coupled with the building of artificial waterways and reservoirs to 'improve' the quality of natural pastures in the drier central and southern parts of Kalmykia, affected the saiga population in a number of ways. Apart from depriving them of important habitats, irrigation facilities created additional sources of drinking water and the saiga became less likely to migrate; since they remained in the same vicinity in large numbers, the nearby pastures were increasingly overgrazed. Furthermore, an expanding network of water distribution channels (which eventually reached a total of over 1,300 km) vastly impaired their seasonal migrations. Built without heed to the animal's existence, irrigation trenches are known to have caused heavy casualties among the saiga, mostly among the newborns accompanying their mothers en route from the birth sites. In May 1977 for example, over 14,000 saiga, most of them calves only three to ten days old, were found dead along a 5-km stretch of an irrigation trench in central Kalmykia, having failed to make it through the water that was being pumped into its bed as they tried to cross it.

As the irrigation network grew more and more dense, so too did the network of transportation routes. In 1960, the total length of paved roads in Kalmykia had been a mere 100 km; by 1986, it was 1,604 km. Like canals, the roads increasingly hampered the animal's migrations and became a major cause of their decline. The Volga River had not previously been a barrier to migrating herds, which had crossed this very large river when it was frozen. Following the construction of many dams, however, and changes in the water regime, the lower stream of the river no longer freezes even during severe winters.

Our observations and interviews with local people and the staff of various conservation organizations revealed the radical changes in the migrations of the saiga population in the territory of the northwest Pre-Caspian region (the left and right banks of the Volga river). During 2002, two herds (600 and 1,000 animals) were observed migrating from Kazakhstan to the Astrakhan oblast. These two herds spent two to three days in Russian territory and later returned to Kazakhstan. Several small groups (five to ten animals) of saigas at the south part of the Astrakhan oblast were also observed.

In the northwest Pre-Caspian region, saiga concentrate at more or less safe zones: Chernyje Zemli Biosphere Reserve (Kalmykia) and the 'Stepnoi' Reserve (Astrakhan oblast). Minor movements, which can hardly be termed real migrations, have a circular character. Poaching and wild fires could very often trigger such nomadic roaming from place to place. In August 2002, for the first time in ten years, several herds (totalling more than 5,000 animals) migrated over long distances (about 150 km) from the southeast to the north. These herds returned in October 2002 but unfortunately, due to poaching, they lost a considerable number of adult males. According to data from the Department of Hunting Management, no more that 0.4 per cent of adult males survived in the European population of saiga that autumn.

In 1995 heightened international awareness of the plight of the saiga led to its listing in Appendix II of the CITES Treaty, and it was also listed in Appendix II of the Convention on Migratory Species (CMS) during the Seventh Conference of the Parties in 2002, in accordance with a proposal submitted by Uzbekistan. In 2002, the Species Survival Commission of the IUCN listed the saiga as a critically endangered species in its *Red List of Threatened Animals*.

Conservation measures are very necessary at this time and must include special protected areas for lambing and rutting dispersed throughout the entire range where the saiga migrate. Special attention should also be given to protecting the most suitable places along migration routes. Protecting the saiga habitat has been an important step in conserving Kalmykia's saiga population. In 1990, more than 90,000 ha in eastern Kalmykia were included in the Chernyje Zemli Biosphere Reserve. Three other sanctuaries with lower levels of protection were also established, restricting land use and access by motorized vehicles. These areas provide the saiga with refuge during the calving period in May, when more than 70 per cent of the European population gathers in the protected areas to give birth, and here they are relatively safe from poachers. Yet Kalmykia's existing protected areas cannot ensure that the saiga are safe, and they need to be improved. The problem is not only that they cover too small a portion of the animal's range but that they are also fixed in space, while the animals are not. Ideally, thirty times more land should be protected to safeguard the saiga's main migration routes. Highways and railroads, canals, fences, pipelines and poachers create obstacles to saiga movements, and it is absolutely necessary to establish ecological corridors between protected areas. In some cases it will be necessary to restore the previous capacity of pastures within the saiga range. Given that poaching for domestic consumption is now a major threat, anti-poaching measures should be strengthened, together with those aimed at curbing the international trade in saiga horns. Captive breeding must also be considered seriously among the many conservation actions that need to be taken to ensure the long-term survival of the saiga antelope.

To save the species, special protection should now be organized, including areas for lambing and rutting and migration routes between winter and summer grounds. Some surveys to justify the optimal scheme of saiga conservation in the Pre-Caspian region have been conducted and relevant recommendations have been passed to decision makers. Yashkul district administration special saiga breeding centre was established with support from the government of the Republic of Kalmykia. The centre now has a reasonable stock of saigas and there are preparations to release adult males into the wild.

At one time, pastures within the Chernyje Zemli ecoregion in the Republic of Kalmykia were used by large herds of livestock and of saiga. As a result of inappropriate management in the latter half of the twentieth century, these pastures have been degraded and many foci of desertification appeared in this area. It is believed that the degradation of pastures has been caused by a large number of Merino sheep which have morphological and behavioural features unsuitable for grazing on poor dryland sand pastures all year around. Many traditional breeds of livestock reared in the territory of the

Republic of Kalmykia before the Second World War disappeared during the mass deportation of Kalmyks to Siberia in 1943. As mentioned above, after 'Perestroika', when the number of livestock in pastures declined drastically, the local people turned their attention to wildlife and the resultant poaching reduced the number of saigas to a critical level.

Currently there are also attempts, supported by the Government of the Republic of Kalmykia, to restore traditional animal husbandry and some of the mutton–wool fat-tail sheep originally raised by the Kalmyks have been imported from Mongolia and China for this purpose. As previously mentioned, sheep and saigas shared the same pastures within the Chernyje Zemli ecoregion, and according to the available literature there was no competition between them. In order to preserve the saiga's gene pool, the government of the Republic of Kalmykia has given the Centre for Wild Animals of Kalmykia (one of the active partners for implementing the Darwin Initiative project) 800 hectares of land in Yashkul district (near Ermeli settlement) with good natural pastures for the construction of enclosures to start a programme of breeding saiga in captivity. The Ermeli breeding centre now has a good number of saigas of different ages, several enclosures have been fenced, a laboratory has been build and a permanent water and energy supply (including power from renewable resources) has been installed. A lot more land belonging to this centre is available for grazing and haymaking. Nearby there are some villages promoting traditional husbandry and sustainable exploitation of the saiga. Ideally, a model farm could be established that would produce (using traditional technologies) milk products, wool, meat and also handicrafts as an additional income for rural people within the saiga range.

Numerous ecotourists and groups of students/schoolchildren visiting the centre would be good customers for such products. In cooperation with the centre, and using its enclosures, it will be possible to conduct experiments on the rational use of pasture capacity by livestock and saigas to prevent in future the desertification that occurred previously. To create the model farm it will be necessary to purchase some pure-bred fat-tail sheep and Kalmyk cattle breeds, as well as equipment for producing cheese, *brynza* and other milk products, and handicraft equipment for making souvenirs from local materials. The success of the farm should encourage rural people in neighbouring areas and provide know-how to apply in their own lives in order to improve their living standards. Such combined experience of saiga breeding and traditional sheep and cattle husbandry with intensive use of fenced pastures should help both to promote saiga conservation and to provide people with additional income.

The following goals should be set:

- Promote optimal range management with use of wild animals and traditional breeds of domestic animals that are well adapted to local conditions.
- Evaluate the capacity of different pastures under different loads of saiga and livestock. The data can be used for other areas in similar condition to prevent the risk of desertification.
- Conserve the cultural heritage of the Kalmyk peoples and promote ecological education through use of traditional handicrafts for producing souvenirs, skills which are practically non-existent today.
- Help to solve the problems of unemployment and improve living standards in rural areas of the Chernyje Zemli ecoregion as the main habitat of saiga.

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30 Restorational succession on deposits

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The management of arid areas as restorable resources requires appropriate exploitation and protection. The problem that arose at the beginning of the twentieth century in the Kalmyk republic involved the increase in long-fallow lands (areas that are uncultivated for long periods). The low yield on arable areas of the bogar lands, and a decrease in fertility caused by secondary salinization of irrigated lands resulted in the increase of long-fallow lands.

According to the State Land Committee of the Kalmyk Republic, long-fallow lands occupied 10,981 hectares in January 2003 (Shanayev et al., 2003). These areas are both a potentially valuable resource and hotbeds of wind and water erosion. It is therefore necessary to study the dynamics of vegetational succession on the degraded lands. Our research studies the course of restoration succession on lands abandoned after rice growing.

The observations were carried out on long-fallow plots of various ages (from one to eleven years). The vegetation study was carried out in accordance with methods laid down by Lavrenko and Korchagin (1964). Rice (*Oryza sativa L.*) has been grown in the northern part of Kalmykia for about forty years. In the early years its yield reached 50–60 c/ha, but later decreased to 30–40 c/ha due to secondary salinity and a deterioration in the quality of the irrigation system. Consequently, part of the rice-growing area was abandoned.

Studies of the floral composition of long-fallow lands showed that in the first years of non-cultivation the vegetation was composed of: *Atriplex tatarica, Poligonum pseudoarenarium, Phragmites australis* and *Bolboschoenus maritimus*. By the fifth year these species had been replaced by annual halophytes: *Bassia sedoides, Petrosimonia oppositifolia* and *Salsola australis*. These in turn were followed by *Tamarix ramossisima* and *Artemisia santonica*. This pattern of species dynamics is perhaps a result of the increasing salinization of the upper soil horizon along with the rise in mineralized ground waters.

Thus the composition of living plant forms in long-fallow lands changes over time, producing phytocenoses. Root perennials and annuals prevail in the vegetation during the first years. Gradually the proportion of perennials increases, and then come semi-shrubs and shrubs. To determine the trend of succession we compared the received data with findings from geobotanic studies of the adjoining long-fallow plots in the area. Whereas *Artemisia lerchiana* dominates the vegetation associations in virgin lands, *Artemisia santonica* prevails in the old long-fallow lands.

The research showed that the species composition of vegetation associations on the long-fallow lands after rice growing stabilizes by the fifth year of non-cultivation. The tendency over time is towards an increase in the proportion of perennial, grassy, long-vegetating species, brushes and under-shrubs. The crop capacity of above-land mass tends to fluctuate in a way that is linked to the change in the phytocenoses' composition of dominants; it varies between 8 and 16 c/ha of air-dry mass in summer and autumn.

A comparison of long-fallow land vegetation with a geobotanic map of adjacent areas demonstrates that restoration of long-fallow lands is occurring, but they are not reverting to the original vegetation. The appearance of species adapted to greater salinization is noted in these areas. The study of succession dynamics in these areas will demonstrate the course of their formation and make recommendations about how to include them once more in the agricultural process of various qualities. They may be restored as arable lands, pastures or hay-producing meadows through a preliminary optimization of their conditions.

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31 Tolerance of soils in conditions of desertification

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The geographical position of Kalmykia, in the southeast of European Russia between 44°50' and 48°10' E, and 41°40' and 47°35' N, defines the nature of its features: a sharp, continental, semi-arid and arid climate, which is the principal cause of the sub-boreal dry steppe and semi-desert. Its territory covers 76,000 km^2, 70 per cent of which comprises natural pastures, 14 per cent is slough lands, and 0.7 per cent is hay pasture. This ratio demonstrates the need to preserve the remaining natural soils and ecosystems.

Most of Kalmykia's territory is used as natural fodder lands and for stock-breeding. The basic types of pasture landscapes include: pre-kaspian young alluvial–sea liman plain with *Artemisia pauciflora, Artemisia lerchiana* and *Festuca valensiaca*; *Stipa lesingiana* semi-deserts on brown semi-desert soils, solonetzs and solonchaks; Chernozemelsk ancient delta sandy plain with *Artemisia lerchiana*; *Agropyron sibiricum* and *Cochia prostrata* deserts on under-developed brown sandy and sandy loam soils; Ergeninsk erosive–elevative plain with *Artemisia lerchiana*; *Stipa lesingiana*, *Festuca valensiaca* and *Artemisia Lerchiana* steppes and semi-deserts on brown solonetzs in combination with light chestnut and solonchaks.

During the past forty or fifty years, pressure on the environment has increased sharply due to the irrational use of nature: the destruction of natural ecosystems, the decrease in biodiversity and the progression of desertification. The southeastern part of European Russia is witnessing desertification processes that are enveloping large areas in the region. As a result of desertification in Kalmykia, several forms of natural ecosystems imbalance have become manifest, including the impoverishment of species and population diversity, and a decrease in the resilient potential and effective functioning of those species. The disruption of the natural balance in pasture landscapes, intensified by anthropogenic factors, has caused an alteration of structure–function relations that were formed in the process of their evolution. Soil exploitation has reached such a level that degradation can be now be characterized as an ecological menace; the question of soils and their conservation has become one of the main theoretical and practical problems that we must study, understand and confront.

Desertification has taken over wide areas of pastureland in Kalmykia, leading to a clearly evident transformation of the morphological soil structure and an alteration of the character of the soil–space organization. This in turn affects the condition of territory's biological and landscape diversity.

The intensity of modern anthropogenic pressure in Kalmykia has caused widespread damage to soil and plant cover in the landscapes. These processes lead to the destruction of the ecological functions of the soils and cause biodiversity impoverishment and a reduction of the natural ecosystems' resistance. It has been observed that the resistance of dry steppe landscapes to such influences is greatest on loamy soils and lowest on sandy complexes with low indices of humidity. This instability is linked with their light granule-metrical composition and liability to processes of higher horizon degradation. It is important to emphasize that the greatest degree of natural equilibrium disturbance in pasture ecosystems occurs on soils of light granule-metrical composition.

Under these conditions, it is crucial that we identify critical points in the development of the whole dynamic natural complex of the region, monitor the condition of separate links in the ecological–dynamic chain, and make accurate estimates of permissible loads. Thus, in order to counter these problems, we are reliant on the elaboration of complex measures that can mitigate the destructive effects of anthropogenic pressure.

To maintain equilibrium in the region, it will be necessary to regulate economic activities in addition to restoring affected geosystems and protecting territories of different classes. The creation of representative landscape reserves or protected areas will help solve the problem of conserving the territory's natural diversity under conditions of desertification. The availability of key soil structures in the system of biosphere reserves will support ecosystem resilience, for the attributes of soil are well known to be central to ecological connections and the maintenance of the substructure of the biosphere. Soil stability and conservation are among the major theoretical and practical problems in combating desertification.

The studies of the ecological functions of soils elaborated by M.V. Lomonosov of Moscow State University show the exceptional role of soils in the processes of functioning, maintenance and conservation of various ecosystems. These processes are promoted by particular soil conservation activities as part of a trend towards nature-conservation. The question of conserving soil diversity is entwined with the problems of conserving biological and landscape diversity. For biodiversity conservation to be achieved, a network of soil protection measures inside the system of biosphere reserves is essential. There we must develop methods of using resources that will provide for the natural evolution of ecosystems.

Kalmykia's nature parks cover a total area of 1,336,000 ha (20 per cent of the territory of the republic), including Chernyje Zemli (the 'Black Lands') Biosphere Reserve, two National Parks and thirteen reserves, most of which are multi-functional and do not act as complex representative landscape reserves. The recently published *Red Book of Soils and Ecosystems of Kalmykia* recommends the inclusion of soil areas in the general system of priority for protected territories. (Thirty-nine ecological inventories of important soil structures have been compiled.) Maximizing different forms of soil cover protection under conditions of anthropogenic desertification will provide an area of natural biodiversity conservation.

The key objective in the conservation of soils and natural ecosystems is to protect and rehabilitate natural, high-productive and key soils. This goal includes the protection of typical virgin soils as well as the preservation of protected territories with unique ecosystems. It involves special measures of surveillance for utilization and protection. Where necessary it must entail preventing economic exploitation of rare, key soils, as well as systematically codifying the status of soil reserves.

If we are to preserve biodiversity, it is necessary to restore natural conditions and rehabilitate the biota. This can be achieved by setting up protected areas and carrying through the project laid out in the *Red Book of Soils and Ecosystems of Kalmykia*. The principal emphasis in the system of measures for protecting and restoring soil is given to soil monitoring. The project cannot be managed without first obtaining indexes of the key soils while maintaining their eco-genetic connections with all the components of the landscape. This is the idea behind the soil-ecological certificate areas for key, rare and unique features of Kalmyk soils and ecosystems, a scheme that will form a potential network not only for soil monitoring but for monitoring territories. The essence of the question lies in a complex approach to the whole ecosystem, in which soil plays the principal role of the biosphere.

Thus the inevitable, critical situation in the desertification process in the region demands new scientific deliberations directed at the conservation of genetic diversity, surveillance of the dynamic equilibrium, and stable development of natural ecosystems.

Workshop report

Conclusions and recommendations

1. Scientists, conservation experts and government officials from ten countries (Azerbaijan, Egypt, India, Islamic Republic of Iran, Jordan, Mongolia, Morocco, Russian Federation, Sudan and Turkmenistan) as well as representatives of the FAO and UNESCO met in Elista, Republic of Kalmykia (Russian Federation), from 23 to 27 June 2004 for an international workshop on 'Traditional Knowledge and Modern Technology for the Sustainable Management of Dryland Ecosystems'. The workshop was organized by the Russian National Committee for the UNESCO Man and the Biosphere (MAB) Programme and the Republic of Kalmykia under the auspices of and with support from the UNESCO–MAB Programme.
2. The workshop addressed issues concerning the sustainable management of dryland ecosystems using traditional knowledge and/or modern technology. Article 18 (on traditional knowledge) of the United Nations Convention to Combat Desertification (UNCCD) and Decision 16/COP 6 on Traditional Knowledge, adopted at the 6th Conference of the Parties (COP 6) of the UNCCD, provided the background for the deliberations of the workshop. This decision:

   > Invites the Parties through their national focal points to involve relevant governmental and non-governmental organizations, research institutions and local and indigenous communities in formulating views on how traditional knowledge can contribute to fulfilling the objectives of the Convention, and especially on the elements proposed for establishing a network on traditional knowledge to combat desertification.

3. During the workshop, case studies on traditional knowledge and modern technology for the sustainable management of dryland ecosystems were presented by the country representatives of national MAB Committees. A one-day field trip to the transition zone of the Chernyje Zemli Biosphere Reserve in Yashkul District further enriched the workshop programme.
4. In essence, workshop participants came to the following conclusions and recommendations:

a) Workshop participants considered that traditional knowledge (TK) was a function of time and space: TK is a dynamic system that evolves over time; the preservation of TK should be practised *in situ* where it has originated.

b) Workshop participants recognized the importance of TK for the sustainable development of dryland ecosystems and for combating desertification, so as to enhance livelihoods and to contribute to poverty reduction. They felt that there was a need for the preservation, promotion and perpetuity of such knowledge, considering that TK makes use of environmentally-friendly and low-cost technologies.

c) Workshop participants also recognized the plethora of knowledge owned by custodians of TK, which provides a valuable source of information for sustainable dryland management.

d) Workshop participants further recognized the importance of modern technology (MT) in managing dryland ecosystems sustainably in the light of the progress that modern science has made for the benefit of dryland management. Many examples were provided at the workshop of the ways in which TK can benefit from MT, such as: the use of remote sensing with satellite imagery; the use of GPS and GIS to enhance dryland management and planning, in particular for dryland crops, pastoral land use and wildlife habitat management; or floodwater spreading for the artificial recharge of groundwater.

e) Workshop participants recognized the need for an integration of TK and MT, which ideally would lead to 'appropriate and adaptive technology' (AAT), and which should be accessible to and affordable by low-income populations of drylands.

f) The World Network of Biosphere Reserves under the UNESCO–MAB Programme was considered an appropriate tool to carry out research on TK and MT through the biosphere reserve integrated concept of environmental conservation, sustainable development and the use of applied science to study human–environment interactions.

g) Biosphere reserves in dryland areas should become the privileged dryland monitoring and testing sites for integrated research on TK and MT, as information exchanges among scientists working in this field can be facilitated through the World Network of Biosphere Reserves. The establishment of a thematic network of dryland biosphere reserves that combine the use of TK and MT in their management should be considered.

h) The workshop participants invited UNESCO to advocate the use of TK, MT and in particular AAT. UNESCO should also encourage studies of indigenous knowledge (IK), as carried out by several scientific disciplines including the social sciences and geography.

i) Relevant colleges (in particular in the fields of agriculture, forestry and animal production) should include TK and MT in their curricula for sustainable land use of dryland ecosystems.

j) Research on TK and its integration with MT for the sustainable land use of drylands should be given due priority in national research systems.

k) When considering research and promotion of TK and MT, it is important to take into account the different roles of men and women with regard to knowledge and technology, and their different relations with the environment.

l) In the light of internationally agreed-upon multilateral conventions, in particular the UNCCD and the CBD, workshop participants recommended that TK should be studied through scientific means that would encompass the following steps and principles:

i TK should be documented through national inventories of existing TK.

ii TK should be scientifically validated, if possible, under controlled conditions and using field experiments.

iii In this way, modern science would be greatly enriched through the wealth of available but largely undocumented TK.

iv It is understood that scientists would only document and validate TK with the explicit consent and approval of the custodians of TK.

v Scientists working on TK will seek prior informed consent from its custodians in research work focusing on TK.

vi As is the customary practice in any serious scientific research, it must be recognized that TK is received from the custodians and that they are its source, so that any benefits deriving from the use of TK will be given to such custodians.

vii In order to ensure that benefits from TK will benefit its custodians, scientists must also involve the government-appointed national focal points of MAB National Committees, UNCCD, CBD and plant variety protection legislation.

viii With regard to research work on TK, participatory approaches are needed, involving local communities, NGOs, CBOs, indigenous people's organizations, custodians of TK, scientists and government officials.

Workshop agenda

The workshop will include thematic (oral and poster) presentations on traditional knowledge and modern technology, focusing on three different economic and environmental problems of drylands: those of agricultural systems, pastoral systems, and wildlife management systems. Specific examples of traditional knowledge/ modern technology from biosphere reserves and similarly managed protected areas will be highlighted. The presentations and workshop discussions will be in English only.

23 June 2004 (Wednesday)

19:30	Arrival of international workshop participants in Elista (capital of the Republic of Kalmykia)
20:00	Accommodation of participants in the City-Chess
21:00	Dinner

24 June 2004 (Thursday)

8:00–8:40 Breakfast

9:00–9:30 Registration of workshop participants in the Hall of the Chess Palace

9:30–10:40 *Opening session*. Chairperson: Mr Valery A. Akuginov, Deputy Prime Minister, Government of the Republic of Kalmykia

Welcome addresses:

- President of the Republic of Kalmykia, Mr Kirsan N. Ilumzhinov
- Chair of the Southern Research Centre of RAS, academician Mr Gennadiy G. Matishov
- People's poet of Kalmykia, Mr David N. Kugultinov
- Representative of the UNESCO-Moscow Office, Mr Uli Graebener

Key note address:

- Mrs Nina G. Ochirova – Traditional knowledge as a factor of the ecological consciousness: formation and conservation of the environment. The Republic of Kalmykia experience
- Video film – 'Cultural and natural features of the Republic of Kalmykia'

Poster presentations:

T. Basangova (Ecological traditions of the Kalmyks); *D. Sharmandzhiev* (The cult of mountains and ecological ideas in the epos 'Dzhangar'); *S. Batyreva* (An ecological aspect of the Buddhist iconography); *L. Namrueva* (Nature-preserving aspects of ethnic culture); *E. Omakaeva* (Folk knowledge in the life-support system of the Kalmyk ethnos); *K. Natyrova* (Traditional knowledge in the Kalmyk Republic as a basis for the development of ethnoeconomics); *K. Nastinova* (The role of Kalmyk traditional nutrition in preservation of health)

10:40–11:00 Coffee/tea break

11:00–13:00 Session 1: *General problems and management of agricultural systems*. Chairperson: Dr Valery M. Neronov, Russian MAB Committee

- Dr Thomas Schaaf – Traditional knowledge and modern technology for the sustainable management of dryland ecosystems: UNESCO's objectives for the workshop
- Dr David Boerma – Local knowledge systems and the management of dryland agro-ecosystems
- Dr Mohammed A. Kishk – Poverty of the environment and the environment of poverty: constraints on adopting modern technology and promoting traditional knowledge in combating land degradation and poverty
- Dr Sayyed A. Kowsar – Re-inventing the wheel: floodwater management for rehabilitation of degraded lands
- Dr Bekdjan A. Tashmuhamedov – Modern biotechnology and problems of secondary salinization of irrigated lands

Poster presentations:

N. Kurepina (Optimization of agrarian use of nature); *G. Nastinova* (Ecological restoration and increase of productivity of degraded arable lands); *R. Djapova, O. Okonova* (Restorational succession on fallow lands); *L. Tashninova* (Tolerance of soils in conditions of desertification); *E. Dedova* (Phytomelioration of saline lands in Kalmykia); *S. Ulanova* (Inland water reservoirs of Kalmykia); *M. Sazanov* (Oasis-type hydro-meliorative systems under Kalmyk conditions); *M. Sazanov, S. Adiayev* (Effects of trickle irrigation).

13:00–14:30 Lunch

14:30–16:30 Session 1: *Continued*. Chairperson: Dr Thomas Schaaf, UNESCO-MAB Secretariat

- Mrs Veena Upadhyaya – Traditional knowledge and modern technology for sustainable development of dryland ecosystems: the Indian experience
- Dr Mukhtar A. Mustafa – Traditional knowledge and technology transfer for sustainable agriculture development in the Sudan
- Dr Mageram P. Babayev – Management of degraded soils processes in Azerbaijan by traditional methods
- Mrs Boshra Salem – Omayed Biosphere Reserve and its hinterland: results of the UNESCO-UNU-ICARDA project

16:30–16:45 Collective photo of the workshop participants

16:45-18:00 Visit to Elista city administration

18:00–20:00 Walking and bus tour of Elista and its suburbs

20:30 Dinner

25 June 2004 (Friday)

8:00–8:40 Breakfast

9:00–10:30 Trip to the Yashkul administrative district of the Republic of Kalmykia

10:30–12:00 Meeting with the district's administration and looking at exhibits on the use of modern technologies for sustainable management of dryland ecosystems

12:00–12:45 Visit to Yashkul gymnasia and its Ecological museum

12:45-14:00 Trip to the 'Kirovskyi' agriculture cooperative, which specializes in traditional livestock breeding

14:00–15:00 Lunch

15:00–16:30 Participation in the Kalmyk traditional ceremony 'Worship of water and land'

16:30–18:30 Visit to the Yashkul Saiga Antelope Breeding Centre

18:30–20:00 Return trip to Elista

20:30 Dinner

26 June 2004 (Saturday)

8:00–8:40 Breakfast

9:00–10:40 Session 2: *Traditional knowledge and modern technology in pastoral systems*. Chairperson: Mrs Irina Springuel, UNESCO Ecotechnie Chair, South Valley University, Egypt

- Dr German Kust – Space imagery processing for land use and rehabilitation of ecosystems in desertifed conditions
- Dr Chary Muradov – Traditional and modern technologies for sustainable development of Turkmenistan
- Dr Baktybek Taubaev – Pastoral stock-raising as an instrument for traditional land use in arid territories
- Mrs Baast Oyungerel – Integration of traditional knowledge and modern technologies for the sustainability of dry land ecosystems in Mongolia

Poster presentations:

N. Tzagan-Mandzhiev (Our experience in combating desertification in 'Chernye zemli'); *B. Gol'dvarg* (Major principles of creating fodder reserves under conditions of market relations); *R. Djapova, Z. Sankuyeva, N. Kenzeyeva* (The effects of constructing linear structures on pasture ecosystems); *B. Taubayev* (Rational use and protection of sand pastures of West Kazakhstan)

10:40–11:00 Coffee/tea break

11:00–13:00 Session 3: *Traditional knowledge and modern technology for wildlife management systems*. Chairperson: Mr Uli Graebener, Moscow UNESCO office

- Mrs Irina Springuel – Indigenous knowledge of plant uses in arid lands: Wadi Allaqi case study
- Dr Ahmad El-oqlah – Traditional knowledge and practical techniques for combating desertification in Jordan
- Mrs Davaa Narantuya – Natural resource

management in the Great Gobi Strictly Protected Area in Mongolia

- Dr Abdelhafid Hamchi – Conservation of forests in the Mediterranean zone of Algeria
- Dr Andrey Bogun – The biodiversity of agroforest landscapes of Kalmykia

Poster presentations:

N. Shamsutdinov (Halophytes of natural flora and their use for breeding and phytomelioration of degraded pasture systems); *V. Badmaev, B. Ubushaev* (Chernyje Zemli Biosphere Reserve and its role in the conservation of biodiversity in dryland ecosystems); *N. Lebedeva, R. Savitsky* (Problems of conservation and monitoring of biodiversity in dry steppe areas around Lake Manych-Gudilo); *Yu. Arylov, A. Lushchekina* (The saiga antelope in the drylands of Russia and how to ensure its sustainable future); *O. Romanov* (The comparative analysis of horn properties and their composition)

13:00–14:30	Lunch
14:30–17:00:	General discussion and adoption of recommendations on traditional knowledge and modern technology in dryland management
17:00–18:00	Press conference of the workshop participants for local mass media
18:30–19:30	Folklore concert in the State Concert Hall of Elista
20:30	Dinner

27 June 2003 (Sunday)

8:30–9:30	Breakfast
10:00–13:00	Visit to the Kalmyk Institute of Humanities Research and its library and museum (coffee/tea will be served)
13:00	Departure of international workshop participants to Elista airport

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Acronyms

AAT appropriate and adaptive technology
AFRI Arid Forest Research Institute
ARC Agricultural Research Corporation (Sudan)
ARG artificial recharge of groundwater
ARUW artificial replenishment of underground water reserves
CAZRI Centre for Arid Zone Research Institute
CBD Convention on Biological Diversity
CBO community based organization
CITES Convention on International Trade in Endangered Species
CMS Convention on Migratory Species
CST Committee on Science and Technology (of UNCCD)
DDP Desert Development Programme (India)
DPAP Drought Prone Areas Programme (India)
EABRN East Asian Biosphere Reserves Network
FAO Food and Agriculture Organization
FOI fine-outline irrigation
FWS floodwater spreading
FWS floodwater spreading schemes (Iran)
GEF Global Environment Facility
GGSPA Great Gobi Strictly Protected Area
GIAHS globally important ingenious agricultural heritage systems
GIC association of irrigation (Gafsa oases)
GIS geographic information system
GPS global positioning system
GTM Generative Topographic Mapping
GTZ Deutsche Gesellschaft für Technische Zusammenarbeit (a German Government Development Agency)
HMS hydro-meliorative systems
ICARDA International Center for Agricultural Research in the Dry Areas
IGF International Foundation for the Conservation of Wildlife
IGFRI Indian Grassland and Forage Research Institute
IK indigenous knowledge
IMF International Monetary Fund
INTAS International Association formed by the European Community (preserves and promotes the valuable scientific potential of NIS partner countries through East–West Scientific cooperation)
IPPM integrated pest and plant management
ISDC Interstate Sustainable Development Commission (Aral Sea basin)
IUCN World Conservation Union
LHF Large Herbivore Foundation
MAB Man and the Biosphere Programme
MT modern technology
NAPCD National Action Programme on Combating Desertification (Turkmenistan)
NES nitrogen-free extractive substances
NIDFF National Institute of Deserts, Flora and Fauna (Turkmenistan)
NOAA National Oceanic and Atmospheric Administration
PRA participatory rapid/rural/relaxed appraisal
PTES People's Trust for Endangered Species
RAS Russian Academy of Sciences
RBRF Russian Basic Research Foundation
RECCA Regional Environment Centre of Central Asia
ROSTE Regional Bureau for Science in Europe
RS remote sensing
SIC ISDC Scientific Information Centre of the ISDC
SLUAM sustainable land use and management
SMRF semi-mechanized rain-fed agriculture
SPA strictly protected area
SUMAMAD Sustainable management of marginal lands
TDR time-domain reflectometry
TEK traditional ecological knowledge
TEM transmission electron microscopy
TF traditional farming
TFKAT traditional farming knowledge and technology
TI traditional irrigated agriculture
TIK traditional indigenous knowledge
TRF traditional rain-fed agriculture
UNCCD United Nations Convention to Combat Desertification
UNDP United Nations Development Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
UNSO Office to Combat Desertification and Drought (UN specialized agency)
UNU United Nations University
USAID US Agency for International Development
VIR N.I. Vavilov All-Russian Research Institute of Plant Industry (collection of plant genetic resources)
VNIIGiM All-Russian Scientific Research Institute of Hydraulic Engineering and Land Reclamation
WABR Wadi Allaqi Biosphere Reserve
WCED World Commission on Environment and Development
XRD x-ray diffraction