GB
618.88
R8
C6
1982
sl



UNIVERSITY OF ARIZONA LIBRARY
3 9001 04966 8968

TIC ROGRAMME /UNEP/

USSR COMMISSION FOR UNEP

COMBATING DESERTIFICATION IN THE USSR: PROBLEMS AND EXPERIENCE

CENTRE OF INTERNATIONAL PROJECTS GKNT MOSCOW

И. С. Зонн, В. Н. Николаев,
Н. С. Орловский, И. П. Свинцов

ОПЫТ БОРЬБЫ
С ОПУСТЫНИВАНИЕМ В СССР

Ответственный редактор
член-корреспондент АН СССР
А. Г. Бабаев

ИЗДАТЕЛЬСТВО «НАУКА»
МОСКВА

UNITED NATIONS ENVIRONMENT PROGRAMME /UNEP/

USSR COMMISSION FOR UNEP

COMBATING DESERTIFICATION IN THE USSR:

PROBLEMS AND EXPERIENCE

CENTRE OF INTERNATIONAL PROJECTS GKNT MOSCOW 1982

First published 1982
Revised from the 1981 Russian edition

Consulting Editor – A. G. Babaev, Corresponding Member of the USSR Academy of Sciences

На английском языке

© Издательство «Наука», 1981
© Published by USSR/UNEP Publications and Information Support Project

CONTENTS

Foreword 7
Introduction 9

Chapter I. Natural Conditions of Deserts in the USSR and Desertification Processes, *N. S. Orlovsky* 10
Natural Conditions and Types of Deserts 10
Desertification Processes 27

Chapter II. Desertification: Its Mechanism and Implications, *N. S. Orlovsky* 30
Natural Factors of Desertification 30
Anthropogenic Factors of Desertification 36
Indicators of Desertification 52

Chapter III. Experience of Development and Rational Management of Desert Rangelands, *V. N. Nikolaev* 55
A Brief Case-History of Desert Range Utilization 55
System of Measures Towards Rational Desert Range Management 63

Chapter IV. Irrigation Development of Deserts and Amelioration of Irrigated Lands, *I. S. Zonn* 75
Irrigated Farming Development in the Desert Zone of the USSR 75
Integrated Approach to Desert Reclamation 83
Ecological Implications of Irrigation 85

Chapter V. Reclamation of Sands by Afforestation, *I. P. Svintsov* 91
Production Management in Reclamation by Afforestation . . . 91
Afforestation as a Method of Shifting-Sand Reclamation in the European USSR 93
Case-History of Shifting-Sand Fixation and Afforestation in the Deserts of Central Asia 96

Conclusion 112
Literature 114

FOREWORD

The past decade has seen mounting concern about the progress of desertification, and combative measures have moved high on the list of problems associated with environmental protection and have acquired global significance. UN statistics have assessed that between 50,000 and 70,000 sq.km of fertile lands annually become unsuitable for utilization mainly due to desert encroachment.

Deserts take up as much as 14 per cent of the territory of the USSR, and the wealth they contain is a valuable economic potential. At present considerable resources of oil, natural gas, coal, sodium sulphate, phosphorites, bromine and iodine, potassium and table salts and other minerals are extracted from these deserts.

Irrigated areas in desert regions, covering 3 per cent of their surface, provide up to a third of the fiber crops cultivated in the USSR, including all the cotton, 77 per cent of the raw silk, over 17 per cent of vegetable oil, as well as great quantities of fruit, grapes and melon crops. Sheep flocks in the desert provide the country's output of Karakul pelts. The harmonious development of industry and agriculture under developed socialism made it possible to transform the former desert regions into flourishing oases, to build large cities and industrial centres, to connect them with communication lines, to construct hydropower stations, reservoirs, large canals furnishing the irrigation and water supplies of the desert regions.

An event of paramount significance, which laid the basis for desert reclamation in the USSR on socialist principles was the historic decree of the Soviet Government "On Allocation of 50 Million Rubles for Irrigation Developments in Turkestan" signed by V. I. Lenin on May 17, 1918. Notwithstanding the great hardships of that period considerable investments were allotted for irrigation developments in the Golodnaya Steppe, now the central area of cotton growing.

"What you need most is irrigation," wrote Lenin, "for more than anything else it will revive the area and regenerate it, bury the past and make the transition to socialism more certain."* The achievements attained in developing desert territories – Golodnaya Steppe and other regions in the republics of Soviet Central Asia, Kazakhstan and Azerbaidzhan – have proved confirmed Lenin's prophecy.

---

* V. I. Lenin, *Collected Works,* Progress Publishers, Moscow, Vol. 32, p. 318.

Desert development in Ferghana, Golodnaya Steppe and Karshi Steppe, the Kara Kum canal zone and other regions encompass territories with differing natural conditions. Irrigation, the water supply of rangelands, an integrated approach to economic development, the establishment of conditions to ensure rational natural resource management are all key issues in the development of these territories.

Much importance is also attached to social aspects – ensuring general well-being, the necessary everyday amenities, establishing a system of cultural, health-service enterprises, etc., and are all taken into consideration in regional planning. Oases and newly developed regions in deserts comprise single territorial-production complexes.

The objectives for the integrated development of desert regions are realized within the framework of capital construction programmes. They are included in the medium- and long-term plans for economic development of regions, union republics and the Soviet Union as a whole. Their implementation highlights the problem of taking into account the requirements of rational nature management and environmental protection.

It should be emphasized that desert reclamation is a complicated and responsible task even with the scientific and technological revolution. On the one hand, it requires considerable capital investment, specialized approach, the application of appropriate methods and techniques, and on the other, it demands rigorous attention to environmental protection problems, the improvement of the ecological situation, the scientifically-based forecasting of any adverse effects caused by man's interference with the established balance in the environment. Special attention should be paid here to the high instability and vulnerability of desert ecosystems. Arid biogeocenoses are fragile and may be easily destroyed by man's interference, but their restoration is a much slower process. The constant improvement of land use in order to attain its most rational forms, and the application of special measures, are needed to preserve the deserts under conditions of intensive economic activity.

The present stage in desert reclamation and desertification combat concentrate on improving the methods and technologies of rational nature management, methods of forecasting changes in the natural conditions and processes, developing a scientific basis for managing economic activity concerned with the utilization and rehabilitation of natural resources.

A. G. Babaev, Corresponding Member
of the USSR Academy of Sciences

INTRODUCTION

The principal conditions and targets in desertification combat are associated with the organization of rational nature management, which, in its turn, requires a constant extension of our knowledge of the natural peculiarities and resources of deserts, of methods for their development and improvement, the working out of techniques and technologies of natural resources' use considering the requirements of nature conservation.

When planning and implementing works to be carried out in desert regions particular account should be taken of such specific features of desert landscapes as their fragility, their highly vulnerable structure and the difficulty of restoring the ecological balance. Such an approach makes it possible to reveal the factors contributing to, and manifestations of desertification in time so as to prevent and compensate for damage that has occurred.

The present book is an attempt to pool the experience accumulated in the Soviet Union in the course of research and development of new regions in the arid zone.

The book may be conventionally divided into two parts. The first part tackles the natural conditions of deserts in the USSR and desertification processes (Chapter I), the mechanism of desertification and its implications (Chapter II). The classification of natural and anthropogenic factors contributing to desertification are given and some indicators of desertification processes are discussed.

In the second part the desertification problem is approached from the viewpoint of practical activity in various economic sectors. Experience gained in this respect indicates the relationship between desertification problems and the improvement of methods of desert reclamation and the organization of nature management.

The following scheme was adhered to by the authors in writing this book: (a) natural specific features of arid regions; (b) conditions of economic activity in a particular sector; (c) possible manifestations of desertification; (d) ways of improving the organization and methods of nature management in order to enhance the efficiency of economic sectors, to identify and prevent desertification.

Desertification problems in arid regions are multifarious and involve various economic sectors. The present book does not claim a full coverage of all the problems. But the authors hope that it will be useful for a wide range of specialists engaged in the study and development of arid territories.

CHAPTER I

NATURAL CONDITIONS OF DESERTS IN THE USSR AND DESERTIFICATION PROCESSES

Deserts in the USSR are mostly met in Central Asia and South Kazakhstan. They cover large expanses from the Caspian Sea in the west to the foothills of Dzhungarski Alatau, Tien Shan and Pamir-Alai in the east and south-east (Petrov, 1973). Their northern boundary runs along the latitude 48°N., thus, coinciding with the southern confine of light chestnut soils and isohyet 180 mm of the average annual precipitations (Fedorovich *et al.*, 1963), and the southern one – along the foothills of the Kopet-Dag and Paropamiz.

This vast territory extending for 1,500 km from north to south and for over 2,500 km from west to east encompass such sand deserts as Kara Kum, Kyzyl Kum, Muyun Kum, Sary-Ishikotrau, Sundukli, near-Aral Kara Kum, Volgo-Urals sandy areas and other, somewhat smaller ones. Some 45 sandy areas covering 336,000 sq. km in total are found only in Kazakhstan (Kurochkina, 1978). Apart from this great expanses are occupied by the crushed-stone gypseous desert of Ustyurt in the north-west and the Betpak-Dala stony desert in the north; a narrow belt of loess deserts stretches along foothills, and solonchak deserts are met only as separate inclusions (Fig. 1).

Natural Conditions and Types of Deserts

Deserts are found in lowlands and on plains whose elevations are ranging from −28 m at the shores of the Caspian Sea and −129 m in the Karagie depression and to +300, or +400 m on the residual uplands. Flat expanses represented mainly by the Turanskaya lowland are intersected by chains of hills and residual uplands: Sultan-Wizdag (485 m), Bakantau (758 m), Tamdytau (888 m), Kuldzhuktau (784 m) as well as mountain ranges of Karatau (2,176 m) and Nuratau (2,169 m) connected with the Tien Shan Mountains.

On the south the Turanskaya lowland comes up directly to the Kopet-Dag mountain system: Greater Balkhan (1,880 m), Lesser Balkhan (774 m), Kyuren-Dag and Paropamiz, on the north-west and north it merges with the highly dissected Krasnovodskoye plateau with an average elevation equalling 220 m and the vast hillock

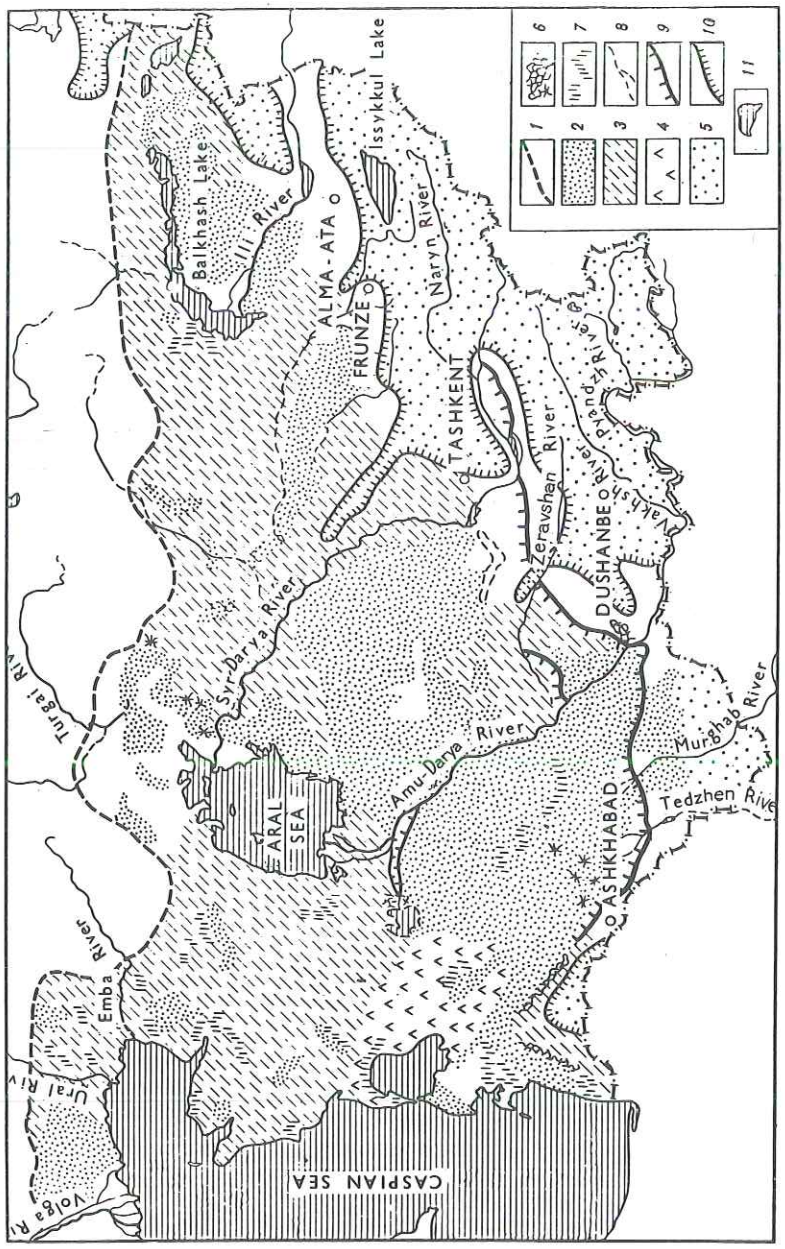


Fig. 1. Schematic map of deserts in Central Asia:
1 – northern boundary of deserts; deserts: *2* – sand; *3* – clay; *4* – gypseous; *5* – loess; *6* – takyr; *7* – solonchak; *8* – intermittent and dry channels; *9* – main canals; *10* – mountain regions; *11* – seas and lakes

Ustyurt plateau, 150 to 230 m high, and on the north-east – with the Turgaiskaya and North-Kazakhstan hillock plains.

V. L. Schultz (1965) defined desert territories of Central Asia as the areas of dissipating runoff originated in the mountains. About 96 mm of precipitations and 201 mm of water as runoff from mountains, received here, got completely lost to evaporation on the flat expanses.

A river network is poorly developed here. Many rivers are lost in sands forming dry channels and deltas or their water is taken for irrigation. Only two largest rivers here – Amu-Darya and Syr-Darya – traverse sand deserts and bring their water to the Aral Sea. On the south-west the Atrek River inflows the Caspian Sea and on the north-east the Ili and Karakol Rivers inflow the Balkhash Lake.

The drinking water supply and pasture water supply in deserts mainly rely on groundwater and intermittent surface runoff. Groundwaters are met here everywhere; in the western regions their high salinity renders them unfit for water supply, and in the eastern regions fresh and slightly saline groundwaters prevail.

Natural conditions reigning in desert regions (high soil permeability, low precipitations and high air temperatures) do not favour the formation of a sizable surface runoff. However, artificial water-impermeable sites or natural takyr watersheds may help to provide from 5,000 to 35,000 cu.m of rain water from a square kilometre for a year (Leshchinsky, 1974). To put these water resources to most advantage in economic activity and at a scale approaching the average annual runoff, the need is to ensure a sound flow regime regulation by storing water in subsurface collectors. This will enable, when necessary, to create artificially fresh groundwater supplies which are to meet the needs of the distant-range animal grazing (Leshchinsky, 1974).

The inland geographical location, considerable extension both laterally and longitudinally, the presence of mountains in the south, south-east and east, openness in the north – all these factors contribute to the climate continentality and aridity here. The specific features of climate in Central Asia and Kazakhstan are given a thorough study and in-depth analysis in the works by Babushkin (1964), Balashova *et al.* (1960), Balashova *et al.* (1961), *Climate of Kazakhstan* (1959), Semenova (1961), Chelpanova (1963), Chetyrkin (1960), and others. That is why it will be appropriate to name but few most general features inherent to the local climate.

All the deserts in the region under study are confined to the arid zone. The latitudinal zonality and the specific circulation regime in the atmosphere are, however, responsible for great differences between the climate in the north and in the south, both in cold and warm seasons.

In the cold season the northern part of the territory is affected by the winter Siberian anticyclone, which brings severe and long winter with continuous frosts and protracted snow-cover periods in most years. In the southern part winter is predominantly mild, with

unstable snow cover and frequent fluctuations of air temperature around 0°C.

Probing into the specificity of vegetation conditions in a winter season, V. M. Chetyrkin (1960) collated the meridian mean air temperature variations in January from Belebei to Mary. The obtained results have indicated that between the latitudes 41°N. and 44°N. drastic changes in the gradient of a temperature increment per one grade occur. He attributed it to the fact that Siberian and Polar air flows seldom move below the latitude 45°N., likewise warm tropical air masses rarely reach Central Kazakhstan.

Circulation peculiarities govern to no less degree the precipitation regime. In the cold season the Iranian branch of the polar front drifts over the Kopet-Dag and Paropamiz Mountains and gives rise to intensive cyclonic activity reaching its maximum in the late winter and in spring (Bugaev, 1961), and having a direct bearing on the distribution of precipitations, this being the reason for the climate instability in winter and spring in the southern regions.

In the warm season the Iranian branch shifts to the north of Central Asia and the thermal low gets established in the southern regions, associated with the monotonously dry, hot weather. Cyclonic activity is low here and the passing of cyclones is but seldom accompanied by precipitations. The thermal low effect is not felt in the northern regions of deserts where the cyclonic activity in a warm season is rather high.

Therefore, the change of air masses during a year over the southern deserts of Central Asia is witnessed: in winter the air masses of temperate latitudes prevail and in summer – that of the continental tropical zone. Meanwhile no pronounced air-mass changes are observed over the northern regions: the air of temperate latitudes is prevailing here year-round. As a result, the gradual increase of precipitations from October to March-April (maximum), going on with the intensification of cyclonic activity, is characteristic of southern regions. Later, precipitations tend to dwindle away and become as low as nil by July. The northern regions are characterized by more even precipitation distribution, having its highest in late autumn and late spring.

Analysing the annual distribution of precipitations over Central Asia and South Kazakhstan V. M. Chetyrkin (1960) has traced the sharp reduction of summer precipitations in the regions located between the latitudes 42°N. and 45°N. It is here that the dividing line between the northern and southern desert subzones usually goes: beginning from the northern part of the Kara-Bogaz-Gol Bay it crosses the Amu-Darya delta and runs further on along the margins of the Bukantau Mountains and along the Karatau ridge. In the east this line goes along the Karatau ridge and Talas Alatau. Major climatic indices for these two subzones are given in Table 1 and Fig. 2.

The average annual air temperatures take an ascending tendency southwards – from 5.0°C to 11.0°C in the northern subzone and from

Table 1

Major Climatic Indices for Deserts of Central Asia and Kazakhstan

Station	Air temperature, °C			Average absolute minimum	Absolute maximum	Period with average daily air temperature	Vegetation period	Sum of air temperatures	Precipitations, mm		
	annual	January	July			<0°C	($t \geq 10$°C)	≥ 10°C	annual	warm season	cold season
						Northern subzone					
Teren-Kuduk	4.8	−15.4	24.5	−35	43	151	157	1973	171	102	69
Ak-Tumsuk	8.9	−7.9	25.2	−26	42	107	173	3466	129	77	52
Sam	8.9	−9.1	27.0	−28	46	126	179	3773	136	82	54
Kungrad	9.9	−6.7	25.3	−26	44	106	186	3751	95	46	49
Kunya-Urgench	10.9	−6.0	26.6	−24	45	102	193	4042	76	31	45
						Southern subzone					
Ekedje	13.2	−3.9	29.7	−22	46	81	205	4697	100	40	60
Darvaza	14.8	−2.0	31.2	−19	46	56	217	3123	97	39	58
Akmolla	15.8	−1.0	32.2	−20	47	44	224	5393	91	34	57
Cheshme	15.7	−0.2	31.5	−20	49	29	225	5292	97	38	59
Bairam-Ali	16.0	1.5	30.2	−16	48	0	234	5268	135	40	95
Serakhs	16.6	3.0	30.2	−15	48	0	242	5402	178	51	127
Takhta-Bazar	16.5	2.7	31.2	−17	48	0	236	5370	241	53	188

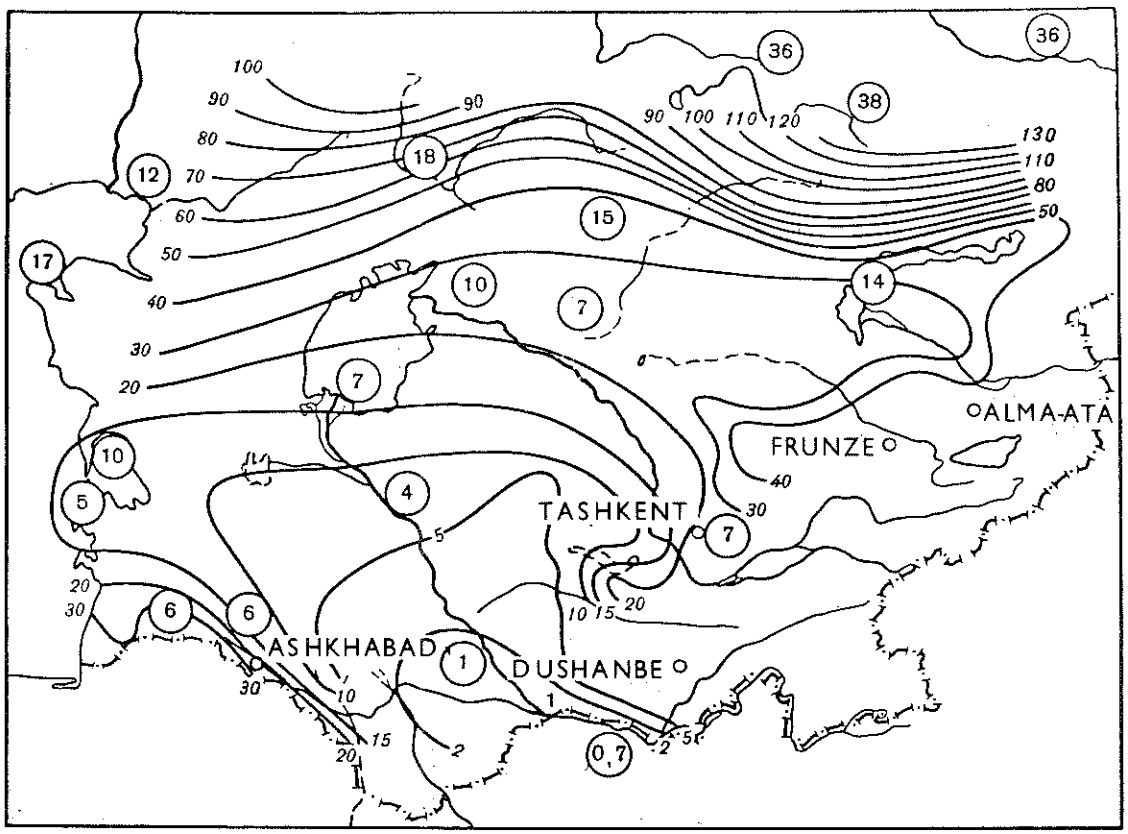


Fig. 2. Precipitations in mm (isolines) and number of days with precipitations ≥ 0.1 mm (circled figures) from June to September (acc. to O. M. Chelpanova, 1963)

13.0°C to 16.6°C in the southern subzone. Maximum air temperatures are recorded in July and minimum – in January.

The winter severity is decreasing also southward: from very severe in the north, to moderately severe in the centre and to mild in the south of the northern subzone. The temperature in January is −15°C in the north and only −6°C in the south. To the north of the January isotherm −6°C territories with prevailing non-vegetative winters which is inherent to the temperate zone, are found (Babushkin, 1964). Almost every year January temperatures get as low as −24°C and −35°C here (see Table 1).

The southern subzone in general is characterized by very mild winters with frosts of only medium severity in the north and insignificant severity in the south. The temperature in the South-East Kara Kum and South-West Turkmenia does not go below zero in January. However, even here it may be as low as −26°C or −35°C in exceptionally cold winters.

The number of days with continuous frosts in the northern subzone varies from 160 in the north to 80 in the south, while in the southern subzone there is no pronounced period with mean daily temperatures below −5°C.

Summer in the northern subzone is short but with high air temperatures ranging from 24.0°C to 27.0°C, while in the southern subzone it is rather long and very hot: mean July temperatures vary from 29°C to 32°C and in separate years they may even hit 46°C or 50°C.

Consequently, the duration and heat supply of the vegetation period are also greatly differing. Hence the period with the mean daily temperatures above +10°C makes up 160-200 days in the northern subzone and 200-242 days in the southern subzone. As a result the sum of temperatures is equivalent to 2,000-4,000°C in the former and 4,000-5,500°C in the latter.

The annual precipitations in both subzones are insignificant, varying from 80 to 200 mm and reaching 250-300 mm in piedmont loess deserts. However, their distribution within a year is highly uneven: in the northern subzone precipitations falling in a warm season surpass or equal that in the cold season, while in the southern subzone precipitations fall mainly in the cold season.

The total precipitations in the southern subzone for the four warm months (see Fig. 2) are meagre and vary from 1 mm in the South-East Kara Kum to 10 mm at the border with the northern subzone. They may be practically neglected. In the northern subzone precipitations in the warm season are insignificant (15-60 mm), but they are enough to support the sagebrush. More important, precipitations are evenly distributed over all summer months.

Apart from the unevenness in precipitation distribution during a year, mention should be made of their high variability. Thus, the annual precipitations may vary within the Turkmenistan territory in individual years from 24 to 564 mm. There are cases when the monthly

sum of precipitations surpass several times the mean many-year monthly norm.

Flat territories of Central Asia mostly do not receive any precipitations. The probability of days without precipitations in a year makes up 70-80 per cent, days with slight or moderate precipitations – 20-30 per cent and days with appreciable precipitations – 1-10 per cent. In southern deserts the probability of slight and moderate precipitations in spring amounts to 30-50 per cent of days in each month, and of appreciable precipitations – 7-25 per cent. The number of days with appreciable precipitations (9 mm and more for 12 hours) here varies from 2 to 6 (Subbotina, 1977). Notwithstanding the infrequency of such precipitations and their shortness they may cause destructive mudflows, water erosion and damage to cotton fields.

High summer temperatures, inadequacy of precipitations and the lack of surface flow – all these combine to contribute to the air dryness here: from June to September the relative humidity in the southern subzone gets lowered to 22-25 per cent and in individual days even to 3-5 per cent. The air humidity deficit is highest in such days.

The climate aridity is conducive to intensive evaporation from the water surface (evaporative capacity), which may reach in southern deserts 1,400 mm or even 2,300 mm per annum, i.e., 15-20 times outstrips the precipitations (Orlovsky, 1971). Soil moisture storage, to which precipitations in autumn, winter and spring contributed, becomes lost to evaporation and transpiration with the air temperature increase, thus, entailing soil drought.

Figure 3 shows the most probable time, in terms of climatic conditions, of the soil drought occurrence. In the East Kara Kum and most of the Kyzyl Kum it happens in the first decade of April. During the second decade soil drought affects the rest of desert territories in Central Asia and during the third decade – loess deserts.

O. A. Lyapina and V. S. Ziyavitdinova (1977) stress that the soil moisture is spent gradually and the transition from the soil moistened enough to meet the needs of natural vegetation to soil drought progresses rather slow. On the contrary, the drying of air goes on much quicker.

Air dryness involves greater transpiration. The combined soil and air dryness cause quicker damage to plants and even the destruction of some organs of a plant or plant as a whole.

Studying air dryness in the continental arid climate of Central Asia, L. N. Babushkin (1964) distinguishes four categories of droughts by the air humidity deficit at one o'clock p.m.: slight, moderate, intensive and very intensive. Figure 4 represents the distribution of the average annual number of droughty days over Central Asia (Lyapina and Ziyavitdinova, 1977). It follows that the Central and South-East Kara Kum emerges as a region with the greater drought recurrence.

The general climate dryness is characterized by the complex fac-

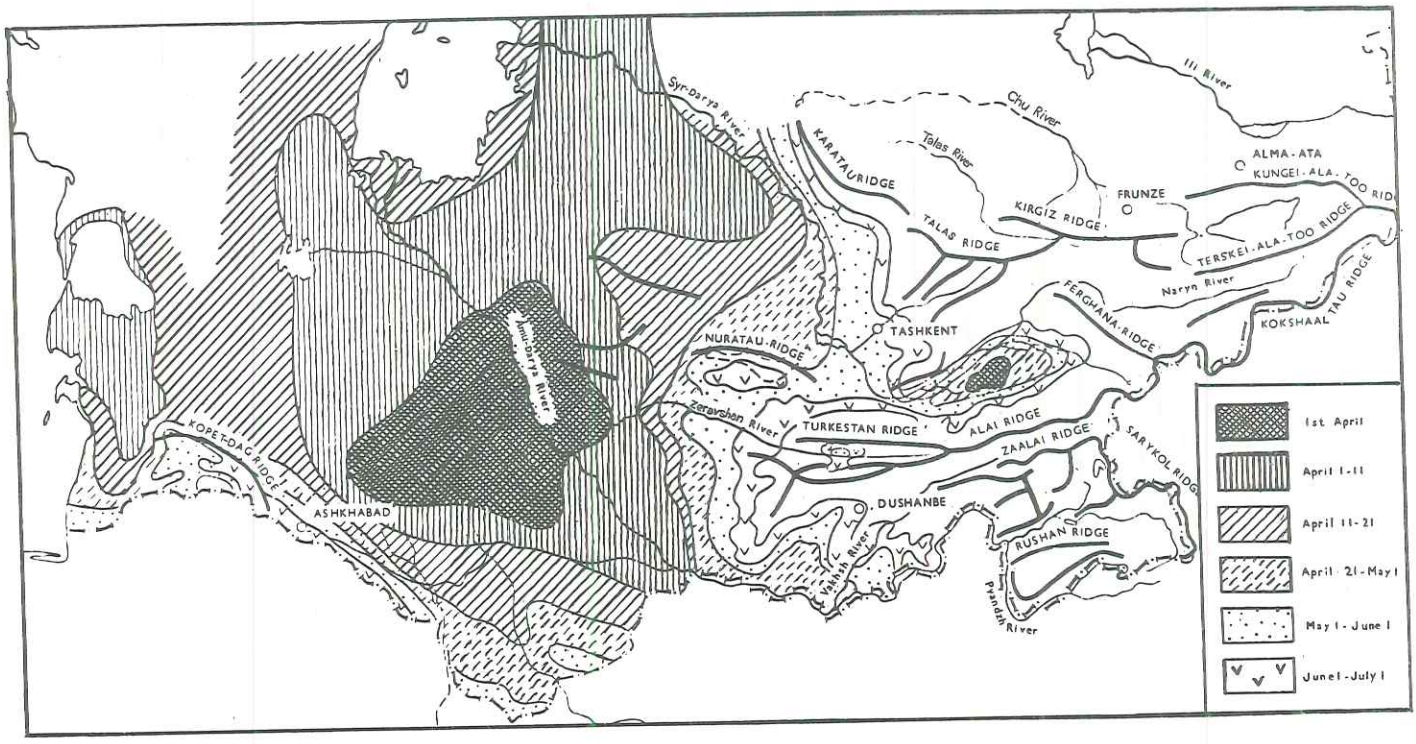


Fig. 3. Incidence of soil drought (acc. to E. G. Brodsky)

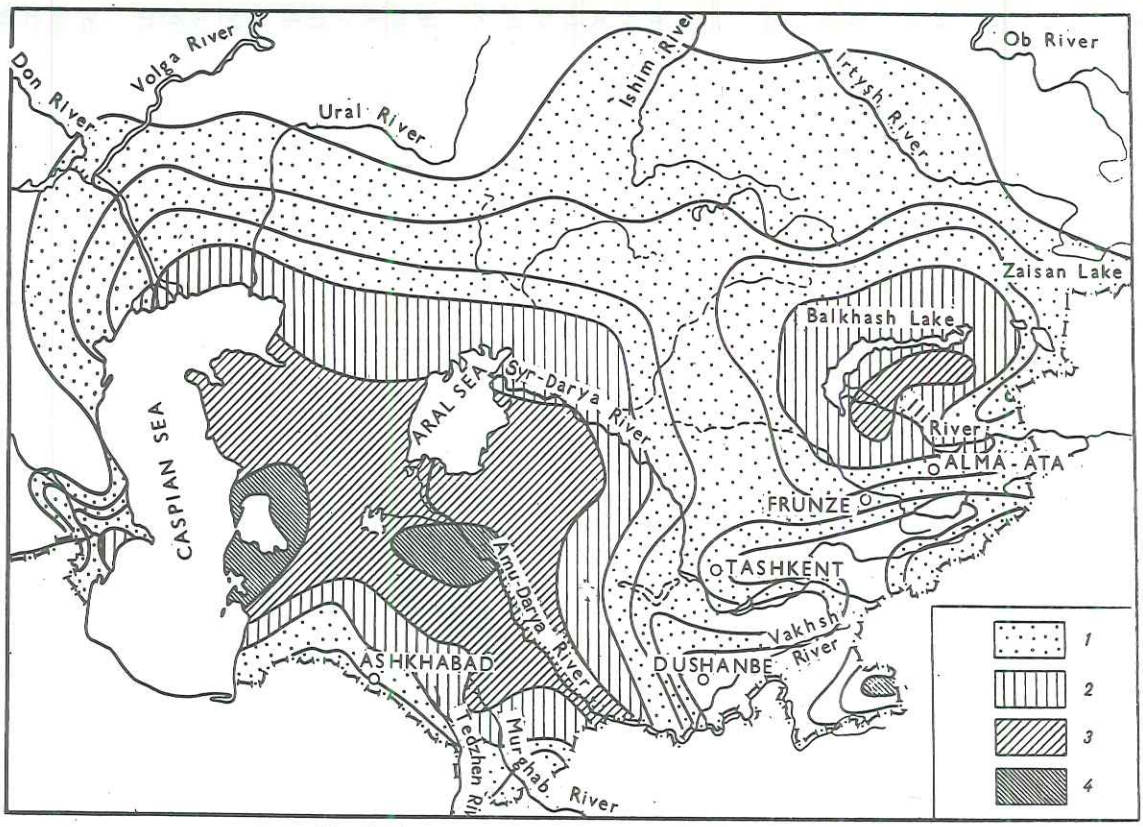


Fig. 4. Average annual number of droughty days

tors or the aridity index. The aridity index, correlating the evaporative capacity to annual precipitations, tends to increase in the northern deserts from 3.0 in the north to 8.0-9.0 in the south, and in the southern deserts from 10.0 to 16.0, thus, pointing to high climate aridity (Zubenok, 1977).

Climate Aridity Index, based on the radiation index of aridity proposed by M. I. Budyko, was prepared for the UN Conference on Desertification which was held in 1977. This index represents a ratio of the radiation balance to the heat needed for evaporating precipitations. This map, in addition to the existing climatic data, displays the aridity of any region. A part of the map is given in Fig. 5.

High climate aridity in deserts, mobility of soil substratum and sparce vegetation become conducive to sand drifting and dust storms even at a slight increase of the wind speed. Sand and dust storms, emanating from the climate aridity and the man-induced destruction of vegetation and soil cover, aggravate the negative effect of droughts, lower soil fertility and destroy soil and crops (Kovda, 1977).

Dust storms usually begin at a wind speed from 9 to 14 m/s, however, in some regions a wind speed of 6-8 m/s is enough (Orlovsky, 1962; Romanov, 1960). They may occur year-round and are dependent on local conditions (Fig. 6). The maximum average annual number of days with dust storms in Central Asia was recorded in the Central and South-East Kara Kum and in West Turkmenia as well (Sapozhnikova, 1970). However, in individual years this number may be much exceeded. The greatest number of days with dust storms was observed in the Central Kara Kum (Cheshme – 113 days in 1948, Repetek – 106 days in 1939), in the Kopet-Dag piedmont areas (Molla-Kara – 146 days in 1939), as well as on the northern and southern shores of the Aral Sea (Muinak – 121 days in 1958, the Aral Sea – 92 days in 1952). The average figure for Central Asia in general is as large as 250 days a year (Romanov, 1960).

In the Kara Kum dust storms mostly occur in spring as a result of quick soil drying and the increased wind speed; in the Kyzyl Kum the peak in the recurrence of dust storms is in summer due to considerable wind speeds; in the piedmont areas of the Kopet-Dag – in autumn, in the Kopet-Dag Mountains – in winter. There are usually two peaks in the recurrence of dust storms during a day – from 10.00 to 13.00 and from 19.00 to 22.00 of local time.

Dust storms mostly last not more than three hours. On the west and utmost south-east of Turkmenia and in some regions of the Central Kara Kum the longest dust storms were recorded, lasting more than 24 hours in over 5 per cent of cases. In May 1950 in Nebit-Dag the dust storm was as long as 73 hours and in November 1951 in Aidin – over 70 hours.

The climate aridity may be blamed for poor development of biological and soil-formation processes, the low humus content, soil structure and high salinity. The soil cover is predominantly represented by desert

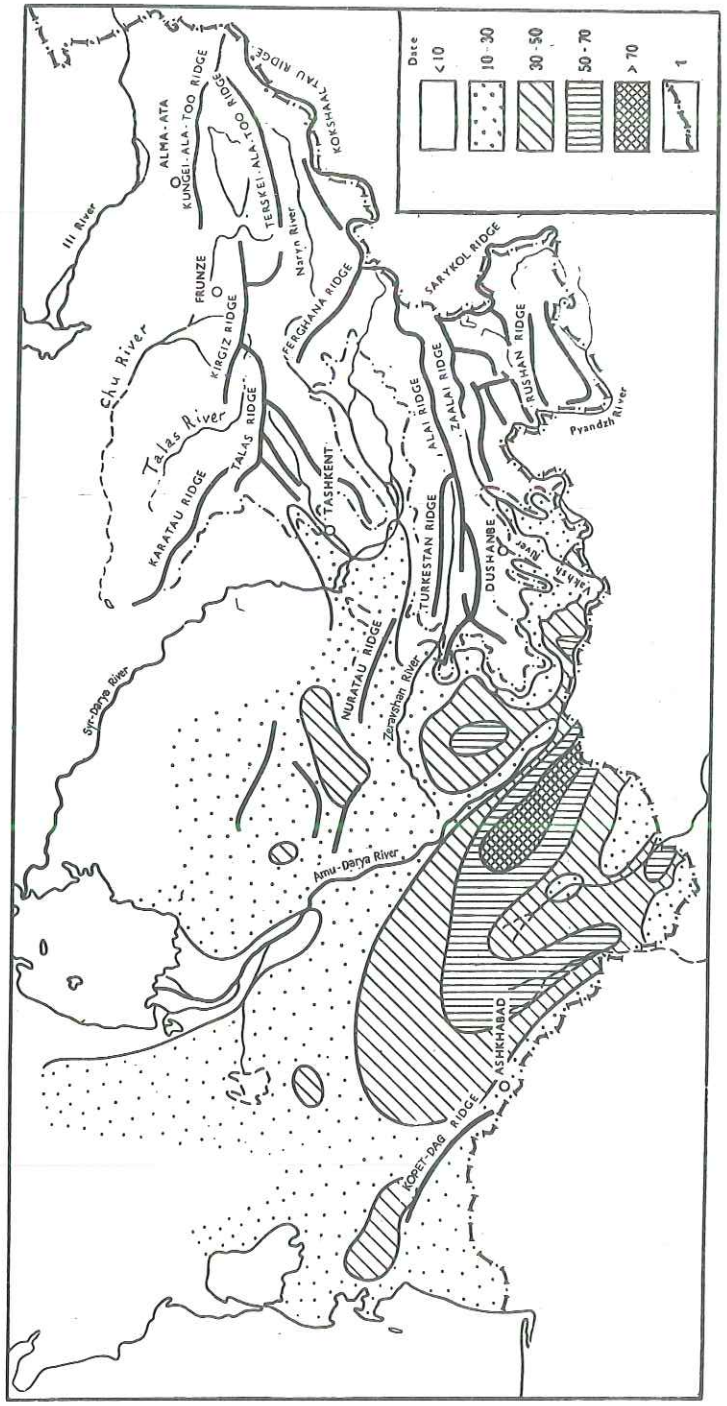


Fig. 5. Climate aridity index

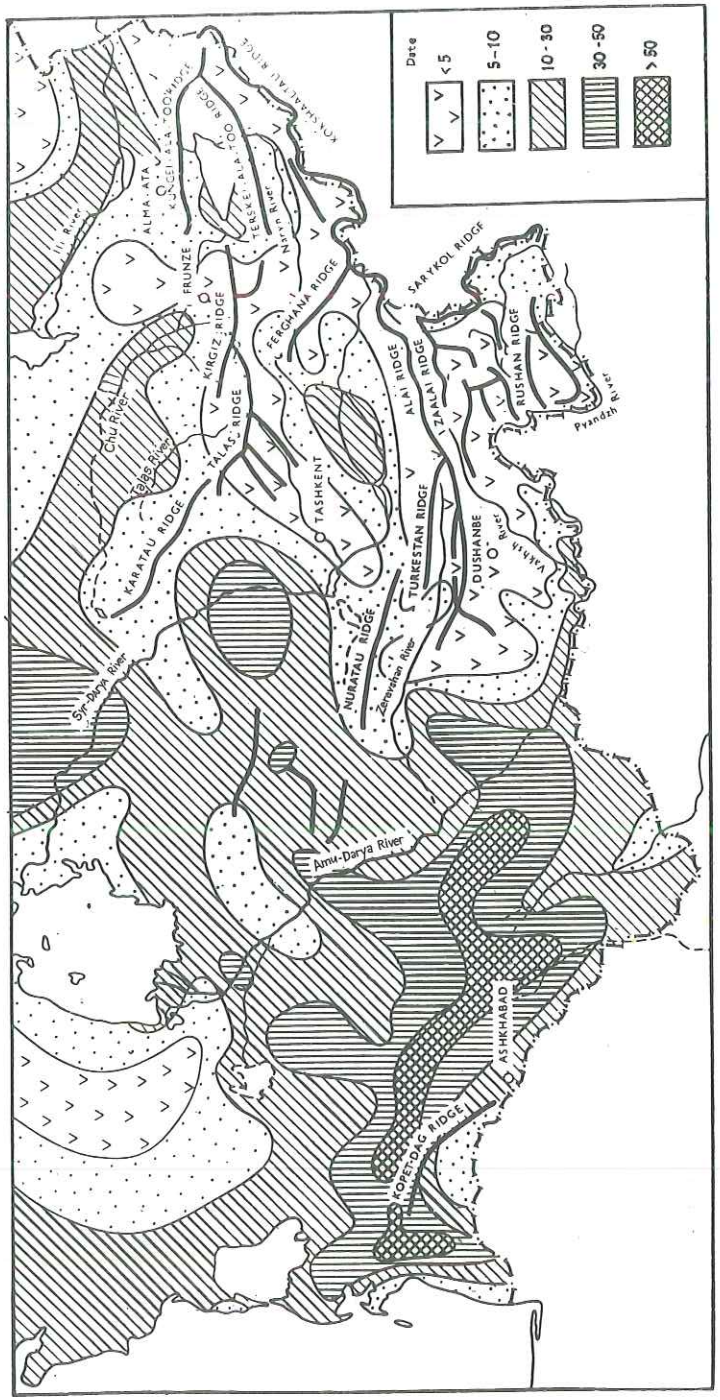


Fig. 6. Average annual number of days with dust storms

gray-brown, desert sandy soils, sandy loams and loamy sands, takyrs and solonchaks. In view of excessive soil wetting with groundwaters in river valleys and deltas hydromorphic soils (alluvial-meadow, boggy-meadow, meadow-takyr and others) come to prevail. In the piedmont plains wetted with atmospheric precipitations sierozems overlaying the loess deposits are developed (Lobova, 1960).

Difference in the texture and hydrology of these soils has a pronounced effect on their water regime which, in its turn, determines the vegetation composition, development and productivity. The vegetation is mostly represented by psammophytes, xerophyte undershrubs and halophytes.

Differences in the hydrothermal regime of the northern and southern subzones are manifested in the general view of soil and vegetation.

In the northern subzone desert gray-brown soils with a high content of sodium and soluble salts are mainly met. A moderate hydrothermal regime does not favour the accumulation of carbonates in soils here.

Insignificant but evenly distributed through the whole summer precipitations enable growth of perennial undershrubs with late vegetation, such as sagebrush and Salsola as a result of which the northern subzone is the zone of sagebrush deserts. The changing wetting regime from north to south in the subzone causes only the change in sagebrush varieties – from water-loving to xerophyte-type. Vegetation is highly thinned. More diversified is the vegetation of sand deserts here, as for example, of Sam, Muyun Kum, Greater and Lesser Barsuki (Kurochkina, 1978), where a wide assortment of vegetation, from mesophyte to xerophyte, is found.

In the southern subzone the soils are heavy carbonate, gray-brown and sierozems. Their high carbonate content may be related to a dry and hot summer. Such hydrothermal regime favours the accumulation of carbonates in soil layers.

Maximum precipitations in spring make for more lavish vegetation here than in the northern subzone where such rainy season is nonexistent. Warm and humid springs contribute to the development of a specific vegetation – ephemerals and ephemeroids – not found in the northern subzone. With the advent of a hot and dry summer the ephemerals wither.

Therefore, the environmental conditions are conducive to plant vegetation in the northern subzone in the warm season, and in the southern subzone – in the cold season. Winter vegetation in the northern subzone is impossible in view of low temperatures accompanied by a small thickness of snow cover, and in the southern subzone at that time climatic conditions favour the development of ephemerals and ephemeroids. In summer in the southern subzone vegetation is impossible, for even xerophytes cannot grow due to high temperatures and lack of precipitations, while in the northern subzone desert xerophytes, but only of late vegetation, are growing.

The following lithoedaphic desert types are distinguished within

each climatic subzone by the lithology of parent rocks and soils: (1) sand deserts on loose deposits of ancient alluvial plains; (2) sandy-pebble and pebble deserts on gypseous Tertiary and Cretaceous structural plateaus; (3) crushed-stone and gypseous deserts on the Tertiary plateaus; (4) stony deserts on low mountains and hummocks; (5) loamy deserts on slightly calcareous top loams; (6) loess deserts on piedmont plains; (7) clay takyrs on piedmont plains and in ancient river deltas; (8) clay badlands on low mountains composed of saline marls and clays; (9) solonchak deserts in salt-affected depressions and on sea coastlines (Petrov, 1973).

The lithoedaphic desert types well agree with the rangeland classification devised by V. N. Nikolaev (1977), who differentiated 10 classes, 39 group-types and 178 types of rangelands for Central Asia and Kazakhstan. Three major classes of rangelands are found within the northern and southern subzones (Fig. 7). Sand-desert rangelands covering large areas in the northern subzone and almost the whole territory in the southern subzone, unfold over more than 44.8 million ha, including 14.7 and 30.1 million ha in the northern and southern subzones, respectively.

In the northern subzone the vegetation of sandy rangelands is predominantly of a shrub-grass nature while different varieties of sagebrush and undershrubs forming an intermediate layer are also met. Amongst shrub varieties peculiar are haloxylong, Salsola and others. Vegetation of rangelands here allows for a year-round grazing of sheeps and camels, with the compulsory stabling of sheeps in the coldest winter months.

In the southern subzone the vegetation of this class of rangelands is represented by a wide variety of vegetation: from large shrubs to annual ephemerals, but two-layer shrub-grass vegetation is most extensive. Nearly one plant is growing on an area of 20-25 sq.m in the sand desert, while one hectare supports, on the average, from 300 to 600 varieties of trees and shrubs. The total coverage makes up 12-15 per cent, reaching in some places 20 to 25 per cent, and being as little as 1-5 per cent on ridge tops (Ovezliev *et al.*, 1979). Studying the forage potential and seasonal eating of grass on rangelands it may be concluded that the rangelands in the sand southern subzone are most suitable for a year-round sheep and camel grazing.

Gypseous-desert rangelands are often met in both the northern and southern subzones, covering the Ustyurt Plateau, some territories in the Trans-Unguz and residual surfaces on the Tertiary-Cretaceous plateaus in the South-West Kyzyl Kum. Their overall area is estimated at 38.0 million ha, of which 21.6 million ha are in the northern subzone. Soils here are gray-brown with a low carbonate content, tending to increase southward. In the southern subzone carbonate gray-brown solonetz and solonchak soils interbedded with gypsum are prevalent.

The vegetation on the gypseous-desert rangelands in the northern

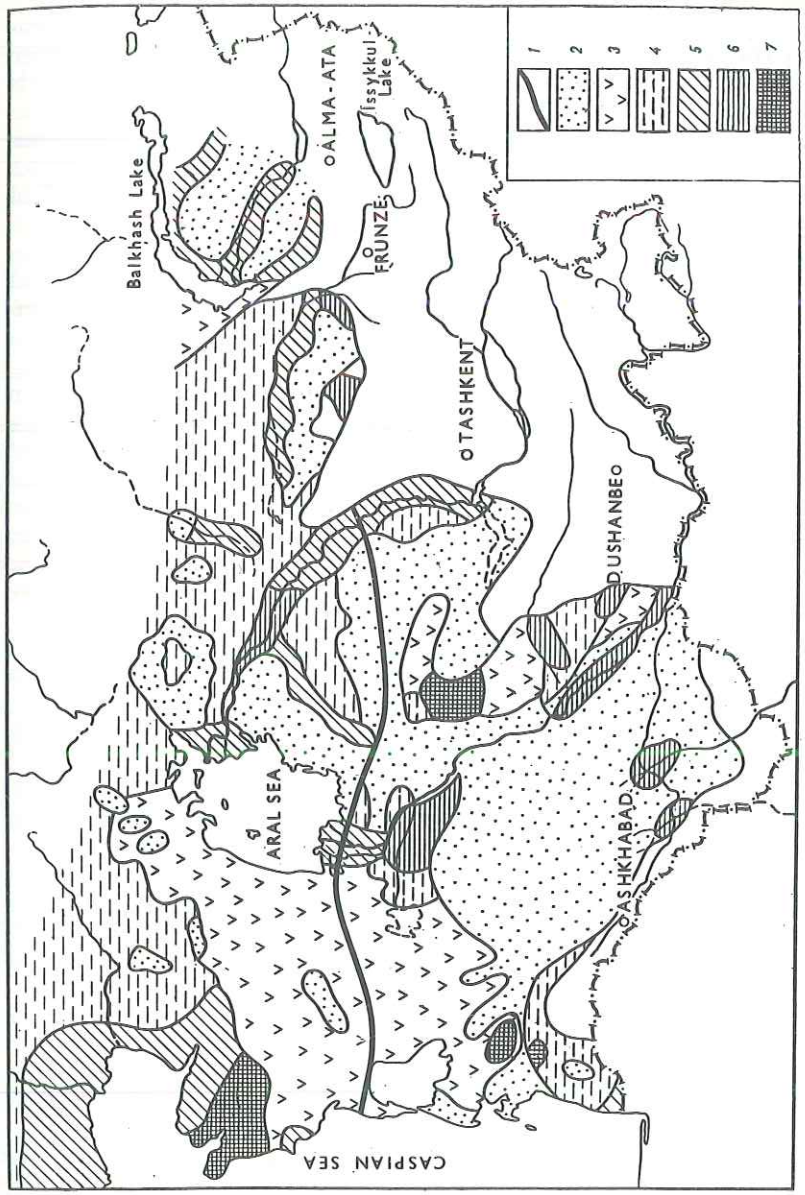


Fig. 7. Principal classes of rangelands:
1 – subzone boundaries; *2* – sand-desert rangelands; *3* – gypseous-desert rangelands; *4* – clay-desert rangelands; *5* – rangelands in river valleys; *6* – oases; *7* – mountain zone

subzone mainly includes Artemisia-Salsola varieties. By the vegetation and the eating of plants most rangelands here may be used for an autumn-winter sheep grazing.

In the southern subzone this class of rangelands is mainly represented by thinned shrub and undershrub varieties with only a small share of ephemerals. Every hectare supports several dozens of thousands of undershrubs from 0.2 to 0.5 m high and with the crown 0.1-0.5 m in diameter. Their coverage makes up 10 to 20 per cent. Notwithstanding severe conditions reigning here the undershrub vegetation possesses high resistance to grazing and is mostly destroyed as a result of fuel gathering.

The rangelands where Artemisia and Artemisia-Salsola vegetation prevail are suitable, by the vegetation composition, for a year-round sheep and camel grazing. The forage consumption drastically increases in autumn and winter in view of better eating of Artemisia and Salsola in these seasons.

Clay-desert rangelands extend over an area exceeding 18.6 million ha and occupy the eastern part of the northern subzone, the south-west of Turkmenia, ancient deltas of the Amu-Darya and Syr-Darya Rivers, the interfluve of the Tedzhen and Murghab Rivers and the right bank of the Amu-Darya River in the southern subzone.

In the northern subzone this class of rangelands is abound in large shrub vegetation, black saxaul and Tamarix, in particular. By the degree of eating of major forage plants clay rangelands here are suitable for sheep grazing in autumn and winter.

In the southern subzone the fine texture and high salinity of soils predetermine the prevalence of Salsola. The ephemeral vegetation is highly thinned, and its overall coverage does not exceed 10 to 20 per cent. The forage vegetation here is such that only a few rangelands may be used for sheep grazing in autumn and winter.

Rangelands in the piedmont deserts take up an area of 10.4 million ha, and are divided into two main types: rangelands in stony deserts and rangelands in loess deserts.

Rangelands of the stony piedmont desert are met by small patches in the contact zone of mountains and a piedmont plain. The soil cover is poorly developed as a rule, abounding in crushed stone and characterized by a low content of small-size particles. The prevalence of shrub-undershrub vegetation with the sagebrush reigning there is witnessed. By the character of grasses here these rangelands may be assessed as satisfactory for a spring-autumn grazing of sheeps and camels.

The greater part of the piedmont desert is given to loess-desert rangelands. Sierozems are dominating here. The vegetation is rather dense and formed by two layers of grasses. Sagebrush varieties grow extensively on individual patches. Rangelands of the loess piedmont desert are superb for spring-summer grazing of sheeps.

Desertification Processes

High climate aridity and instability, thinned vegetation, high soil susceptibility to erosion and poor natural drainage – all these factors are responsible for very strenuous and highly vulnerable interrelations existing amongst landscape components. If disturbed, they are not self-compensating and their restoration is very slow. The most vulnerable of these are vegetation, soil and fauna. They may be infringed by quick and often irreversible processes.

The apposite example to this end is the development of sandy rangelands' deflation as a result of overgrazing and cutting trees and shrubs. The changed soil water regime, affected by irrigation, leads to salinization and waterlogging. In both cases the decreased biological productivity of landscape is observed. V. A. Kovda (1977) has noted that sand deflation and vegetation development are going on together which results in certain dynamic equilibrium. Any outside interference can shift this equilibrium in favour of sand deflation and make it prevalent over sand stabilization with vegetation.

Consequently, the infringement of environmental equilibrium in arid regions sets loose the desertification processes. The term "desertification" has appeared quite recently, and controversy is still raging as to its proper definition. Here are some of its interpretations.

Scientists understand and explain the desertification phenomenon differently, thus, the existence of two terms – desertification and desertization. Le Houerou (1975) defines desertization as the intensification of desert conditions in arid regions receiving from 50-100 to 200-300 mm of precipitations, while desertification, in his opinion, is the process of desert encroachment on semi-arid and sub-humid landscapes.

Pointing to the geographical narrowness of the definitions proposed by Le Houerou, another scientist A. Rapp (1974) extended it, by including regions with greater precipitations. He defined desertization as the process of stepping up of desert conditions into arid and semi-arid regions with up to 600 mm of precipitations. In on-going studies A. Rapp (1979) called these two definitions synonymous comprehending them as "the extension of desert conditions into the areas outside deserts". The wider approach to interpreting the term "desertification" was taken by the "Plan of Action to Combat Desertification" (1977) adopted by the UN Conference on Desertification. Here desertification is defined as the diminution or destruction of the biological potential of the land which can lead to desert-like conditions.

Defining desertification as the intensification (Le Houerou, 1977) or extenstion of desert conditions (Mensching and Ibrahim, 1977; Rapp, 1974, 1979 and others) provides only the assessment of processes underlying it, but do not unveil its causes, dynamics and implications for man.

Some scientists (Chigarkin, 1979; Dregne, 1977) look upon deserti-

fication as a combination of droughts and unwise land use, others (Borovsky and Kuznetsov, 1979) reduce this notion to solely anthropogenic processes. No doubt desertification processes have most pronounced and varied manifestations as a result of man's interference into fragile and sensitively balanced ecosystems. However, desertification is a complex process of interaction of physiographical (natural), social, economic and political factors.

The definition suggested by N. G. Kharin and M. P. Petrov (1977) is deemed most satisfactory and complete. They understand desertification as a complex of physiographical and anthropogenic processes, causing the destruction of arid and semi-arid ecosystems and the degradation of all forms of organic life, which, in turn, results in the diminished natural-economic potential of these territories. These processes are mostly developing over relatively small areas which may be attributed to the intensification of desert conditions induced by local factors. Only in rare cases does desertification have a considerable extension.

It follows from the above definition, that the major causes of desertification should be sought in physiographical (natural) and anthropogenic factors and their combinations. Climate variations, aridization and progressing soil and groundwater salinity give rise to natural desertification, while irrational man's economic activity – to anthropogenic desertification. Manifestations of desertification are degradation of vegetation, soil and water resources – three basic elements on which man's existence depends.

The causes of desertification, both natural and anthropogenic, are very complex, varying from region to region, but interrelated. Their intensity determines the duration, magnitude and degree of desertification. B. V. Vinogradov (1976) noted that "desertification is long-term successions of landscapes during which sub-arid steppe, semi-desert and savannah landscapes are replaced by desert ones, and also shorter-term exogenous successions during which complex desert ecosystems are destructed and the primitive destructive complexes with prevailing mineral arenas are formed in their place". Thus, desertification processes, caused by climate variations, may last for centuries, while catastrophic mudflows may do this in several days.

Desertification may be classed by its magnitude into zonal, provincial, regional and local. It may have a continuous, spotted, stripped and point (diffusive) distribution. Desertification is characterized by the following dynamic processes: climatic, hydrogeologic, morphodynamic, soil, phytogenous and zoogenous. The territory vulnerability to desertification and its degree are dependent on climate (degree of aridity, precipitations and their annual distribution, climate fluctuations), soil structure and texture, topography, vegetation composition, population density, grazing intensity, mechanization.

Notwithstanding the diversity of desertification processes the most general factors contributing to desert conditions development in various regions may be outlined, which was done by B. G. Rozanov (1977) who included here:

(1) vegetation degradation and attendant soil erosion as a result of overgrazing;

(2) enhanced erosion and deflation of dry lands caused by intensive and unwise land use for rain-fed farming without proper account of natural peculiarities;

(3) destruction of vegetation for fuel;

(4) destruction of vegetation and soil in the course of road building and industrial construction, geological surveys, minerals mining, construction of settlements and irrigation facilities;

(5) destruction of vegetation and soil by motor transport;

(6) destruction of vegetation and breaking of soil by cattle around improper located and unwisely organized water points;

(7) secondary salinity build-up, alkalinization and groundwater rise in irrigated areas and adjoining territories;

(8) extenstion of salt deserts in drainless basins.

CHAPTER II

DESERTIFICATION: ITS MECHANISM AND IMPLICATIONS

As it was mentioned earlier, two factors – natural and anthropogenic – give rise to present-day desertification. These are acting conjointly, thus, hampering their analysis which may often lead to incorrect conclusions.

Natural Factors of Desertification

Deserts mainly appear in subtropical zones of high atmospheric pressure formed within a system of the general atmospheric circulation whose variations may influence the location and intensity of atmospheric processes conducive to desertification. In the past climate had changed more than once, urging deserts to shift their boundaries. Therefore the study of these changes is of great importance for the comprehension of the mechanism of climate evolution.

Studying the climates of the past, M. I. Budyko (1971, 1974, 1977) has noted that as early as in the Parmian period the thermal zonality began to manifest and the arid regions extended significantly. In the Mesozoic the zone of insufficient humidity also existed. However, in the late Cretaceous the zone of hot climate got contracted with the attendant extension of the arid-climate zone.

In the transition to the Cainozoic no pronounced climatic changes were recorded. In the Eocene (Markov *et al.*, 1965) forest and forest-steppe landscapes were reigning in Central Asia and Kazakhstan. Steppe extension (aridization) was going on here in the second half of the Tertiary period (in the middle of the Oligocene) when the climate got progressively colder and added in continentality. This process accelerated in the Pliocene.

By the Quarternary period the climate coldness and especially its aridization enhanced. In this period desert landscapes in the southern regions of this country sprang up, but the arid conditions were not so pronounced as nowadays (Markov *et al.*, 1965).

Actually, one change of climate, at least in the northern hemisphere, i.e., the significant climate warming, lasted for nearly 2 thousand years (7 to 5 thousand years ago), was observed in the post-glacial period. The semi-arid and semi-humid regions in Tropical Africa,

Arabian Peninsula and Iranian Plateau were more humid 12 to 7 thousand years ago than at present (Grove, 1973). In many parts of Tropical Africa the aridization process was going on for the last 5 thousand years, but it was never of a constant or even nature and did not engulf the whole territory. Moreover, the present climate emerges as not the most arid for the mentioned period. For example, it was found out that the Sahara Desert extended 5° to 6° to the south of its present boundaries in certain historical periods.

The climate in the north-west of the Indo-Pakistan region turned out more arid in the late Pleistocene, but some 10,300 years ago a humid phase started due to the increased precipitations. But a dry period came again 3,800 years ago, which with slight deviations survived into the present. The amount of precipitations here makes up less than a third of the norm recorded in the early Holocene.

Climatic changes in the Holocene were undoubtedly brought to life by natural causes. At the beginning of the first millennium B.C. a tendency to a colder climate dominated and this was accompanied by the changed precipitation regime, which has gradually come close to that existing at present.

Perceptible climate warming took place in the late first millennium and the early second millennium A.C., when polar ice receded to higher latitudes, but the progressing coldening of the climate, started in the 13th century and climaxed in the early 17th century, was accompanied by the growth of mountain glaciers. Then the next warming period came again urging glaciers to move back. And in the 18th-19th centuries climate did not differ much from the present one.

The most drastic climatic changes for the period of instrumental observations took place in the late 19th century (Budyko, 1977) featuring the gradual air temperature rise in the northern hemisphere with its maximum recorded in the 1930s. But beginning from the 1940s the climate became colder and this process was still going on until recently.

It is of interest to note that in the period of climate warming the amount of precipitations falling in the water-deficient regions tended to decrease. This resulted in the increased aridization, being manifest in the diminished river flows, the lowered water level in some inland water bodies and the greater frequency of droughts. It may be quite possible that now we are witnessing new climate variations, however, to prove it will be difficult until we have an assurance that these variations are not of a short-term nature.

Table 2 shows the types of climatic changes and causes for climate long- and short-term variations. The participants of the International Conference on the Physical Basis of Climate and Climate Modelling have, however, underlined that our knowledge of physical, chemical, and biological processes interacting when contributing to the modern climate formation is hitherto far from being complete as we have no idea as to the causes of climate variations in the past (*Physical Basis of the Climate Theory and Climate Modelling*, 1977).

Table 2

Climatic Variations

Variation	Duration, years	Origin
Climatic revolution	$>10^6$	Geotectonic activity (continental drift, orogenesis, large-scale changes in land and water distribution). Possibly solar variations
Climatic change	10^4-10^6	Changes in solar emission – aperiodic or periodic (period of 10^4 years). Changes in extraterrestrial insolation due to long-term changes in orbital elements (orbital eccentricity, ecliptical inclination, precession)
Climatic fluctuation	10^1-10^4	All other natural climatic variations with duration in excess of 10 years. Aperiodic – volcanic; quasi-periodic – changes in sun-spot rhythms; changes of magnetic field, ocean currents and other physical factors
Climatic iteration	<10	Very stort-term quasi-periodic natural variations (e.g., during 2-3 years, caused by atmospheric processes)
Climatic alteration	10-?	Anthropogenic causes can be global, regional or local in scale. Global scale: changes in atmospheric concentrations of CO_2 and NO_x. Regional scale: power production, industrialization, urbanization, clearing of vegetation. Local scale: urbanization, agriculture, grazing, water storage, deforestation, afforestation

The general mathematical model of atmospheric circulation in arid and semi-arid regions has rendered the forecasting of climate changes much easier. Another model is to simulate the mechanism of feedback, i.e., will help to assess the effects of changes in albedo and soil moisture storage. The development of three-dimensional models of air circulation in relation to the temperature regime of the continents and oceans will considerably facilitate the forecasting of droughts. Research has already been undertaken in this respect. Thus, A. Gilchrist (1975) has probed into the relationship between precipitation anomalies in North and Central Africa and water temperature anomalies in the tropical zone of the Atlantics. G. Flon (1977) has noticed that recurring droughts in the Sudan-Sahelian zone in Africa coincide in time with the diminishment of monsoon rains in the northern and central parts of India-Pakistan, and M. I. Budyko (1973) has unveiled the dependence between the changes in the thermal regime in individual climatic zones and on the globe as a whole and the aerial distribution of precipitations.

I. I. Borzenkova (1977), studying the century-wise dynamics of precipitations in various climatic zones of Africa, has supposed the existence of certain relationships amongst global temperature dynamics, the location of the intertropical convergence zone and the intensity

of the humid monsoon. She believes that with the global air temperature rise the intertropical convergence zone is shifting to the north opening way for the humid monsoon from the Gulf of Guinea to the subtropical zone, thus, creating favourable conditions in terms of humidity. On the contrary, when the global air temperature lowers, the intertropical convergence zone is shifting to the south and the dry north-eastern trade winds are reigning in the subtropical regions.

M. I. Budyko (1971, 1974, 1977) has more than once pointed in his works to the probable effect of air temperature variations on the water cycle, although these works are mostly of the theoretical rather than practical nature and only outline the trend for further research. It may be awaited that this method of establishing distant relationships be used in future for drought forecasting. The information available on this subject is so far inadequate.

To probe into the feedback mechanism will contribute much to understanding the essence of desertification, the most important of this being the variation of albedo as affected by soil and vegetation changes.

Studies of albedo, or the radiation balance of arid regions in a wider approach, are highly important for understanding desertification. For example, J. Charney (1977) has revealed that the radiation balance on the upper atmosphere boundary over the Arabian deserts and Sahara has negative values in hot summer days. He explains this by high albedo of sandy and stony soils (some 0.35), the absence of clouds, the intensive heating of the sand surface and the low humidity. Thus, the desert regions, with other equal conditions, are losing more thermal energy than the surrounding territories. As a result desert in the warm season is characterized by a radiation flow. To maintain the thermal balance the air over desert lowers and simultaneously gets dried, thus, desert intensifies its own aridity.

On the basis of mathematical modelling J. Charney has established that the increase of albedo induces the diminishment of cloudiness and precipitations – within a week they have dwindled by 40 per cent. The diminishment of convective cloudiness was almost the same. Then the author makes a conclusion that the present drought in Sahel might be caused, at least partially, by rangeland overgrazing, which entailed the growth of albedo, gave rise to downward flows, and induced shifting of the intertropical convergence zone to the south.

Similar mechanism of desertification was suggested by A. Rapp (1974) who has stated that in wet years the cattle population and the arable area tend to increase, entailing desertification development in subsequent dry years. The following wet years fail to make up for what was lost in dry years. The albedo variation, which may emanate from drought, overgrazing, or land cultivation, can cause the drying out of the soil proper.

Also available are other theories explaining the mechanism of climatic desertification. For exemple, R. Schnell (1975) propounded a

hypothesis concerning the cores of condensation. He believes that vegetation is a source of organic cores of condensation which, seeding cumuli and nimbi, bring precipitations. Destruct it and, consequently, the source of cores, and no precipitations fall in a desert. Laboratory studies have corroborated this hypothesis as valid, but the existence of these cores of condensation in actuality has not been proved so far.

Should we look upon droughts in the late 1960s and early 1970s as manifestations of the existing climate or should this be a corollary of progressing climatic aridization which may diminish the productivity of arid regions for some time or forever? Having analysed historical, archaeological, geographical, hydrological and other data, A. V. Shnitnikov (1975) concluded that the twentieth century partially covers the protracted period of aridization. Since this process goes on rhythmically, i.e., climatic fluctuations are being overlapped by irregular climatic cycles, droughts are often following each other during 2-3 and more years. Such droughts are especially conducive to desertification.

The short row of observations is a hindrance to proving the progressing climate aridization. Many scientists, however, believe that the world deserts are at present in a state of drought.

Natural factors contributing to xerotization and aridization are (Petrov, 1966; Kovda, 1977):

(1) allround diminishment of glaciers area;
(2) prevalence of sheet wash and enhanced deflation;
(3) flow reduction and partial convergence of a concentrated flow into a sheet one;
(4) decreased area of enclosed lakes and their growing salinity;
(5) vegetation degradation to its complete destruction in flat interfluves;
(6) suppressed flora and fauna varieties' formation;
(7) progressing soil salinization in flat interfluves, the increased carbonate and gypsum content in modern hydromorphic soils; conservation of salt crusts;
(8) progressing groundwater lowering;
(9) development of river channels and gullies and their increased drainage role;
(10) upward movement of the permanent snow confines in mountains and the diminished recharge of rivers and groundwater aquifers in lowlands.

Due to the enhanced aridization the black saxaul growths in the north-west of the Kopet-Dag piedmont plain have disappeared, and due to the increased aridity and decreased inflow of low-saline waters from the Kopet-Dag and desalinization of the Kara Kum ground flow in the zone of its contact with the groundwaters of the piedmont plain got diminished. As a result no vegetation in many solonchak depressions here survived (Grave, 1957; Kharin and Kalenov, 1978). The reason for intensified natural aridization

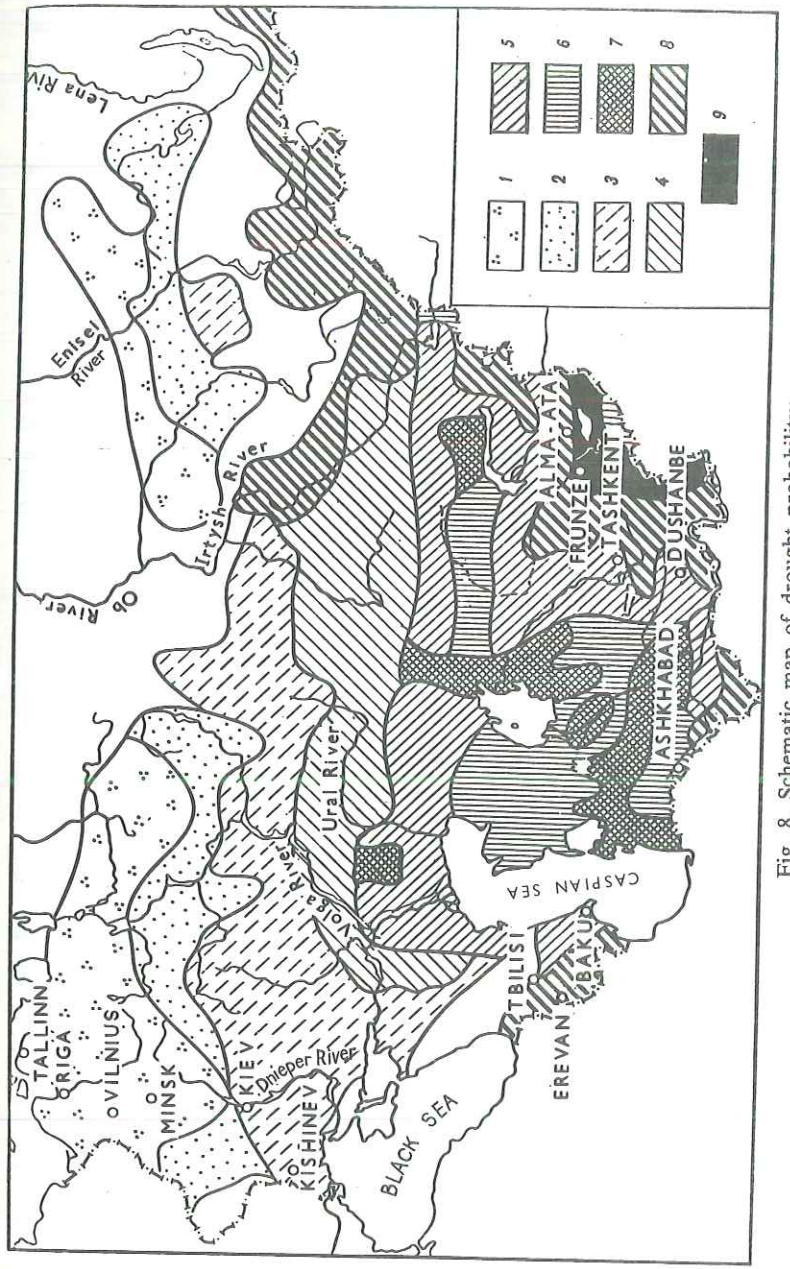


Fig. 8. Schematic map of drought probability:
1–very rare (to 5%); *2*–rare (5-10%); *3*–frequent (25-30%); *4*–rather frequent (30-50%); *5*–very frequent (50-75%); *6*–continuous (75-95%); *7*–deflation and semi-fixed sands; *8*–mountain steppes, light forests, shrubs and savannahs with drought probability over 50%; *9*–mountain deserts and semi-deserts with the absolute prevalence of high aridity

or desertification of arid territories should be sought in the irrational natural resources use. The aridization has become even worse due to wide use of groundwaters (Kovda, 1977). All the above allowed V. A. Kovda to make a conclusion on the growing probability of droughts in the future.

Figure 8 shows a fragment of the World Map of Land Aridity and Drought Probability, prepared by V. A. Kovda, B. G. Rozanov and S. K. Onishchenko, which, unlike traditional climatic maps, allow to make judgements as to the areas prone to desertification.

The studies conducted (Budyko, 1971, 1974, 1977, etc.) have indicated that the global climate variations observed in the recent decades became dependent not only on natural factors, but also on man's economic activity. However, it still presents difficulty to assess the man's effect on climate and the probable implications. The most important practical goal coming to the fore presently is the maintenance of microclimate through the rational land use patterns.

As it was noted, while discussing the Plan of Action to Combat Desertification at the UN Conference on Desertification, not rare are the cases when climate itself is conducive to desertification, especially as a result of the irregular precipirations and recurring droughts. But so far nothing confirms that the enhanced desertification stems from the increased aridization of climate.

Anthropogenic Factors of Desertification

Apart from droughts, desertification may be induced by anthropogenic factors which, in some instances, become decisive and the climate emerges as the corresponding precondition for this. It is believed now that man's economic activity is the main reason for vegetation, soil and water resources degradation. Its sizable and multifaceted effects are especially felt by desert rangelands. Here are overgrazing, felling of trees and shrubs, mechanical destruction of vegetation in the course of various construction operations (road building, reclamation construction, etc.).

Among factors most strongly affecting rangeland vegetation, grazing emerges as the overriding one. It causes changes in the soil cover, vegetation composition, varieties population, age composition of dominants, the structure and number of associations and microassociations, the phytomass, and on sandy territories also the relief, groundwater table, microclimate, etc. The sand desert may provide the most apposite illustration to the grazing-affected vegetation (Morozova, 1946, 1959; Nechaeva, 1946, 1954, 1979a; Rodin, 1961; Kurochkina, 1978, and others).

Let us discuss two basic forms of the grazing effect on rangelands: (a) directly affecting plants; (b) directly affecting soil. Unwise

grazing management is especially detrimental to vegetation, because valuable grass varieties get gradually reduced in number or disappear altogether, and become replaced by weeds or uneatable varieties. The increased load on rangelands also brings about the substitution of quick-vegetating annual plants with a shallow root system for perennial plants.

The effect of grazing on soil, and, consequently, on plants is also multifarious. Especially dangerous are soil loosening and breaking by cattle which, in the conditions of sand deserts, lead to progressing deflation. However, if it is done within admissible limits, it even becomes a positive factor, for cattle breaks the surface crust thus improving soil aeration and seeds embedding (Nechaeva, 1954).

The major reason for overgrazing should be sought in the inadequate water supply of rangelands: the amassing of cattle near water points will inevitably lead to heavy soil breaking and the emergence of moving sands. Scattered water points are the seats of desertification. Moving away from water points it may be noticed that the degree of sand fixation changes as well as the character of vegetation, forming around water points a kind of concentric grazing belts which correspond to various stages of rangeland degression. The area around a water point, mostly affected by overgrazing, is equivalent to the radius of a daily migration of sheeps (5 to 6 km).

The most comprehensive study of vegetation changes induced by grazing in a sand desert was conducted by N. T. Nechaeva (1946, 1954, 1979b) and that of sand deflation – by M. P. Petrov (1950). They helped to ascertain stages of the rangeland degression, the sequence of vegetation groups, the change in varieties' composition, phytomass and relief forms. O. I. Morozova (1959), L. Yu. Kurochkina (1978) and others also contributed to the study of this problem.

The progressing rangeland degression becomes clearly manifest in a sand desert. Below there is given a brief characteristic of grazing effect on rangelands (Nechaeva, 1979; Petrov, 1950).

In the areas remote from water points (4 to 6 km) with a relatively even grazing the load is moderate and the original vegetation (mostly white saxaul) is preserved. This is the first belt of the rangeland degression for which medium sand compaction and the growths of trees, shrubs and undershrubs are characteristic.

Due to the moderate load on the flank of a sand ridge the Carex physodes-Calligonum rubens-Mausolea eriocarpa association typical of wildlife reserves becomes replaced by the Carex physodes-Mausolea eriocarpa-Calligonum rubens association (Table 3), but changed is only the coverage while the number and composition of trees, shrubs and undershrubs remain as it was (Table 4). At the moderate load the coverage is as large as 70 per cent. Carex physodes takes up 30 per cent of the area, its density being 150 plants per one square metre. The grass composition is varied and its quantity is high. However, with the increased grazing, loose-bush Gramineae – Aristida karelinii, Turnefortia sogdiana and

Table 3

Effect of Rangeland Degression on Plant Associations

Relief forms	Regime of utilization, stages of rangeland degression	Associations
Sand ridges	Nature reserve, 7th year of conservation, ass. 2	(Calligonum rubens)-Mausolea eriocarpa-Carex physodes
	I DD, ass. 2a	Calligonum rubens-Mausolea eriocarpa-Carex physodes
	II DD, ass. 2b	Calligonum rubens-Turnefortia sogdiana-Bromus tectorum
	III DD, ass. 2c	(Calligonum rubens)-Aristida karelinii-Bromus tectorum
	Sands near water points	Aristida karelinii
Small-hillock sands	Nature reserve, 7th year of conservation, ass. 3	Salsola arbuscula-Artemisia kemrudica-Carex physodes
	I DD, ass. 3a	(Salsola arbuscula)-Artemisia kemrudica-Carex physodes
	II DD, ass. 3b	Calligonum rubens-Turnefortia sogdiana-Bromus tectorum
	III DD, ass. 3c	Calligonum rubens-Artistida karelinii-Bromus tectorum
	Sands near water points	Aristida karelinii
Takyr-like plains	Nature reserve, 7th year of conservation, ass. 4	Salsola gemmascens + Artemisia kemrudica-Gamanthus gamocarpus
	I DD, ass. 4a	Salsola gemmascens + Artemisia kemrudica-Gamathus gamocarpus
	II DD, ass. 4b	Artemisia kemrudica-Gamanthus gamocarpus + Climacoptera lanata
	III DD, ass. 4c	Artemisia kemrudica-Climacoptera lanata
	Sands near water points	Peganum harmala

annual Gramineae – appeared, and some winter-spring annual grasses disappear, thus diminishing the grass assortment from 47 to 44 varieties. The total biomass is decreasing (Table 5) as also the forage stock (by 15 per cent).

At the first stage of the rangeland degression the moderate sand loosening occur. In summer deflation hollows or blowouts are developing on windward, north-western, slopes of ridges and hillocks; it needs favourable wind regime and several years to let them "heal".

Nearer to the water point (2-3.5 km) the second grazing belt by the degree of degression (II DD) is being formed where high load on rangelands prevail. Here over 70 per cent of annual grasses disappear and the enhanced surface sand loosening is witnessed; as a result deflation progresses. The deflation blowouts tend to develop more extensively, damaging the original vegetation. Isolated barkhan chains start to appear in some areas.

In this grazing belt the major component of vegetation is the

Table 4

Effect of Rangeland Degression on the Number of Plant Varieties

Relief forms, No. of association	Life-form of plants	Reserve	Degression stages		
			I DD	II DD	III DD
Sand ridges 2	Tree-shrub	5	5	4	3
	Undershrub	8	8	5	2
	Perennial	9	12	7	4
	Annual	25	19	21	16
	TOTAL	47	44	37	25
Small-hillock sands 3	Tree-shrub	5	5	4	2
	Undershrub	6	6	5	2
	Perennial	7	10	5	3
	Annual	29	19	14	13
	TOTAL	47	40	28	20
Takyr-like plains 4	Tree-shrub	1	1	1	—
	Undershrub	4	4	3	3
	Perennial	8	5	1	2
	Annual	22	15	6	4
	TOTAL	35	25	11	9

Table 5

Dynamics of Phytomass in Respect to the Regime of Utilization (average many-year figures, t/ha)

Relief forms, No. of association	Indices	Nature reserve	I DD	II DD	III DD
Sand ridges 2	Biomass	8.7	6.4	6.4	2.5
	overland	3.2	2.7	3.1	1.4
	subsurface	5.5	3.7	3.3	1.1
	Dead mass	0.6	0.8	0.3	0.2
	Overall phytomass	9.3	7.2	6.7	2.7
Small-hillock sands 3	Biomass	7.0	5.0	6.3	2.3
	overland	2.0	1.7	3.1	1.3
	subsurface	5.0	3.3	3.2	1.0
	Dead mass	0.6	0.5	0.3	0.1
	Overall phytomass	7.6	5.5	6.6	2.4
Takyr-like plains 4	Biomass	3.8	1.6	0.6	0.6
	overland	2.6	1.0	0.4	0.4
	subsurface	1.2	0.6	0.2	0.2
	Dead mass	0.8	0.3	0.2	0.2
	Overall phytomass	4.6	1.9	0.8	0.8
		Grazing at moderate load	Grazing and felling		
Ridge-hillock sands 1	Biomass	8.7		5.4	
	overland	3.8		2.1	
	subsurface	4.9		3.3	
	Dead mass	0.1		0.1	
	Overall phytomass	8.8		5.5	

Calligonum association with annual Gramineae. The vegetation composition gets worse due to the disappearance of trees, large shrubs and well-eatable plants. The growths of Carex physodes and Mausolea eriocarpa become meagre and in some places they are not met at all being replaced by plants more tolerable to barren sands. The number of Calligonum, Aristida karelinii, Turnefortia grows. Bromus tectorum prevails among annual grasses. But the number of varieties decreases to 37 (see Table 4). The vegetation coverage amounts to 50 per cent and Carex physodes takes up no more than 10 to 15 per cent.

At the second stage of degression in the ridge-takyr complex of the Kara Kum (associations 2 and 3 in Table 5) the increment of the overland biomass is observed, which emanates from the great propagation and extension of Calligonum rubens due to well-embedded large fruits and removal of competitive requirements for water of Carex physodes. This is, however, only a seeming "well-being" as high yields are obtained for only a short time, they are monotonous in composition and the rangelands have turned from year-round to late-spring (Nechaeva, 1979b).

Consequently, the unwelcome restructuring of the association takes place at the second stage of the rangeland degression: plants-edificators get replaced by ezodominants and ingredients, the ratio of overland to subsurface biomass is shifted in favour of the former. N. T. Nechaeva (1979) has emphasized that these changes may be regarded as indicators of the rangeland degradation and, consequently, of the desertification processes.

The third stage of the rangeland degression (III DD), observed round the water point at a distance of 0.5 to 1.5 km from it, is characterized by a very high load giving rise to the Calligonum rubens-Aristida karelinii association with annual grasses. As a result of intensive sand deflation the area of moving sands increases and the barkhan-type relief is shaping. This leads to a complete change of vegetation: many shrubs, undershrubs and perennial grasses disappear as well as Carex physodes while the bushes of Calligonum rubens are met but very rare; optimum conditions for the development of Aristida karelinii are formed. The plant composition becomes poorer, only 25 varieties remain. The area under vegetation is decreasing to 20 per cent, the overall biomass is dwindling by 70 per cent and the overland biomass dominate over the subsurface one only slightly. The forage yield drastically diminishes and is composed mostly of low-eatable Aristida.

Directly surrounding the water point is a belt of barkhan sands up to 0.5 km wide. This is the last stage of the rangeland degression. Parallelly arranged barkhan chains cover vast expanses. Vegetation is very sparse here and met mostly in inter-barkhan lowerings. The vegetation composition is especially poor – only 12 varieties are left.

All the above describes only one form of the rangeland degression,

which is highly varied, in general. In various types of deserts the replacement of vegetation in the course of progressing deflation goes on differently, but in case of sand breaking and deflation only one way exists – fixed sands differing in relief turn into moving sands with a barkhan and barkhan-hillock relief.

The lifetime of this or that degree of degression depends on the reasons evoking it. When affected by overgrazing rangelands degrade during 5 to 8 years. When ameliorating rangelands it takes 6 years to re-establish vegetation on sands and takyrs of the second degree of degression whereas on those of the third degree of degression of sands even 17 years are not enough since there are no seeds of some trees and shrubs (Nechaeva, 1979b).

Overgrazing directly affects not only the vegetation but the wind-erosion control of rangelands. Witnessed also are the soil compactness by cattle and destruction of vegetation. This worsens the percolation of precipitations into soil, augments the surface flow, diminishes the moisture content and increases albedo of soil. As a result, water erosion intensifies and the rangeland vegetation suffers from moisture insufficiency. All the above leads to the appearance of xerophytes, the decrease of the rangeland's grazing capacity and the development of soil erosion. This is illustrated in Fig. 9.

Erosion and soil deflation, in their turn, induce the diminution of the rangeland productivity, which is manifested, in the opinion of R. Dzhanpeisov and E. U. Dzhamalbekov (1978), first, in the decreased rangeland area as some plots fall in disuse; second, in turning part of rangelands into unsuitable lands; third, in the diminished soil fertility and worsened grass composition. Changes in the elements of the rangeland ecosystem affected by erosion and deflation are shown in Table 6 (Dzhanpeisov and Dzhamalbekov, 1978).

Wind erosion is usually accompanied by the reduced content of organic matter, physical clay, nutrients, and the emergence of crushed stone on the surface.

Compared to vegetation cutting overgrazing has less detrimental consequences. Animals cannot eat all new annual sprouts, while felling, especially the overall one, fully destructs shrubs and undershrubs, and this may become the first impulse for desertification. In severe climatic conditions Haloxylon and certain other trees and shrubs help to survive to some other plants that need microclimate provided by the former. That is why the destruction of Haloxylon entails the disappearance of many valuable plants, usually cohabiting with Haloxylon community.

Trees and shrubs in desert ecosystems also take up soil-protection role, their removal will result in erosion and progressing aridity. Cattle become devoid of their staple winter forage, natural shelters from cold winter winds and daytime summer heat waves.

Before the Great October Revolution the predatory utilization of desert vegetation, expressed in the improper grazing management and random use of trees and shrubs as firewood, led to the intensifi-

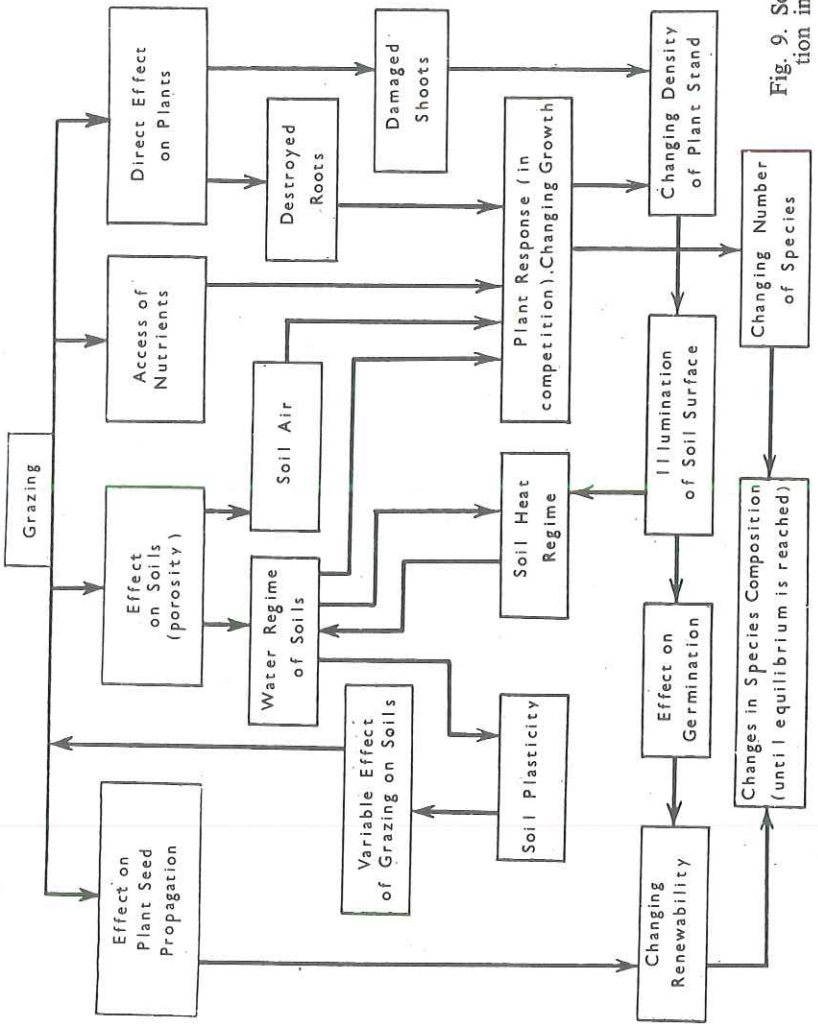


Fig. 9. Scheme of desertification induced by grazing

Table 6

Effect of Erosion and Deflation on Rangelands

Components of rangeland ecosystems	Effect	
	erosion	deflation
Vegetation	Decreased area for growing and nutrients supply; xerophytization; suppression of all types; covering and washing out by runoff products	Decreased area for growing and nutrients supply; xerophytization; suppression of all types; covering and damaging with the products of eolian erosion
Root system	Exposure, decreasing mass of roots	Exposure, decreasing mass of roots
Sod	Scouring, slipping down	Covering
Top horizon	Washing out, trickle scouring, increasing stony and crushed-stony character	Blowing out, coarser texture, increasing crushed-stony character, eolian relief
Humus horizon	Decreased depth, content of humus, nitrogen and other elements of fertility	Decreased volume and fertility
Soil water properties	Decreased moisture capacity, water permeability and water stability of soil aggregates	Decreased moisture content, destruction of aggregates
Underlying rocks	Exposure, scouring	Exposure
Groundwaters	Lowering, decreased flow	Lowering or rising

cation of deflation and the growth of moving-sand areas in oases margins, around water points and settlements. Not rare were the cases when sands buried the whole oases, incurred damage to cultivated lands. Thus by 1925 over 80,000 ha of irrigated lands in the Bukhara oasis and several settlements were buried under sand in the Zeravshan river downstream. Sand was encroaching on the irrigated lands in the Bukhara oasis by a wave 150-200 km wide. Up to the mid-1950s sand drifts were threatening irrigated lands in the Ferghana region, in the Amu-Darya lower reaches, in Surkhan-Darya and Murghab oases.

Enormous fuel deficit was responsible for mass destruction of large shrubs in the desert. In the 1920s-1930s deserts annually provided up to 100,000 tons of Haloxylon and other shrubs, which resulted in intense degradation of shrub vegetation in a belt 75 to 100 km wide, adjoining settlements, oases and railways (Petrov, 1972).

Beginning from 1930s systematic afforestation measures have been undertaken in the zone of moving sands in Central Asia. This enabled to arrest the advance of anthropogenic sands at the oases margins and later put them to agricultural use. In some regions, however, there are still incidents of unsound use of Haloxylon and the ensuing destruction of their growths and the diminishment of their area. The recent two decades have witnessed the moving of the

boundary of Haloxylon forests 10-15 km to the north in the Tau Kum; the area of Haloxylon aphyllum and Haloxylon ammodendron in the Caspian Sea basin is also decreasing (Victorov, 1970; Kurochkina, 1978).

Apart from the overgrazing and destruction of Haloxylon vegetation the desert ecosystems also suffer from the intensive development of their natural resources. Industrial development is accompanied by the construction of new settlements, roads, gas and oil fields, irrigation facilities, which brought to the desert machinery. Besides high economic effect, which desert development gives, it may induce numerous negative implications.

Arbitrary, unorganized operation of earthern roads causes much damage to sand territories, because every driver makes new road here. As a result the width of many roads reaches 0.5-1.0 km. Near water points and settlements these roads converge and the area around becomes fully destroyed by transport. Here impeded are not only cattle grazing, but also transport movement, and what is more extensive seats of deflation are formed. Intensive geological surveys and transportation of drilling rigs are to be blamed for turning 18 per cent of rangelands in the Southern Mangyshlak plateau into temporary unsuitable lands where from 70 to 80 per cent of vegetation are destroyed (Dzhanpeisov and Dzhamalbekov, 1978).

The seats of deflation also spring up near pipelines and canals. For example, in the Kara Kum canal zone during its construction part of the sand excavated and removed has turned into barkhans. The destroying of vegetation in construction zone set loose the eolian processes. Extensive areas of barkhans formed at the outskirts of settlements of building workers and this was aggravated by constant cattle grazing here, road building, spontaneous cutting of trees and shrubs for firewood (Grave, 1976).

Figure 10 shows the wind erosion dynamics at the first stage of the Kara Kum canal construction. Distinguished are moving barkhan sands and moving barkhan surfaces, which appeared as a result of the construction machinery operation. These sands are devoid of vegetation and mainly extend along the canal by a belt 0.5 km wide. Further on from the canal (1-1.5 km) semi-fixed sands prevail. Marshes and filtration lakes sprang up along the canal route and here the natural desert vegetation was replaced with water-loving plant varieties and weeds. Here only a few of the multiple after-effects of the canal construction in deserts on vegetation and soil are mentioned.

Other man-induced factors contributing to desertification may be uncontrolled tourism, gathering of wild plants and damage to animals in their critical periods. This may cause the diminishment or even elimination of the most valuable plants and animals.

Burrowing rodents also assist deflation progress. By building hundreds of holes, eating and trampling down vegetation on fixed sands, rodents are facilitating the appearance of small deflation seats, which, under favourable conditions, turn into large deflation

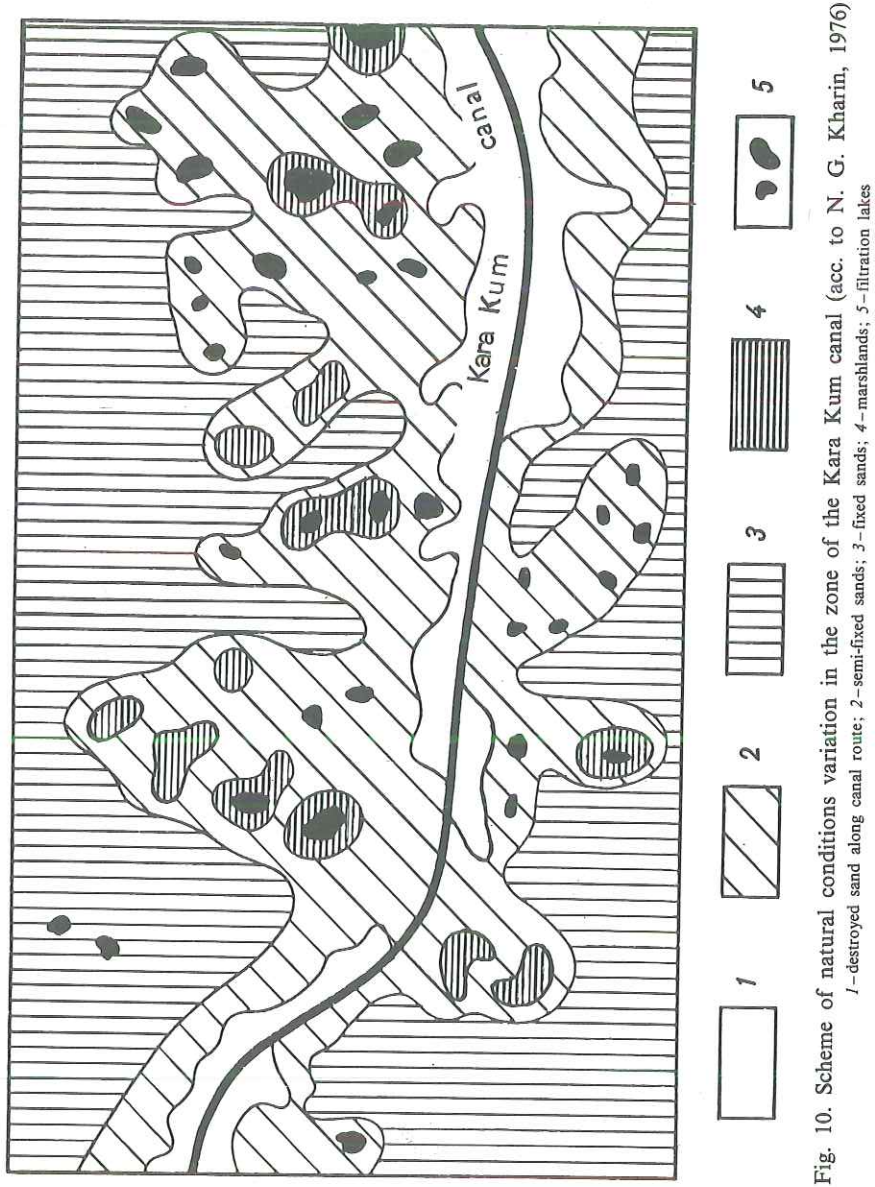


Fig. 10. Scheme of natural conditions variation in the zone of the Kara Kum canal (acc. to N. G. Kharin, 1976):
1 – destroyed sand along canal route; *2* – semi-fixed sands; *3* – fixed sands; *4* – marshlands; *5* – filtration lakes

hollows. According to A. G. Babaev's estimations (1973), the average number of holes on one hectare of sands in the Murghab oasis is as large as 850-900, in the Lower Amu-Darya oasis – 740-800 and in the Tedzhen oasis 490-550. In the years most favourable for rodents multiplication the number of holes reaches 1,500-1,600 per hectare and more.

Desertification may develop not only in the grazing zone but in the irrigated areas as well.

Specific climatic conditions of deserts – abundance of solar radiation, small precipitations, high air temperatures and great humidity deficit – are conducive to intensive evaporation not only of the precipitations fallen, but also of groundwaters. This results in the increased salinity of groundwaters, and in case of their shallow occurrence – in the salt build-up in the top soil and formation of solonchaks.

Irrigation of lands with poor drainage characteristics brings about the groundwater rise and, ultimately, soil salinization. Thus the problem of the soil salinity control always accompanied the irrigated farming development through many centuries. Various remedies were used in different places, in different historical periods, and in different socio-economic conditions.

Before the Great October Revolution irrigation facilities in Turkestan were very primitive, and irrigation was conducted at a low land-use coefficient. This made artificial drainage not necessary, as dry drainage quite met the requirements, since excessive rates of irrigation made salts migrate to unwatered plots. Thus, irrigated lands were leached, and the adjoining areas where drainage water evaporated got salinized. In that irrigated lands took up less than 30 per cent of the oases territory and the rest territory was covered by century-old salt accumulations and salt lakes. This has essentially affected the water-salt balance here.

Further development of virgin lands made dry drainage inadequate and then, in the period of nomadic land use, peasants got down to leaching saline soils and removing salts by mechanical means (*Irrigation in Uzbekistan*, 1975). Salts were removed by means of surface flushing. As a result the disposed water inundated the adjoining areas and induced their salinization. In the ancient Khorezm oases salts were removed together with the top soil which was replaced with non-saline soil mixed with manure and sand. But these methods were fit only for small private land holdings. Private ownership of land and water drastically impeded the development of irrigation and drainage and led to the improper irrigation network development and predatory land and water use. Consequently, extensive areas were salinized and waterlogged, in other words, secondary desertification developed but this time caused by irrigation.

In the years of the Soviet power comprehensive programme of irrigation and new lands development in the arid regions of the USSR was implemented. Thus, in 1978 over 7.5 million ha were irrigated in Central Asia and Kazakhstan. In 1972, when drought

affected many regions of the Soviet Union, irrigated lands provided over 9 million tons of grain, 7.3 million tons of raw cotton and large crops of vegetables, potatoes, sugar beet and forage.

However, emphasizing the success achieved in irrigated farming and development of new lands, mention should also be made of adverse impacts and the necessity to search for the ways and means of their elimination or abating.

Irrigation intruded upon nature, infringing its equilibrium and often bringing unexpected impacts which may give rise to desertification, salinization, waterlogging, and wind and water erosion. Especially acute these problems arise when irrigating lands with poor natural drainage and coarse soil texture.

Until 1956 the efforts were mainly directed to the construction of earthen canals, selective building of widely spaced and shallow collecting-and-drainage networks, levelling of individual plots. Because of the reservoir construction, seepage from irrigation canals and irrigation of large territories, the quick groundwater rise was witnessed. For example, for 3-5 years of irrigation in the Golodnaya Steppe the groundwater table established at 1 to 3 m from the ground surface. The average annual groundwater rise in the Murghab oasis made up from 0.5 to 0.6 m, and in some places even from 0.8 to 1.0 m. This was attended by land salinization and the increased salinity of groundwaters.

In the period 1936-1956 the processes of soil salinization and desalinization in the arid regions of the USSR were going on at various intensity. Considerable secondary salinization of irrigated lands was recorded in the 1940s and the attempt to remove salts with mechanical means was a failure. The leaching of saline soils by flooding with the subsequent water diversion had certain effect, but a short-standing one. After leaching was terminated the salt content quickly restored. Leaching based on the use of small surface ditches has proved more effective, but in this case the salt content also quickly returned to its former level. The construction of large collectors and extensive drainage systems undertaken in 1956-1960 appeared most advantageous for controlling secondary salinization.

Land reclamation made it possible to reduce the area of highly saline soils in the Tadzhik SSR from 35 per cent in the past to 9 per cent in 1972, the area of solonchaks in the Khorezm oasis by 34,100 ha, and the area of solonchaks and highly- and medium saline soils in the Ferghana Valley by 82,000 ha in comparison to 1936 (Kovda, 1977; *Irrigation in Uzbekistan*, 1975). However, the engineering level of some irrigation systems is far from perfection. As a result the Bukhara oaies faces the increase of salt-affected lands, and the Amu-Darya delta – of solonchaks and other types of saline soils. In the zone of old irrigation patches of saline soils in cotton fields still survive.

Of 2,750,000 ha of irrigated lands in Uzbekistan nearly 60 per cent are affected by salinity in different degrees and are in need of

ameliorative and preventive measures. In the Turkmen SSR amelioration is required on an area of 516,300 ha of irrigated lands, of which more than 50 per cent are in the zone of the Kara Kum canal (*Irrigation in Uzbekistan*, 1975).

Grand tasks in respect to desertification combat in the zones of new irrigation are awaiting their solution. Many of these zones are composed of soils with poor drainage, characterized by the presence of saline horizons and need desalinization improvements. In the zone of the Kara Kum canal improvements are needed on an area of 1.4 million ha of the total 1.9 million ha of lands suitable for irrigation, in the Karshi Steppe – 0.8 million ha out of 1 million ha, and in the Golodnaya Steppe virtually all lands may be developed only through drainage improvements.

The extensive construction of the collecting-and-drainage network gives rise to the problem of disposal of the evergrowing amount of drainage water outside oases. Drainage waters are often diverted into depressions located in the desert, beyond the irrigation systems. As a result, a whole system of solonchaks started to develop in the contact zone of desert and oases where salt deflation begins its progress. This leads to the worsened grass stand and salinization of cultivated lands.

One of the important problems is the effect of irrigated farming on man's health, as irrigation water may become the source of some infectious diseases, the most dangerous of which are malaria, schistosomiasis, typhoid fever, and dermal leishmaniasis. An outbreak of these diseases is indicative of violations in the operation of irrigation facilities and drinking water supply (Zonn and Mrost, 1976).

Sanitary-hygienic preventive measures carried out together with the improved operation of irrigation facilities, control of irrigation water losses, and perfection of water application technique have led to fully erasing the danger of formerly menacing epidemics in the arid regions of the USSR.

Irrigation development and flow regulation undertaken in the recent two or three decades in the Syr-Darya, Amu-Darya and Ili River basins have caused drastic changes in environment there. Induced by the irrigation intake from the Syr-Darya River and the diminished flow of the Amu-Darya River, the water level in the Aral Sea has lowered: in 1977 the water level on the eastern shore receded by 50 km and solonchaks started developing on the dried-off area formed (1000 sq.km). In lagoons, depressions, and former filtration lakes a salt crust or a loose layer of salt deposits of considerable depth formed (Kostyuchenko and Bogdanova, 1979). Here deflation processes are progressing. As a result halogeochemical processes show the tendency for changing in the Aral Sea basin. Earlier this sea was receiving salts brought by rivers from irrigated areas, and nowadays the drying-off coast becomes the "supplier" of salts, i. e., salts are transferred from here to nearby lands with wind. The possible after-effect is the increased salinization of rangelands, and irrigated

lands and their decreased productivity (Borovsky and Kuznetsov, 1979).

In addition, desert advance on vast territories of the Amu-Darya and Syr-Darya deltas is taking place. Flow regulation and cessation of spontaneous river inundations resulted in the changed hydrology of the river valley and the drying-off of meadows along the Syr-Darya lower reaches, 500 km to the east of the Aral Sea shore. Also drastically reduced are forage yields; sheep flocks in the Kyzyl-Orda region was cut down by 103,000 heads in 1977 compared to 1971, and only 75 per cent of the remaining flock was provided with forage (Borovsky and Kuznetsov, 1979).

The biological productivity of vegetation was drastically cut down as a result of a sharp diminishment of reeds' area – from 4,000 sq. km in 1948 to 200-300 sq.km in 1974. It is only in the Kazalin delta that Salix and Elaeagnus vegetation on an area of 500 ha and Glycyrrhiza associations on an area of 1,200 ha have disappeared. Vast expanses in the Syr-Darya and Amu-Darya deltas become devoid of water-loving vegetation, which is gradually being replaced by thinned xerophyte vegetation (Kurochkina *et al.*, 1979).

The fact that during floods the Syr-Darya water got to the dry Zhana-Darya channel had positive implications – favourable conditions were created for the growth of Haloxylon aphyllum forest covering an area of nearly 300,000 ha. At present this does not happen and the forest is gradually disappearing.

Desertification is progressing in dried-off deltas of the Syr-Darya and Amu-Darya Rivers. Intensive salinization of marshlands is responsible for the formation of meadow solonchaks. Meadow solonchak soils gradually transform into desert solonchaks and drying-off marshlands will turn with time into the takyr-like soils (Kurochkina *et al.*, 1979).

These are the major causes of desertification in arid regions of the USSR. To realize its scale within Turkmenia the staff of the Desert Research Institute of the Turkmen Academy of Sciences have prepared a map of desertification (Fig. 11) on the basis of the following factors contributing to desertification:

(1) natural features (sand expanses and moving sands. accumulation of stones and crushed rocks, outcrop of parent rocks, clay surfaces devoid of vegetation, solonchaks, water-erosion affected territories, etc.);

(2) anthropogenic impacts (areas with a high population density and places of intensive grazing).

For arid regions the critical indices for anthropogenic impacts are assumed to be the population density equalling 7 persons per 1 square kilometre and pressure on rangeland – one sheep per less than 5 ha. The integrated assessment has identified territories, where the vulnerability to desertification is ranging from high to medium at a high population density or a high pressure on rangelands, as of very high probability of desertification, while those characterised by

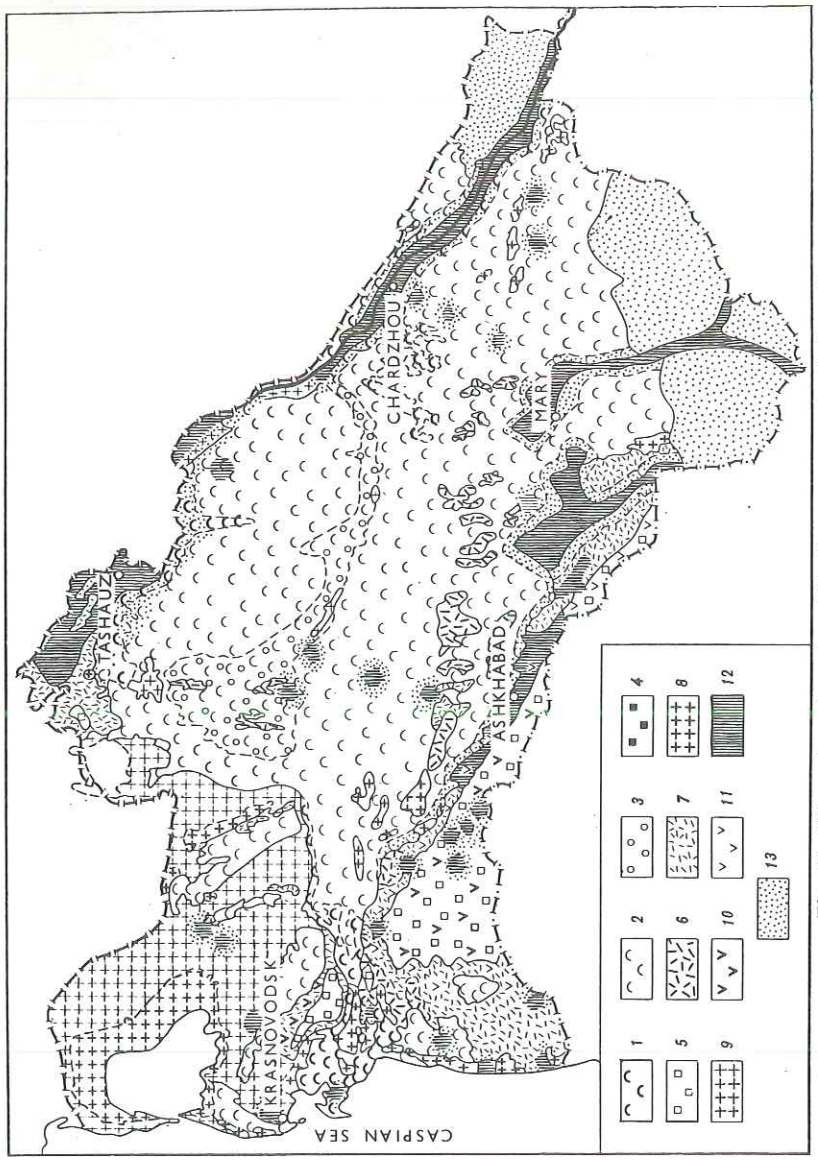


Fig. 11. Map of modern desertification processes in Turkmenistan:

1–fixed sands from high to medium vulnerability to desertification; *2*–same, from medium to low; *3*–accumulation of stones; *4*–accumulation of crushed rock, outcrops of parent rocks of high vulnerability to desertification; *5*–same, of low vulnerability; *6*–compacted clay surface devoid of vegetation of high vulnerability; *7*–same, of low vulnerability; *8*–saline gray-brown soils with patches of solonchaks of high vulnerability; *9*–same, of low vulnerability; *10*–water-erosion-affected areas of high vulnerability; *11*–same, of low vulnerability; *12*–areas with relatively high population density; *13*–areas with relative overstocking

the medium to slight vulnerability at a high population density or a high pressure on rangelands – as of medium probability of desertification. The territories whose vulnerability ranges from medium to slight are referred to the third group (low probability of desertification). In Turkmenistan, the contact zones of desert and oases as well as areas around settlements and water points are identified as regions of medium probability of desertification. High probability of desertification is virtually non-existent.

The more detailed scheme of desertification manifestations in South-East Turkmenia was devised by N. G. Kharin and G. S. Kalenov (1978) on the basis of space surveys. The obtained photos vividly show various forms of desertification: continuous areas of moving sands, local patches near water points, and waterlogged and salinized areas (Fig. 12).

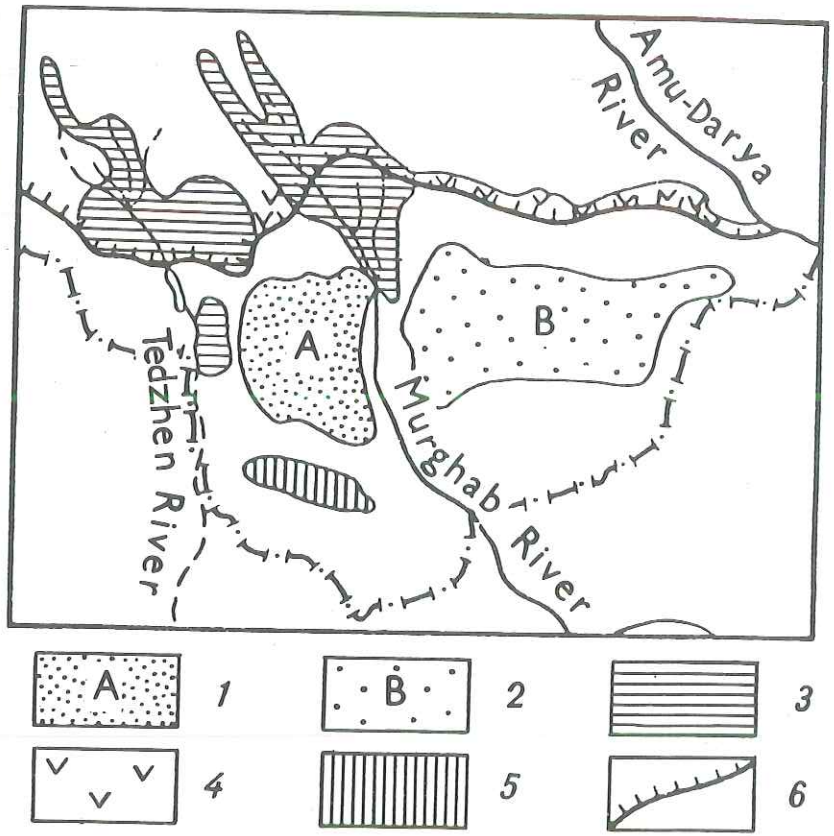


Fig. 12. Desertification manifestations in South-East Turkmenia:

1–regions of desertification patches occurrence in the Tedzhen-Murghab interfluve; *2*–same, in the Murghab-Amu-Darya interfluve; *3*–oasis zone with patches of waterlogged and saline soils; *4*–regions of desertification along Kara Kum canal; *5*–reserve territory not affected by grazing; *6*–Kara Kum canal

Local patches of desertification are most often met in the vicinity of water points, the distance between them in the interfluve of the Murghab and Amu-Darya Rivers is usually as large as 7 to 10 km, the average diameter being 2 km (Kharin and Kalenov, 1978). The affected area near a water point is dependent on the borehole yield, intensity of its use, season, relief and exposure to wind erosion. The overall area of barkhan sands in the depressions with water points makes up 350 sq.km in Turkmenistan and takes up nearly 10 per cent of the Kyzyl Kum territory (Ovezliev *et al.*, 1979; Vinogradov, 1976).

The man's impact upon deserts will take an ascending tendency in the nearest future. Thus, to arrest desertification the need is to concentrate efforts on desert environment protection and restoration of natural resources there.

Indicators of Desertification

Failure to properly cope with desertification may be explained by various reasons, the most obvious of which are late identification and incompleteness of combative measures (not all factors are accounted for).

There may be assumed two stages of desertification: first, when desertification features are perceptible, but their manifestations are so far slight, and the whole process is still reversible; second, when the process is almost irreversible. The conventional nature of such division is quite obvious since desertification is a continuous process. However such approach opens up possibilities to devise methods for recognizing and controlling certain physical, biological and social factors to ensure the timely identification of negative processes in arid ecosystems.

The idea of developing indicators of desertification was first voiced and discussed at two international seminars in Nairobi (Nechaeva, 1978) and the USA (*Handbook of Desertification Indicators*, 1978). There also was identified a complex of the most important indicators, reflecting the desertification degree caused by man's activity.

Indicators are needed to assess the vulnerability of ecosystems in respect to desertification; to forecast this process in advance; to monitor it in affected areas; to evaluate its implications and to devise combative measures.

These indicators are called to help the correct decision-making at the present, and further on they may be used for monitoring in the final assessment of the state of the region and to plan measures to do away with desertification.

Making use of sounding technique it has become possible to undertake effective and regular survey of vast territories employing computers; the same territories may be selectively studied in more detail.

The potentially valuable indicator of desertification may be the reflecting capacity of the Earth. It may provide information on the vegetation density, soil erosion, soil salinization, water-logging, etc.

Indicators are grouped to meet the requirements of individual farms, regions and countries. Many of them may be measured by simple reliable methods, not requiring special training. Some others need carrying out analysis of samples.

Physical indicators are: (1) degree of soil salinity and alkalinity; (2) groundwater depth and quality; (3) depth of the root zone; (4) number of dust and sand storms; (5) availability of soil crust; (6) organic matter content in soil; (7) changes of water flow and sediment runoff; (8) water-erosion-affected territory, and surface water turbidity.

These physical indicators are to be further detailed with regard to physiographical peculiarities of various natural zones. A very important drawback of the listed indicators is the absence of the soil texture; this indicator is highly essential for arid regions (Nechaeva, 1978), as coarse soils easily vulnerable to deflation are mostly met there. Hence, in furthering physical indicators, especially for desert conditions, soil texture should not be overlooked.

Any change in indicators reflects the progress of desertification. It is very rare that to assess some particular effect of land use on desertification only one measurement will be enough. Repeated measurements at various intervals are very essential with some indicators.

Direct measurement cannot be applied to two vital factors – soil fertility and structure. These indicators are characterized by the erosion level, the presence of the crust, etc., as well as the changing level of organic matter and chemical elements. The assessment of these should be carried out at representative, for the given region, plots and at certain time intervals.

Mention should be made that climatic conditions (rainfalls, temperature, wind speed, etc.) are not referred to physical factors contributing to desertification, as short-term climate variations cannot be indicators. But the climatic and meteorological information for the definite region or time period is still necessary to correctly comprehend data on several physical indicators.

Biological (agricultural) indicators. Good indicators of the ecosystems are vegetation, its density, distribution, composition, age range of cenopopulations, biomass (primary product) as well as zoocenosis.

Monitoring is required of natural ecosystems of protected, unutilized territories likewise of territories in economic use.

Plant varieties, being indicators of desertification, are not necessarily the most widespread in this region. These may be sub-dominants and ingredients, very sensible to ecological conditions. The green yield and the secondary product emerge as important indicators.

Below are listed biological (agricultural) indicators which are to be further developed with regard to various desert types:

1. Vegetation: (a) types and life-forms – distribution, structure of cenopopulations; (b) type of tree-shrub vegetation canopy; (c) overland grass vegetation; (b) mosses and lichens; (e) plant communities; (f) biomass (overland and subsurface) and forage yield (economic produce).

2. Animals: (a) major species (including wild mammals, birds, insects, etc.); (b) domestic cattle stock; (c) animal population; (d) population composition; (e) specifics of breeding; (f) secondary product.

Special need must be given to the fact that to assess desertification a combination of physical and biological indicators is often used.

Social indicators. Not a single indicator taken separately is capable of fully characterizing the intensity of desertification; a combination of indicators is needed. It is assumed, therefore, that social indicators will be used together with physical and biological indicators since the processes studied are complex in nature.

Social indicators are:

1. Land use: (a) irrigated farming; (b) rainfed farming; (c) animal husbandry; (d) use of vegetation for fuel and building; (e) mining industry; (f) tourism and recreation.

2. Principle of the regional planning and management: (a) settlements location; (b) industries location; (c) types of engineering structures, irrigation facilities and water supply systems; (d) transport organization; (e) future trends of region development.

3. Settlement structure, especially in rural areas: (a) new settlements, location of dwelling houses, cultural and everyday-service enterprises, industrial enterprises, greenery, etc.; (b) extension of settlements; (c) abandonment of settlements.

4. Population structure and number.

As any other regions Central Asia and Kazakhstan have their own specific natural conditions and national traditions. Thus each region requires special adjustments be made in respect to local conditions. Besides a number of indicators pertaining to the organization and development of arid territories are awaiting their further verification.

CHAPTER III

EXPERIENCE OF DEVELOPMENT AND RATIONAL MANAGEMENT OF DESERT RANGELANDS

A Brief Case-History of Desert Range Utilization

The Soviet Union's natural rangelands total over 370 million hectares, discounting the tundra and forest-tundra range. Almost a third of this total area under rangelands and grasslands, or about 122 million ha, lies in the desert regions stretching far and wide in Central Asia and Southern Kazakhstan – the Kazakh Soviet Socialist Republic.

In the total balance of agricultural lands these desert rangelands make up 95 per cent in the Turkmen Soviet Socialist Republic (Turkmenistan), 84 per cent in the Uzbek Republic (Uzbekistan) and 89 per cent in Southern Kazakhstan (Nechaeva and Pelt, 1963). In the past few years it has been estimated that this range area supports nearly 17 million sheep, including 13.5 million of the karakul breed, plus tens of thousands of camels (Nikolaev *et al.*, 1977).

Karakul sheep, the race originated in Central Asia and recognized world-wide for the unsurpassed spectacular quality of its fleece, is ranking currently amongst the most numerous sheep races out of those husbanded in the USSR. The use of range forage provides the karakul-breeding sector of animal husbandry with large potential for future development and high rate of profit. If it is considered further that, in addition to supplying karakul lambskins, sheep husbandry on the desert range turns over mutton and wool by tens of thousands of tons per year, it will be readily apparent that the sector contributes on a vast scale to the national economies of the Central Asian republics and Kazakhstan.

The desert rangelands are suitable for use all the year-round. Moreover, the range forage has some advantages over and compares well with other forages because of the variety of nutrients it provides and because of their good digestibility in the animal body and low production costs. The latter, in its turn, has the effect of bringing a reduction in the cost of livestock output. So much so that the Central Asian republics majoring in the use of desert rangelands have attained the lowest production costs of wool and mutton, both staple products of animal husbandry, relative to other economic regions in the Soviet Union.

Alongside the advantages, however, the desert pastoral livestock

husbandry has some disadvantages attached to it. The major ones of these are low-to-modest forage yields, seasonal patterns of use over a substantial portion of the range area, large interannual swings of productivity, and inadequate water supply in some of the regions

The Soviet Union's desert range occupies a vast area extending 20°SN and 36°WE. Central Asia's open geographic relations with the neighbouring countries have been, no doubt, the determinant factor in setting up here a potentially favourable situation for the unhampered settlement and spread of vegetation.

In total, the vegetational variety in these parts adds up to over 5.5 thousand plant species and forms. The broadest range of species is typical of the mountain regions, with a mere 800-1000 plant species found in the plains. Of these, the overwhelming proportion has some nutritive value with respect to different kinds of livestock.

It should be particularly emphasized that the contribution of different forage plants to the livestock grazing rations varies strongly with their frequency of occurrence and palatability at different seasons.

Under the present classification of rangelands, in the Soviet Union's desert regions there are three pastoral subzones, each with clearly distinctive climatic pattern of its own – northern, southern, and foothill. They are then subdivided further according to the nature of soil and plant cover into pastoral classes, groups, and types.

Central Asia's livestock husbandry of the former years was characterized by the presence of three main types – desertic, oasis and mountainous, and three principal kinds of livestock – sheep, goats and camels. The northern desert regions were essentially the areas of advanced droving horse-breeding, the oases majored in cattle husbandry and the mountains were largely the domain of sheep and goats. Besides the local races in droving horse-breeding widespread over the vast expanses of Kazakhstan, broad reputation went to the race-horse breeds reared in the downstream Amu-Darya and Akhaltekin oases.

Yet rearing sheep and camels has at all times been the most important single trend in the desertic animal husbandry. Karakul sheep were being raised most intensively in the deserts of Kyzyl Kum and Kara Kum – on the land tracts clinging to the Amu-Darya, while coarse-fleece sheep races claimed all of the remaining area. In the past, the desert rangelands were utilized, in the main, by way of seasonal and year-long transhumance, sometimes over very long distances.

Private livestock husbandries maintained at that time the nomadic way of life, with far-away seasonal migrations and the livestock was destined to subsist all through the year on grazing forage alone.

There was no strict allocation of rangelands among the households

and anyway it was not rangelands believed to be one's property but wells and other water sources which only the wealthiest of the stockmen could have the means to build. The available historic records on the character of range use in the past as it was practiced in different natural regions of the desert provide evidence enough to draw in outline the schematic lay-out of seasonal migrations (Fig. 13).

Commencing their movement early spring from the south the nomads advanced gradually with their livestock way north, following green grass. As cool temperatures descended in the autumn, the herds were brought back. For the winter they withdrew into the sands, covering in all, hither and thither, up to two thousand km and more.

The vast country embracing the Muyun Kum sands, River Chu floodplain, and the deserts of Betpak-Dala and Sary-Arka represented even then a single economic area from the standpoint of livestock production, kept in year-long use by means of continuous migration. Camping for the winter in Muyun Kum, with the advent of spring the stockmen moved the animals over to the sagebrush rangelands of Betpak-Dala, grazed them through the summer on the sagebrush-grassy ranges of Sary-Arka and returned in late autumn way south, to Muyun Kum. Between Sary-Arka and Muyun Kum there were four major driveways with a well-developed network of watering points, and the livestock were driven in large numbers and all at once along the driveways.

In the Kyzyl Kum ranges located in the interim area of the Syr-Darya and Amu-Darya, sheep-breeding has long since been patterned on a sequence whereby the sheep stayed there through the spring, summer and autumn, but were taken to the river floodplains for the winter. A relatively minor proportion of the sheep population never left Kyzyl Kum during the year, less so in mild winters. If there is a common unifying feature of nomadic livestock husbandry in the desert it was its total dependency on weather conditions. Indeed, all livestock were fed off grazing forage all through the year because no systematic grass stocking for hay was done on any regular basis. As a result of this malpractice there were incidents of mass death losses of livestock in the years harsh for weather conditions – when droughts descended or snow fell deep upon the ground in cool winters. From the recorded testimonies of veteran herders, in the winter of 1899 deep snowfall in Kyzyl Kum, followed by icing, took the toll of 90 per cent of the sheep and goat population. In the winter of 1910 strong winds and freezing colds in Ustyurt killed the greater part of the herds. Finally, in the winter of 1917 enormous snowfalls buried under thick snow the vast territory of Kara Kum and Kyzyl Kum and subsequent icing for a lengthy period after that caused an almost total death of livestock.

As the transhumant-pastoral economies of state and collective farms came to replace the former nomadic private husbandries, the research and production organizations in charge were confronted with a whole series of problems which had to be dealt with quickly

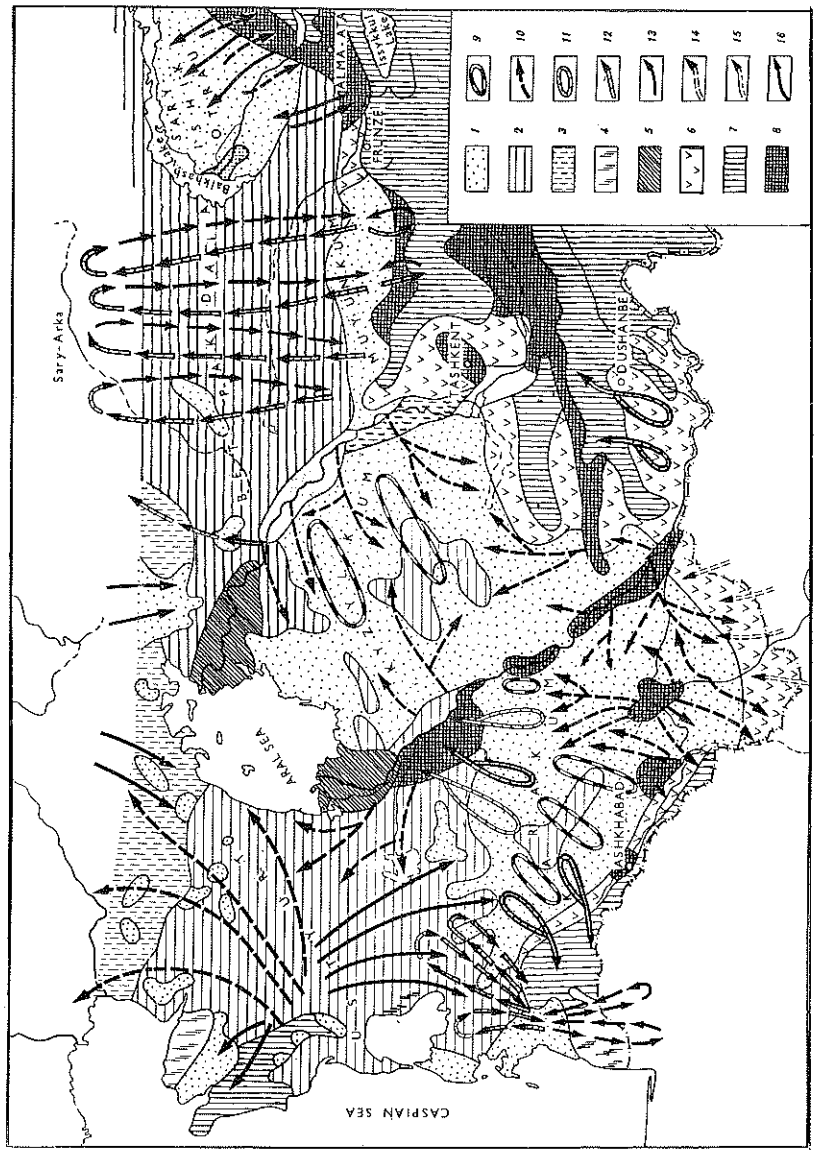


Fig. 13. Rough scheme of rangelands management in Central Asia and Kazakhstan in the past:
Desert types: *1*–sand; *2*–gypseous; *3*–clay; *4*–solonchak; *5*–river floodplain; *6*–piedmont regions; *7*–mountains; *8*–oases. Seasonal migration with cattle: *9*–year-round; *10*–spring-summer-autumn; *11*–autumn-winter-spring; *12*–spring-summer; *13*–autumn-winter; *14*–spring; *15*–summer; *16*–winter

and efficiently if further development were to continue in the desert. The desert rangelands were to be fully inventoried and their potential estimated within the very brief schedule allotted, and efforts had to be carried through to reinstall the already sparse and damaged network of watering wells and to bring water to new pastoral regions.

With these goals in mind and in order to identify the types of rangelands, their forage production potentials and seasonal suitability for proper allocation of sheep populations, route surveys of grazing areas had been undertaken since the early 1930s simultaneously in all Central Asian Soviet Republics and Kazakhstan, under the methodological guidance of the USSR National Institute of Feeds and Forages. They resulted in inputs for the compilation of republican medium-scale general maps, complete with detailed tabulated data on forage yields, their seasonal and annual dynamics, the potential grazing capacity of rangelands and practical annual grazing rates per head of livestock.

Since the 1930s comprehensive geobotanical surveys of rangelands to cover the whole desert territory of the USSR have been maintained on a periodic basis, for which the republican agencies in charge of survey design contribute the needed resources and research institutes the required methodological support. Part of the programme is likewise devoted to producing pastoral maps with respect to administrative regions, districts and economies. The survey findings are then generalized (Table 7), enabling the productive capacity of the desert rangelands to be estimated and the uncommitted production potential to be thus identified (Nikolaev *et al.*, 1977).

Table 7

Potential Grazing Capacity of Rangelands in the Desert Regions of Central Asia and Southern Kazakhstan (in terms of karakul sheep population)

Republic	Area, M ha		Mean annual forage yields, t/ha	Total forage, M t	Grazing capacity, M head
	total	range			
Turkmen SSR	49.1	41.0	0.13	5.41	5.7
Uzbek SSR	45.1	33.5	0.29	9.74	10.3
Kazakh SSR (southern regions)	74.4	54.6	0.31	17.25	18.2
Total	168.6	129.1	0.25	32.40	34.2

On the whole, the total pastoral territory of Central Asia and Southern Kazakhstan makes up around 129 million ha, with nearly 122 million ha situated on the desert range and the remaining area in the mountains. Given the whole range area were developed to livestock husbandry, it should be able to support about 34 million sheep in the average year for productivity. For comparison, it can be noted that in the recent years this pastoral area has supported over 17 million sheep and almost one million cattle. In terms of

conventional sheep units this means that their actual number will run the total to 22 million suggesting the presence of a yet untapped potential of grazing lands, to be developed in the next few years.

The inputs from the large-scale geobotanical survey of the desert range were taken as a basis to allocate the pastoral area among the collective and state farms committed to livestock husbandry. This sizable as well as essential undertaking was accomplished by land-management agencies in the Soviet republics involved in the short time. The transfer of rangelands to state farms and assigning them to collective farms for long-term use did a great deal to abolish the previously existing lack of clear-cut commitment to the rangelands and set the stage for their planned development.

The development of the desert rangelands for pastoral livestock production relies heavily on their watering. Livestock maintenance out in the open range is impossible without first providing a network of watering points, yet perhaps nowhere are perpetual water shortages as severely obvious as in the desert.

Before the Great October Revolution no practically meaningful hydrogeological investigations had ever been undertaken in the desert regions, thus complicating enormously the execution of range watering programmes in the initial period. As early as the 1930s, however, all Central Asian republics and Kazakhstan launched detailed hydrogeological surveys that have been continued since well into the present. A short time was taken to compile large-scale hydrogeological maps for the whole pastoral area of the desert regions, the move allowing the hydraulic construction personnel to get range watering fully underway and pursue it according to plan.

The most common method of range watering in the desert takes advantage of ground fresh and low-mineralized waters by building wells. Yet the very process of well construction, especially in drifting sands, is labour-consuming and hazardous. The difficulties that arise are particularly grave in the construction of deep-water wells where the ground water occurs below 300 m. The complexities besetting water development there stem from low yields, to the exclusion of water lift with the help of drilled wells. The long-accepted traditional practice on such minor groundwater lenses has dictated preference for open wells of the crater type, with obligatory construction of an underground water-holding pool. Soviet hydraulic construction specialists designed a screened-cemented and later armorclad well of the crater type. The ease of construction, long service life and moderate building costs assured for this well design wide-scale acceptance throughout the desert regions of the USSR.

Over the past decades much has been done towards watering the desert rangelands. In addition to the construction of watering wells, other extensively used techniques involve well drilling, capping wells, construction of facilities to collect surface rainfall waters, and installation of water-supply mains. In order to place watering programmes on the solid foundation of industrial methods, all Central

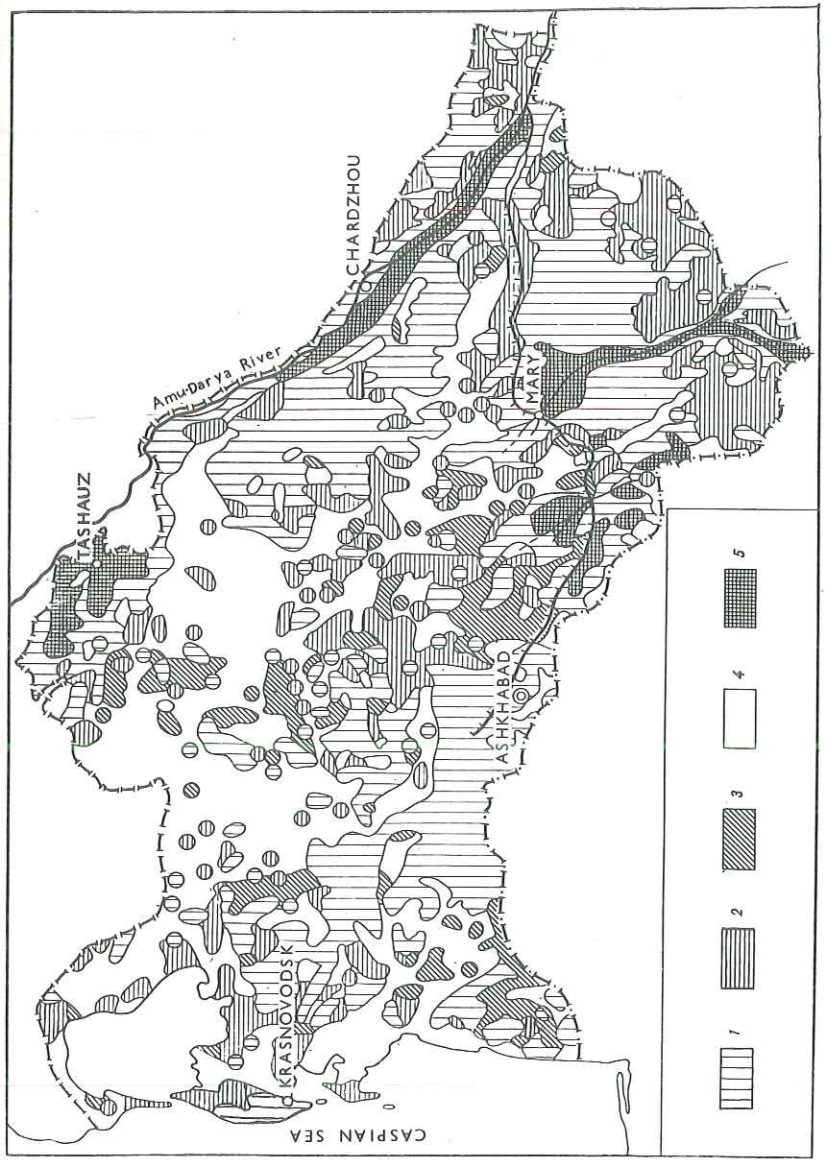


Fig. 14. Water supply of rangelands in Turkmenia at present:
Water supply: *1*–year-round; *2*–only in autumn and winter; *3*–only in spring; *4*–areas not provided with water; *5*–oases

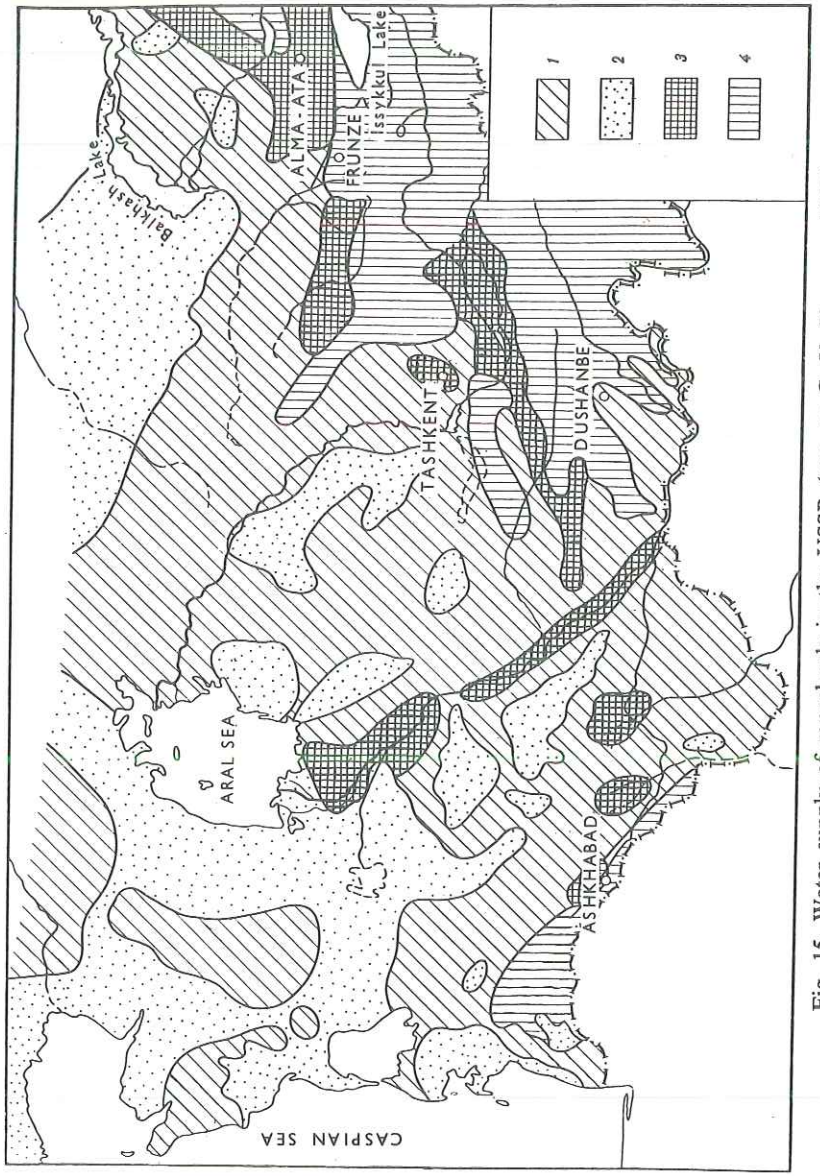


Fig. 15. Water supply of rangelands in the USSR (acc. to G. V. Kopanev, 1967): *1*–rangelands provided with water; *2*–rangelands not provided with water; *3*–oases; *4*–mountains

Asian republics and Kazakhstan established, as long ago as the 1940s, specialized range-reclamation construction trusts and provided them with skilled manpower and equipment. A method presently in wide use embarks on the construction of multiple-user water-supply mains to cater to the pastoral regions where other ways of water supply prove largely inefficient. The current pattern of water supply for the rangelands in the Turkmen Soviet Socialist Republic is schematically illustrated in Fig. 14.

An equally fast and vigorous pace in conducting desert range watering programmes was maintained elsewhere in the USSR. A general idea about the state of the art in desert range watering in the USSR can be had from G. V. Kopanev's schematic in Fig. 15. Despite this, there are still extensive range spaces in Ustyurt, Kara Kum and Kyzyl Kum, Betpak-Dala, and other regions with only a scarce network of watering points disallowing rational range use there. In these areas watering has already come underway, to become fully operational in the several years to come.

Over and above the sweeping programmes to bring water to the desert rangelands, another wide-scale effort, initiated immediately after the establishment of livestock-producing state and collective farms, was directed to efficient intra-farm land management on the pastoral territory. Effective keys to the intra-farm land management could not have been provided prior to the development of a scientifically based system of rational range use, avoiding the adverse effects of grazing in perpetuity of adequate range productivity for the longer term.

System of Measures Towards Rational Desert Range Management

The present system designed for rational use of the desert rangelands, or a system of rotational range management, consists of planning for and carrying through a whole series of management and production measures to block out the devastating impact of overgrazing on range preservation and assure the annual intake of livestock production in optimal quantities from a unit range area. In practice, the system is operated through the introduction of an intra-farm long-term plan of range use. The plan provides for the allocation of the farm's rangelands among its livestock divisions and production teams, adaptation and utilization of an optimal pasture-rotation sequence, drawing up feed balance sheets for different years in terms of productivity with the indication of the sources from which to make up for the likely deficit of nutrients in range forages at individual seasons, and implementation of advanced range-grazing methods and facilities.

As part of the intra-farm land management programme, a coordinated approach is needed to the watering of different range sites and the

building of production facilities, cultural premises and housing.

In the context of desert range management, a greater output and improved quality of livestock production are largely dependent on whether the animals receive adequate feeding at all seasons of the year. In order to feed animals properly, a pre-knowledge of responses by the animal organism to the feeds, and the latter's palatability and nutritive value at different seasons is necessary. It is not surprising, therefore, that research work on the quality of forages from the desert-zone rangelands is the focus of attention at the specialized national and republican scientific centres. With a large body of factual data accumulated to date, it has been possible to provide insights into the seasonal dynamic patterns of chemical composition and nutritive value with respect to the principal species of desert range plants and formulate pastoral rations for sheep grazed on different types of rangelands. Taking advantage of the research programmes in the qualitative evaluation of range forages the planning and production organizations have been able to move on to drawing up tentative feed balances for range-based livestock husbandry.

The qualitative and quantitative estimates of range forages are integrated by numerous specialists for compiling a land cadastre (register) of natural grazing areas. The land cadastre is known to include, as its major constituents, the following items: a quantitative estimation of land by the type of agricultural areas; a qualitative evaluation of lands also known as land appraisal; an economic assessment of lands; cadastral maps.

For the conditions of the desert zone, range appraisal employs on a wide scale such criteria as the range forage yield and its nutritive value in feed units, corrected for the content of digestible protein, the single most important forage constituent. Presently, with the appraisal of desert ranges in mind, special appraisal scales have been developed to permit an objective assessment of the rangelands within extensive areal limits.

In the desert zone bedevilled by wide and abrupt fluctuations in weather and grazing conditions on its rangelands year-by-year, rational management of the livestock economy is hardly possible unless supported by advance and current information about the condition of rangelands, to be provided for each calendar year.

The information can come on hand as a result of ground and aerophotometric range surveys accompanied by the production of current-awareness pastoral maps.

The development of data in the course of a comprehensive study of a pastoral territory and their circulation to the practitioners at sheep production farms enable them to work out management and production measures aimed at rational use of rangelands.

As arrangements are being made for the sound management of natural forage resources, the pattern of range-area allocation among the farms is clearly an important element. It is generally acknowledged that the institution of "dwarf" livestock farms minor in area

and livestock numbers in the desert conditions leads often to the failure to manipulate rapidly livestock grazing areas, should infavourable grazing conditions descend upon the range. This is compounded further by the fact that in Turkmenia, for example, the farms possessing a modest population of small livestock have of necessity to run diversified economies where the specialist manpower resource has to be diffused to other activities, to no small detriment of the selection and breeding programmes.

Alternatively, experience has shown that specialized livestock "giant" farms, where they are established, are unable, by virtue of being over-sized, to expedite the development of livestock husbandry in the desert because their divisions are much too distant from the centre and one another and because the production process becomes poorly manageable. As a result, the effective utilization of range areas is solely practicable at those livestock farms which embrace a wise and rational compromise between the specific features of their natural and grazing situation and the practical dimensions of the pastoral area.

The inter-farm allocation of rangelands is based on a general scheme (master plan) of their integrated development. The scheme offers keys to the effective management of the entire range of problems concerned with rational distribution of the pastoral resource to farms, whether operating or being designed. It assists also in defining overall future projections for the development of livestock husbandry and unerring selection of the proper trend in the latter's specialization.

Another important consideration in the inter-farm allocation of range areas refers to the need for optimal size of sheep-production farms to be identified in relation to different natural regions. In trying to find out the optimal size, consideration must be given, along with the economic parameters of production activity, to the grazing (or carrying) capacity of rangelands, with special reference to the topography and soils. The same factors have still greater relevance in devising the farm's internal territorial layout. Indeed, the size of a flock, division or farm as a whole depends in a significant way upon the possible radius of migration of livestock population which, other conditions being equal, is invariably much shorter in the case of a rough terrain with moving sands than on a plain with hard soils. In its turn, the shorter radius of livestock migration away from the watering point determines the smaller area of the pastoral site around the well, bound to affect unavoidably the size and dimensions of the range area attached to a division or farm as a whole.

Areal determination of sheep-breeding farms as to their optimal size for specific natural regions in the desert zone becomes increasingly relevant now that the scheme of integrated future development of the desert rangelands is well underway. In the estimation of optimal dimensions for sheep-breeding farms regard must be also had, in addition to carrying capacity, season-of-use, and watering prospects,

to the areal extension of the territory and the allied remoteness of grazing lands from the farm's central location.

As an example, in Trans-Unguz Kara Kum it is nowhere that the central locations of sheep-breeding farms can efficiently be established, except in the Tashauz oasis in the north and the Amu-Darya floodplain in the east. As a consequence, the pastoral territories of the farms in these locales must be configured so as to have a north-south extension up to 180 km, as in the Tashauz region, and an east-west extension up to 200 km, as in the Dargan-Atin district. This configuration alone provides for the farms the only alternative layout enabling them to keep within their production scope and turnover the farthest-distant range areas.

In Central Kara Kum the central locations of farms are laid out along a span of the Kazandzhik-Chardzhou Railroad. Whilst, on the one hand, this gives them the advantage of an uninterrupted flow of supplies and easy shipment of livestock products off to the points of processing and consumption, this dictated, on the other hand, the farms' configuration as a strip elongated from the south northward to as far as 250 km.

South-East Kara Kum is markedly different in natural geographic and production conditions. There, central locations can be easily put up in the western, northern and eastern portions of the region and the pastoral area can thus be arranged in a more compact way, while the higher productivity of the rangelands promotes heavy concentration of livestock on the farms.

The problem of livestock farm lay-out is handled with much greater ease in South-East piedmont Kara Kum, with the greater part of its area occupied, currently, by sheep-production farms and the average farm size in terms of pastoral area and livestock quantity approximating the optimum.

All of the foregoing was closely considered in recommending the following average areal sizes of sheep-breeding farms for the various natural regions in Turkmenia (Table 8).

In keeping with the recommended areal dimensions of the sheep-breeding farms in Turkmenia's natural regions, work is now in progress to mount up about one hundred large highly-specialized farms with much greater potential for livestock production in lieu of the formerly existing 318 sheep-production divisions of collective farms and 24 divisions of state farms.

In the allocation of rangelands to farms it should be also borne in mind that the recommended farm sizes were arrived-at with consideration to net range areas only. In practice, however, in assigning territories to farms marginal lands also fall into this category, therefore the total areal size of a farm may actually be much greater depending on the marginal areas included.

Pasture rotation. In the system of measures designed for effective management of the pastoral economy the priority of pasture rotation cannot be more obvious. Scientific trials and years of experi-

Table 8

Optimal Size of Sheep-Breeding Farms for Natural Regions in Turkmenia

Natural regions	Range area, M ha	Grazing capacity of sheep ranges, thous. head	Yearly grazing rate per sheep, ha	Average farm size		Number of farms
				range area, thous. ha	number of animals, thous. head	
North-West Turkmenia	4.8	480	10.0	500	50	9
South-West Turkmenia	3.2	244	13.1	650	50	5
North (Trans-Unguz) Kara Kum	9.8	920	10.6	530	50	18
Central Kara Kum	10.6	1431	7.3	400	55	26
South-East Kara Kum	6.8	977	6.6	420	60	16
South-East (foothills)	3.5	847	4.1	290	70	12
Southern (mountains)	2.3	783	3.0	210	70	11
Turkmen SSR	41.0	5682	7.2	–	–	97

ence with sheep husbandry in the desert zone have proved that, with respect to different biological and utility groups of range plants, there exist certain limits on the allowable removal of forage mass which should never be exceeded if the biological equilibrium were to be maintained and inhibition of forage plants avoided. It has been found, in particular, that for the overwhelming majority of the range plants sustained biological equilibrium is solely possible if not more than 50 per cent of the gross forage yield is removed. With a much greater proportion of the yield inevitably removed under overstocking, the range is doomed to degradation.

A second but equally important factor of range preservation under sustained utilization consists of alternating the grazing schedules for the same pastures. It is no longer questionable, for example, that where the ranges with abundant ephemers are opened for use in the spring season year after year these herbs gradually disappear from the stand because the most palatable plants are also the first to be removed by animals, never letting them have enough time to produce seed. About the same picture will obtain where the ranges with abundant annual saltworts are grazed off annually in the fall.

Thus, range management in the desert environment should demand above all compliance with the stocking rates per unit area and regular alternation of grazing use schedules (seasons-of-use) for the same pastoral areas in different years. The marriage of these two principles into a certain system was termed pasture rotation.

The system of range management with pasture rotation, first originated by I. V. Larin, was followed up and tailored to the desert conditions of Uzbekistan by I. S. Amelin, O. I. Morozova and L. S. Gaevskaya, Turkmenistan by N. T. Nechaeva and I. A. Mosolov, Tadzhikistan by O. I. Morozova and L. P. Sinkovsky, and

Kazakhstan by A.V. Kashirina, A.P. Makarov and V.I. Matveev.

For Turkmenia, N. T. Nechaeva and I. A. Mosolov (1954) offered the following three principal rotational grazing sequences:

1. A pasture rotation formula with an annual alternation of grazing consecutively in all seasons of the year. Under this approach, the same pasture is the first year grazed in spring, second year in summer, third year in autumn and fourth year in winter. Yet the usability of the formula is restricted solely to the ranges whose composition of forage vegetation renders them suitable for use round the year.

2. A pasture rotation formula with an alternation of the spring with winter and summer with autumn seasons-of-use. Under that pattern, some part of the range area is open for grazing through the spring and winter and the other part through the summer and autumn. The formula has the advantages of being more economical and easy to implement because of the substantial reduction in the needed amount of construction to build wintering premises for livestock at different pastures.

3. A pasture rotation formula with an alternation of the spring with summer and the autumn with winter seasons. The sequence is acceptable for the farms whose rangelands, for some part, have the composition of forage plants and especially the quality of water in the watering wells to make grazing counter-productive in any other season but the autumn and winter.

In the development of a long-term range management plan with pasture rotation provisions are made for the season-of-use to be alternated on every pastoral area around the wells. In different desert environments, a pasture rotation cycle may take from 4 to 8 years to complete, depending on the selected formula.

A survey of the pattern and presently applied formulas of range use at the farms located in different natural regions of Turkmenia has found that not all of the surveyed farms are practising the system of range management with pasture rotation. Analysis of the survey data revealed the following primary constraints on broad incorporation of the recommended range rotation patterns. This is above all the non-uniform and inadequate availability of water throughout the range territory, coupled with the low yields and severe salinity of water in some of the sources, and the need for a denser network of watering points to be installed on the previously watered rangelands and for additional cultural premises, production facilities and housing to be built where necessary. If it is considered further that up to now not all of Turkmenia's sheep-breeding farms have been adequately provided with the necessary number of sheepyards, artificial insemination stations and other structures, while in numerous instances the introduction of pasture rotation is conditional and calls for an added number of these facilities to be raised at different pastoral sites, then the good reason behind the arguments seeking

to account for the insufficient scope of pasture rotation so far becomes readily apparent.

Having in mind the natural regions of Turkmenia's plains we have designed what seems to be the most simple pasture-rotation formula, with an alternation of the spring with summer season-of-use and of the autumn with winter seasons. Nevertheless even this sequence can be implemented, in practice, in the majority of farms on the condition of herding the animals on the pastoral area around the well for two consecutive seasons and rotating the seasons-of-use interannually within the area. This is the only alternative that requires no extra construction of watering points or livestock shelter and structures.

Some of the state and collective farms possess even now the adequate water-management and feeding conditions to go ahead with gradual adaptation and utilization of pasture rotation to the full extent. Further on, as water availability for the rangelands is improved and new premises built against the background of increasing general standard of range management, the farms will be able to make one step further and establish a suitable situation for the application of other, more sophisticated patterns of pasture rotation.

Drawing up a forage balance is essential in the formulation of the many-year plan. The key input addressing the productivity of rangelands is the range map complete with the tables of forage yields in their seasonal dynamics.

While working out the forage balance, these items need to be specified and updated each year by the farm's specialists who draw upon the data of supplementary surveys with the aim to locate and absorb current year's distinctive characteristics. Forage yields and their nutritive value are estimated for each pastoral area around the well as dictated by the accepted system of range management. Adequacy of range forage for the livestock population at the main seasons of the year is estimated in terms of three parameters, namely, air-dry fodder, feed units, and digestible protein, with consideration given to the zootechnical standards regarding different livestock groups by sex and age.

The forage balances offer a way to judge whether a surplus or deficit of particular nutrients arises during sheep grazing on the range at a specific season. As an example, one can refer to the forage balance in the year-long grazing of karakul sheep on the saxaul-sedge type of range (Table 9). A review of the tabulated data shows that in the spring, while grazing on the saxaul-sedge type of range and consuming their normal amount of range forage, the sheep receive some surplus protein. Yet the aminoacid composition of the albumins, altogether favourable for the concentrations of lysine and tryptophane, proves to be way below normal for the contents of methionine and cystine, sulphur-containing aminoacids. In the spring season green range forages exhibit an excess of carotene (provitamin A) and an almost normal microelement concentration whereas in

Table 9

Tentative Forage Balance in Year-Long Grazing of Karakul Sheep on Saxaul-Sedge Type of Range in Central Kara Kum

Parameters of forage balance	Air-dry fodder, kg	Major nutrients								
		feed units, kg	digestible protein, kg	Essential aminoacids, g			Carotene	Microelements		
				lysine	methionine and cystine	tryptophane		copper	molybdenum	cobalt
				Spring						
Requirement	190	91	9.1	1,056	646	152	1,520	1,520	150	80
Available in forage	190	163	24.0	1,590	424	371	42,132	1,561	146	70
±(surplus, deficit)	0	+72	+14.9	+534	−222	+219	+40,662	+41	−4	−10
				Summer						
Requirement	245	123	12.3	1,624	298	209	2,460	2,220	220	110
Available in forage	245	128	9.0	556	142	168	2,580	1,470	128	93
±(surplus, deficit)	0	+5	−3.3	−1,068	−56	−41	+120	−750	−92	−17
				Autumn						
Requirement	135	76	7.6	806	494	122	1,520	1,290	130	60
Available in forage	135	73	5.5	278	87	78	6,443	1,109	71	36
±(surplus, deficit)	0	−3	−2.1	−528	−407	−44	+4,923	−181	−59	−24
				Winter						
Requirement	150	100	10.0	891	549	126	1,800	1,440	140	60
Available in forage	150	61	6.1	465	169	83	811	774	80	44
±(surplus, deficit)	0	−39	−3.9	−426	−380	−43	−989	−666	−60	−16

the winter insufficient concentrations of all these nutrients are found in the range forage.

With the forage balances to assist them, the workers of desert pastoral livestock husbandry can handle quickly and efficiently the questions related to balanced diets for agricultural animals, covering nutrient deficits through supplementary feeding.

The accepted range management pattern and feed balance are taken into account in sheep distribution to the flocks. To achieve a smooth and well-structured production process it is broadly accepted to make flowcharts of monthly allocation and movement of the flocks through the pastoral areas around wells. Conventional signs are used in the flowcharts to denote the number of flocks staying at every well and their composition by sex and age. The flowchart is an aid to the zootechnician in making expeditious and fast decisions to get the sheep moved over from some pasture to some other – in a way consistent with the general state of veterinary services and breeding programmes.

In planning for the allocation of animals to rangelands care must

be taken to have the same pastoral areas around wells assigned to the same herder teams year after year. This helps avoid the lack of personal commitment in the utilization of rangelands and assures their longer life.

Livestock grazing on rangelands ranks among the key factors bearing directly on range productivity and longevity under lengthy service. The experience of best livestock workers suggests that the only way to keep all animals in the herd well-fed is through the application of the more advanced methods of range grazing, with the uniform feeding of all animals.

A close study of the vast experience accumulated over years by research establishments and advanced farms in the field of range utilization sequences for different kinds of livestock as managed in different natural zones offers convincing evidence to support the validity of the conclusion above. Comparison of the four existing grazing practices – unsystematic (free), on large pastures, on small pastures and in fenced enclosures – shows undisputed preference for the latter practice over all the others. Nevertheless the small-pasture and particularly fenced-enclosure grazing, both of them up-to-date ways of utilizing the range, have won broad distribution on high-level production rangelands. A note is in order that the enclosure grazing is usually practised with a portable electric fence for cattle grazing.

Under the pasture-based system of range management, attention must be paid to the time of keeping animals on each pasture, a factor of major significance for disease prophylaxis. As was evident from the research work done before the war by I. V. Orlov, helminthic eggs and larvae co-disposed onto the range with sick animals' faeces remain under-developed during the first six days on the range and perish in the animal body after being swallowed by healthy livestock. The helminthic larvae are especially hazardous in the first one-and-half month whereupon their viability drops sharply and the major part of them dies. Mindful of this, it is recommended, as a prophylactic measure to prevent helminthic invasions during livestock grazing exposure, that livestock be herded on the same pasture for five or six days and not to be brought back until after one-and-half month.

The recent experience of livestock grazing in fenced enclosures has proved the method to bring good gains on the desert rangelands of Central Asia and Kazakhstan. The data obtained over these years suggest the application of fences to be also possible for pasture grazing management in Turkmenia, particularly its south-eastern areas where range productivity is better and effective techniques for range improvement are readily available. Yet for the major pastoral regions in Kara Kum and West Turkmenia the productive potential of fencing is heavily limited.

In this context, it is well to give a reminder about the specific method of pasture-grazing without fencing described by N. T. Nechaeva and I. A. Mosolov (1954) from watching the working practices

of the best herders at karakul production state farms.

The method of pasture grazing without fences is fairly simple but, regrettably, has not been widely accepted so far and is being applied for the time being only by the most experienced and skilful herders. In essence, it is as follows. The range area allotted to the flock for a specified period is grazed consecutively by small pastures which the herder delineates by sight. This pattern of grazing one-day pastures is practicable if they are laid out along one direction from the watering well in a sector or a strip. Having grazed off the first strip in a matter of five to six days, the herder delineates a second strip so that each pasture of the following strip should half-overlap the pasture of the preceding strip. Furthermore, each of the one-day pastures always consists of two equal parts, with one half involving ungrazed pastures and the second one the pastures grazed several days before. When animals leave such a pasture, one half of it remains completely grazed and the other half only slightly, to be grazed up in full when the animals are brought on to the next strip. Meantime the partly grazed pastures are aired, a move altogether essential hygienically.

The second material condition for effective range grazing pasture-by-pasture without fencing demands observance of the original grazing sequence in a circle. The circular shape of the pastoral area enables the herder to delimit the necessary daily area by measuring only its radius.

While moving animals in a circle, an experienced herder will invariably have his flock turn about sharply at regular intervals along the flock's migration front. The turns allow for uniform consumption of forage by stronger sheep who move in front using more desirable parts of the plants, but also let weaker sheep pulling behind the stronger animals have their share of the feed as the rear sheep become forward ones for some time after the turn. The similar grazing pattern offers a way to hold the flock within the limits of an unfenced range unit but, more importantly, to assure uniform weight gains for the animals.

The pasture grazing method without raising costly fences, in the desert conditions with scarce forage resources scattered over vast areas, does a great deal to make range utilization economical and rational while maintaining long-term productivity on the rangelands involved.

Together with the rational use of natural rangelands in the Soviet Union's desert zone, much attention is being paid to range improvement, or enrichment, by expanding the range and variety of the more valuable forage plants and improving the overall forage productivity. Until now various range improvement methods and techniques have been developed and handed to the state and collective farms for production transfer as routine practices. Of the improvement methods whose efficiency has won good reputation for them, the following are worth mentioning.

The method designed by the USSR National Institute of Karakul Sheep Breeding in cooperation with the Institute of Deserts and the Turkmen and Tadzhik regional institutes of livestock husbandry for the establishment of autumn-winter grazing lands in the foothill areas (Nechaeva *et al.*, 1959; Sinkovsky, 1958; Shamsutdinov, 1960). Rangelands with a plant cover of Kochia prostrata, Artemisia badhysi, Salsola orientalis, Aellenia subaphylla and other plants should best be installed on plowed strips alternating on unplowed virgin patches supporting ephemeroid vegetation. Improved rangelands offer adequate forage to fill its deficit in the autumn-winter season, as they double or triple the total productivity.

The method formulated by the USSR National Institute of Karakul Sheep Breeding to initiate range shelter belts of Haloxylon aphyllum (Sergeeva, 1954). It is recommended for and works well on the pastoral areas with the depth to ground water not more than 12-15 m; it provides for a 15-20 per cent increase of the total output of forage production.

The method developed by research establishments in Uzbekistan, Tadzhikistan, Kirghizia and Turkmenistan for the goal of setting up summer seeded pastures out of a series of cultural and wild-growing forage plants (Shamsutdinov, 1963; Karimov, 1964; Sinkovsky, 1966). It is recommended as a sure way of raising range productivity two to four times as high in the foothill regions.

The method elaborated by the Institute of Deserts to increase 4-6 times the forage productivity of saltwort rangelands, taking advantage of the local surface runoff of precipitation waters on takyrs (claypans) (Lalymenko, 1964).

The Institute of Botany of the Uzbek Academy of Sciences offered several methods to improve the productivity of sagebrush-saltwort rangelands on the grey-brown soils of Ustyurt (Momotov, 1973).

One could also cite the methods now being evolved at the Institute of Deserts, Turkmen Academy of Sciences, with the specific goal of improved range productivity in Kara Kum, seeking to achieve yield increases under extreme climatic conditions.

The work on new improvement methods for the pastoral areas in the desert is continuing and the areas of improved pastoral territories keep expanding livestock numbers in these regions in future.

The management of pastoral livestock husbandry in the Soviet Union's desert regions has acquired nowadays an entirely new dimension associated with further specialization and concentration in all sectors of livestock husbandry. The present period in the pastoral livestock economy should be seen as a new stage of transition from the small- and medium-scale commercial sheep-producing divisions of collective farms to large-scale livestock complexes (concerns), state-owned or inter-farm or cooperative, managed under principles of industrial production of livestock output. The present-day livestock complex is, above all, a large and highly specialized economy possessing hundreds of thousands of hectares of range area, offering a good

prospect of expanded tens of thousands of sheep, with high-level mechanization and electrification of the production processes.

In the current integrated development of the desert rangelands for livestock husbandry many key issues are going to be solved yet. The present philosophy demands solution of the whole problem of intensifying the pastoral economy as a whole, rather than its individual aspects.

Under the present conditions, effective development of the desert areas to supply the needs of ever-expanding livestock husbandry requires not only that a favourable situation be established for the optimization of the production processes and their integration with ecological conditions, but also that obligatory solution be achieved of another key objective – that of providing improved working and living conditions for the livestock-husbandry workers.

Desert range development today provides for uniform all-round watering of the pastoral territory, science-based inter-and intra-farm land management, effective approaches to the problem of assured supplementary forage production, further improvement of the rangelands, construction of production, cultural, housing and welfare facilities with the initiation of cultural centres in the desert, construction of roads, supply and communication lines, and other relevant efforts.

The drive to bring under development new pastoral areas and modernize the territories having been developed by now is being accomplished on the basis of long-term integrated development schemes designed in the past few years in all Central Asian republics and Kazakhstan. A pertinent example is the integrated development scheme of the desert rangelands in Turkmenia, now well into the implementation stage. In accordance with the scheme's recommendations, a new detailed geobotanical survey of Turkmenia's pastoral territory is being undertaken, complete with large-scale pastoral maps and total appraisal of the forage potential of the rangelands. New large livestock farms are being started. In Central and South-East Kara Kum construction of multiple-user water-supply mains is in progress to provide water for the newly established pastoral areas. Schools, hospitals, movie-houses and other facilities are being built in the central locations of livestock farms. Construction of new roads and high-voltage power transmission lines is continuing. Finally, the forage base of livestock husbandry is being reinforced fundamentally, chiefly at the expense of an expanded forage output from irrigated lands. The efforts to install livestock-keeping premises out on the range are being maintained on a sweeping scale and in a way tailored to the accepted range rotation sequences.

The practical accomplishment of the objectives and programmes geared to the integrated development and rational and efficient management of the desert rangelands contributes materially to attaining ecological equilibrium within the desert ecosystem, preventing desertification and perpetuating the biological potential of land.

CHAPTER IV

IRRIGATION DEVELOPMENT OF DESERTS AND AMELIORATION OF IRRIGATED LANDS

Irrigated Farming Development in the Desert Zone of the USSR

Vast land expanses in arid and semi-arid zones of the Soviet Union, conceiving sizable economic potential, emerge as a backlog for farming extension, taking into account natural-climatic conditions here, and first of all, prolonged vegetation period, large sum of effective temperatures, high soil fertility. In their natural state these lands are characterized by rather low productivity, tending to diminish still more in view of the unwise land use, which mostly results in the semi-desert transformation into deserts, especially in marginal areas.

The sole way for intensified use of these lands is irrigation. It is highly instrumental for enhancing farming efficiency, and will enable growing of the valuable agricultural crops (cotton, rice, fruits, etc.) in deserts.

Irrigation practices in arid regions have gone through drastic changes, manifested, first of all, in engineering improvements of the existing irrigation facilities which contributed to considerable rise in irrigated lands productivity. Developed and under construction are large projects of integrated use of the largest in Central Asia and Kazakhstan rivers' flow: Syr-Darya, Amu-Darya, Ili, Murghab, Tedzhen, Vakhsh, Zeravshan and others. These opened up possibilities for the "attack" on deserts through irrigation development of abandoned lands of old irrigation and development of virgin lands.

In Central Asia and South Kazakhstan nearly 92 per cent of the overall plant output are obtained presently from 6.2 million ha of irrigated lands which provided employment for 95 per cent of rural population here. At the same time upwards of 50 million ha, fit for irrigated farming, are found mainly in the desert-like conditions (Duhovny, 1977). The stepping up of irrigated lands to deserts, which took place in the years of the Soviet power, was responsible for sizable augmentation in the raw cotton production. Uzbekistan and Turkmenia are two Central Asian republics where the bulk of irrigated lands in the desert zone is found. Table 10 shows the dynamics of irrigated lands increment in the recent decade here.

Irrigation has significantly added up in scale in Uzbekistan and Turkmenia in the years following the establishment of the Soviet power. The most important water projects here in the period 1931-1937

Table 10

Growth of Irrigated Lands, thous. ha, and Cotton Production, thous. tons

Republic	Indicator	1965	1970	1975	1976	1977	1978
Uzbekistan	Irrigated area	2639	2696	3006	3132	3210	3284
	incl. under cotton	1550	1709	1773	1778	1797	1824
	Raw cotton output	3746	4495	5014	5338	5680	5500
Turkmenia	Irrigated area	514	643	819	846	906	917
	incl. under cotton	257	397	487	491	503	506
	Raw cotton output	553	869	1078	1046	1170	1027

were: Pervomaiskaya dam, Darghom canal, Narpai irrigation system on the Zeravshan River, irrigation system at the Kumkurghan canal in the Surkhan-Darya river valley, irrigation systems in the Uchkurghan and Savai Steppes, irrigation of the Dalverzin Steppe and irrigation development in the zone of the Northern Golodnostepsky canal, Dzhun canal and collecting network in the Chirchik floodplain, development and improvement of left-bank canals in the Amu-Darya lower reaches. From 1938 to 1941 there were built: the Greater Ferghana canal, Northern and Southern Ferghana canals, Tashkent canal, right-bank Zeravshan canal and others, as well as Kampyrravat and Kuiganyar headworks on the Kara-Darya River.

In the severe years of the Second World War efforts were made to build the hydropower station on the Chirchik-Bozsu canal and improve water supply of irrigation systems on the right bank of the Chirchik River. The Farkhad headworks on the Syr-Darya River was constructed to assure irrigation water supply of the Golodnaya Steppe.

In the 1950s collecting-and-drainage networks have undergone partial improvement and the existing irrigation network was rehabilitated with a view of irrigated plots consolidation (up to 25 ha) to use agricultural machinery to more advantage. There were also built such large projects as Kampyrravat, Temiktash and Kuiganyar headworks on the Kara-Darya River; Pervomaiskaya, Akka-Darya, and Damkhodzhin diversion dams on the Zeravshan River; Gazalkent and Troitskaya (Trinity) dams on the Chirchik River; Shamalek headworks on the Akhangaran (Angren) River; Sarykurghan and Kokand headworks on the Sokh River; Uchkurghan headworks on the Naryn River; Karshi headworks on the Kashka-Darya River. Complete is the Takhiatash headworks on the Amu-Darya River. At present the Syr-Darya River is regulated by the Toktogul, Kairak Kum and Char-Darya reservoirs. In the Tadzhik SSR the construction of the Nurek headworks on the Vakhsh River is completed which, together with the Tyuyamuyun headworks being under construction, will assure the reliable water supply in the lower Amu-Darya. The building of the Rotun headworks is initiated.

Presently large reclamation projects in Uzbekistan are being constructed with a view to develop deserts and semi-deserts in the

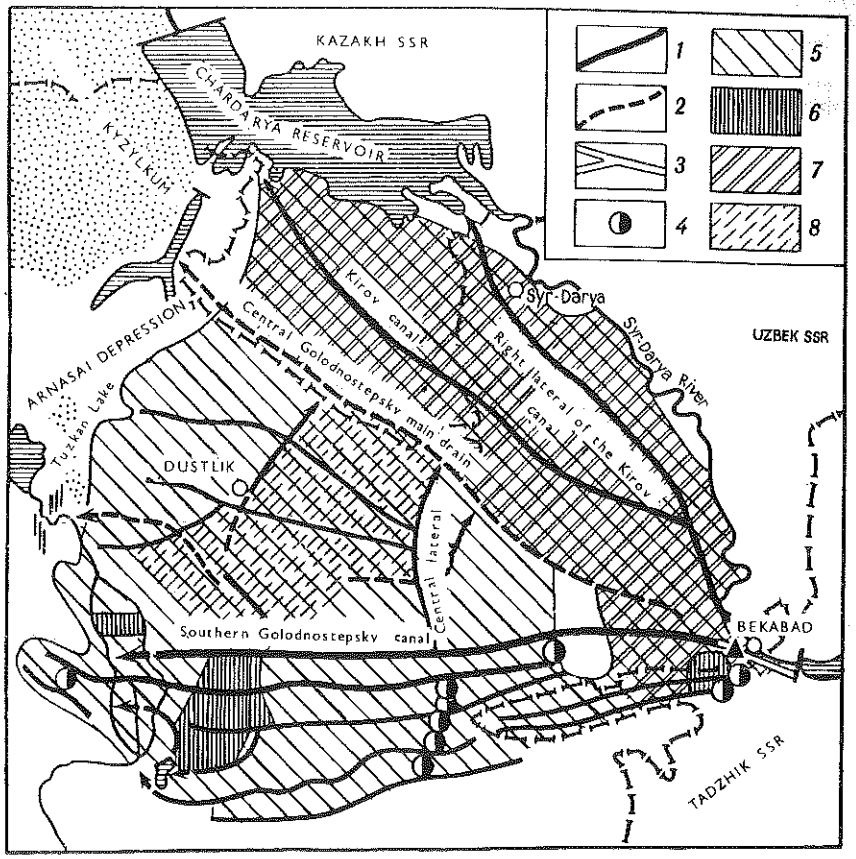


Fig. 16. Irrigation development of the Golodnaya Steppe:

1–irrigation (main) canals; *2*–collecting-and-drainage canals; *3*–diversion canal; *4*–pumping stations; *5*–cotton rotations; *6*–vegetable-forage rotations and perennial plantings; *7*–existed irrigation (old zone); *8*–newly developed lands

Dzhizak and Karshi Steppes, in the Central Ferghana Valley, in the Sherabad area and in the Lower Amu-Darya and Zeravshan.

The Golodnaya Steppe emerges as the large region with an area over 1 million ha carrying typical features for the desert zone in Central Asia (Fig. 16). Efforts to bring irrigation to the Golodnaya Steppe were undertaken as early as before the October Revolution. However these were rather primitive and did not rely upon strict water application rates, drainage improvements which, usually, brought about land salinity, and abandonment of these lands.

The first years of the Soviet power faced the build-up of efforts to improve the existing and construct new irrigation systems. The basic undertaking here was the Northern Golodnostepsky canal, and with time it became longer and with greater carrying capacity. As a result the irrigated area in its zone has sustained a seven-fold increase (from 30,000 to 200,000 ha) in the span of several years.

The irrigation development has pointed to the need of the diversion dam and the Farkhad headworks was built with the branching-off right-bank Dalverzin canal (discharge – 74 cumecs, irrigated area – some 50,000 ha) and left-bank power canal with a carrying capacity of up to 500 cumecs, on which a hydropower station 130 MW in output was constructed. The new Southern Golodnostepsky canal, 126 km long (discharge – about 300 cumecs, irrigated area – over 350,000 ha), was taking water from the dam upper pool through the sluice offtake regulator. The Northern Golodnostepsky canal gets water through the head structure on the outfall canal of the Farkhad hydropower station. To irrigate lands in the Golodnaya Steppe in the Tadzhik SSR a pumping station was built on the power canal upstream the hydropower station. Territories where lift irrigation is furnished are found in the commanded area of both the Southern and Northern Golodnostepsky canals.

At the first stage of the Golodnaya Steppe development nearly 400,000 ha are planned to be irrigated, of which half is already irrigated. The development of the Golodnaya Steppe is nearing completion.

The desert development in the Golodnaya Steppe presented much more difficulty than the development of the zone of old irrigation. Apart from the complexity of natural conditions, the total lack of settlements and appropriate roads, the building industry base, the development of virgin lands was further aggravated by the fact that from the very beginning the methods and practices applied in the past were mechanically transferred into present.

It is a necessity for the irrigation development of deserts that the groundwater level be maintained below the critical level, thus, obviating the danger of secondary salinization. Drainage systems of appropriate density and depth were constructed and operated, which, in combination with seepage losses control in canals, careful land levelling, employment of advanced water application techniques and rational water application rating, making irrigation and saline lands leaching easier and enhancing irrigation efficiency, helped to attain the desired effect.

The distributaries are lined with mass concrete or precast reinforced concrete slabs. The reinforced concrete flumes and asbocement pipes supply water to furrows by irrigation hoses with designed openings.

The vital role in irrigation and drainage improvements is given to horizontal or vertical drainage. For the period of intensive leaching the use of temporary surface shallow drainage will be most appropriate.

The collecting network is open and to a depth of 4 m and more. The subsurface collectors which were extensively used in the recent years have shown high dependability in operation and are less costly. One more advantage of subsurface collectors and drains is that they serve to raise land use and, consequently, increase the gross output and income, improve the territory arrangement and the resultant better use of high-efficiency machinery.

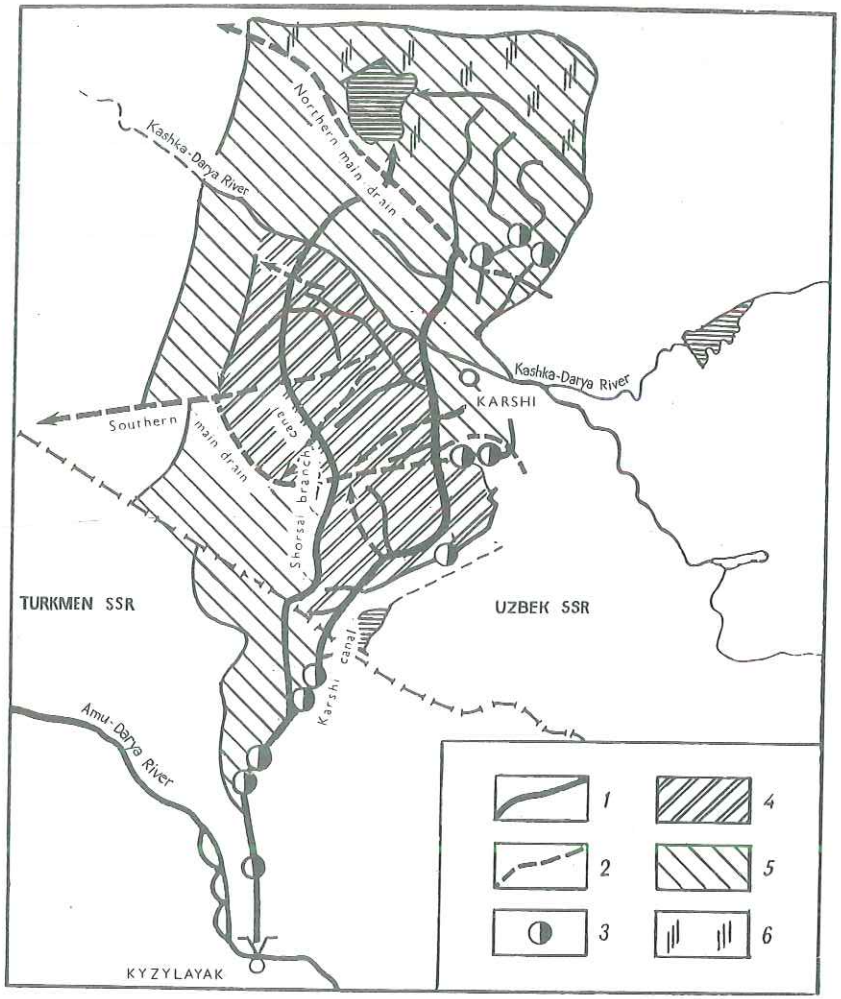


Fig. 17. Irrigation of the Karshi Steppe:

1 – irrigation (main) canals; *2* – collecting-and-drainage (main) canals; *3* – pumping stations; *4* – lands of first-priority irrigation; *5* – zone of future irrigation

The Karshi Steppe extends over an area of 1 million ha (Fig. 17). The main river here – the Kashka-Darya – when fully regulated will be capable of furnishing irrigation to 150,000 ha. For bringing irrigation here (mainly for fine-fibre cotton), the most water-deficient region of Uzbekistan, two undertakings were carried out: in 1955 the Eski-Angar canal, 184 km long, was built branching off from the Zeravshan River and having a head discharge of 48 cumecs. It provides water for irrigating 27,000 ha (have been recently reconstructed). Simultaneously the Chimkurghan reservoir on the Kashka-Darya River was built, planned for irrigating 40,000 ha. Besides, the

Pachkamar reservoir was constructed on the Ghuzar River capable of storing 280 million cu.m of water.

However, all the above measures failed to resolve the problem of land irrigation in the Karshi Steppe, inasmuch as it may be solved only on the basis of the Amu-Darya water resources. Nowadays extensive efforts to implement the integrated scheme of the Karshi Steppe irrigation and development are being taken up. At the first stage (200,000 ha) the river water intake is planned to be constructed. Further on it is planned to build the low Kyzylayak dam with two regulators – right-bank for the Karshi canal and left-bank for the Kara Kum canal.

From Kyzyl-Ayak water is supplied along the Karshi main canal, 200 km long, to the Karshi Steppe. The canal's carrying capacity is equalling about 200 cumecs (first stage). Water is lifted by 6 pumping stations to a height of 132 m. In 1973 the Amu-Darya water was directed to the Karshi Steppe by the branching-off Ulyanovsky canal.

The natural depression located 80 km from Kyzyl-Ayak along the Karshi main canal is used to build the Talimardzhan reservoir nearly 1 billion cu.m in storage capacity. The reservoir will ensure the year-round water supply from Amu-Darya: water stored in winter will be used for irrigation purposes in summer. It will halve the discharge capacity of the approach canal and the pumping stations' output. Downstream the Talimardzhan reservoir the working part of the Karshi main canal with a discharge of 350 cumecs begins. By virtue of seepage-proof linings the canal efficiency rises as high as 0.97.

Irrigated territory in the Karshi Steppe may be divided into two zones: the upper one with the irrigated area being equivalent to 350,000 ha and the lower one with the irrigated area – 500,000 ha (water is supplied by the Shorsai canal branch).

The Amubukhara pump canal was built with the aim to furnish irrigation water to a part of the Bukhara Region from the Amu-Darya River to enhance reliability of water supply of other lands, having been irrigated from the Zeravshan River, as well as to add another 15,500 ha to the irrigated land stock.

For a time being water is taken 12 km upstream Chardzhou. The approach channel, 3 km long, is acting as a settling basin, being cleaned by dredgers.

The first stage of the Amubukhara canal, finished in 1965 (196 km long from the Amu-Darya), made it possible to provide 90,000 ha of lands in the Bukhara oasis with the Amu-Darya water and augment irrigated area by another 24,000 ha.

After the second stage is completed, 89 cumecs of water will be supplied to the Shafirkan headworks on the Zeravshan River, which will enable irrigation of the rest 12,700 ha in the Bukhara oasis with the Amu-Darya water.

Irrigated farming in the Turkmen SSR has a century-old history.

From ancient times it was practised in six large oases: in the northern parts of the Chardzhou and Tashauz oases and in the southern parts of the Murghab, Tedzhen, Kopet-Dag and Atrek oases.

Irrigated farming in the south of Turkmenia is highly favoured by natural and economic conditions but its development in the previous years was hampered by the great local water shortages. Of 4.4 million ha of lands suitable for irrigation, only 160,000-170,000 ha or 4 per cent, were actually irrigated (at a very low water supply).

In view of this fact the Amu-Darya flow transfer scheme was planned, but engineering complexities and the lack of appropriate economic basis prevented its fulfilling. It was only after the establishment of the Soviet power that this project has been realized on the basis of effective construction machinery and skilled personnel.

The uneven flow distribution of the Murghab, Tedzhen and Atrek Rivers is witnessed both within a year, and from year to year. The reliable and highly effective irrigated farming is impossible here without their regulation by reservoirs.

The overall capacity of reservoirs on the Murghab River (silting is also accounted) made up 306 million cu.m, which was inadequate for full flow regulation. Hence, a new Sary-Yazin reservoir, 1,200 million cu.m in storage capacity (first stage – 660 million cu.m) is being constructed. Beginning from 1950 three reservoirs were built on the Tedzhen River: Tedzhen I (150 million cu.m in storage), Tedzhen II (180 million cu.m in storage) and Khor-Khor (20 million cu.m in storage). In the recent years two off-channel reservoirs – Mamedkul (20 million cu.m) and Delilin (16 million cu.m) – were constructed on the Atrek River. The regulation of these rivers has yielded the following irrigation capacities, appraised by the average year: Murghab – 82,000 ha, Tedzhen – 30,000 ha, Atrek – 8,000 ha.

But the lands suitable for irrigation in their basins much outstrip their irrigation capacity: in the Murghab basin they are estimated at 370,000 ha, in the Tedzhen basin – 730,000 ha, in the Atrek basin – 960,000 ha. Similar situation is observed in the piedmont plain of the Kopet-Dag Mountains and in the west of the republic, where local water resources are very scarce. The availability of unoccupied population, the developed system of communications, favourable natural conditions – all these contribute to successful development of new lands on the basis of the Kara Kum canal. It will bring water to another 1 million ha. The canal will run as far as the Atrek River and its length will be 1,400 km, the head discharge – 960 cumecs, and the flow share taken from the Amu-Darya River will be equivalent to 19 billion cu.m. To regulate the autumn-winter flow, reservoirs are under construction here, their overall storage capacity will be as large as 1.8 billion cu.m. Already finished are the Khauz-Khan reservoir (460 million cu.m in storage) and the Ashkhabad reservoir (48 million cu.m in storage), nearing completion is the Kopet-Dag reservoir (190 million cu.m). Besides, to regulate

the Amu-Darya flow a Zeid reservoir, 3.5 billion cu.m in capacity, will be built at the head of the Kara Kum canal.

The Kara Kum canal construction is called to resolve a cluster of problems: irrigation of lands, water supply of rangelands, towns and settlements, industrial enterprises, development of fisheries, navigation. Power generation aims are not excluded. Powerful pumping stations are being built in the canal zone and new are planned for construction in the Murghab and Tedzhen oases.

The construction of the Kara Kum canal is a highly beneficial undertaking: the development of 1 million ha of lands in the canal zone will give a net profit equalling 1.25 billion rubles annually.

The result of the extensive efforts on water construction was the increase of water supply for irrigation in the republic from 8 cu.km in 1960 to 15.5 cu.km in 1979.

The collecting-and-drainage network annually diverts up to 2.5 cu.km of drainage waters and with them – up to 15 million tons of salts, thus ameliorating some 40,000 ha of secondary desertified lands in poor state.

Below the description of the Kara Kum canal is given by construction stages.

The first stage. Canal length – 400 km (including 300 km in the Kara Kum Desert), head water discharge – 130 cumecs, withdrawal from the annual Amu-Darya flow – 3.5 billion cu.m. The increment of irrigated lands in the Murghab oasis amounts to 88,000 ha. The first stage of the canal was put into operation in 1962.

The second stage. Canal length – 535 km (including the newly built 138-km stretch), head discharge – up to 198 cumecs with a corresponding reconstruction of the first-stage canal stretch. Flow withdrawal – 4.7 billion cu.m. The increment of irrigated lands in the Tedzhen oasis is equivalent to 72,000 ha. The Khauz-Khan reservoir is built in the Murghab-Tedzhen Rivers interfluve. In 1966 the canal stretch was put into operation.

The third stage. The first priority project here was the construction of the pioneer canal Tedzhen-Ashkhabad, 258 km long, with an aim of the water supply of Ashkhabad and the establishment of an agricultural zone around it. The Ashkhabad reservoir was built capable of storing 48 million cu.m of water. In 1962 the Amu-Darya water came to Ashkhabad. The canal length built at the third stage makes up 837 km. The head discharge has increased and reached 317 cumecs involving the reconstruction of the already built canal stretches. Water withdrawal from the Amu-Darya became 8.3 billion cu.m. The irrigated area growth in Kopet-Dag has grown by 50,000 ha. Water supply of 150,000 ha is improved. The overall irrigated area made up 240,000 ha. The capacity of the Khauz-Khan reservoir has increased to 875 billion cu.m.

The fourth stage. The fourth stage of the canal is under construction now. Its completion is expected to add another 470,000 ha to irrigated lands. It is planned to prolong canal westward and furnish irrigation

of all lands along the canal route. The Kopet-Dag reservoir capacity will increase up to 550 million cu.m. The head discharge will reach 550 cumecs.

The flow withdrawal from the Amu-Darya will make up 13.5 billion cu.m. The pioneer canal of the fourth stage running from Geok-Tepe to Kyzyl-Arvat is being built.

The next decade will face the exhaustion of the uppermost irrigation potential of water resources in the Aral Sea basin. But the problem of the partial flow transfer of Siberian rivers to Central Asia is very complicated. Its solution requires the in-depth study of the whole complex of works in their interrelation and especially to forecast possible environmental implications.

Integrated Approach to Desert Reclamation

The successful and efficient implementation of irrigation projects in desert regions involve a sizable volume of construction, operation and maintenance and other works. All they should take into account are the nature conservation requirements and socio-economic conditions. This urged to formulate and develop the integrated methods for construction and land development on the basis of irrigation.

The integration principles in the arid zone are based on the necessity of:

(a) integrated utilization of natural resources in combination with the optimum trends of the region development in order to secure maximum economic effect based on the economical water use;

(b) planned and proportionate development of different economy sectors in the region, taking into account the need to attain the planned agriculture development targets on the basis of irrigation;

(c) creating conditions for the sustained growth of the national income from the newly developed lands so that to ensure, apart from the high irrigation efficiency, the settling down of people here;

(d) natural resources conservation in the process of development and increase of their potential productivity.

The above principles may be observed if to approach the development of new irrigated lands as the formation of a single natural-production complex (NPC), under which we understand the optimum combination of controllable natural resources and specially established production and economic base aimed at developing highly efficient irrigated farming and all applied branches.

V. A. Duhovny (1977) suggests considering the natural-production complex as a combination of natural resources and economic factors with the emphasis on the active role of the first. In doing so, the NPC's specific features are considered to be:

(1) common territory and pattern of water supply;

(2) degree of the territory aridization;

(3) similar technological linkages due to the similar goals of acceler-

ated development of intensive irrigated farming;

(4) integrated use of natural resources at the maximum efficiency of a water factor and purposeful changes of natural conditions with a view of attaining their enhanced potential productivity;

(5) high capital-intensity and high labour productivity;

(6) single planning, construction and much of financing; establishment of single management authorities.

In the complex under study the main resource – water – not only affects the whole economy, causing certain changes there, but also influences other natural resources, changing their characteristics and being changed itself while interacting with them. And the success or failure of the whole complex are dependent on the direction of these changes.

Two parts may be distinguished in the NPC – natural and production. However the natural part does not represent the initial constituent conditions, but the changed and transformed through engineering structures and measures.

Having removed the undesirable, from the production viewpoint, elements of the natural system, it becomes possible to establish irrigated lands, to change climatic, hydrogeological and other conditions. Besides waste and drainage waters are being formed, and the volume and quality of river flows are changed.

Irrigated lands are understood here as the transformed with the help of engineering means (canals, drains, land levelling, irrigation technique, structures) and ameliorative measures (land improvement, leaching, etc.) formerly unirrigated lands whose fertility is created (or restored) and which are supplied with water in quantities adequate to meet the requirements of agricultural crops and land reclamation and from which drainage waters are disposed (Duhovny, 1977). Thus, while territorially lands remain the same, but in quality they become sharply different from the initial ones.

But definite production activity, production subdivisions, technological and economic linkages become established within the complex. And the main sphere is irrigated farming ensuring the output of cotton, rice, grain vegetables, fruit, melon crops and others, as well as the high-efficient animal husbandry on the basis of crop rotation and sowing of forage crops. This part of the complex exists in the form of state farms and specialized enterprises for the fattening of youngsters, for raising poultry, etc.

To provide the proper functioning of the major, agricultural, part of the complex the need is to establish a number of auxiliary services: repair and maintenance, supplying and transport, for technical servicing of machinery, for provision with chemicals, fertilizers and spare parts, with materials, oil products, fuel, etc.

To process agricultural produce the respective enterprises should be set up: cotton-processing plants and cotton-purchasing points; butter factories for processing animal products; canning plants and refrigerators for processing and storing fruit, vegetables.

The regular activity in irrigated farming is possible only at the smooth functioning of operation and maintenance services in water projects responsible for water distribution, maintenance of inter-farm facilities, technical serving of on-farm structures, land condition, etc.

The described integrated approach to desert land development, resulted in the formation of the NPC, emerged especially effective in the development of the Golodnaya Steppe, Karshi Steppe, the Tedzhen and Gyaur territories in Turkmenia, etc.

Ecological Implications of Irrigation

Irrigation in arid zones is called to do away with water deficiency, and to create conditions for converting deserts into highly productive lands and reducing the danger of desertification in farming. However, irrigation, intruding upon natural environment and drastically violating the natural equilibrium reigning there brings about unexpected implications leading to re-desertification. This process is especially severe under specific conditions, for example, when irrigating lands with poor natural drainage, as a result intensive salinization is developing (irrigation desertification); when irrigating slopes of piedmont valleys, where intensive erosion processes are going on (erosional desertification).

World practice may provide a wealth of apposite examples: the formerly irrigated lands in the Tigris and Euphrates interfluve have turned into barren deserts; vast expanses of saline lands in Pakistan; erosion-affected slopes in Tanzania, to mention but only a few.

Of all problems connected with the irrigation impact on arid environment we will emphasize only four, most vital in our opinion, i.e., irrigation water quality, secondary salinization, return water quality, relief variations.

The effect of the irrigation water quality on environment is highly complicated and diversified, and it is still more so in view of the increased salinity of river waters used for irrigation, witnessed in the recent decades.

V. A. Kovda (1977) has pointed out that at present the world scientific and production community comes to face the need for the in-depth study of the quality and chemical composition of irrigation water.

Really, the case study of Central Asia helped to reveal that the sustained growth of irrigated areas has brought considerable rise in water salinity of the Amu-Darya, Syr-Darya, Zeravshan Rivers (Chembarisov, 1974).

The water quality effect is two-sided: on the one hand, it is the effect of irrigation water per se (i.e., water used in its main function) on "cultural" media – field (this effect is felt in the course of man's agricultural activities), and, on the other hand,

it is the effect of the quality of water used for irrigation on environment. This effect often outgrows the limits of the man's agricultural activity and acquires the ecological and often socio-economic nature. Irrigation system in that emerges as a conveyor for geochemical and biogenous elements in the "environment-cultural media-environment" system.

It is this aspect of the effect of water quality that has been hitherto neglected. It is manifested through the effect on soil conditions and plant growth.

Disregarding the source, the irrigation water contains dissolved salts, suspended inorganic and organic matter. Their amount and composition are dependent on the water source and the way water passes from the intake point, as well as climatic, geological and hydrogeological specifics of a territory and the agricultural practices used.

V. A. Kovda has indicated that the chemical effect of water on irrigated soils may be direct, indirect and combined. The chemical composition of irrigation water is changing from season to season under the influence of evaporation and precipitations.

Especially pronounced is the effect of irrigation water (its salinity and temperature) on soils in arid regions, where evaporation usually outstrips precipitations either on an annual or seasonal basis. This explains extensive incidence of secondary salinization. Besides, salinization also affects the quality of agricultural produce. Saline lands require much more water than non-saline, which sharply diminishes the irrigation capacity of rivers.

And, at last, great economic and social damage is incurred when saline lands fall in disuse. This results not only in the termination of agricultural activity in the whole regions, but also in the urge for re-settlement amongst thousands of people.

The man's activity may be called among the main reasons of soil salinization: unwise interference in nature using such a powerful means as irrigation, induces the accumulation and redistribution of salts due to the groundwater rise; the use of water of higher salinity due to the absence of artificial drainage, etc.

This process gets another impetus for development at the unjustifiable extension of irrigated lands not supported by the increase in water intake.

Among factors governing the degree and nature of salinization mention should be made of irrigation regime, water application rates and terms, crop composition. Border and furrow irrigation leads to the infringement of a water-salt balance. Sprinkler irrigation, subsurface and drip irrigation abate or reduce practically to the nil this process.

The introduction of advanced irrigation systems provided with the collecting-and-drainage networks enables to maximally meet the nature conservation requirements which may be attained through the establishment of the optimum reclamation-environmental regime.

The return flow is an element of the water cycle, thus, the solution of the problem pertaining to its detrimental effect on nature is indispensable to the water resources management in general. The main constituents of the return flow during irrigation are seepage water losses from canals, surface runoff from irrigated lands and water losses to deep percolation.

Part of irrigation water gets back into river networks or groundwater aquifers with the return flow from where it may be again taken for irrigation. That is why the return flow and its constituents may be looked upon as a system having several subsystems: "water supply", "irrigated field", "water disposal". The "water supply" subsystem includes water conveyance from the source to the irrigated field. The major problem here is to control seepage losses from canals.

Water, seeping from canals, may give rise to numerous detrimental impacts: in case of shallow groundwater occurrence under canal it may cause its rise; in case of poor natural drainage it may bring waterlogging; in case of high groundwater salinity, soil salinization is a probable outcome.

The "irrigated field" subsystem comprises water application for irrigation until it is disposed beyond the irrigated territory. The pattern of water use in this subsystem controls to a great extent the quality of the return flow. The employment of progressive irrigation technique (sprinkling, subsurface irrigation, etc.), apart from water saving, the increased agricultural yields and other advantages, serves to drastically diminish surface runoff and losses to deep percolation, which, in this turn, reduce the content of salts, nutrients, suspended particles and bacteria in the return flow.

The "water disposal" subsystem embraces the removal of surface and drainage water from the irrigated territory to a water receiving basin.

The surface flow may be either recycled for irrigation or diverted into a water receiver. The subsurface flow may be either diverted by drains, or may percolate into deeper-lying horizons where it may add up in salt content at the expense of saline horizons and then get into the river network.

In the given subsystem a number of means to prevent the detrimental effect of the return flow exists, and among them its diversion into the specially reserved places, thus, preventing the pollution of surface waterstreams; the return water treatment before removal; recycling for irrigation; dilution which may prove more effective in regions of good-quality water surplus.

Therefore, the combative measures to be effective should be carried out in all three subsystems which, alongside the positive agricultural effect, will sizably diminish the damage incurred by the return flow.

The return flow is also the carrier of two important functions of "linking". First of all, it links the water receiving basin (rivers,

lakes, reservoirs, etc.) with new sources of irrigation water. The water quality in the latter determines to a great extent the quality of the return flow and of the water in the receiving body. Second, the return flow links (geochemically) the receiving basin with new territories found under active man's impact (irrigated lands). The resultant effect of this is the removal, with the return flow, of salts, fertilizers, chemicals, organic remnants, bacteria, pathogens and microelements into the basin of a water receiver.

Even now the high water salinity in receiving basins presents a serious challenge in some regions, and it may be traced to irrigation water salinity, the amount of water applied, the amount of water percolated into soil and the number of repeated use of irrigation water. Methods of controlling the receiving bodies salinity should be considered for each subsystem of the return flow.

The most widespread method to control the return flow salinity in the "water supply" subsystem is canal lining. Assessing its economic validity account should be made not only of the benefits provided by water saving, but also of the slackening hazardous effect of seepage from canals.

The effective method in the "irrigated field" subsystem is the improvement of irrigation technique directly on a farm level. No less vital are effective agricultural practices, including regulation and speed of water application, overcoming the unevenness in water distribution and controlling deep percolation. And the application of advanced irrigation technique (sprinkling, subsurface irrigation) in lieu of surface methods is most becoming to this end.

Methods in the "water disposal" subsystem comprise the construction of facilities tapping surface and subsurface irrigation flows and facilities for the tapped flow treatment and disposal. Deep percolation can be controlled by means of water-impermeable membranes.

The increased water salinity of receiving bodies caused by the return flow from irrigated fields is not a sole problem connected with the general effect on surface and ground waters. In some cases no rise in salinity may be recorded or its role in the changed water quality of the receiving body may be insignificant. However one must not think that the return flow is harmless in these cases.

Pollution of receiving water bodies with the return flow is no less important than salinization. The fact is that the major thrust in agriculture development nowadays – the intensification of production – supposes not only the introduction of irrigation and drainage, but also the wider application of fertilizers, herbicides, insecticides, fungicides and other chemicals. All these, getting into surface and ground waters with the return flow, present a real danger for aquatic inhabitants, and in some cases, even for animals and man. Water pollution with the return flow, if severe enough, may cause the diminishment in water use, then it induces not solely environmental implications but economic as well. This problem gains in importance

still more if to take into account that irrigation is most often practised in water-deficient regions, where even small rivers, which most suffer from pollution with the return flow, play a significant role.

If to approach the mechanism of the receiving bodies' pollution from three sides, corresponding to the three subsystems of the return flow, then certain deviations from the mechanism of salinization

Table 11

Effect of Irrigation on Natural Components

Natural components and their stability to irrigation	Changes in natural components induced by irrigation	Nature of changes	Negative impacts pertaining to natural components' changes
Lithogenic components, most stable	1. Creation of agro-irrigation relief	Irreversible	Formation of gullies, padings, blowouts
	2. Change of soil-formation conditions		Worsening of soil physical properties, its decreased productivity
	3. Change of soil water properties	Reversible	Mostly positive aftereffects
	4. Change of salt content in the zone of aeration	"	Soil salinization, decreased productivity, fallout of agricultural areas in disuse
Hydroclimatic components, medium stability	1. Change of rivers' flow	Reversible	Infringement of river flow, increased water salinity, changed vegetation in river basins, worsened habitat of hydrobionts
	2. Change of river water salinity due to diversion of return flow	"	
	3. General deterioration of water quality in rivers due to diversion of return flow	"	Increased biological and chemical requirements in oxygen, greater content of toxic elements in water, eutrophication, spread of disease-carriers, changed colour and taste of water
	4. Change of groundwater table	Reversible	Salinization, groundwater depletion
	5. Change of groundwater salinity	Reversible, sometimes long-term	Soil salinization
	6. Change of microclimate, wind, moistening pattern in the zone of aeration	Reversible	Mostly positive aftereffects
Biogeneous components, low stability	1. Change of natural vegetation and fauna	Irreversible	Mostly negative aftereffects
	2. Change of cultivated vegetation	Reversible	Mostly positive aftereffects

described above may be traced. First, less significance is attached to seepage water losses from canals in the "water supply" subsystem. Second, the significance of the surface flow in the "irrigated field" subsystem grows and, naturally, absent are such specific processes of the growing salinity of the return flow as "concentration effect" and "carrying capacity".

Most environmentalists contend that irrigation is one of the most powerful instruments in transforming natural landscapes into agro-irrigational. And no less important factors to this end are soil changes and creation of a new microrelief.

The major mesorelief forms, where irrigated farming is practised and the above changes take place, are alluvial, socle and sheet plains, volcanic plateaus, valleys, terraces and river deltas, alluvial fans, individual mountain regions.

By the mesorelief form, lithology and irrigation technique there may be distinguished the irrigation-erosional or irrigation-accumulative newly formed microrelief. Considerable surface slopes, availability of loose or karst rocks and the surface irrigation serve to set loose erosion and suffosion processes which lead to the formation of padings, subsidence phenomenon, cones, and gullies, i.e., the specific irrigation-erosional relief. The follow-up changes after land levelling may be also referred to erosion.

Accumulative processes related to irrigation also cause changes into microrelief: the original relief becomes converted into the irrigation-erosional or irrigation-accumulative relief, and this conversion is rather dynamic and short-term.

Table 11 shows the classification of changes in nature components induced by irrigation and their direction.

CHAPTER V

RECLAMATION OF SANDS BY AFFORESTATION

Production Management in Reclamation by Afforestation

Reclamation programmes in the sand deserts are committed to the solution of one universal objective – desertification control. More specific goals within this general problem are achieved through the fixation and afforestation of barkhan sands, restoration of shrub vegetation on low-productive range and integrated productive utilization of the reclaimed areas.

More than a century-long history of vegetative conversion (phytoreclamation) has resulted in the formulation of a fundamental theory of reclamation management in the sand desert and a vast practical experience accumulated over these years in the productive use of low-yielding sandy areas.

The present structure of transplant production for reclamation purposes is illustrated in Fig. 18.

Management measures and protection are clearly important elements in the production efforts to supply the needs of reclamation. Their accomplishment does well for plant preservation on sands against all kinds of earthwork, especially in the construction of pipelines, transport of equipment, range management, etc. Preventive measures and protection are the means to achieve stabilization of natural processes, and the recovery of grassy and shrub vegetation in some instances.

Some researchers estimate that millions of hectares in the sand deserts are currently in need of reclamation. Planned scopes of reclamation programmes can well be carried through if aided by the mechanization of labour-consuming processes and introduction of new technology. It is on these grounds that mechanization is a key to efficient reclamation procedures.

Broad new vistas in the accomplishment of the stated objectives are opened up with the production transfer of reclamation irrigation practices based on the use of local water sources, e.g. surface water catchment, ground and artesian well water.

Establishment of reserves provides a form of sustaining natural model (standard) biocenoses prone to a varying degree of degradation. Regular development patterns of the biocenoses need to be identified with a view to their further use as inputs to current and long-term prognostication of the likely effects upon natural processes

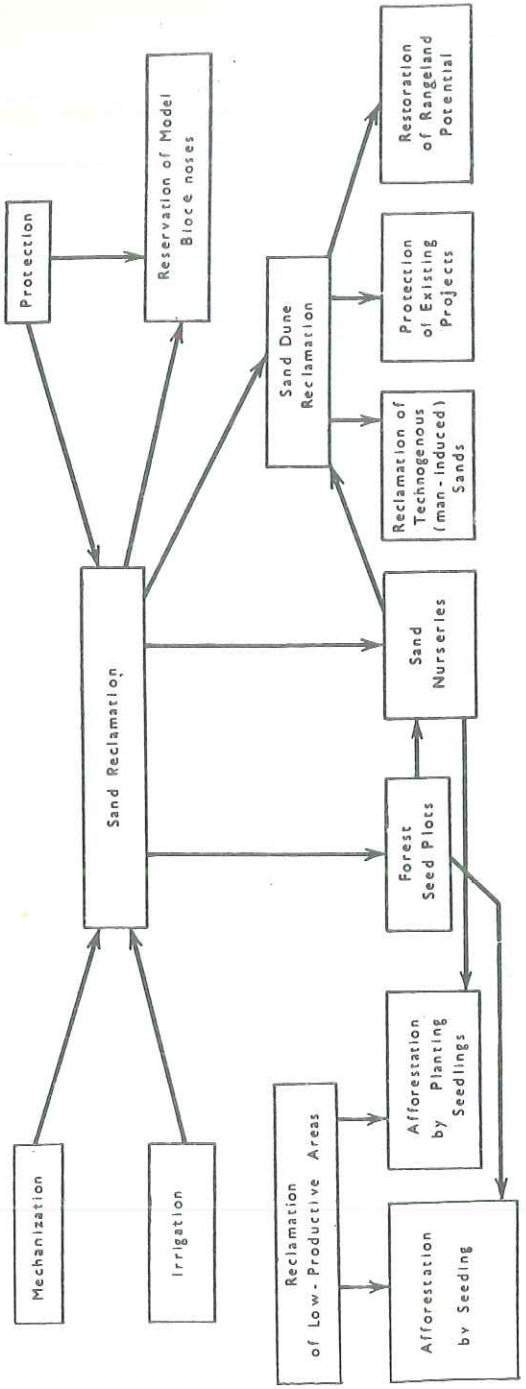


Fig. 18. Scheme of reclamation works

going on in the sand desert by the implementation of various projects.

As an object of reclamation, the sand desert is categorized into two different parts in terms of their natural potential and intensity of deflation processes, namely, barkhan sands and low-productive sandy territories.

With respect to barkhan sands, their reclamation management methods are developed with primary attention to the aim in view. Distinction is made between the measures to achieve reclamation of technogenic sands, protection of production facilities against sand drifts, and restoration of the grazing potential of an area.

On low-productive sandy areas reclamation activities seek to ensure the recovery of grassy and shrub vegetation, i.e., to reinstall natural biocenoses and increase their productivity via the introduction of new and more valuable species.

Selection of reclamation plants and the methods for their management (seeding and planting of the seedlings) are varied with regard to site-specific conditions. For example, in the European part of the USSR massive pine plantings proved best to be established in the zone receiving 300-350 mm annual rainfall and tree groves in the zones with 250-300 mm rainfall.

In the forest-steppe and steppe zones, poplars grow well on areas with root-accessible ground waters (at the two-metre depth). White acacia plantings have been found possible to cultivate in the south and south-west European Soviet Union – on sands with buried soils and clay intercalations.

In the deserts of Central Asia where annual precipitation falls into the 100-200 mm range, the only possible way of reclaiming barkhan sands is by means of psammophytic plants. A theory of purposeful selection of a range of psammophytic plants in the desert zone derives from M. P. Petrov's investigations (1950, 1952) in the typology of habitat conditions.

Forest seed plantations and sand nurseries are contributory elements in forest production management. Quality seeds and standard elite seedlings make up the necessary transplant material to assure high survival and good preservation of cultural plantings on afforested areas.

Afforestation as a Method of Shifting-Sand Reclamation in the European USSR

Sandy areas in the European portion of the USSR are the scene of man's varied production activities. Sands have a good chance of widescale utilization in the national economy here because of adequate heat in combination with more or less sufficient rainfall and high-level productivity of the vegetative cenoses equal to 2-2.5 t/ha of above-ground plant mass (Kulik, 1977).

Extensively used throughout the region are: afforestation to provide reclamation support and protection and obtain timber and by-products of forestry; pastoral land use; crop production, orchardry and viticulture.

Sand management for multiple uses can be convincingly exemplified by the experience of development in the sands of the South Ukraine, until very recently a region totally devoid of vegetation. The integrated development of these wastelands resulted in the establishment of pine plantings by tens of thousands, of vineyards returning yields upwards of 5 t/ha, orchards with an apple productivity of 20 t/ha and more, and melon beds producing at 20 t/ha. Great success was achieved in the development of sands in the Terek-Kuma interfluve and other regions (Vinogradov, 1977).

Notably, shifting-sand reclamation by afforestation in the European Soviet Union always precedes and invariably attends the integrated development of sands. The reclamation value of protective plantings on poorly bound soils is enormous; it becomes clearly evident by levelling and stabilizing the relief and promoting the overgrowth of the row spacings by forage herbs. By decreasing wind velocity, building up moisture and preventing its intensive evaporation, the tree shelterbelts bring yield increases of forage grasses by 0.2-0.6 t/ha and of winter rye (hay) by 0.2-0.3 t/ha. When dust-storms strike the system of tree belts reduces wind erosion to 6 to 30 times as low as in control (Vinogradov, 1977).

In the European portion of the USSR forest plantings, by design, may be strip, grove or massive. The plantings managed on sands come under the 1st group of forests.

The early basics of afforestation on shifting sands were originated in the past century when willow planting was a standard practice and the plantings were established on sites fixated with mechanical protection barriers. Presently, afforestation is based on proper consideration of the site-specific conditions and the broad use of mechanization.

The Ukrainian Forestry Research Institute (UkrNIILKh) and the Low-Dnieper Experimental Station developed and applied on a wide-scale the method of establishing pine tree plantings on sands in the steppe zone where the top 3-4-metre sand layer becomes wetted each year (Ivanov and Dryuchenko, 1969).

All forest planting jobs are done by machines. The job sequence calls for pre-planting strip soil preparation to the depth of 50-60 cm in 80-90-cm-wide strips, to be undertaken concurrently with soil priming by hexachloran to control root-gnawing pests, and the subsequent width extension tillage to widen the row spacings to 150 cm.

Sand afforestation in the steppe and forest-steppe zone relies primarily on the use of Scotch pine at the per-hectare rate of 5-6 thousand transplants, which are arranged in rows placed at 2.5-3-m intervals with plants in a row 0.7-0.8-m apart.

In the semi-arid regions of the European USSR, on the sands

subject to intensive deflation the method becomes increasingly common whereby large-size seedlings of tree and shrub species are machine-planted to large depths, thus saving the need for mechanical protection barrier application. Pioneered by V.S. Gabai and A.M. Polyakova (1967), the method consists essentially in planting on barkhan sands 120-250-cm high rooted plants to a depth of 60-70 cm. The deep planting of the large-size transplant material enables arboreous vegetation to grow in sands where the effects of deflation processes result in sand removal from reclaimed areas to 40-cm-deep. The advantage of using large-size planting material is that it reduces greatly the cutting action of the wind upon the plants, as the transplant crowns appear way above the active range of the windsand flow. The plant roots, by being deepened to 60-70 cm, acquire the ability to withstand blowout throughout the growing season, the feature allowing for their good rooting and growth.

As the transplants keep growing they have the effect of progressively stabilizing the relief of shifting sands in the third or fourth year of life. By that time 40-80 per cent of the initially planted quantity, a sufficient proportion to achieve sand fixation, has remained on the planted area (Kulik and Zyuz, 1975).

In order to get sands afforested by the method of deep large-size seedling planting the rate of 2,000 plants per one hectare seems adequate provided the following, most rational scheme is applied: the row spacings are 3-4-metre-wide and drawn parallel to the crest of the barkhan chains, and there is a 1.5-metre interval between the plants in a row.

The various species selections suggested for planting depend on the amount of rainfall, depth to ground water and availability of nutrients in the sand. For the Western Near-Caspian, for example, receiving a 300-mm rainfall or more per year, on silty fine-grain sands and with a 6- to 8-metre depth to ground water it is practical to make use of Euroamerican poplar. On sands having the above-listed conditions one may grow, in addition, white (false) acacia and small-leaved (Chinese) elm. Tamarisks are recommended for planting on saline sands. In the Northern Near-Caspian, with significantly more rigid tree-growing conditions, sand afforestation by the deep planting method should best be undertaken with the use of juzgun, Caspian willow, sharp-leaved willow, and Russian olive.

The application of up-to-date afforestation practices has made it possible to establish tree plantings totalling 300 thousand ha of previously low-productive and wasteland areas in the South and South-East (Vinogradov, 1977).

Case-History of Shifting-Sand Fixation and Afforestation in the Deserts of Central Asia

Shifting sands make up 5-7 per cent of Central Asia's total desert space (Petrov, 1950; Ivanov, 1969) and stand out in patches against the general background of the desert.

Shifting sands in the sand deserts are generally attributed to action of eolian processes, brought about by high wind velocities, low-to-modest rainfall, sparse vegetation and broad distribution of loose quaternary deposits.

Various forms of poor production management in the desert are cited among the contributory factors to the everexpanding areas of shifting sands.

The spreading pattern and genesis of barkhan sands and the forms of protection management can be examined with the example from Turkmenia's deserts, where shifting sands claim 1,323 thousand hectares. In the northern portion of the West-Turkmenian Lowland, their areas run the total to 334.17 thousand ha, or 430 thousand ha with the addition of deflated solonchak surfaces (Levadnyuk, 1963). In South-Eastern Kara Kum they occupy 815.7 and 65 thousand ha, respectively, on the riverbank and downstream Amu-Darya, and 12.8 thousand ha in Central and Trans-Unguz Kara Kum (Svintsov and Movchan, 1978).

The formation of shifting sands in different regions of Turkmenia occurred at different geologic times. For the greater part of the West-Turkmenian Lowland, its barkhan relief developed in the post-Khvalyn time and the period of the low-standing Caspian water when marine and alluvial deposits began to experience strong deflation exposure under the influence of wind processes (the shifting sands of Dardzha Kum and Kyzyl Kum). Here, too, there are comparatively young barkhan formations, e.g. the Kelkor barkhan land, known to have evolved from the deflation of the New Caspian sediments already in the historical time – roughly over the last 120 years. Presently, the relief-building processes in the region are having great intensity, thereby promoting further complication of the existing relief and giving rise to young eolian forms in the Caspian littoral zone.

Dzhilli Kum, the largest single area of shifting sands in Lowland Kara Kum, emerged from the eolian reworking of the Trans-Unguz series sediments, which has persisted in the region despite the regression of the Akchagyl sea, and the subsequent erosional activity of the pra-Amu-Darya (Kalenov, 1973).

South of Dzhilli Kum, masses of shifting sands evolved under the impact of anthropogenic (man-caused) factors in the recent period because of the deflation of the sandy-clayey alluvial sediments in the old Amu-Darya delta.

The rise of shifting-sand masses induced by anthropogenic factors is particularly noted in Kara Kum, near watering points, in shrub-

cutting areas and the sites where gas- and oil-pipelines are laid or geological exploration carried out.

Shifting sands present a dynamic form of relief whose migration pattern depends on the force and sense of prevailing winds, and the particle size and extent of moisture of the sand. In Kara Kum the factors setting sands into motion are constant, wind being the only variable. It is wind, therefore, that controls the intensity of the movement.

V. A. Dubyansky (1928), B. P. Orlov (1928), and M. P. Petrov (1950) found experimentally that barkhan sands set upon the oscillatory type of movement as induced by periodically alternating winds that are opposite in direction but equal in force; barkhan chains experience the oscillatory-progressive movement with the wind of one direction prevailing over others; finally, the progressive type of sand migration is common in the area where prevailing winds blow in one direction only.

In the Turkmenian deserts there are two regions distinguished by the type of shifting sands. In Lowland, Trans-Unguz and South-Eastern Kara Kum the shifting sands migrate one to nine metres southward in response to the action of prevailing northerly winds. Seasonal migrations of the barkhan chains may be as large as 20 m. In the northern portion of the West-Turkmenian Lowland the shifting sands are induced by prevailing northerly and north-easterly winds into progressive movement alone. During the twenty-two-month observation programme barkhan forms were noted to have migrated to 90 m away near the railway station of Aidin and 86 m near Kum-Dag.

Shifting-sand migration due to wind exposure leads to burial by sand of production facilities, irrigated lands, railways and highways, or to blowout of sand from the foundations of power transmission-line constructions, and gas- and oil-pipelines. In the Mid-Amu-Darya oasis in the 1920-30s sand drifts swept over irrigated lands at the rate of several tens of hectares a year.

The risk of being completely overcome by sand posed a real threat to Turtkul, a town on the Amu-Darya; a disastrous situation arose in the Bukhara oasis where thousands of hectares of irrigated lands were lost to sand drifts (Petrov, 1950); and severe damages were dealt by shifting sands to crop farming in the downstream Amu-Darya and other regions.

Traditional methods of shifting-sand fixation and afforestation. Early references to control of shifting sands in Central Asia date back to the 1880s – the period when, in order to protect the railway track against sand drifts and blowout in the on-going Trans-Caspian Railroad project, covers of clay and ballast and mattings of dry grass and brush were set up.

High (up to 1 m) protection barriers in the form of fences first came into use in the nineties of the last century on V. A. Obruchev's recommendation. They were employed as a means to keep the

advancing sand away from the railway track and then accumulate it to produce sand fences which were believed to be able to perform themselves the protective role.

In more recent years, vigorous efforts by numerous researchers resulted in more modern designs of high-row protective barriers. One-row protection layouts were replaced by systems of protective fences laid out in parallel rows or checkers and their height was reduced to 20-30 cm, gaining for the protection structures the name of standing half-buried.

Standing, standing half-buried, solid and band matting protection types came handy where sand transport and deflation were to be fully arrested and favourable conditions created for the growth and development of newly established plantings.

The use rates of the protection material to install high-row and standing half-buried barriers and solid mattings were until recently quite impressive, reaching 300-500 cu.m/ha (Khodzhaev, 1947).

In the late 1950s the Central Asian Research Institute of Forest Management tested all of the then existing mechanical protection types and designs out of rush and sagebrush for stability and sand-fixating efficiency at wind speeds of 17 to 18 m/s. Depending on the ability to endure the high-wind exposure in the field, the application parameters of particular protection types were determined, their designs adjusted and the expenditure of protection material specified accordingly (Stepanov, 1959). Recommended for production uses were:

1. Standing dense, somewhat lighter mechanical barriers from 0.3- to 0.7-m-high with the expenditure of plant straight-stem material for their construction equal to 90 to 100 cu.m/ha for the standing and 150 cu.m/ha for the checker type;
2. Half-buried standing mechanical barriers up to 20-cm-high with 60 to 90 cu.m/ha of straight-stem plant material required for their construction;
3. Row mechanical protective mattings with the expenditure of straight-stem plant material for their construction ranging from 60 to 90 cu.m/ha;
4. "Longitudinal" mechanical mattings with a row width of 25 to 35 cm and 30 to 40 cu.m/ha of any locally available plant material required for their construction.

In the case of the standing mechanical barriers the construction process is as follows: a 20-cm ditch is dug out along a pre-marked line and the protective material is laid out on one side of the ditch, raised into a vertical position, filled with sand from both sides and rammed.

To build the row protective mattings a 5- to 7-cm-thick layer of plant material is arranged and its stability achieved by throwing on sand in the centre part of the row.

The "longitudinal" protective mattings are usually made of straight-stem plant material, mostly rush, aligned in a band

10- to 15-cm-thick and 25-cm-wide. As the material is laid out along the protection line, the bundles of stems should overlap one another and the sand strewn at the joints.

In barkhan sands the construction timing of mechanical protective barriers is from November through late January (Gvozdikov, 1962), because at that period sands maintain a more or less stable profile and the protective barriers are much easier to install on the moist substrate base.

The protective matting construction may be scheduled for any season of the year though spring is believed to be by far the best timing. With any earlier construction schedules, the mattings fail to hold the seeds in place as they are buried by sand.

Optimal spacings between the mechanical barrier rows are cited in Table 12.

Table 12

Spacings between Rows of Mechanical Protective Barriers, m, with the Height of 30 cm (Stepanov, 1963)

Protection types	Windspeed, m/s	Inter-row spacings for slope steepness of		
		5°	10°	15°
Standing	<17-18	4.2	3.0	2.1
	>18	3.3	2.1	1.2
Matting	<17-18	4	3	2
	>18	3	2	1

All mechanical protective types should efficiently be arranged in the lower half of the windward slopes of barkhan chains where favourable conditions obtain for tree planting and the barriers sustain lesser damage by wind.

Cultivation of the plantings makes an integral part of the protection programme. The method to establish the plantings was by seeding or by planting culms or seedlings of sand-fixator plants. In practice, the following seeding or planting rates were used per one hectare of fixated area: for seeds – 3 kg of saxaul, 4 kg of Paletsky cherkez, and 8 kg kandym; for culms – three thousand; for seedlings – three thousand.

Seeding was done right after the installation of the mechanical protective barriers. The seeding methods included broadcasting without incorporation, or with incorporation into holes, or in string. The freshly obtained culms or seedlings were planted out along the mechanical barriers in February-March. The autumn planting was done after the plant growing season was over and the sand had been wetted by rainfall to at least 50 cm. In the barkhan sands fixated by the mechanical protective types planting was done to beneath the Kolessov planting tool or beneath the shovel.

Combined plantings-seedings of psammophytic shrubs whose for-

mulation included 50% of the seeding rate plus 1500 culms or seedlings per hectare were considered maximum efficient.

Design of effective shifting-sand stabilization methods set the scene for successful efforts to protect production facilities against sand drifts. In the protection programme their use was differentiated with regard to the forest-growing conditions, intensity of the wind regime and the nature of the facility to be protected.

On sites with favourable forest-growing conditions and weak-to-moderate wind regime (average annual wind velocities equal to 2 to 4 m/s) the use of protective matting bands for relief stabilization and the seeding to establish tree plantings provided an effective key to the management of general reclamation programmes. In the areas with rigorous forest-growing conditions – those involving saline sands, deep ground waters and strong wind regime (average annual wind velocities above 5 m/s), this was accomplished with the use of the checker standing half-buried protection type and initiation of the plantings by planting seedlings.

Protection of several types of facilities has been found possible on the condition of strict adherence to certain rules. Canals, drainage collectors, railways, agricultural lands, and industrial locations have been protected if the advance of sand to them either as barkhan forms or in the wind-sand flow was arrested. The necessary requirements were met by making the standing or half-buried protective fences. For the environment of Central Asia where the average sand transport amounts to 22-25 cu. m/m/year all of the oncoming sand is held up by the half-buried mechanical protective types installed in rows at every 3 m in a strip 150-180-metre-wide (Stepanov, 1963).

At gas-, oil- and water-pipelines accumulation of transported sand is thought to be a welcome factor affording them necessary protection. The desired effect is achieved by providing different mechanical protective types and planting the seedlings of sand-fixator plants.

Protection of motor roads against sand drifts and prevention of blowout on slopes and roadsides relied on a variety of methods. Pouring gravel or clay or applying chemicals was the method used to prevent the processes leading to deflation on the roadside or slopes. The mechanical protective types were extensively applied as the method to hold in check the sand advance on to the road. In some places good conditions arose for non-accumulative sand transport across the roadway as a result of flattening the roadside or its stabilization with gravel or binders.

Aided by the traditional ways of protection, about 640 thousand ha were fixated and afforested in Turkmenia and Uzbekistan during the period from 1945 to 1965 alone, and another 180 thousand ha were added to the protection area in the decade from 1968 to 1978 (Petrov, 1977). The menace of sand drifts burying irrigated lands in the Amu-Darya floodplain, Bukhara oasis and downstream Zeravshan area was wiped out for good and all. Protection for the

agricultural lands in each of these regions has been assured following the establishment of wind-break plantings on sands totalling 80, 150 and 60 thousand ha respectively. The protective facilities mounted in the sands adjacent to the Mid-Amu-Darya oasis covered up to 15 thousand ha. The Kara Kum canal, Central Asia's largest hydroengineering project, was afforded protection by the mechanical barriers erected over an area of 2,000 ha. Unfailing operation of the Central Asian (Trans-Caspian) railroad has been made possible through the accomplishment of a series of protective measures, including the erection of mechanical protection totalling about 25-30 thousand ha in area. In fact, protective barrier installation along the railways in Turkmenia has progressed until now at 150 ha a year.

Technical methods of shifting-sand fixation and afforestation. The sand-fixation programmes completed to date in the Central Asian deserts with the aid of the traditional methods have done a great deal to eliminate the sand-drift hazard to towns, irrigated lands, canals and other facilities. Yet the major shifting-sand areas situated far away from the oases remained outside the scope of sand stabilization efforts. Their reclamation based on the existing technology and land management practices has been found uneconomical from the standpoint of required inputs.

Nevertheless, the reclamation of large barkhan areas received new relevance and urgency when intensive industrial and agricultural development of natural resources in the desert came underway. The research work done in this country in relation to these problems can be seen as the second phase in developing the ways of combating shifting sands, taking advantage of maximum mechanization of labour-consuming processes.

In the extra-arid environment of Central Asia mechanization of sand-fixation and tree-planting jobs is known to be practicable if chemicals are applied to stabilize the sand surface. By now the research institutes concerned with sand-fixation chemicals have identified a series of substances whose commercial use ensures reliable stabilization and afforestation of the sand surface. More than one hundred binders have been tested already (Fazylov, 1977) and some of them – like nerosin, wastes of petroproducts, ССБ (slops from alcoholic fermentation of sulfite liquor), Gossypol resin (cotton tar) and others – have been found prospective for use in the USSR. A parallel effort involved design of the processes to apply the binders over the sand surface (Gabai and Podgornov, 1973; Zakirov and Molderf, 1974; Svintsov and Movchan, 1978). Provisions were made for all-round mechanization of the labour-consuming processes involved and developing the capability to proceed with sand-fixation jobs at once with tree-planting.

Forest planting in barkhan sands following the new job sequences makes use of the forest-planting units ЛПА-1, ЛМБ-1 and some other, with the necessary traction from the ДТ-75 tractor. The transplant

material consisted of kandym and cherkez seedlings, both of them being plants best-adapted to growth on reclaimed lands.

The new planting processes require forest planting to be done in strips spaced at every 6 m and drawn parallel to the chain crest. In different types of relief (small-, medium-, large-, and high-barkhan chains) strip plantings are laid out at different sites. In small-barkhan sands the transplants are located in the areas between the chains and in the lower part of the chains themselves. In medium-barkhan sands they are planted into the inter-barkhan depressions and onto the windward slope to two thirds up its height. Finally, in large- and high-barkhan sands the plantings are set up only on the windward slopes to two thirds up their height. Under the recommended layout five to seven strips can be placed on the windward slopes of large- and high-barkhan chains.

Mechanized forest planting normally employs transplants with a well-developed taproot system no less than 30-cm-long and with at least a 50-cm-high above-ground part. Once planted, the seedlings need not to be trimmed. Rather, two thirds of their above-ground part should be clipped off to increase survival.

The mechanical planter unit is operated by a tractor-driver and two workmen and has the capacity to handle planting of six to ten thousand seedlings during a seven-hour workday.

Sand-fixation jobs are performed with the aid of different sand-fixation machines. The sand-fixation units now in use in the USSR demonstrate the proven ability to apply the binding substance to the sand surface in one- or two-metre-wide bands or 10-metre-wide bands.

In the band fixation of windward slopes the very lowest row of the planting is stabilized the first, and then the rows higher up the slope, or in the reverse order.

The binder application procedure is the following. The sand-fixation unit starts along the row so that the transplants should appear in the clearance between the tracks and coats the binder over the surface as it moves forward. Thus the sought-for effect is achieved and the planted spot fixated.

While the band fixation width may be up to two metres, the unstabilized patches in the spacing between the bands may reach 4 metres. Varying the spacing between the planting strips it is possible to change also the unplanted and unstabilized width if so required.

For massive stabilization of windward slopes a coat of binder is applied first over the lower portion of the slope and then on higher relative elevations.

The lines controlling the sand-fixator run on the windward slope the driver commonly picks up by sight though the cast-iron rule to abide by requires a necessary overlap of the margin of the fixated site upon the site being fixated. The process of fixation has its natural limits in the windspeeds of 8 m/s for strip fixation and 6 m/s for massive stabilization.

The sand-fixation unit is operated by the tractor-driver and one

workman. During a seven-hour workday a unit driven by the ДТ-75 tractor sprays 6-9 t of binding stuffs, applying 3,000-5,000 linear metres of bands up to two-metre-wide at the rate of binder application equal to one litre per one sq.m, or treats 15,000 sq.m under massive fixation at the binder application rate of 0.4-0.5 litre per one sq.m. In fact, the use rate of binding substances per sq.m area varies with the binder type applied and the surface fixation method used (Table 13).

Table 13

Expenditure of Binding Agents for Stabilization of Sand Surface

Binder	Surface stabilization method	Expenditure per 1 sq. m, l	Thickness of covers produced, mm
Nerosin	Massive	0.4-0.5	4-5
	Band	0.6-0.7	6-7
Black oil	Massive	0.8-1.0	8-10
	Band	1.0-1.5	10-15
Gossypol resin (cotton tar)			
ССБ*	Massive	0.45-0.5	10-12
Oil*	Band	2	20

* From the data of A.M. Adylkhodzhaev (1976) and A.A. Leontiev (1975)

Application of nerosin, petroleum, black oil and other petroproduct derivatives helps obtain protective covers possessing a measure of elasticity while Gossypol resin and ССБ produce hard crusts. The covers with flexible bonds are more stable to mechanical impacts whereas the hard crusts become easily impaired by mechanical action.

The examined chemicals provide covers which yield totally to ageing and natural destruction in the third or fourth year. The hard-crust covers have a shorter service-life. This way or the other, the covers are sufficiently durable to allow for the growth and development of the transplants once the plantings have started to perform their anti-corrosive and sand-fixating roles.

Tree-planting and sand-fixation programmes in barkhan sands must be antedated by a period of preparation work, with the major goal of building temporary access roads to the object of reclamation. The access roads are laid at 500 m intervals across relief to allow for the movement of the tree-planter and sand-fixator units from one barkhan chain to the next.

The plants genus Calligonum proved to be effective vegetative reclamation agents for barkhan sands in Central Asia, featuring survival within 80-90 per cent and the subsequent preservation range of 60-70 per cent; similarly, white and black saxauls are considered effective sand-fixator plants at the later phases of sand afforestation programmes.

The "Rules of Acceptance into Service of Shelterbelt Forest Plantings at State and Collective Farms and Other Agricultural Production Units" approved in 1972 by the State Forestry Committee, USSR; Ministry of Agriculture, USSR; and "Turkmengiprozem" Research and Design Institute, provide that reclaimed lands be transferred to the category of forested areas if in the fourth year they still support on one hectare over 250 bushes uniformly distributed about the area.

Planting survival in barkhan sands, where kandym seedlings were used as the transplant material, enables the required minimum to be attained upon having planted 500 seedlings per hectare. In established natural desert biocenoses there are 650-750 bushes per hectare. Therefore, 1,000 or 1,100 kandym or cherkez seedlings need to be planted on one hectare of a reclaimed area in barkhan sands to speed up surface overgrowth but most importantly to let the established plantings attain the density of natural biocenoses.

Barkhan-sand relief in the deserts is shaped out by barkhan chains, regardless of the region. The latter's extension may vary from meridional to latitudinal. The pattern of barkhan chains is asymmetrical, with a clearly defined, gentle windward slope and steep leeward slipface. In barkhan sands favourable conditions of plant growth are found only in the inter-barkhan depressions and on windward slopes. These types of areas account for as much as 70 per cent in barkhan sands, thus making reclamation programmes possible only on 70 per cent of their total area, or 0.7 ha out of every hectare. On that area it is good and well to plant 1,000-1,100 kandym or cherkez seedlings. The latter are arranged in rows six metres apart and one metre apart in the row.

In the execution of general reforestation programmes on barkhan sands the length of the superposed protection bands adds up to 1,100 linear metres per one ha of reclaimed (physical) area, with the area beneath the cover of binding substances equal to 2,200 sq.m for the two-metre band width. Protection of production facilities against sand drifts is achieved by massive stabilization of the surface. In this event the stabilized area in per hectare terms amounts to 7,000 sq.m (Table 14).

Table 14

Expenditure of Binding Agent per One Hectare Depending on Application Method

Binder	Application method	Expenditure, t/ha	Price for one ton, roubles	Cost of binder, rou./ha
Nerosin	Band	0.9-1.1	50	45-55
	Massive	4.2-4.9		210-250
Black oil	Band	1.8-2.2	24	43-53
	Massive	7.0-10.5		168-252
Gossypol resin	Massive	3.5-5.6	20	70-112
Petroleum	Band	4.4	12	52

The cost of binders to stabilize one hectare of physical area in barkhan sands depends on the substance being used and the sand-surface fixation method. The cost of binder expenditure for the band fixation by black oil and petroleum is 45-55 roubles but increases to 170-250 roubles for the massive fixation.

Adequate provision of the tree-planting production units with technology is one of the conditions for effective performance of mechanized forest-planting and sand-stabilizing activities in barkhan sands. The farms planning these activities should first make sure they are well-provided with binding substances, transplant material, and customized machinery to handle the planting of seedlings, application of binding stuffs and the transportation of both.

In the USSR the manufacture of certain of the binding substances involves some specific features that require them to be shipped off to the consumer in 50-60 t batches, as for nerosin, cotton tar and others. This makes the purchase or construction of tanks for their storage first priority.

Experience has shown that in order to bring all of the operations together in one production cycle, both the tree-planting and sand-fixating jobs should be carried out in an integrated manner – by one production team equipped with a tree-planter in one unit with a ДТ-75 tractor, two sand-fixation machines, two АНМ-53 trucks for binder transport and a bulldozer for building access roads.

The system of machines currently proposed for mechanized performance of forest-planting and sand-fixation jobs makes possible tree-planting on an area of 4.5 ha, band fixation on an area of 2.7 ha and massive fixation on 2.1 ha – each within a seven-hour workday.

Mechanized forest planting in barkhan sands using the ЛПА-1 planter brings an increase in labour productivity five times over hand planting. In sand-fixation with the sand-fixating unit the labour productivity spirals up to 20-25 times the productivity of mechanical barrier installation. Direct expenditure on all types of jobs involved in sand reclamation is reduced with the use of mechanization by a factor of four or five, i.e., from the 950-1200 roubles required for the placement of 3 by 3 and 2 by 2 m checker protective mattings and tree planting, to 180-300 roubles – the expenditure on sand-surface stabilization with bands of binding substances and forest planting.

In the USSR effective application of various chemical binding substances has already enabled sand stabilization to be accomplished over thousands of kilometres along pipelines, particularly the inter-continental gas mainlines from Bukhara to the Urals and Central Asia to the Centre, together with hundreds of kilometres of highways. Widescale binder applications are being run to stabilize barkhan relief as part of sand afforestation programmes.

Reclamation of low-productive sand ranges by land tillage and afforestation. Rational use of that method can be exemplified by the

experience of increasing the productivity of sand ranges through raising range shelterbelts.

Establishment of plantings on low-productive ranges in Central Asia employs a variety of methods. Wide and narrow range shelterbelts receive priority in some areas while massive reclamation of desert lands with a view to providing perennial winter ranges is practised in preference to other techniques in other areas.

The method to establish range shelterbelts of black saxaul in wide strips was designed at the USSR National Research Institute of Karakul Production, MA of the Uzbek SSR. Under the method, black saxaul is grown by seeding into plowed 25-metre-wide strips spaced 150-200 m apart. The method is recommended for use on sites with favourable forest-planting conditions and in submontane plains possessing well-developed sandy desertic poorly gypsized soils and receiving a comparatively high rainfall in the range of 180-200 mm.

The establishment of range shelterbelts has been proposed as a way to reclaim low-productive ranges of SredazNIILKh Institute (Leontiev, 1962; Leontiev *et al.*, 1973). Yet it is generally considered to be practical to initiate the 25-m-wide range shelterbelts by plowing the strip not in its entirety but rather in five narrow 1.5-metre-strips with the subsequent seeding of saxaul into them. The spacing between the narrow strips should preferably be equal to 5-8 m. The strips thus arranged are expected to perform the same range-protection functions as the solid 25-metre ones. The use of a system of the narrow strips permits of the preservation of natural vegetation on unplowed sites, which otherwise takes from six to seven years to recover in the wide strips. The narrow-strip technique is recommended for application in the typical sand-desert environment with 80-120 mm annual rainfall and ground water depths which make it beyond reach for the plants.

The Institute of Deserts, USSR Academy of Sciences (Ovezliev *et al.*, 1972) suggests that range shelterbelts be laid out on reclaimed lands in strips 1-1.5-metre-wide and spaced 5-6 m apart. It is desirable to utilize for tree plantings gently rolling, and medium-hummocky sands where ground water occurs at three metres. Plowing then is used as the pre-seeding soil preparation method and seeding as the method to initiate the shelterbelts.

In practice, range shelterbelts in Kara Kum as prescribed in the design assignments, are to be established by rows. The latter present, in effect, a system of three 1-1.5-metre-wide strips spaced at every 5-6 metres. On the reclaimed area the rows are placed 30-50 m apart. The method represents an extension of the Institute of Deserts and SredazNIILKh recommendations for integration of Turkmenia's traditional reclamation methods into the current afforestation practices in respect of low-productive ranges.

Improvement of rangelands and initiation of winter ranges in desert zone where the average annual rainfall varies within 170-250 mm

though the soils are fertile (loess-like) were first suggested by N. T. Nechaeva (Nechaeva *et al.*, 1958, 1974). The pre-seeding soil preparation here consists of plowing rows 10 to 15-metre-wide while leaving unplowed intervals that are equivalent or double as wide. The plantings are produced by seeding with subsequent incorporation of the seeds.

In areas with rigorous tree-planting conditions (compacted grey-brown soils or takyrs and takyr-like soils) improvement of rangelands is proposed to begin when sand- and moisture-accumulating furrows have already been made (Momotov, 1973). The furrows are produced by the K3Y-0.3 cutter or custom-built plows. The land tillage techniques applied for the cultivation of forage plants involve preliminary sand-dusting in the furrows or their charging with moisture from the surface runoff of precipitation water, and then seeding the plants to be cultivated.

In the Central Asian deserts, range shelterbelts return a 14-16% increase of the forage plant yields from the interstrip spacings and expand by 30-40% the grazing capacity of the ranges. With respect to their effects, the shelterbelts somewhat inhibit sagebrush but stimulate growth in saltworts and ephemers. Under the protection of the shelterbelts the latter show excellent preservation in dry stand in terms of being less afflicted by lodging and shattering. By 1979 the shelterbelts on plowed strips have been established on an area of 298.1 thousand ha in the Turkmen SSR and 357.3 thousand ha in the Uzbek SSR. Accordingly, range productivity increases were achieved from 1.4 mln ha in Turkmenia and 1.6 mln ha in Uzbekistan.

The role of the shelterbelts on rangelands is not confined to reclamation alone as they provide also a shelter for sheep in bad weather. In the harsh snowy winter of 1968-69 the sheep flocks staying among saxaul plantings sustained almost no damage, whereas some part of the population kept out in the open was lost. The role of shelterbelts as protective facilities remains also great in summer as well. The sites supporting forest plantings have the ability to transform any critical weather conditions causing disruptions of the normal physiological functions. As a result, there comes a 10-18% gain in meat production, 8-15% increase in the survival and preservation of young stock (sheep) and 7-13% rise of wool yield (Vinogradov, 1977).

The principles governing the selection of forest-planting areas and land tillage practices in the establishment of range shelterbelts are quite specific. The lands allotted to range shelterbelts represent level and tractor-negotiable areas, provided with water and utilized for grazing but either poor in vegetation composition or deteriorated by overgrazing and shrub overcutting for fuel. The ranges slated for improvement are ones having their productivity reduced to two thirds or one half of the original one.

In site selection for saxaul seeding it must be borne in mind that the best conditions for saxaul growth are found in areas where in

spring and early summer the surface moisture horizon developed from atmospheric rainfall joins the underlying moistened horizons. If so, the saxaul roots find it easy to reach these underlying moist soil layers, thus assuring good preservation of the plants. If, on the contrary, these moist horizons are separated by a sand layer with hard-to-access moisture the growth of the shrubs seems precarious.

Mean monthly storages of accessible moisture in the one-and-a-half metre layer of soil should amount in spring–March, April and May–to a minimum of 220-250 cu.m/ha (Leontiev *et al.*, 1973). The moisture storages, A. A. Leontiev suggests, should be estimated from the formula: $Q = VB \cdot H$, where Q is moisture storage in cu.m/ha; V is the volume weight of soil; B is the moisture content of sand in %; and H is the thickness of the horizon in cm.

A. A. Leontiev argues that the storage of accessible moisture in the two-metre soil layer equal to 220-300 cu.m/ha is sufficient to grow on one hectare on an average of 600-700 black saxaul bushes each with a height of 1-2 metres and a crown diameter about 1.5 m.

The conditions listed above should also be considered in the selection of the areas set aside for afforestation, because adequate soil moisture storages and favourable in-soil conditions are needed above anything else in forest planting as well.

In sodded sands soil plowing constitutes an essential soil-tillage practice in strip seeding and planting of psammophytic plants to assure the plants' survival in the competition with the grassy vegetation and in the improvement of soil hydrophysical and chemical properties. The depth of plowing varies with soil texture, and equals 20-22 cm on light sandy-loam soils and the sod spreading depth (25-30 cm) on thickly overgrown and sodded soils; where grey-brown soils occur, as on salwort, astragalus-bindweed, and sagebrush-ephemeral rangelands, it should be also deepened to 28-30 cm (Leontiev *et al.*, 1973).

Soil harrowing is an indispensable element of the pre-seeding soil preparation. Harrowing makes for better distribution and incorporation of seeds and increased productivity of the forest plantings. The best harrowing timing is in late autumn, after the first precipitation falls (underwinter plowing). With autumn plowing and spring seeding, secondary harrowing is necessary on takyr-like soils sometime before seeding. The strips are to be plowed across prevailing winds.

With the establishment of range shelterbelts in mind, narrow-strip seeding, primarily by string, is preferable. It is normally done by custom-built drills (CCT, a saxaul-grass drill) or, in the absence of the special drills at the farm, seeding is performed from a tractor or truck followed by incorporation with a harrow. The seeds of saxaul are to be incorporated to the depth of 2-3 cm, of cherkez to 2-3 cm, and kandym to 5-7 cm. The seeding dates are from December through mid-March. In the southern regions seeding should best be finished by February 15-20 and in the northern by mid-March.

The seeding rates accepted for planting saxaul range shelterbelts are three kg per one hectare of improved land area and the seeds suitable for seeding are those of the lst or 2nd quality grade (Table 15).

Table 15

Seeding Rates for Black Saxaul Seeds against Their Production Suitability
(USSR State Standard, GOST, 13855-68)

Quality grade	Production suitability, %	Seeding rate, kg/ha	
		unspecified seeding	incorporation seeding
1	38,5	5	3
2	33.0	6	3.6
3	27.5	7	4.2

Advanced domestic and foreign experiences suggest also other techniques for afforestation in extra-arid environments permitting of high survival and good preservation of the plantings. In particular, it is proposed for plantings establishment to make use of transplant material rather than seeds, or of transplant material with the enclosed root system.

In Turkmenia the initiation of protective forest plantings out of psammophytes by planting seedlings has been a standard practice since the early 1970s. Thus far Central Asia has only a limited area under the forest plantings produced by planting seedlings though in Turkmenia the new plantings thus established keep expanding at the rate of 500-600 ha annually. But plans are ahead to increase the scope of planting programmes to 10-15 thousand a year and employ for the purpose the seedlings of black saxaul, tree-ike kandym and Paletsky cherkez. The results of the tree-planting afforestation efforts are summarized in Table 16. It addresses the areas where mechanized planting was done into plowed strips, pre-planting soil preparation involved autumn strip plowing with the trenching plow to a 40-50 cm depth and a rotation of the layer; the kandym and cherkez transplants were used also on virgin soils.

Preservation of the plantings on the sites, as shown by the tabulated data, varied a great deal, depending on the species composition of the sand-fixator plants, the site-specific tree-planting conditions that occurred on the reclaimed lands and the planting sites–whether on virgin lands or in areas with pre-planting soil preparation.

Good preservation towards the end of the observation schedule was noted on gently rolling sands only for black saxaul. The kandym plants die. Also, substantial death losses of kandym and cherkez over the seven-year period were seen to have occurred in semi-overgrown sands with and without soil preparation.

The non-uniform preservation of the kandym plantings on the

Table 16

Survival and Preservation of Tree Plantings Installed by Mechanical Planting of Seedlings in the Zone of the Kara Kum Canal's Phase 3

Site	Species	Survival as of May 4, 1974, %	Preservation			
			1974		1975	1979
			June	Nov.		
Gently rolling sands	Black saxaul	95	95	87	83	72
	Kandym	92	92	57	9	0
Hummocky sands	Kandym	94	93	93	75	70
Semi-overgrown	Kandym	91	90	64	40	28
hummocky sands	Cherkez	94	89	47	33	30
On areas without soil preparation						
Gently rolling sands	Kandym	88	82	24	6	3
Semi-overgrown	Kandym	94	90	52	41	37
hummocky sands	Cherkez	73	61	42	34	30

test sites is attributed to the activity of the harmful soil entomofauna.

Plant growth increment in the planting locales was higher during the observation schedule than in the first growing season. In saxaul it reached 40-50 cm but then exceeded 20-30 cm not once during the growing season. In kandym, the first-year increment was 65-85 cm, only to be limited to 40-50 cm all through the growing season. In cherkez the increment was 50-60 and 35-40 cm in the first and following growing seasons respectively. This downtrend in the plants growth increment in the following growing seasons below the first one was due to the deteriorated water budget as the planting sites became progressively overgrown by grassy vegetation. As for saxaul, kandym and cherkez, their adequate survival and preservation were recorded also in other soil-climatic regions of Turkmenia.

Improved efficiency of plantings can be attained by allocating greater attention to the quality of the sand-fixator transplants and resorting to supplementary tilling measures. In fact above-50% survival has been noted in the seedlings of black saxaul with the above-ground part higher than 50 cm and the root neck 10-mm-thick, and the kandym and cherkez with the above-ground part higher than 60 cm and the root neck 5-mm-thick. Another substantial quality characteristic of the black saxaul transplants was the structure of the root system.

The transplants possessing a taproot system exhibit higher survival in autumn than the similar-size seedlings with fibrous roots. The taproot system seems to be better-adapted in terms of root regeneration, therefore the plants with the fibrous root system must be sorted out from the suitable black saxaul stock. The former constitute usually 25-30 per cent in the total number of transplants.

Close consideration to the ecologo-biological characteristics of the transplants must be the only way to assure their effective planting on afforested areas. An example to illustrate the need to have this condition fulfilled in carrying out forest-planting operations can be derived from the results of planting white and black saxaul on sodded sands with large depths to ground water (15-20 m). There, black saxaul plantings showed 19 per cent and white saxaul 47 per cent survival.

In commercial planting programmes the plantings depend very much for their survival on whether the recommendations for the use of a particular sand-fixator plant species in a certain edaphic environment have been closely followed.

The establishment of range shelterbelts in areas with rigorous conditions for tree growth relies heavily on mineral fertilizer application, cutting the transplants to the stump and some other plant management practices to improve the overall effectiveness of the plantings. With respect to fertilization, it is good practice to apply mineral fertilizers – nitrogen and phosphorus – simultaneously with planting the seedlings to the bottom of the planting furrow at the use rates of 100 kg ammonium nitrate and 150 kg superphosphate per one hactare of the treated area. The mineral fertilizer application should be differentiated as the white saxaul transplants show better responses to the nitrogen-phosphorus fertilizer mixture and those of black saxaul, kandym and cherkez to phosphorus fertilizers. Favourable forest-growing conditions plus mineral fertilizer application produce a growth increment of 40-50 cm in white saxaul, 60 cm in black saxaul and 80-100 cm in kandym and cherkez during one growing season. In control plantings the respective growing-season increments were 30-35, 30-40, 40-50, and 30-40 cm.

Trimming the above-ground part of the transplants is a practice for promoting improved survival of the transplant material that has long been used in forestry. Likewise, its application in the afforestation programmes based on sandy species proved also quite productive. In fact this practice alone can ensure improved survival up to an estimated 40-47 per cent.

CONCLUSION

Rich experience gained in the USSR in resolving tasks of arid regions development and efforts to combat desertification are important preconditions for successful development of the economy in these regions not infringing the environmental equilibrium.

Studies of natural peculiarities enable to identify desertification-affected regions, to improve methods of landscape indication, and to outline ways for rational nature management.

Animal grazing is dependent on the condition of the natural forage base in deserts, thus, a system of measures aimed at the rational grazing management on the basis of zoning and organizational undertakings was devised. The process of shaping this system and its introduction is still going on. The system encompasses distribution of rangelands among farms in compliance with the master plan of their integrated development and water supply; defining optimal sizes of sheep-breeding farms for different regions; pasture rotation; making up forage balances; improving the rangeland utilization; establishing systems for grazing monitoring and management.

Of great significance for researches into the problem of combating desertification is the experience amassed on the development of desert regions through irrigation and drainage construction. On the example of regions being developed in different years, the vital role of integrated approach taking into account local natural peculiarities is unveiled. In such an approach the priority is given to the construction of irrigation and drainage systems. In the course of irrigation development of territories a single natural-production complex, making for the optimum natural resources use, is being formed. Various levels of such approach are demonstrated on the example of land development in the zone of the Greater Ferghana and Kara Kum canals, in the Golodnaya and Karshi Steppes and other regions.

Besides traditional measures employed to combat moving sands, new methods of afforestation are progressively brought into use, which made it possible to extend the scale of afforestation (only in Turkmenia up to 80,000 ha are ameliorated annually), to restore the economic potential of vast barkhan areas and to rule out the possibility of sand drifts on large linear-type facilities (irrigation canals, railways and highways), industrial enterprises and fields.

Certain success is achieved in the application of space survey to studying desert landscapes, preparing thematic maps, and identifying affected regions (Kharin, 1980).

In view of the escalating utilization of desert natural resources more pressing become the problems of optimization of development and management of the whole entity of natural resources in a region, and the shaping and introduction of systems for environment management with regard to nature conservation requirements. Further improvement of research methods, designing and implementation is needed in this context.

LITERATURE

Adylkhodzhaev, A. M. New viscous materials for the fixation of drifting sands, *Tez. dokl. Vses. nauchn. konf. po kompleksn. izuchen. i osvoen. pustyn. ter. SSSR*, Section I, Ylym, Ashkhabad, 1976, pp. 6-7.

Amelin, I. S. *Pasture Rotation in Karakul Farming in Central Asia*, Samarkand, 1944 (in Russian).

Artsybashev, E. S. Application of satellite data for forest fire control in perspective, *Proceedings of the UN Training Seminar on Remote Sensing*, Baku-Elm, 1977 (in Russian).

Babaev, A. G. *Oases Sands in Turkmenistan and Their Development Trends*, Ylym, Ashkhabad, 1973, p. 353 (in Russian).

Babaev, A. G., N. T. Nechaeva, *et al.* Integrated desert development and desertification control in the Turkmen SSR, *UN Conference on Desertification*, Nairobi, 1977.

Babaev, A. G. and Z. G. Freikin. *USSR Deserts: Yesterday, Today, Tomorrow*, Mysl, Moscow, 1977, p. 352 (in Russian).

Babushkin, L. N. Agrochemical Description of Central Asia, *Tr. TashGU*, Issue 236, 5-185 (1964).

Balaban, G. I. and E. S. Strokova. Nourishing potential of rangelands for karakul farming in Uzbekistan, *Tr. Vsesoyuzn. inst. karakulevodstva*, Samarkand, Issue 5, 1951.

Balashova, E. N., I. G. Sabinina, and O. A. Semyonova. Climate of the Kyzyl Kum Desert, *Sb. rabot Tashkent. GMO*, Tashkent, Issue 1, 5-69 (1961).

Balashova, E. N., O. M. Zhitomirskaya, and O. A. Semyonova. *Climate of Central Asia,* Gidrometeoizdat, Leningrad, 1960 (in Russian).

Belyaeva, I. P., V. I. Rachkulik, and M. V. Sitnikova. A Method for evaluating yielding capacity mostly of desert rangeland vegetation. *Auth. Cert. No. 185142, 1965, 7, Byull. izobr., prom. obrazts., tovarn. znakov*, 16, 118 (1966).

Borovsky, V. M. and V. A. Kornienko. Problems of the Aral Sea today, *Probl. osvoen. pustyn*, 2, 7-12 (1979).

Borovsky, V. M. and N. T. Kuznetsov. The Siberian rivers transfer as a solution of the Aral Sea problems, *Probl. osvoen. pustyn*, 2, 18-24 (1979).

Borzenkova, I. I. Specific features of century-wise precipitation variations in different climatic zones of Africa, *Tr. GGI.* Issue 247 (1977).

Budyko, M. I. *Climate and Life*, Gidrometeoizdat, Leningrad, 1971 (in Russian).

Budyko, M. I. *Climate Variations*, Gidrometeoizdat, Leningrad, 1974 (in Russian).

Budyko, M. I. *Modern Climate Variations*, Gidrometeoizdat, Leningrad, 1977 (in Russian).

Budyko, M. I. and K. Ya. Vinnikov. Modern climate changes, *Meteorol. i gidrol.*, 9 (1973).

Bugaev, V. A. *Studies of Dynamic Climatology in Central Asia*, Gidrometeoizdat, Moscow, 1961, p. 96 (in Russian).

Chaplina, Z. P. Chemical composition of fodder plants on desert and piedmont semi-desert rangelands in Central Asia, *Tr. Vsesoyuzn. inst. karakulevodstva*, Samarkand, **9** (1959).

Charni, J. Desert dynamics and drought in Sahel, in: *Physical Basis of the Climate Theory and Its Modelling*, Gidrometeoizdat, Leningrad, 1977 (in Russian).

Chekeres, A. I. *Weather, Climate and Distant-Range Grazing*, Gidrometeoizdat, Leningrad, 1973 (in Russian).

Chelpanova, O. M. *Climate of the USSR*, Issue 3 – *Central Asia*, Gidrometeoizdat, Leningrad, 1963 (in Russian).

Chembarisov, E. I. Water salinity dynamics in some Central Asian rivers as a result of irrigation, *Sc. Cand. (Agricul.) Dissertation*, Moscow, 1974 (in Russian).

Cheremushkin, S. D. On economic assessment of lands, *Mater. nauchn.-issled. rabot Vsesoyuzn. inst. ekonomiki selsk. khoz.*, Issue 32, 1959.

Cheremushkin, S. D. *On the Basics of Land Cadastre in the USSR*, Moscow, 1961 (in Russian).

Cheremushkin, S. D. *Theory and Practice of Economic Assessment of Land*, Izd. sots.-ekonom. liter., Moscow, 1963 (in Russian).

Chetyrkin, V. M. *Central Asia. Experience of Comprehensive Geographical Characterization and Zoning*, Izd. SaGU, Tashkent, 1960 (in Russian).

Chigarkin, A. V. *People and Desert*, Nauka, Alma-Ata, 1979, p. 185 (in Russian).

Climate of Kazakhstan, Gidrometeoizdat, Leningrad, 1959 (in Russian).

Desertification, an Overview, *Proceedings of the UN Conference on Desertification*, Nairobi, UNEP, 1977, p. 96.

Dzhanpeisov, R. and E. U. Dzhamalbekov. Soil conservation in Kazakhstan, *Probl. osvoen. pustyn*, 4, 63-69 (1978).

Dobrin, L. G. Man-induced changes in landscapes of the Kara Kum, *Probl. osvoen. pustyn*, 4, 14-17 (1978).

Dregne, H. E. Desertification of arid lands, *Economic Geography,* **53**, 4, 322-331 (1977).

Dubovny, V. A. Golodnaya Steppe. USSR. Case Study, *A/Conf. 74/23*, Nairobi, 1977.

Dubyansky, V. A. Sand desert in the South-East Kara Kum, *Tr. po prikl. bot.*, **19**, Issue 4, 224 (1928).

Fazylov, T. I. Experience of sand fixation with viscous material. Control of sand drifts on railroads, *Sb. nauchn. trudov, Tashkentsk. inst. inzhenerov zh.-d. transporta*, Issue 139, 3-9 (1977).

Fedorovich, B. A., A. G. Babaev, and A. S. Kes. Natural conditions in deserts of Central Asia and Kazakhstan and ways of their development, in: *Natural Conditions, Animal Husbandry and Forage Base in Deserts*, Izd. AN TSSR, Ashkhabad, 1963, pp. 7-22 (in Russian).

Fedoseev, A. P. Assessment of meteorological conditions for sheep winter grazing in Kazakhstan and Western part of the Caspian basin, *Sb. rabot po operativn. agrometobsluzh. otgonnogo zhivotnov.*, Gidrometeoizdat, Moscow, 1959a (in Russian).

Fedoseev, A. P. Climatic conditions for sheep winter grazing in Kazakhstan, *Tr. KazNIGMI*, Issue 13, 3-12 (1959b).

Fedoseev, A. P. *Climate and Rangeland Grasses of Kazakhstan*, Gidrometeoizdat, Leningrad, 1964 (in Russian).

Flon, G. History and intransitivity of climate, in: *Physical Basis of the Climate Theory and Its Modelling*, Gidrometeoizdat, Leningrad, 1977 (in Russian).

Gabai, V. S. and S. A. Podgornov. *Recommendations on the Application of Nerozin for Drifting-Sand Fixation in the USSR Deserts and Semi-Deserts*, Volgograd, 1973, p. 13 (in Russian).

Gabai, V. S. and A. M. Polyakova. *Recommendations on the Mechanized Deep Planting of Trees on Drifting Sands without Mechanical Protective Means*, Volgograd, 1967, p. 12 (in Russian).

Ghose, B., S. Singh, and A. Kar. Geomorphic evidence of desertification in the Rajasthan desert (India). Problems in the development and conservation of desert and semidesert land, *Pre-Congress Symp. K-26, Ashkhabad, USSR, July 20-26, 1976*. Univ. New South Wales Kensington.

Gilchrist, A. Two climate change experiments, *Technical Note 11/50,* MS, 1975.

Gonin, G. B. and N. S. Ramm. Photogrammetric interpretation of space photographs using computers and modern instrumentation for natural resources, survey, in: *Space Surveys of the Earth's Resources*, Nauka, Moscow, 1976 (in Russian).

Grave, L. M. Technogenic mass exchange and complexes in the Kara Kum canal zone, *Probl. osvoen. pustyn*, 3-4, 155-163 (1976).

Grave, M. K. *Northern Piedmont Plain of Kopet-Dag*, Izd. AN SSSR, Moscow, 1957 (in Russian).
Grigoriev, A. A. and M. I. Budyko. Climate Classification in the USSR, *Izv. AN SSSR, Geography Series*, 3 (1959).
Grove, A. T. Desertification in the African Environment, in: *Drought in Africa, Report of the 1973 Symposium, Centre for African Studies*, U. of London, 1973.
Gvozdikov, A. V. Theory and practice of fixation and afforestation of sands in Central Asia, *Tr. TashSKhI*, Issue 13, 343-439 (1962).
Handbook of Desertification Indicators (Ed. P. Reining), A. A. A. S. Washington, 1978, p. 141.
Houerou, H. N. *The Nature and Causes of Desertification*. Boulder Westview Press, 1977, pp. 17-38.
Irrigation in Uzbekistan, 1975 (in Russian).
Ivanov, A. E. *Wind Erosion of Sands, Sandy and Loamy-Sandy Soils in the USSR and Combative Measures*, Moscow, 1969, p. 58 (in Russian).
Ivanov, A. E. and M. M. Dryuchenko. *Integrated Development of Sand Territories*, Lesnaya Promyshlennost, Moscow, 1969, p. 302 (in Russian).
Kalenov, G. S. *Vegetation in the Kara Kum Lowerings as Affected by Soil Conditions*, Ylym, Ashkhabad, 1973, p. 141 (in Russian).
Karimov, K. K. Astragalus vegetation in sagebrush-ephemeral deserts of Uzbekistan, *Tr. Vsesoyuzn. inst. karakulevodstva*, Samarkand, **14** (1964).
Kashirina, A. V., A. P. Markov, and V. I. Matveev. *Agrotechnical Basis of Pasture Rotation in Different Zones of Kazakhstan*, Kazgosizdat, Alma-Ata, 1955 (in Russian).
Kharin, N. G. *Remote Sensing Techniques for Vegetation Studies*, Nauka, Moscow, 1975 (in Russian).
Kharin, N. G. Remote sensing techniques and the monitoring of desertification processes in arid areas, *Probl. osvoen. pustyn*, 3-4, 45-54 (1976).
Kharin, N. G. Remote sensing techniques and the monitoring of desertification in arid areas, *Material for the UN Conference on Disertification*, Moscow, 1977.
Kharin, N. G. *Remote Indication of Desertification*, Nauka, Moscow, 1980 (in Russian).
Kharin, N. G. and G. S. Kalenov. Studies of anthropogenic desertification by space photographs, *Probl. osvoen. pustyn*, 4, 25-28 (1978).
Kharin, N. G. and R. G. Moiseev. Aerial survey in phytoreclamation, in: *Problems of Protective Afforestation*, Krasnoyarsk, 1963 (in Russian).
Kharin, N. G., K. Nurberdyev, and E. Serkhenov. Aerial surveys for sand studies and mapping, *Vestn. selkhoz. nauki*, 6 (1963).
Kharin, N. G. and M. P. Petrov. Glossary of terms on natural conditions and desert development, *Materials for the UN Conference on Desertification, August 29-September 9, 1977*, Nairobi, Kenya, Moscow, 1977.
Khodzhaev, A. A. *Sand Drift Control on Railroads*, Moscow, 1947 (in Russian).
Khodzhakuliev, M. Mechanization of afforestation processes in forestry farms in the Turkmen SSR, in: *Afforestation in Turkmenistan, Tezisy dokl. Turkm. LOS*, Ashkhabad, 1977, pp. 6-7 (in Russian).
Koksharova, N. E. and K. Shchukurov. Relationship between seed quality of saxaul and its ecoforms, in: *Protective Afforestation of Sand Territories in Central Asia*, 1973 (*Nauchn. trudy/SredazNIILKh*, Issue XV, Tashkent) (in Russian).
Koksharova, N. E., I. P. Svintsov, and K. Shchukurov. *Recommendations on Establishing Permanent Forest-Seed Blocks of Black Saxaul*, Tashkent, 1977 (in Russian).
Kopanev, G. V. *Economics and Organization of Pasture Water Supply*, Nauka, Moscow. 1967 (in Russian).
Kormanovskaya, M. A., E. V. Barlyaeva, E. I. Vorobyova, *et. al. Chemical Composition and Nourishing Capacity of Forage in Kazakhstan*, Kazgosizdat, Alma-Ata. 1969 (in Russian).
Kormanovskaya, M. A., V. I. Matveev, E. V. Barlyaeva, *et al. Chemical Composition and Nourishing Capacity of Forage in Kazakhstan*, Kazselkhozgiz, Alma-Ata, 1962 (in Russian).

Kostyuchenko, V. P. and N. M. Bogdanova. Studies of sources of likely wind removal of salts from the dried-off southern shore of the Aral Sea, *Probl. osvoen. pustyn*, 4, 3-10 (1979).
Kovda, V. A. *Land Aridization and Drought Control*, Nauka, Moscow, 1977, p. 272 (in Russian).
Kulik, N. F. Study of the integrated approach to sand territories development, *Byull. VNIIA*, Volgograd, Issue 1 (23), 9-15 (1977).
Kulik, N. F. and N. S. Zyuz. Afforestation of the Tersko-Kumski and Astrakhan sand territories, *Lesnoye khozyaistvo*, 10, 54-56 (1975).
Kuriltseva, A. A. On the identification of burns, in: *Problems of Forest Aerial Survey and Mapping*, Krasnoyarsk, 1963 (in Russian).
Kurochkina, L. Ya. *Psammophytes in the Kazakhstan Deserts*, Nauka, Alma-Ata, 1978 (in Russian).
Kurochkina, L. Ya., M. Sh. Ishankulov, and V. A. Kornienko. On the extent of the environmental implications of water lowering in the Aral Sea, *Probl. osvoen. pustyn.*, 2, 25-33 (1979).
Lalymenko, N. K. *Recommendations on the Vegetation Growing on Takyrs and Takyr-Like Soils Using Local Surface Flow*, Izd. AN TSSR, 1964 (in Russian).
Lapkin, K. I. and E. D. Rakhimov. Socio-economic assessment of implications of the Aral Sea drying-off, *Probl. osvoen. pustyn*, 2, 84-90 (1979).
Leontiev, A. A. *Sand Deserts in Central Asia and Their Afforestation*, Gos. izd. UzSSR, Tashkent, 1962, p. 157 (in Russian).
Leontiev, A. A. *Recommendations on the Application of Narrow-Strip Oil Films or Nerozin for Sand Reclamation*, SredneazNIILKh, Tashkent, 1975, p. 7 (in Russian).
Leontiev, A. A., N. E. Koksharova, and I. K. Kurbanov. *Agrotechnical Conditions for Afforestation of Sand Territories in Uzbekistan*, Tashkent, 1973, p. 54 (in Russian).
Leshchinsky, G. T. Average annual flow in the deserts of Central Asia and West Kazakhstan, *Probl. osvoen. pustyn*, 3, 43-49 (in Russian).
Levadnyuk, A. T. *Sand Territories in the North of the Western-Turkmen Lowland*, Ashkhabad, 1963, p. 142 (in Russian).
Lobova, E. V. *Soils of the Desert Zone of the USSR*, Izd. AN SSSR, Moscow, 1960 (in Russian).
Lyapina, O. A. and V. S. Ziyavitdinova. Droughts, in: *Hazardous Hydrometeorological Phenomena in Central Asia*, Leningrad, 1977, pp. 35-50 (in Russian).
Mainguet, M. and L. Canon. Vents et paléovents du Sahara, Tentative d'aproche paléodynamique, *Revue de géographie physique et de géology dynamique*, **XVIII**, 2-3 (1976).
Markov, K. K., G. I. Lazukov, and V. A. Nikolaev. *Quarternary Period*, Moscow, 1965 (in Russian).
Mensching, H. and F. Ibrahim. The problem of desertification in and around arid lands, *Applied Sciences and Development*, **10**, Tubingen, 1977, pp. 7-43.
Mikheev, G. D. Composition and nourishing capacity of Haloxylon-Carex rangelands of the Kara Kum, *Izv. AN SSSR, Biol. Series*, 2 (1962).
Mikheev, G. D. and T. I. Gavrilova. *Fodder of the Turkmen SSR: Its Composition and Nourishing Capacity*, Ylym, Ashkhabad, 1977 (in Russian).
Minervin, V. N. *et al. Fodder Plants on the Plains of Turkmenia*, Izd. Turkmen. FAN SSSR, Ashkhabad, 1940 (in Russian).
Momotov, I. E. Gypsophytes and ways of phytoreclamation of gypsum desert rangelands in Uzbekistan, *Sc. D. (Biol.) Dissertation*, Tashkent, 1973 (in Russian).
Momotov, I. F. and K. Faizilov. *Development of Artificial Phytoconditioners in Water-Accumulating Furrows*, FAN, Tashkent, 1973 (in Russian).
Momotov, I. F., D. K. Saidov, and K. Faizilov. *Development of Artificial Phytoconditioners in Sand-Accumulating Furrows*, FAN, Tashkent, 1973 (in Russian).
Morozova, O. I. *Rangeland Management for Karakul Farming in Central Asia*, Mezhkniga, Moscow, 1946, p. 300.
Morozova, O. I. *Rangelands in a Desert and a Piedmont Desert*, Selkhozgiz, Moscow, 1959, p. 302 (in Russian).
Nechaeva, N. T. Effect of grazing on rangeland vegetation in the Kara Kum, *Izv. Turkmen. FAN SSSR*, Issues 3-4, 81-89 (1946).

Nechaeva, N. T. Effect of grazing on Kara Kum rangelands, in: *USSR Deserts and Their Development*, Vol. II, Izd. AN SSSR, Moscow-Leningrad, 1954, pp. 370-391 (in Russian).
Nechaeva, N. T. Problems of the desertification indicators development, *Probl. osvoen. pustyn*, 4, 18-24 (1979a).
Nechaeva, N. T. Effect of the management regime on the vegetation productivity in the Kara Kum, *Probl. osvoen. pustyn*, 6, 8-18 (1979b).
Nechaeva, N. T., K. G. Antonova, *et al. Vegetation Productivity of the Central Kara Kum with Regard to Various Management Regimes*, Nauka, Moscow, 1979, p. 256 (in Russian).
Nechaeva, N. T., N. A. Mordvinov, and I. A. Mosolov. *Kara Kum Rangelands and Their Management*, Turkmengiz, Ashkhabad, 1943 (in Russian).
Nechaeva, N. T. and I. A. Mosolov. *Principles and Methodology for Planning Rangeland Management with Pasture Rotation in Sheep-Growing Farms*, Izd. AN TSSR, Ashkhabad, 1954 (in Russian).
Nechaeva, N. T. and N. N. Pelt. Forage base of sheep farming in deserts of Central Asia and Kazakhstan, in: *Natural Conditions for Animal Husbandry and Forage Base of Deserts*, Izd. AN TSSR, Ashkhabad, 1963 (in Russian).
Nechaeva, N. T. and S. Ya. Prikhodko. *Artificial Winter Rangelands in Piedmont Deserts of Central Asia (Experience of Developing Artificial Phytocenoses)*, Ashkhabad, 1966, p. 277 (in Russian).
Nechaeva, N. T., S. Ya. Prikhodko, and A. N. Bashkatova. *Rangeland Improvement and Establishment of Rainfed Hay Areas in Turkmenistan Deserts*, Ashkhabad, 1958, p. 46 (in Russian).
Nechaeva, N. T., S. Ya. Prikhodko, A. N. Bashkatova, and R. M. Kiyanova. *Desert Rangeland Improvement in Turkmenistan*, Izd. AN TSSR, Ashkhabad, 1959 (in Russian).
Nechaeva, N. T., Z. Sh. Shamsutdinova, and G. M. Mukhammedov. *Desert Rangeland Improvement in Central Asia*, Ylym, Ashkhabad, 1978, p. 60 (in Russian).
Nikolaev, V. N. *Natural Forage Resources of Turkmenistan*, Ylym, Ashkhabad, 1972 (in Russian).
Nikolaev, V. N. and A. A. Amangeldyev. Evaluation criteria of desert rangelands, *Probl. osvoen. pustyn*, 3-4, 83-90 (1976).
Nikolaev, V. N., A. A. Amangeldyev, and V. A. Smetankina. *Desert Rangelands: Forage Evaluation*, Nauka, Moscow, 1977 (in Russian).
Nikolenko, G. S. *Economic Assessment of Lands*, Kainar, Alma-Ata, 1968 (in Russian).
Novikoff, G. Pratiques pastorales traditionneles et leur adaptation aux conditions modernes en Tunisie et dans les contrees Saheliennes, *Ecological bulletin*, N 24, Stockholm, 1976.
Orlov, V. P. Winds in the south-east of the Transcaspian Kara Kum (by observations of the Repetek Sand Research Station), *Meteorol. vestn.*, 10 (1928).
Orlovsky, N. S. On dust storms in Turkmenia, *Sb. rabot Ashkhabad. GMO*, Issue 3, 17-41 (1962).
Orlovsky, N. S. *Evaporation from Small Water Bodies of Turkmenia*, Ylym, Ashkhabad, 1971, p. 96 (in Russian).
Orlovsky, N. S. and Z. I. Volosyuk. *Weather and Distant-Range Granzing of Cattle in Turkmenia*, Ylym, Ashkhabad, 1974 (in Russian).
Otterman, J. Baring high-albedo soils by overgrazing: a hypothetized desertification mechanism, *Science*, **86**, 8 (1974).
Ovezliev, A. O., L. G. Dobrin, G. S. Kalenov and O. R. Kurbanov. *Phytoreclamation of Deserts in Turkmenistan*, Ylym, Ashkhabad, 1979, p. 116 (in Russian).
Ovezliev, A. O., I. P. Svintsov, and Yu. A. Romanov. *Sand Fixation and Afforestation in the Middle-Amu-Darya Oasis. Recommendations*, Ylym, Ashkhabad, 1972 (in Russian).
Petrov, M. P. *Drifting Sands and Their Control*, Moscow, 1950, p. 454 (in Russian).
Petrov, M. P. Typology of vegetation and types of agroafforestation measures on sands along the Main Turkmen Canal, *Tr. Vtoroi Sessii AN Turkm. SSR*, Ashkhabad, 1952, pp. 106-137 (in Russian).
Petrov, M. P. Once more about Asia "shrivel", *Izv. VGO*, **97**, 3, 205-211 (1966).

Petrov, M. P. Desertification processes in arid regions and combative measures, in: *Dokl. k XXII MGK*, Leningrad, 1972, pp. 69-88 (in Russian).
Petrov, M. P. *Deserts of the World*, Nauka, Leningrad, 1973, p. 435 (in Russian).
Petrov, M. P. *Nature Conservation and Re-establishment of Natural Resources*, Vol. 3, VINITI, Moscow, 1977, p. 145.
Physical Basis of the Climate Theory and Climate Modelling, Gidrometeoizdat, Leningrad, 1977 (in Russian).
Plan of Action to Combat Desertification, 74/3, Nairobi, UNEP, 1977.
Rapp, A. A review of desertification in Africa, *Water, vegetation and man*, SIES, Stockholm, p. 77 (1974).
Rapp, A. and U. Hellden. *Research on environmental monitoring methods for land-use planning in African drylands*, Lunds Universitets Naturgeografiska Inst., 42, Lund, 1979, p. 124.
Resources Sensing from Space, Prospects for Developing Countries, National Academy of Sciences, Washington, 1977.
Rodin, L. E. *Vegetation Dynamics in Deserts*, Izd. AN SSSR, Moscow-Leningrad, 1961, p. 227 (in Russian).
Romanov, N. N. Dust Storms in Central Asia, *Tr. TashGU*, Issue 174, 198 (1960).
Rozanov, B. G. Degradation of arid lands in the world and international cooperation in desertification control, *Pochvovedenie*, 8, 5-11 (1977).
Rules for Acceptance of Protective Shelterbelts in State and Collective Farms and Other Agricultural Enterprises. Instructions, Ashkhabad, 1972 (in Russian).
Sapozhnikova, S. A. Schematic map of a number of days with dust storms in the arid zone of the USSR and adjacent territories, *Tr. NIIAK*, Issue 65, 61-69 (1970).
Sayan-Wittgenstein, L. and A. H. Aldred. *Environmental monitoring, the role of remote sensing*, Forest Management Institute, Ottawa, 1976.
Schnell, R. C. Biogenic ice nucleus removal by overgrazing: A factor in the Sahelian drought? Final report to Directors, Rockefeller Foundation, MS, NCAR, Boulder, Colorado, 1975.
Semyonova, O. A. Climate in the Kara Kum, *Tr. SANIGMI*, Issue 6(21), 95-151 (1961).
Sergeeva, G. A. Experience of establishing autumn-winter rangelands for karakul sheeps in a piedmont semi-desert, *Karakulevodstvo i zverovodstvo*, 1 (1954).
Serkhenov, E. and E. A. Ryabikhin. Interpretation of serial and space photographs for studying wind erosion in deserts, *Tez. dokl. nauchn. konf. Turkm. geogr. ob-va, posvyashch. 60-letiyu Velikoi Oktyabrsk. Sots. revolyutsii*, Ashkhabad, 1977.
Shamsutdinov, Z. Sh. Organization of fodder production for karakul farming in semi-deserts and deserts of Central Asia, *Mat. Vsesoyuzn. soveshch. po karakulevodstvu*, Izd. UzASKhN, Tashkent, 1960 (in Russian).
Shamsutdinov, Z. Sh. Ways of enhancing desert rangeland productivity, *Ovtsevodstvo*, 3 (1963).
Shnitnikov, A. V. Variability of general humidity of continents in the Northern Hemisphere, *Zap. Vsesoyuzn. geogr. ob-va, new series*, Vol. 16, Moscow-Leningrad, 1957 (in Russian).
Shornikov, A. On economic evaluation of fodder crops, *Ekonomika selsk. khoz.*, 7 (1968).
Shultz, V. L. *Rivers of Central Asia*, Parts I and II, Gidrometeoizdat, Leningrad, 1965 (in Russian).
Shvan-Guriisky, I. P., A. S. Sinkovskaya, and I. K. Vilyams. *Rational Management and Ways of Improving Arid Rangelands*, VNIITEISKh, Moscow, 1974, p. 75 (in Russian).
Sinkovsky, L. P. On pasture rotation in Tadzhikistan, *Selskoe khozyaistvo Tadzhikistana*, 1 (1952).
Sinkovsky, L. P. Experience of rangeland improvement and establishment of emergency hay stocks on winter rangelands in Tadzhikistan, in: *Pasture Water Supply and Improvement*, UzGIZ, Tashkent, 1958 (in Russian).
Sinkovsky, L. P. Improvement of ephemeroid-sagebrush rangelands in Central Asia, *Luga i pastbishcha*, 2 (1966).

Stepanov, A. M. Some aerodynamic specifics of wind-permeable and solid mechanical protective means, *Uch. zap. SredazNIILKh*, Issue 1 (1959).
Stepanov, A. M. Fixation and afforestation of drifting sands in West Turkmenia with mechanical protective means of various design, Dissertation, Ashkhabad, 1973.
Subbotina, O. I. Significant and heavy precipitations, in: *Hazardous Hydrometeorological Phenomena in Central Asia*, Gidrometeoizdat, Leningrad, 1977, pp. 163-183 (in Russian).
Svintsov, I. P. and N. E. Koksharova. Principles of establishing forest-seed plots, *Inform. listok Respubl. inst. nauchn.-tekhn. inform. i propagandy Gosplana TSSR*, 66(24129) (1978).
Svintsov, I. P. and V. Ya. Movchan. *Temporary Recommendations for Afforestation and Fixation of Barkhans Through Application of Viscous Material and Mechanization*, Turkmenistan, Ashkhabad, 1978, p. 15 (in Russian).
Thie, L. and C. Wachman. Remote sensing for environmental monitoring and impact assessment, *Proc. Symposium on Remote Sensing and Photo Interpretation, Banff, Alberta, Canada, October 7 to 11, 1974*, Canadian Institute of Surveying, Ottawa, 1 (1975).
Tkachev, I. F. New methods of determining edibility and digestion of grass, *Zhivotnovodstvo*, 2 (1959).
Transitional project to monitor desertification processes and related natural resources in arid and semi-arid areas of the Southern Asia, 1977a, UN Conference on Desertification, Nairobi, 1977.
Veremeeva, T. L. and S. G. Chanysheva. Dust storms, in: *Hazardous Hydrometeorological Phenomena in Central Asia*, Gidrometeoizdat, Leningrad, 1977, pp. 138-153 (in Russian).
Viktorov, S. V. Protection of deserts as a man's habitat, in: *Problems of Geography*, Issue 82, Mysl, Moscow, 1970, pp. 95-102 (in Russian).
Viktorov, S. V. Vegetation protection and restoration in Ustyurt, *Probl. osvoen. pustyn*, 4, 77-82 (1978).
Vinogradov, B. V. *Aerial Survey for Studies of Arid Vegetation*, Nauka, Moscow-Leningrad, 1966, p. 361 (in Russian).
Vinogradov, B. V. Desertification forms identified by aerial and space surveys, *Probl. osvoen. pustyn*, 3-4 (1976).
Vinogradov, V. N. Scientific basis for planting forests, orchards and vines on sands in the Lower Dnieper River, Dissertation, Kharkov, 1968 (in Russian).
Vinogradov, V. N. Role of afforestation in arid territories development, *Byull. VNIIA*, Issue 1(23), Volgograd, 1977, pp. 3-8.
Vostokova, E. A. Application of remote sensing techniques for mapping anthropogenic and natural impacts in environment protection, *Proceedings of the UN Training Seminar on Remote Sensing*, Baku-Elm, 1977 (in Russian).
Zakirov, R. S. and V. E. Molderf. On a new method of sand fixation, *Probl. osvoen. pustyn*, 1, 83-88 (1974).
Zheltikova, T. A. Effect of the Calligonum seedlings quality on their adaptability to forest plantings, *Byull. UzbNII lesn. khoz.*, 1948, pp. 29-32.
Zhirin, V. M. Application of remote sensing for the appraisal of forest conditions, *Proceedings of the UN Training Seminar on Remote Sensing*, Baku-Elm, 1977 (in Russian).
Zonn, I. S. and A. Yu. Mrost. *Environmental Implications of Irrigation*, Moscow, 1976, p. 64 (in Russian).
Zubenok, L. I. Evaporation capacity of world deserts, *Probl. osvoen. pustyn*, 4, 48-54 (1977).

USSR/UNEP Publications and Information
Support Project
107053, Moscow, B-53, P.O. Box 438

Stepanov, A. M. Some aerodynamic specifics of wind-permeable and solid mechanical protective means, *Uch. zap. SredazNIILKh*, Issue 1 (1959).
Stepanov, A. M. Fixation and afforestation of drifting sands in West Turkmenia with mechanical protective means of various design, Dissertation, Ashkhabad, 1973.
Subbotina, O. I. Significant and heavy precipitations, in: *Hazardous Hydrometeorological Phenomena in Central Asia*, Gidrometeoizdat, Leningrad, 1977, pp. 163-183 (in Russian).
Svintsov, I. P. and N. E. Koksharova. Principles of establishing forest-seed plots, *Inform. listok Respubl. inst. nauchn.-tekhn. inform. i propagandy Gosplana TSSR*, 66(24129) (1978).
Svintsov, I. P. and V. Ya. Movchan. *Temporary Recommendations for Afforestation and Fixation of Barkhans Through Application of Viscous Material and Mechanization*, Turkmenistan, Ashkhabad, 1978, p. 15 (in Russian).
Thie, L. and C. Wachman. Remote sensing for environmental monitoring and impact assessment, *Proc. Symposium on Remote Sensing and Photo Interpretation, Banff, Alberta, Canada, October 7 to 11, 1974*, Canadian Institute of Surveying, Ottawa, 1 (1975).
Tkachev, I. F. New methods of determining edibility and digestion of grass, *Zhivotnovodstvo*,
Transitional *and related natural resources*
in arid
Desertif
Veremeeva
Phenom
(in Rus
Viktorov,
Geogra
Viktorov,
pustyn
Vinograd
Lening
Vinograd
Probl.
Vinograd
sands
Vinograd
VNIIA,
Vostokova, E. A. Application of remote sensing
nic and natural impacts in environment protection, *Proceedings of the UN Training Seminar on Remote Sensing*, Baku-Elm, 1977 (in Russian).
Zakirov, R. S. and V. E. Molderf. On a new method of sand fixation, *Probl. osvoen. pustyn*, 1, 83-88 (1974).
Zheltikova, T. A. Effect of the Calligonum seedlings quality on their adaptability to forest plantings, *Byull. UzbNII lesn. khoz.*, 1948, pp. 29-32.
Zhirin, V. M. Application of remote sensing for the appraisal of forest conditions, *Proceedings of the UN Training Seminar on Remote Sensing*, Baku-Elm, 1977 (in Russian).
Zonn, I. S. and A. Yu. Mrost. *Environmental Implications of Irrigation*, Moscow, 1976, p. 64 (in Russian).
Zubenok, L. I. Evaporation capacity of world deserts, *Probl. osvoen. pustyn*, 4, 48-54 (1977).

ERRATA

Page	Instead of	See
19	Map in Fig. 4	Map in Fig. 5
21	Map in Fig. 5	Map in Fig. 4

USSR/UNEP Publications and Information
Support Project
107053, Moscow, B-53, P.O. Box 438

UNITED NATIONS ENVIRONMENT PROGRAMME /UNEP/

USSR COMMISSION FOR UNEP

The book discusses major natural and man-made factors contributing to desertification in arid regions of the USSR. Summarized is the experience gained in the USSR on controlling desertification in animal rangeland management and irrigated farming. Desert rangelands of the USSR, their water supply, utilization and improvement are studied in detail. The book also provides recommendations for refining the assessment methods and the system of measures with a view to more rational grazing management. Outlined are also major problems of arid lands' irrigation and development, serving to lower the risk of desertification: control of salinization, waterlogging, seepage, water and wind erosion, etc.

The book is intended for geographers, forestry experts, botanists, soil scientists, specialists in water management, especially those coping with the problems of rational management and conservation of desert environment.

CENTRE OF INTERNATIONAL PROJECTS GKNT MOSCOW