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Deserts and Desertification

For most people deserts are barren areas that hardly support life. Arid regions can be found in most climatic zones from the hot and warm tropical deserts to the cold polar deserts. Drylands cover nearly 40 % of the earth's land surface. Even the polar regions can be considered as arid and semi-arid. Annual precipitation in Antarctica can be below 50 mm and in central Greenland around 100 mm. However in the driest regions of the Sahara several years can be without any rain (e.g., Aswan average annual rainfall 3 mm).

Deserts and aridity

The lack or scarcity of water in combination with extreme temperatures is symptomatic of deserts and limits plant growth. The term "dryland" is defined as "environments which are permanently, seasonally or temporally subjected to a significant deficit in moisture" (*Barrow* 1992). "Dryland" is therefore less specific than "desert". In order to demarcate the two, different aridity indexes have been defined based mainly on climatic parameters *(Textbox 1)*. Aridity is not only controlled by the relation between precipitation and potential evapotranspiration but also by geomorphology and soil conditions. Surface properties play an important role as well. Therefore, for the definition of aridity the hydrological water balance has to be considered *(Textbox 2)*.

For deserts and desert margins high precipitation variability is the characteristic feature. Droughts can be regarded as seasonally or annually varying short-term hazards. Under such harsh environmental conditions, flora and fauna with special adaptation strategies have developed mainly to avoid environmental stresses (*Walter* and *Breckle* 2004). However, deserts can be also regarded as hotspots of biodiversity. A rich flora with a high number of local endemits can be found in the Succulent Karoo, a winter rainfall desert in South Africa, and the succulent deserts in Mexico.

Human life in deserts

Humans have settled in drylands for thousands of years. More than 3,500 years ago several advanced civilizations developed in the deserts. Large rivers like the Euphrates, Tigris and Nile supported emerging civilizations (*Hillel* 1994) which invented new agricultural techniques and built settlements. Caravan routes connected the different trading centres with each other – a first step to a global market. Cities like Petra, Avdat, Damascus, Jericho and others grew along trading routes. Nowadays, megacities with millions of inhabitants, like Cairo and Urumqi, develop in deserts and influence the ecological and social-economic situation of their surroundings.

Desertification

The severe droughts in the African Sahel in the late 1960s, 1970s and 1980s had drastic effects on the vegetation and human life in the affected regions. The reduction of the vegetation cover south of the Sahara was quite obvious. Therefore desertification was defined as "the reduction or destruction of the biological potential of the ground which may lead to desert conditions" (UNCOD 1977).

The concept of an extension of the Sahara desert into the Sahel was based on the decrease of rainfall, destruction of perennial vegetation and increasing erosion. During the drought periods a shifting of the 400 and 600 mm isohytes by an average of 2° latitude was observed (*Mainguet* 1999). It was reported that the southern boundary of the Sahara shifted south by approximately 90 to 100 km (*Helldén* 1984). This popular concept related "desertification" to "desert encroachment" *(Figure 1, Model A)*. However, this perspective is too simplistic to explain the complex processes of land degradation in other regions.

Figure 1: The spatial patterns of desertification (A) Model 1: Desert encroachment; (B) Model 2: Local desertification caused by human activities.
Design: M. Veste

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "the degradation of the land in arid, semi-arid and dry subhumid areas caused by various factors, including climatic changes and human activities". Dryland ecosystems and especially desert margins are very vulnerable to over-exploitation and inappropriate land-use practices and climatic changes. Desertification processes start around human activities, like settlements, roads and waterholes *(Figure 1, Model B)*. Various aspects are involved in the initialisation and acceleration of desertification (*Breckle* et al. 2001):

- overgrazing,
- deforestation, lumbering,
- over-use of water resources,
- inadequate irrigation practices,
- salinization,
- mining,
- erosion, sand movement,
- climatic drought.

Overgrazing affects the vegetation in many drylands *(Textbox 3)*. A huge ecological disaster is the drying of the Aral Sea in Central Asia. Water from the rivers is used for huge and inefficient irrigation projects. The consequence is a new desert covering more than 50,000 km^2 . Salt dust storms pose a threat for the entire region.

Land degradation leads to a drastic decrease of soil fertility, water availability, net primary production, plant cover and biodiversity. Food security is threatened by soil degradation and climate change. The destruction of the environment has effects on the social and economic situation of people. Increasing health problems and poverty are typical problems in the regions. Under such extreme conditions people react to the changes in the environmental conditions, for example through migration from rural areas to cities which can be observed in all regions.

Political background: establishment of the UNCCD

More than 250 million people in over 110 countries are directly affected by desertification, and about 1 billion are at risk. Desertification and its combat were important topics on the agenda of the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. At the conference the international community initiated the UNCCD in countries experiencing serious drought and desertification. In December 1992, the UN General Assembly adopted Resolution 47/88 which, after the 50th ratification was received, went into effect on 26 December 1996 and is now international law for more than 190 countries. UNCCD (www.unccd.int) facilitates cooperation on specific and regional issues. National Action Programmes to combat desertification are developed to encourage affected countries to implement projects and to prevent devastation. Thematic Programme Networks and Regional International Cooperation Networks work together with national governments and local organizations to promote exchange of information, techniques and data between different regions.

A global mechanism was established to mobilize financial and technical resources to support the implementation of the Convention to Combat Desertification. A special focus is also put on the involvement of science and education.

Textbox 1: Aridity

Water is the major driving factor for vegetation in arid and semi-arid regions. Various aridity indices are used to express the relationship between climatic variables and the environment and imply the relation between annual precipitation/evapotranspiration and vegetation cover. These approaches used by climatologists are correct on a global scale, but on a regional scale hydrological processes have to be included in the aridity concepts *(Figure 2)*.

Bioclimatic aridity index P/PET after FAO/UNESCO soil map
P = annual precipitation, PET = potential evapotranspiration
Source: Mainguet 1999

Semi-arid zones: 0.20 < P/PET < 0.50
Steppe vegetation and tropical bush; perennial plants most frequent here; extensive livestock breeding is possible.

Arid zones: 0.03 < P/PET < 0.20
Barren areas or those covered by a sparse vegetation of perennial and annual plants; pastoral nomadism is possible, but no rain-fed agriculture.

Hyperarid zones: P/PET < 0.03
Extreme deserts without vegetation except for some vegetation in the beds of the wadis.

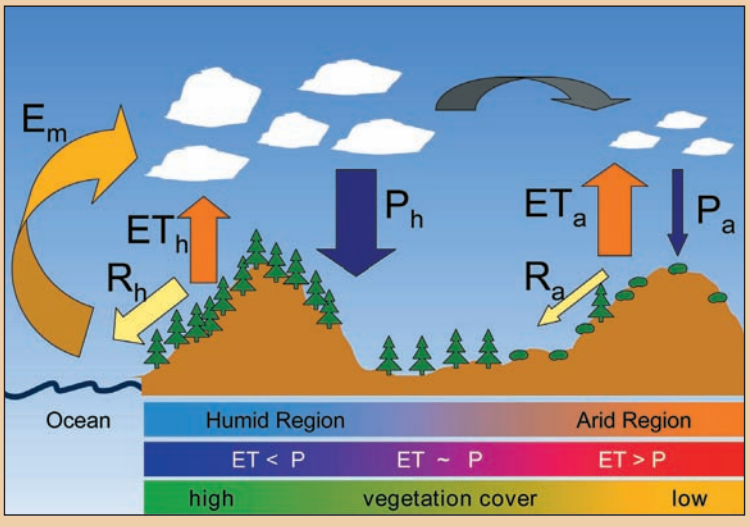

Figure 2: Global and regional water cycles in arid and humid regions; E = Evaporation; ET = Evapotranspiration; P = Precipitation; R = Run-off; a = arid; h = humid; m = marine
Source: Breckle et al. 2001; Design: M. Veste

Textbox 2: Water fluxes in deserts and the equation of water balances

In arid regions rainfall and redistribution of water play an important role for plant productivity and vegetation patterns. Water accessibility for plants is influenced by water storage and soil properties, while surface crusting limits infiltration resulting in surface run-off.

$P = V_E + V_T + V_A + V_G + \Delta W$
Water input: P = Precipitation (rain, snow, dewfall),
Water output: V = Water losses: V_E = Evaporation, V_T = Transpiration, V_A = Surface runoff, V_G = below ground losses, seepage, ΔW = Water storage within the soil, buffer term (+ , –)

Run-off from the upper hill slope to the lower part *(Figure 3)* can locally increase the amount of water sufficient to support tree growth even in arid ecosystems. Furthermore infiltrated water is not fully used by trees or vegetation and penetrates into deeper soil layers. Subsurface flow occurs and can support the vegetation with water which can be used by deep rooting plants. A patchy vegetation pattern is the result of the redistribution of water within the ecosystem. Surface and soil properties have to be included in the definition of aridity (*Yair* 1994).

A thin layer of fine material and loess limits infiltration and enhances run-off whereas sand increases infiltration. Dams and small catchments can locally increase the water availability for the vegetation by changing the water balance on a small scale and can counteract the climatically controlled aridity. Since ancient times this knowledge has been used for rainwater harvesting in rocky deserts like the Central Negev (*Evenari* et al 1982).

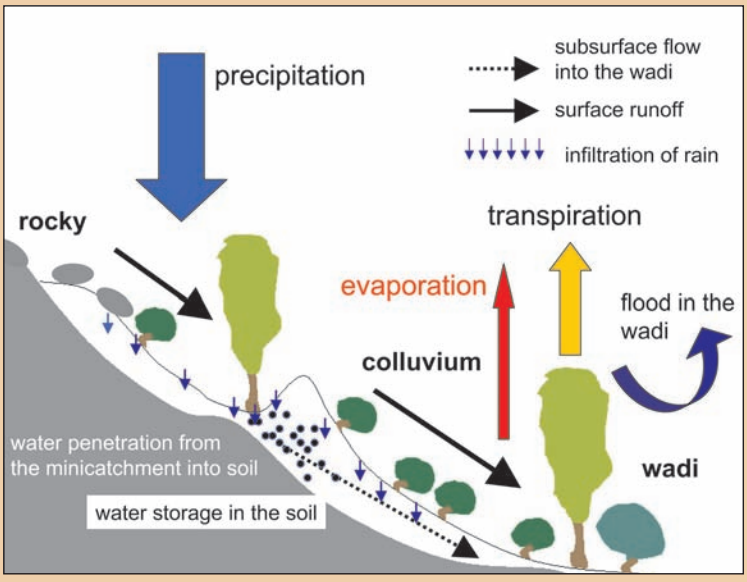

Figure 3: Water redistribution on a watershed in a rocky desert
Source: Schreiber et al. 1995;
Design: M. Veste

In the recent decade the three Rio conventions of biodiversity, climate change and combating desertification increased the political awareness of environmental issues worldwide. With the International Year of Deserts and Desertification in 2006 (www.iydd.org), the United Nations will increase the awareness of desertification and promote further actions by the international community. ■

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Textbox 3: Fence lines revealing desertification

Grazing by livestock has drastic effects on the vegetation cover and composition in drylands. Differences in land-use practices can be demonstrated along fence lines. A sharp contrast between the Israeli and Egyptian side of the arid Sinai-Negev sand dunes can be observed in satellite images (*Otterman* and *Waisel* 1974). Intensive grazing and trampling by goats and camels led to a drastic destruction of the vegetation cover on the Egyptian territory whereas on the Israeli side, the vegetation remained undisturbed *(Photo 1)*.

In semi-arid regions the consequences of livestock grazing on biodiversity are more complex. Light grazing may increase species richness due to a reduction of competition between species. In the Succulent Karoo of South Africa, heavy grazing resulted in a change of species composition. Overgrazing increases the density of unpalatable plants, whereas species richness showed no response to different grazing regimes (*Todd* and *Hoffman* 1999).

Another phenomenon in southern Africa is the increase of woody plants in the savannah. Bush encroachment is also a result of inappropriate grazing management. Both processes lead to a reduction of forage quality and grazing productivity and finally to land degradation. These examples show the complex ecological responses of the vegetation to grazing pressure in arid and semi-arid regions.

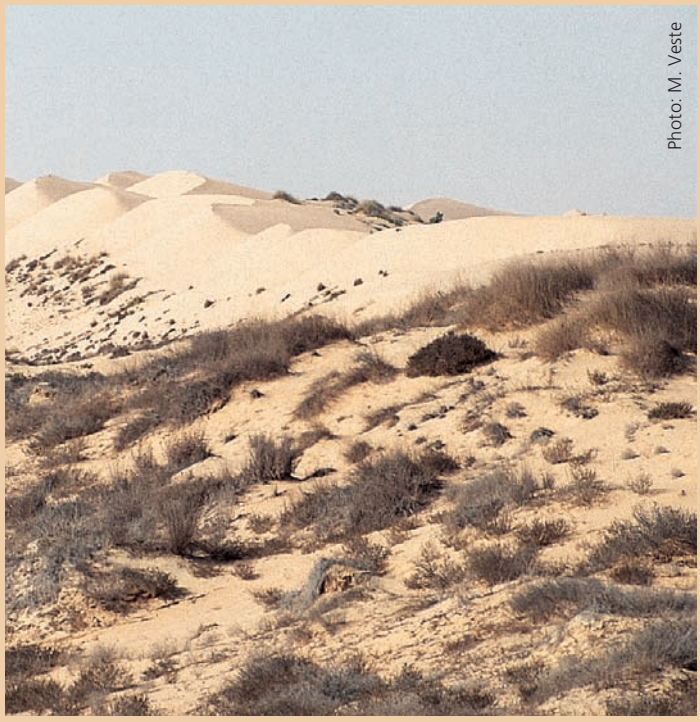

Photo1: Sand dunes on the Israeli-Egyptian border demonstrating different land-use practices (the Israeli side is in fore front, bare sand dunes in background are on Egyptian territory)

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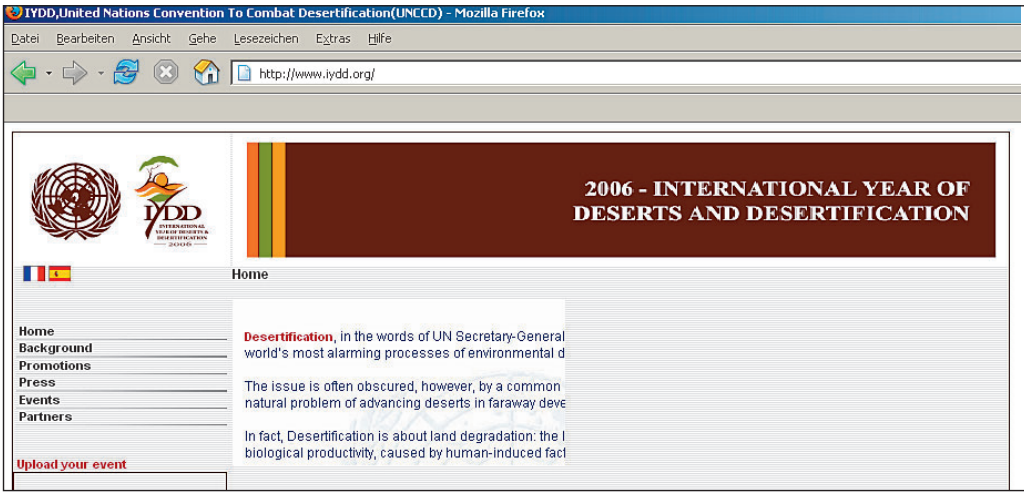

The United Nations Convention to Combat Desertification (UNCCD, www.unccd.int) has established a special web site for the 2006 International Year of Deserts and Desertification (www.iydd.org)