Deserts, Land Use and Desertification

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Abstract. Deserts are arid areas on the globe where plant growth is scarce. The lack of water during longer periods is due to climatic conditions. This is known from all parts of the climatic temperature zones of the globe. Deserts and their adjacent semidesertic regions, such as the Sahara, the Negev and Sinai, the Namib, the Atacama and Altiplano, Central Australia, the Mohave in Southwestern USA, the Kyzylkum and Aralkum, and the Kawir in Iran and the Afghan deserts often exhibit severe changes in their environmental design according to human impact. Fluvial and aeolian soil erosion, enhanced salinity by waterlogging, pollution by pesticides and other toxics, thus, the loss of productive areas, are some of the severe effects of inadequate use by man. Desertification often takes place by this human influence in ecotopic areas where a shift to desertic conditions by a slight change in environmental factors may cause a severe additional degradation.

Introduction

In deserts distinct climatic factors prevail. In this short introduction a review of the main factors is given and examples will be mentioned as the basic knowledge for evaluation of desertification processes. Relevant or specific literature is cited.

Deserts are arid areas on the globe where plant growth is scarce (Breckle et al. 1994, Breckle 2000a). The lack of water during longer periods of the year is mainly due to climatic conditions. This is known from many parts of the climatic zones of the globe to a smaller or greater extent (Wallace and Romney 1972; Walter 1974; Walter and Breckle 1983, 1984, 1985, 1986a, b, 1991, 1999; Agachanjanz 1986; Archibold 1995). Various examples of warm or hot deserts, excluding the arctic and antarctic polar cold deserts, have similar features; some characters differ, especially the floristic realm, depending on the vegetation history.

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The Abiotic Factors in Deserts

Climatic conditions of aridity lead to high radiation and high evaporation. Lack of water by climate can be the main reason under all temperature regimes (see Table 1). Arid regions are defined as areas where potential evapotranspiration (ET) is higher than precipitation (P) (Fig. 1).

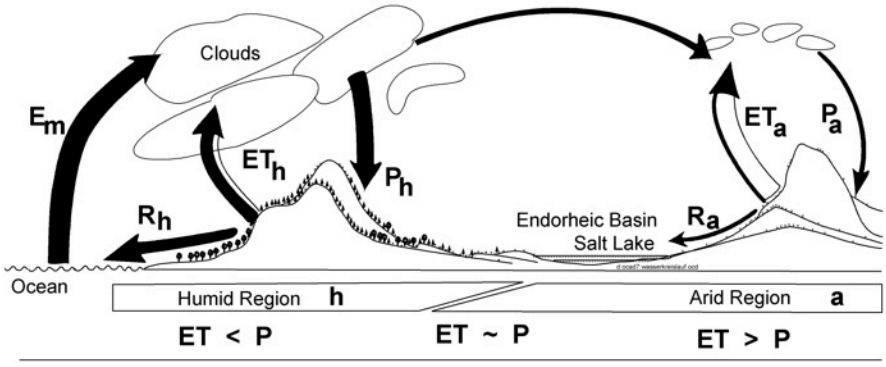

Fig. 1. Global and regional water cycling in arid and humid areas. E Evaporation; ET Evapotranspiration; P precipitation; R run-off; a arid; h humid; m marine

Aridity is not only controlled by temperature and rainfall, but also by the soil conditions, the transformation of rainfall into runoff and the nature of the rainfall (Yair and Berkowicz 1989). For a distinct area the hydrological water balance can be expressed by the formula given in Fig. 2.

In each landscape the various terms of the water balance formula can differ and are characteristic for the region (Walter and Breckle 1991). This is very basic, but often forgotten.

According to rainfall distribution or temperature regime, various desert types can be distinguished.

Equation of water balance:

$$N = \mathbf{\Delta W} + V_E + V_T + V_A + V_G$$

Water input: N = precipitation (rain, snow, dewfall)
Water output: V = water losses
E = evaporation T = transpiration
A = surface runoff G = below ground losses, seepage
$\mathbf{\Delta W}$ = water storage within the system, buffer term (+,-)

Fig. 2. Water budget of plant cover, or of a distinct part of land surface

On a smaller scale, the geomorphology with the main processes of weathering, erosion and accumulation of substrate material leads to a typical landscape pattern, where also desert types can be distinguished. According to particle size, those desert types have been named according to Arabic or Persian names (Table 1).

Table 1. Abiotic parameters in deserts and various desert types

Climate		Desert types
High radiation		
Lack of water (aridity, high evaporation)		
Distinct rainfall distribution, fog	→	Summer rain desert Winter rain desert Fog desert Extreme desert (without rain)
Temperature regime	→	Hot desert Temperate desert Cold desert Polar desert (arctic, antarctic)
Wind		
Geomorphology		
Predominance of physical weathering		
Erosion and accumulation, causing particle size sequences: catena	→	Hamada rocks, blocs reg Stones and sand serir Pebbles erg Sand takyr Clay sebkha salt
Sand movement (deflation, accumulation: dunes)		
Episodic rivers, wadis (oeds, rivieres)		
Soils		
Slow soil formation, low organic matter		
Main capillary water movement upwards: formation of crusts		
Inorganic crusts: rock varnish, limestone, gypsum, salt crusts		

One of the striking features in deserts is the salt factor (Waisel 1972; Chapman 1974; Breckle 1982, 1989, 1990, 1992, 1995, 2000b; Shainberg and Shalhevet 1984; Ungar 1991).Salinization in endorrheic basins is a natural factor. Salt in small quantities is transported by rainwater and thus accumulates in arid basins.

Evolution of halophytes has taken place in several arid regions, the Chenopodiaceae have one of their evolutionary centers in the Caspian and Aral Sea area. The other striking geomorphological factor is the accumulation of sand, the formation of sand dune areas, according to the specific wind regime in the respective area (Freitag 1986; Mandaville 1986).

The Biotic Factors in Deserts

Flora and fauna exhibit strong adaptations to desert conditions, mainly the avoidance of stresses, so that many examples of tolerance to drought or heat are known. The biotic processes which play an important role in desert organisms are shown in Table 2. The adaptation to salt, heat, drought etc. has led to many specific desert organisms and an often typical flora and fauna for each desert.

Table 2. Biotic processes as desert characteristics

Flora and vegetation, fauna	Special features
• Adaptation to drought (CAM, C_4, succulence; life forms) and to high radiation	
• High root/shoot ratio	
• Contracted vegetation	
• Night activity (mainly in animals)	
• Adaptation to salinity (halophyte types)	
• Biodiverity in most taxa low, but very specific according to desert type	
• Convergent evolutionary processes (in every floristic kingdom)	High degree of endemism
• Important role of cryptogams	Formation of biotic crusts
Human interference	
• Oasis economy	
• Nomadism	
• Hunting	
• Disappearance of wild animals	
• Overgrazing	
• Change of albedo	Climate change
• Disappearance of woody species	Degradation
• Desertification	• Soil deterioration, erosion, salinization, aggressive neophytes, deposition of pesticides, etc.

Examples of Deserts

A short list with the relevant bibliography will be given here. The Department of Ecology has done preliminary or larger casestudies mainly to identify typical halophytic flora and their ecology, ecophysiology of typical desert species, transects of climatic gradients etc. in the following deserts:

Sahara (Egypt, Wadi Allaqi; South–Tunisia) [Batanouny 1983; Batanouny and Ghabbour 1996; Barakat and Hegazy 1997; Breckle and Veste 1995; Evenari 1985; Knapp 1973; Spooner and Mann 1982; Walter and Breckle 1984, 1986a]

Area wise the biggest desert on earth, with huge areas almost rainless today, with contracted vegetation and traces of the effects of water everywhere, sand seas and huge hamada bloc types and with black rock varnish. Beduins are an example of humans adapted to a very specific desert life style, The Nile is an example of a tropical river crossing the desert and feeding Egypt and the huge city of Cairo. SouthTunisia is an example with sophisticated irrigation systems (Chenini) with three-storey cultivation (Nefta), but also with strong sand storms and large sebkhas (Shott el Djerid) and an interesting long gradient to arid mediterranean landscape pattern.

Negev and Sinai [Zohary 1973, 1982, 1983; Evenari et al. 1982; Walter and Breckle 1984, 1986a; Danin 1986; Yair and Berkowicz 1989; Blume and Berkowicz 1995; Breckle and Veste 1995; Veste and Breckle 1995, 1996, 2000]

The Negev, the eastern part of the Sinai, with a small-scale diverse mosaic of landscape, exhibiting all types of desert geomorphology, deep rooting shrubs and shaded therophytes, salt and limestone crusts, but also biotic crusts stabilizing sanddunes, antique runoff farming techniques and their restoration in new experiments (Avdat, Sede Boqer)

Namib and *Karoo* (Namibia; South Africa) [Knapp 1973; Walter and Breckle 1984, 1986a; Jürgens 1986, 1991; von Willert et al. 1992; Herppich et al. 1996; Jürgens et al. 1997; Cowling et al. 1997; Dean & Milton 1999]

The Namib, a very diverse, very old desert with a great part of sandy desert with huge dunes, salt pans, inselbergs (Spitzkoppe) and their typical rock varnish, lichen beds, lacking higher plants, succulents, the vast stretching "nara", the *Acanthosycios horrida* (Cucurbitaceae) and the relict gymnosperm, the unique *Welwitschia mirabilis*, fog basking beetles (tenebrionids), with a small population of desert elephants and giraffes in the wadis (riviere) and old rock paintings in the Brandberg and Twyfelfontain, demonstrating long-lasting human influence. The Succulent Karoo, a winter-rainfall desert is characterized by a high biodiversity and a large number of succulent species, in particular in the families of the Mesembryanthemaceae and the Crassulaceae.

Atacama (Chile); *Altiplano* (Bolivia, Chile) [Chong–Diaz 1984; Walter and Breckle 1984, 1986a, 1991]

The Atacama, one of the most extreme deserts, small, but very mountainous, up to the Andes, with soda lakes at 4200 m (Lago Minuchi), with many active volcanoes, causing destructive effects, with lava bombs and lava streams, geysers, with many trace elements in the soils and rocks (borax, Li, As), with cacti cushions and *Azorella*, with lichens on columnar cacti (fog desert) and nitrate-rich brine in salt crusts (Salar de Atacama, Pampa de Tamarugal).

Australia (Central Australia) [Stocker 1982; Beadle 1981; Walter and Breckle 1984, 1986a]

The sandy semidesert, the blue bush country (*Maireana sedifolia*), Gilgai plains, Olga mountains, Ayers Rock and Mt. Connor (inselbergs) indicate a moderate desert and a mosaic of dry savanna types with summer rains in the north (billabong formations) and winter rains in the south and southwest. The red soils, the Red Heart of the country, again indicate an old origin. Many very specific plant species (*Acacia, Eucalyptus*) of the Australian floristic kingdom and the typical fauna indicate an old separate development of the area.

Mohave (USA) [Moore et al. 1972; Wallace and Romney 1972; Breckle 1976; Wood 1980; Tiedemann et al. 1983; West 1983; Osmond et al. 1990; Walter and Breckle 1991, 1999]

A temperate desert with cold winters, with a mosaic of mountain deserts and semidesert, shrub steppes, with a "deep hole", the Death Valley, and very high summer temperatures, with specific succulents (cacti, *Yucca*) or C_4–plants (*Tidestroemia, Atriplex hymen-elytra*), with the Great Salt Lake and a great variety of halophytic communities

Kyzylkum (Uzbekistan); *Aralkum* (Kazakhstan) [Walter 1974; West 1983; Walter and Breckle 1986b, 1989; Breckle et al. 1998; Bruk et al. 1998]

Very continental with very hot summers and icy winters, with salty dust storms in spring (biskunaq), with all desert types, one of the evolutionary centres of Chenopodiaceae, where *Haloxylon aphyllum* can become a small tree, and where *Tamarix* also has its highest diversity. The Bactrian camel feeds on many geophytes and *Salsola* species. The dry sea floor of the retreating Aral Sea has become the biggest succession experiment that mankind is currently undertaking. The present area of the Aral Sea is less than half the original one, the Great and Small Aral Seas are now separate. Some fishing villages from 1960 are now located almost 100 km east of the current coast line, thus anchors and boats are rotting in the desert far from water, where huge terraces of *Zostera* indicate many old coast lines. The old sea floor is covered by *Cardium edule* shells in between many halophytes, where now the dam between the Small and the Great Aral Seas has broken a second time (April 20, 1999), and where the use of water of the

Amudarya and the Syrdarya should be modernized. The Aral Sea crisis will be one of the focus points in this symposium.

Kawir (Iran); *Afghanistan* (north and south) [Breckle et al. 1969, 1975; Walter 1974; Breckle 1981, 1982, 1983, 1986, 1989; Spooner and Mann 1982; West 1983; Freitag 1986; Walter and Breckle 1986b, 1989]

Huge catenas from the mountains to the flat Kawir areas, with immense amounts of accumulated salts, with wild camels (dromedars), with rivers and salt flats, clay pans, devoid any vegetation, but with some populations of the wild ass (*Hemionus*) and again interesting endemics in the Iranian and Afghan deserts (*Halarchon vesiculosum*).

Many results are included in synthetic surveys and textbooks (Walter and Breckle 1983, 1984, 1985, 1986a, b, 1989, 1991, 1995, 1999); other examples of specific or interesting papers are already mentioned above.

Conclusions

The basic knowledge of ecological factors and ecosystem processes is a necessary precondition, if means and techniques for preventing environmental damages are to be developed and applied in a proper, sustainable way. Humans and scientists know many facts (West 1983; Evenari 1985; Burrows 1990; Archibold 1995; Walter and Breckle 1999) and have a good knowledge of important functions and processes in ecosystems by the great advancement of science. We can now see many things from the distance by fascinating satellite remote sensing techniques. We need, however, more efforts to train the young generation better (UNESCO), especially to train them in basics in ecology and biology and practical applications. This might lead to an increased consciousness that each one of the natural resources is limited. We have a good knowledge of the long-lasting (historical) (Waisel 1986) and the ever-increasing human impacts in the past few decades, most severe in deserts (Batanouny 1983), we must use this knowledge to find better means for a sustainable use and maximizing the use of renewable resources and minimizing human impacts and desertification processes, especially in cases of irreversable damage. The Aral Sea crisis is a very recent example, through the overgrazing of many huge areas and the salinization by inadequate irrigation, monitoring of desertification processes. Means of reclamation and combating desertification, even a renewable desert agriculture by national and international efforts and programs should lead to better social and economical conditions in the affected countries. All these aspects are tackled in this seminar.

Mankind is spending a lot of money in the wrong way, and we do not use it properly and early enough to combat environmental impacts (UNCCD) or

desertification problems (McKell et al. 1972; Spooner and Mann 1982; Mooney and Godron 1983; Shainberg and Shalhevet 1984; Breckle 1983, 1999; Breckle and Veste 1995; Bruk et al. 1998). However, we also have to keep in mind that desertification processes are not only taking place in desert areas or on the fringe of deserts, but also in many other semiarid or semihumid regions.

Humans must discuss problems and find new solutions. The use of renewable energy is of focal interest, yet in the desert areas, where solar energy is plentiful. And even more, a very rational use of water with an optimal waste water use and recycling is necessary. Better cooperation and new joint projects, irrespective of how small the scale of this work and cooperation for mutual understanding might be. This fascinating planet, between Mars and Venus, surrounded by deserts, is so unique that we must take care of it. This international seminar is one step.

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