DEVELOPMENT OF SANDY AND STONY DESERTS

I.P. Svintsov
Head of Department of Water and Woodland Reclamation and Protective Forestation, Russian Agricultural Academy, Moscow, Russia

Keywords: Desert, semi-desert, transformation into desert, dunes, barchan, mechanical protection, ground resources, biogroup, forest, flora, halophytes, saxaul, forest stripe, forestation, bogara.

Contents

Summary

Arid regions occupy about 31% of the Earth. Depending on geological and geomorphological features, various types of deserts are generated: sandy, sandy-shingle, rubble, stony, solonchak, clay, etc. Sandy deserts occupy about half of the total area of deserts.

A wide variety of natural conditions can be found in deserts, depending mainly on geological and climatic factors. Many features are common to all deserts, however: extreme drought, constant deficiency of humidity and mevap-transpiration out far exceeding atmospheric precipitation. Surface flow is generally lacking but ephemeral streams can follow the short periods of heavy rain. The vegetative resources are invariably poor.

Arid regions attract various forms of economic activity. High agricultural potential and presence of land suitable for arable promote development of agricultural activity .The presence of various minerals encourages development of extractive and process industries. Practically all arid regions are used for some form of grazing.

Ecosystems of arid regions are vulnerable to both natural and anthropogenic influences. Sometimes the processes of degradation reach a scale meriting the term ‘ecological disaster’, e.g. the Sahel zone, the Aral Sea region, and the northern part of the Caspian Sea basin.

Preservation of natural ecosystems and rational use of natural resources in arid regions is a global problem. The issue has been considered many times at UN conferences. According to the accepted documents the general approach on prevention of degradation of arid lands is a system of measures which focus attention on both preventive and proactive steps for rational use of natural resources, and preservation of agricultural potential. Thus all measures are interconnected with the normative documents and acts.

Reclamation of degraded land is provided by various methods and technologies. Meliorative effects can be achieved on a regional scale by afforestation (both field protective and mass afforestation). Forest reclamation of saline ground can be achieved by using halophytes.

Agricultural production in arid areas is considered from the viewpoint of possible transformation of biocenoses, but in ways that can ensure the survival of biodiversity and landscape features.

1. Introduction

The word *desert* is used to describe extensive natural areas with extremely droughty and hot climates, and rather sparse vegetation. The insignificant amount of precipitation (less than 250 mm), its non-uniform distribution through the seasons of the year, and extremely high inter-year variability, are typical of deserts. In deserts evaporation exceeds precipitation, and there is no perennial surface flow.

Desert lands are typically characterized by high aridity, as determined by a ratio of 0.2 to 0.03 for annual atmospheric precipitation to annual evaporation. The driest deserts,

which are known as hyper-arid, have a ratio of less than 0.03, i.e. the evaporation exceeds atmospheric precipitation by a factor of 33.

Deserts are distributed throughout all the continents, except for Antarctica. They can be split into three natural zones, characterized by climate (temperate, subtropical and tropical), latitude and longitude

1.1. Distribution of deserts

The deserts of the first longitudinal region are in Northern America, in the temperate and subtropical zones between latitudes 22 and 44^o North. They extend a distance of more than 2500 km, and include the deserts of the Mohave, Chihuahua and Sonoran. The general area of arid land in North America is 4.26 million km^2 or 20% of the continent. Deserts currently occupy about 9% of the land and do not form a continuous desert zone, but are located in inter-mountain hollows, plateaus, and table-lands.

The second region of deserts is located in South America, where, alongside the Pacific Ocean coast, a narrow strip almost 3000 km long comprises the Peruvian-Chilean deserts (Sechura to Atacama), mainly occupying foothills and coastal plains across three climatic zones—tropical, subtropical and temperate. Arid land in South America occupies about 19% of the territory, and deserts about 9%, or 3.69 million km^2. Deserts also occupy part of the plains of Argentina (in Patagonia and the Gran Chaco).

The third desert region is the African-Asian and this occupies a huge area. It extends across a continuous strip almost 11 000 km long, from the Atlantic coast of Africa to the valley of the Huang Ho river in China. It includes the greatest deserts on Earth—the Sahara, the deserts of Arabia, Central Asia, Iran, the Tar, Takla-Makan, Gobi, etc. On the African continent, deserts lie approximately between 15 and 30^o N; in Asia, between 15 and 35^o N; in Arabia, between 22 and 48^o N, and in Central Asia, between 36 and 46^o N. The deserts of Central Asia are in the temperate zone, while in North Africa and Arabia they are tropical and subtropical.

Arid land occupies 51% of the area of North Africa, and deserts about 37%. In Central Asia deserts make up 55% of the area; in the Arabian peninsula 95%; in India 11%, and in Pakistan 18%. As a whole on the Asian continent, arid land occupies 15 million km^2 or 37% of the continent, and deserts more than 9 million km^2 or about 22%.

The fourth desert region is in the south-west of Africa; it occupies more than 2.3 million km^2 and is located in the tropical and subtropical zones between 6 and 33^o S. It includes the deserts and semi-deserts of the Namib and the Kalahari and upland semi-desert of the Great Karoo. The Namib desert is reminiscent of the Atacama desert in Chile, being an apparently rather lifeless strip of land, extending for 1000 kilometres, close to the Atlantic coast.

The fifth desert region is represented by the deserts of Australia. Arid land occupies about 80% of all continent. True deserts, however, are located mostly in the tropical zone between 20 and 34^o N over an area of 3.9 millions km^2.

A large area of desertified land has appeared in recent decades on the Eurasia, in the

Northern part of the Caspian Sea basin, in the lower part of the river Kura. The general area of arid and semi-arid land here occupies about 752 000 km^2, of which more than one million hectares has become mobile sand over the last two decades.

Desert also occurs in the north-west extremity of the Yucatan peninsula (Mexico), on the Caribbean coast of Colombia, in the eastern extremity of Brazil, in the south-west extremity of the island of Madagascar, on the east coast of the island of Sri Lanka, in Siberia and Transbaikalia.

Eolian processes are of great importance in shaping the modern relief of deserts. Under their influence in deserts, traces of former influence of all other processes are erased, and a huge new geological formation is created.

1.2. Sandy deserts

The sandy deserts of the world occupy about half of the general areas of true deserts, corresponding in size to 4.6 to 7.0 million km^2. This represents 3.0 4.6% of the total area of the Earth's surface. To this area it is possible to add 20 000 km^2 of intra-continental sandy massif in the humid zone.

1.3. Stony deserts

The stony deserts comprise a variety of landscape formations. They may be flat or with low hills, with rubble or a sandy-shingle surface, coarse-grained gravel, grey-brown soils and poor rarefied vegetation. There is no surface water. Subterranean water can be abundant. Such deserts are widespread in Asia, on the Arabian peninsula, in the Sahara, Australia, and in North and South America.

1.4. Formation of types of deserts

Sandy deserts are formed from friable sandy alluvial deposits mainly of river and marine origin. Most of the large sandy deserts of the world are of ancient origin. They include the Erg-Iguidi, Great Erg Occidental, Great Erg Oriental, Erg Chech and other sand massifs of the Sahara, the Great Sandy Desert and Great Victoria Desert in Australia, the Great and Small Negev and the Rub-Al-Khali on the Arabian peninsula, the Thar Desert in India and Pakistan, and the Karakum Desert in Turkmenistan.

The sandy deserts of coastal lowlands occupy smaller areas. This type includes the coastal sandy deserts of Western Sahara, the Great Sandy Desert in Western Australia, and the sandy deserts of the Northern part of the Caspian Sea basin in Russia and Kazakhstan..

Sandy deserts of foothill plains usually occupy a small area. They are formed on sandy and sand/shingle deposits. Such deserts can be found in the foothill areas of Koppeh Dagh in Turkmenistan, on the Arabian peninsula, and less often in the Sahara. The largest sandy deserts of this type are available in the arid areas of on the eastern seaboard of South America (Atacama).

Sand/shingle deserts can be found on late tertiary and cretaceous deposits, on plateaus,

foothill plains and on inter-mountain hollows. The surface layer is composed of sandy conglomerates and shingle. Local names for such deserts include reg (Iran), serpr (Arabia), and gobi (Mongolia).

Sand/shingle deserts have a wide distribution in Central Asia—in Ordos, Alashani, Western Tsaidam (China), Gobi (Mongolia), Djungarian and the Tarim basin (China). This landscape is typical of Sahara, the Arabian peninsula and Australia (the Simpson Desert). In Central Asia they are widespread on the raised plains of Zaunguzskiye Karakumy (Turkmenistan) and Kyzylkum (Kazakhstan).

Deserts with a surface covering of stones and boulders, have been created by removal of all the finer surface material, i.e. dust and fine sand, by wind and water.

Stony deserts are usually formed on low hills. They are distributed across Asia, particularly on the Iranian foothills, in the Sahara, Arabia, and Australia.

The relief of sandy deserts is diverse. It can be divided into two basic groups: a) deserts in which the surface is stabilized by shrubs and other vegetation, and b) mobile naked barchan and barchan-knobby sand almost bare of vegetation. The height of the eolian features is very variable. On ground with well established vegetation the scale of relief is usually between 5 and 40 m, but on bare sand it may reach 250 to 300 m, e.g. in the Sahara, Rub-Al-Khali, in Taclamacan (China) and other places. In sand/shingle, boulder and stony deserts the relief is normally smooth and has a generally flat character.

2. Natural resources

The land area in the arid zone occupies 47.7 million km^2 or about 31% of the land area of the globe. Throughout this huge territory, located in temperate, subtropical and tropical zones, a large variety of natural conditions can be expected.

2.1. Climatic resources

The climate of desert regions can be very varied, depending on latitude, the extent of oceanicity or continental climate of the region, its relief, and its altitude, etc.

The climatic resources of arid and semi-arid land also depend on the unpredictability, or non-uniformity of climatic parameters and their deficit, particularly from the absolute volume and duration of rainfall, and the season and the length of dry periods. Based on the seasonal rhythm of wet and dry periods, the annual variation in temperature and the influences of these factors on development of vegetation and ecological features, it is possible to distinguish four categories of deserts:

1. Deserts where precipitation occurs in winter and the droughty period is in summer.
2. Deserts where the precipitation occurs in summer and the droughty period is in winter.
3. Deserts with two seasons of precipitation or without any reliable rainy season.

4. Deserts where there is no natural seasonal rhythm of precipitation, or precipitation is generally very rare.

Despite the large variation in the natural conditions of the deserts of the world, it is possible to observe certain common features:

- Firstly, they have common features of climate: extreme droughtiness, constant moisture deficit and great excess of evaporation over precipitation.
- Secondly, the classical features of desert hydrology—the presence of ephemeral and temporary rivers, and lakes without any outlet and which dry out for part of the year.
- Thirdly, soil horizons in which plant roots may be found are similar in all deserts. Their moisture content and the dynamics of the water regime is completely dependent on the amount and timing of atmospheric precipitation, temperature regime and intra-soil condensation.

2.2. Water resources

The total stock of water on the Earth is estimated to be approximately 14 billion km^3, of which 3.5 billion km^3 or 25%, is freshwater. Only about 134 million km^3 of freshwater circulate annually, as the great majority of the world's freshwater is unavailable, except on a very long timescale, being locked in glaciers, ice sheets and groundwater.

The resources of surface freshwater of deserts represent less than 1% of the total volume of the earth's river flow. Rivers flowing through arid land are generally transit rivers, draining remote areas which receive higher rainfall. The valleys of large rivers flowing through arid territories have been the cradles of many civilizations, centers of agriculture, culture etc.

2.3. Soils and soil resources

The soil cover of deserts is indicated by the surface material, which may be sandy, stony, shingle or various crusts—limy, gypsum, or salty. Many soils from specified formations have a relict character. Sandy deserts are the most widespread, comprising up to half of the total area of present-day deserts.

The degree of agricultural development of arid land in different places is variable and depends on the character of the soil cover. The most significant concentration of arable land in arid regions is usually associated with alluvial plains. In many countries this land is centered around an oasis.

In Africa only 7% of arid land is used for arable cultivation or permanent crops, but in Asia the figure is as high as 41%. The practice of rainfall agriculture (bogara) is widespread in arid regions, focusing on cultivation of cereals, using only natural atmospheric precipitation. Traditional culture of wheat, sorghum, barley, and millet is strongly associated with semi-arid areas, where the sparse rainfall confers a high level of risk to the production of the crop.

The growth of the human population and the widespread use of agricultural land for industry and transportation leads to expansion of the agricultural area, often onto marginal land on the climatic and edaphic limits for production of cereals. This often leads to land degradation.

It is necessary to use irrigation on most arable farmland in arid areas. This represents a third of all the irrigated land in the world—more than 100 million ha out of a total of 264.8 million ha. The largest area of irrigated land, exceeding 1 million ha, is concentrated in Asia. Of this, 46 million ha is in the former Soviet republics of Central Asia, Pakistan, Iran, and Iraq; North and Central America (mainly USA and Mexico) has 21.8 million ha, and Africa has 7.9 million ha (mainly in Egypt, Sudan, and the Republic of South Africa).

In arid regions huge areas are used as pasture—grazing for sheep (c. 30%), goats (60 to 70%) and more half the world's stock of large horned cattle. The wood resources of arid territories are generally insignificant and of low productivity. Other land is unproductive and includes land used for settlements, industry and transportation.

The methods used and the pattern adopted in management of arid land is often irrational and results in frequent transformation of areas and borders, and temporary removal from economic production, thus incurring additional capital investment for reclamation. As the population increases, such problems are exacerbated. Each additional person requires 0.3 to 0.5 ha for food production and 0.07 to 0.08 ha for housing and infrastructure.

2.4. Plant resources

The bioefficiency of natural and artificial plant communities in desert ecosystems is very low. It is determined by features of soil cove and hydrothermal conditions, and is also influenced by the structure of growing plants.

The vegetation of deserts is generally sparse, but areas with a good hydrothermal regime (e.g. oases, valleys and river deltas, land around freshwater lakes, and areas of groundwater seepage) can have very different and diverse plant communities. On the other hand, areas with a deficiency of soil and atmospheric moisture usually have dense soils, and excess harmful soluble salts (e.g. barchan sands, degraded pastures, takyrs, solonchaks). They are generally either lacking in vegetation or it is present only as individual specimens.

Endemic plants invariably comprise the great majority of natural vegetation cover. The biomass is always low but can vary from 5 to 6 t/ha in the sandy deserts of Central Asia (with much black saxaul) down to only a few kg/ha in the most droughty deserts of Africa.

3. Trees and shrubs of the arid zone

In the harsh ecological conditions of the arid zone, the only plants to be found are those adapted to hot, dry conditions. Practically all these plants have thermoregulation mechanisms to prevent damage from excess temperature and a tolerable water regime.

The different kinds of adaptation are very varied and require specialized morphological and anatomic features for water and osmotic balance.

The physiological adaptive attributes include features concerned with photosynthesis, respiration, transpiration, the ability of the protoplast to tolerate high temperatures, osmotic balance, and synthesis of water-retaining material.

The biological forms of the adaptations are reflected in the rhythm and rate of development, conferring the ability to live and grow during favorable conditions of heat and moisture, and surviving unfavorable conditions of temperature and drought in an anabiotic condition, e.g. dormancy.

Plant species can be subdivided, according to their ecological adaptations, into different phytocenoses. The plant species all differ in their specific structures, and their seasonality. The originality of floristic structures is well illustrated by the adaptations of the endemic plants of the deserts of the world (many of which are effectively genetically isolated).

3.1. Psammophytes

Many of the most interesting plants which grow in the arid zone are psammophytes—plants which live on friable or even mobile sands. Adaptations to a mobile substrate include the ability to regrow after part of the plant has been covered with sand, and to develop numerous roots from runners growing on the surface.

When the roots are exposed by a blow-out, vegetative shoots can appear. Both shots and roots are protected by thickenings which consist mainly of large cells or parenchyma, and they have storage devices to hold both starch and water.

The root system of psammophytes is original. For tree-like forms the lateral roots are distributed in the top horizons to a depth of 25 to 30 m. The tap root is strong and can descend to a depth of 20 to 25 m. The fruits of psammophytes also have specialized adaptations. Many have wings, bristles or hairs to enable them to ride on the wind, ensuring wide distribution across the desert.

In the sandy deserts of Central Asia psammophilic vegetation is represented by various species of *Calligonum, Ammodendron conollyi, Eremosparton flaccidum, Smirnovia turcestana, Caragana microphylla, Heliotropium arguzioides, Tournefortia sogdiana, Arisanta tectorium,* etc.

-
-
-

Bibliography

Mensching H.G. (1990). *Desertification. Darinstads: Wissenschaftliche Buchgesellschaft.* [This work provides rich data concerning the general types of desertification and causes which provoke this process].

Petrov M.P. (1973). *Deserts of globe*, 430 pp. Leningrad (in Russian). [This presents the distribution of deserts on the Earth, and shows geographical, ecological, social and economical aspects of their development].

Plantenburg I.P.M., Gischler M. (1999). *Environmental assessment in the Aral Sea basin. Land and water international*, 93, 9-12. [This represents the first full-scale environmental assessment in arid areas of the Aral Sea basin and gives water, pasture, and agriculture characteristics of desert areas].

Spurr S.H., Barnes B.V. (1980). *Forest ecology*. New York: John Wiley and Sons. [This work describes methods for studying forest in the different natural zones, their ecology and global distribution].

United Nation Convention to Combat Desertification (1995). UNEP. [This document shows the present situation with process of desertification on the world scale and ways of combating desertification in arid regions].

United Nation Environment Programme (1997). Global Environmental Outlook. New York and Oxford: Oxford University Press. [This report provides information about the global state of the environment].

Walter H., Box E.O., Hilbig W. (1983). *The deserts of Central Asia – Temperate Deserts and Semi-Deserts*. Amsterdam. [This work describes the deserts and semi-deserts of the Central Asia region, and their natural resources].

Biographical Sketch

I.P.Svintsov, Chief of a Department of a water and wood land reclamation and protective forestation, Russian agricultural academy, Moskow