Baumhauer, R. (2007): Accelerated desertification. In: Lozán, J. L., H. Grassl, P. Hupfer, L. Menzel & C.-D. Schönwiese. Global Change: Enough water for all? Wissenschaftliche Auswertungen, Hamburg. 384 S. Online: www.klima-warnsignale.uni-hamburg.de

3.2 Possible consequences

3.2.1 Accelerated desertification

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***SUMMARY:** Desertification, together with its economic and social impact and side effects, is a major problem in large parts of the drylands of the world. It is mainly for climatic reasons that these regions are susceptible to the processes of desertification. Predictions of climate development suggest changes of the two climatic parameters most significant for desertification: temperature and precipitation. Introductory remarks on the definition, distribution, causes and process of desertification are followed by a discussion of the possible effects climate change will have on the frequency and intensity of climatic extreme events, on water budget respectively the availability of water, and also on vegetation. All of them are either inherent parts of desertification processes or closely related to them. In spite of all the uncertainties involved in climate prediction it is quite likely that there will be winner and looser regions. Those with already extreme climatic conditions today – i.e. mainly the arid and semi-arid regions – will be among the latter, if it turns out that there will really be an acceleration of desertification.*

For many countries of the arid, semi-arid and dry subhumid regions of the Earth desertification is a major ecological, economic and social problem. These regions comprise about 40% of the Earth's land mass. About 70% of it, with a total area of 3.6 billion ha, and thus about a quarter of the terrestrial surface threatened by desertification processes. Although figures may vary according to definition, desertification is emphasised as a global problem with enormous extension. Climate change and world population growth are likely to accentuate desertification in the future. This chapter will trace the effects of climate change with regard to a number of desertification-relevant parameters such as extreme climatic events, water budget and access, as well as vegetation, and discuss their potential role in accelerating desertification.

Desertification

Seuffert (2001) and Mensching & Seuffert (2001) regard desertification as the final stage of land(scape) degradation due to inappropriate, mainly agricultural practices (animal husbandry, farming). This process results in desert-like environmental conditions at the local, regional and possibly even zonal scale in originally non-desertic landscapes. It will exclusively operate in drylands due to their natural predisposition. In contrast, the Agenda 21 defines desertification in more general terms as land degradation in the arid, semi-arid and dry subhumid regions of the Earth, due to various causes, among them climate change and human influence. Under more practical considerations, desertification is frequently summarised as all those processes in arid regions which, due to human interference, will lead to land degradation, restricting the range of possible land uses. For instance the GTZ (German Agency for Technical Co-operation), on its home page (www.gtz.de) states, that desertification is only randomly referring to deserts, but is rather a problem of water shortage and soil and vegetation destruction in the settlement and production space of drylands. It results in malnutrition, poverty, political crises and the misery of refugees. While searching for an adequate definition of the term, its political component should not be ignored. The fact that »only« increasing degradation processes are called desertification, reflects how the term is used in media and the public in general. Nonetheless, which definition will be finally accepted, there are some generally important elements:

- The hallmark of desertification is the degradation of soils and vegetation as well as a negative effect on water resources which, will finally lead to desert-like conditions in regions where, due to the planetary atmospheric circulation, there should be no desert at all.
- Desertification affects drylands with only limited carrying capacity and regeneration potential due to physical deficits i. e. shortage of water.
- Humans, through inappropriate land use, have a causal relationship with desertification.
- Degradation will cause a decrease of agricultural yields, with famines as possible consequences.

Spatial extent, indicators and causes

Because of the absence of a generally accepted definition the spatial extent of desertification is hard to grasp. The »World Map of Desertification« (1977) published by UNCOD (Unted Nations Conference on Desertification) is based on the definition reached by the Nairobi Conference of the same year. It describes desertification as reduction or destruction of the biological potential of regions, eventually leading to desert-like conditions. Three levels of desertification hazard are distinguished, with the a priori exclusion of the hype-rarid natural deserts.

Indicators of desertification are changes in the aspect of a landscape due to human influence, either indicating where certain processes are just about to operate or where

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they have already done their work. With their help the degree of desertification of a given area can be determined. Mensching (1990) characterises four groups of physical indicators:

- Vegetative indicators, such as the spotty or areal destruction of plant cover, changing species composition, or reduced growth rates;
- Hydrological indicators: decreasing soil moisture, sinking ground-water level, lowered ground-water recharge rates
- Pedological indicators: physical and chemical soil changes in the course of »aridification«, formation of duricrusts and other structural and textural changes, and
- Morphodynamic indicators: among the fluvial indicators like truncated upper slope soil profiles, deposition of soil sediments in talwegs or buried soil profiles of lower slopes, an aeolian indicator would be the reactivation of formerly vegetation-covered sand dunes.

Furthermore, there are several socio-economic indicators such as decreasing crop yields and amount of domesticated animals, wood and fodder shortages, changes in settlement and population structure, spatial mobility, social behaviour, or increasing political unrest**.** Anyway their causal relationship is not always easy to identify and difficult to correlate with desertification processes. Desertification comprises complex interactions between biological, physical, political, social, cultural and economic factors. It may have positive or negative interdependencies and there may be shifts in each case among the dominant triggers and their consequences, depending on causal and regional differences. Although desertification manifests itself in the landscape as degradation and reduced carrying capacity, the causes will almost always be found in the socio-economic realm. Triggers or causes of inappropriate land-use leading to desertification processes, especially when coinciding with climatic extremes, may be historical, political, social or economic, such as rapid population growth, unfavourable land leasing terms (e.g. short leasing periods not enticing peasants to sustainable use), insufficient administrative regulation of use, market-orientation instead of subsistence economy or no access of the poor to land with a relevant carrying capacity. The desertification process is started and significantly steered by humans. Inappropriate land use, i. e. overuse of fields or pastures, deforestation, overexploitation of ground-water reserves inadequate irrigation techniques leading to salinisation and/or desiccation, will destroy the plant cover, degrade the soils, and reduce availability and quality of water. The condition of soil and vegetation and its various feedback mechanisms, are particularly significant for the onset of desertification. Soil degradation, erosion and induration, have negative effects on the soil water budget, which in turn will reduce vegetation cover, so that erosion of the less protected soil surface will be accelerated. Damage to the vegetation cover over large areas will cause the aridification of the near-surface climate. This again will enhance soil desiccation and induration, by simultaneously reducing infiltration capacity and increasing surface runoff. Accelerated soil erosion mainly affects the solum, i.e. the upper fine-grained parts of the soil profile where humus and nutrients are concentrated. This leads to increasingly unfavourable conditions for vegetation growth. In drylands, if no measures are taken, the outcome will be a desert-like environment, maninduced by desertification and facilitated by climatic conditions. The people in such a region will loose their livelihood, will be threatened by famine, increasing poverty, and thus a growing potential of crises and conflicts. It is generally fact that desertification processes are a set of highly complex cause-and-effect interactions, different in each special case and each region with respect to the factors and mechanisms, and thus not to be explained monocausal (Mensching & Seuffert 2001).

Desertification accelerated by climate change?

The connection between climate and desertification is clearly shown in the concentration of threatened regions in specific climatic zones. Two meteorological parameters are most relevant for desertification prediction: temperature and precipitation. Possible effects of climate change on parameters such as the frequency and intensity of climatic extreme events, water budget/water availability, and vegetation which have a strong effect on desertification have to be discussed. From the analysis of Greenland or Antarctic ice cores it is known that up to the onset of the industrial revolution in the 18th century the CO_2 content of the atmosphere had been more or less constant for centuries. Since then there has been a steady rise in the concentration of greenhouse gases, accelerating since the middle of the 20th century. This is mainly attributed to the burning of fossil fuels and changes in land use. The IPCC (Intergovernmental Panel on Climate Change), in its third assessment report on the state of the climate (2001) reports a rise of the mean global temperature by 0.6 °C + 0.2 °C for the 20th century, with regional variations. In all likelihood the 1990s were the warmest decade of the last millennium, with 1998 being the warmest year since the beginnings of standardised weather monitoring. Up to the year 2100 a further rise in temperature of between 1.4 and 5.8 °C is predicted. It is also assumed that warming will be more rapid on land than above the oceans, and that warming will be more pronounced in subtropical drylands than, for instance, in tropical rain-forest regions. Changes in the atmospheric and ocean circulation, sea-ice distribution and the acceleration of the water cycle will result in modifications of the world's precipitation pattern. The IPCC

(2001) predicts a general increase in precipitation by 5–10% during the 20th century. Especially for the higher latitudes an increase of both summer and winter precipitation is thought to be very likely. For some of the desertification-prone semi-arid regions a reduction of rainfall has already been observed, among them North and West Africa and parts of the Mediterranean. Generally a steepening of the gradient between humid and arid climates is expected.

Possible Causes of Climate Change… ...with regard to extreme weather events

It is assumed that climate change will affect the frequency and intensity of extreme events such as heat waves and extended droughts, flood-like rainfalls or heavy storms. The first two are closely related to desertification processes.

Cubasch & Kasang (2001) expect that warming causes more frequent heat waves and drought periods. Both are important factors for desertification, as they will make soils more vulnerable to degradation, decrease the amount and quality of available water. That induces crop failures and jeopardises local water supply. Estimated extensions of regions under hazard in North America, Asia and southern Europe are up to 30% by the middle of the 21st century (Wetherald & Manabe 1999).

Another effect of climate change is the probable intensification of the global water cycle. Warming should increase evaporation and consequently also increase the atmospheric storage capacity of water vapour. On the one hand this should increase the hazard of extreme rainfall events, on the other hand the greenhouse effect should become stronger because of the higher amount of water vapour in the atmosphere. It is suggested, though, that heavy rainfall events will mainly affect the mid- and high latitudes of the northern hemisphere with exception of parts of the Mediterranean region. For southern Europe the IPCC (1996) not only predicts a higher drought hazard in summer, but also a more pronounced concentration of rainfalls to the winter months. For that reason flood hazard will be increased, but bulk water supply won’t. More intensive rainfalls will mainly lead to increased surface flow, but as the infiltration capacity of the soils will be unaffected, most additional water will run off, not significantly contributing to an increase of field capacity. Increased surperficial runoff, however, will accelerate soil erosion, the most important desertification process. This once more underlines the ambivalence of water in drylands: for most of the time there is not enough, and if there is plenty of it during a rainstorm, it will mostly cause flooding and soil erosion. Beyond those basics, one should keep in mind, though, that predictions about changes in hydrological climate components, i. e. precipitation and evapotranspiration, within the context of climate change are less reliable than those on temperature (Frederick & Major 1977).

…with regard to water budget and water availability

There is a general agreement that global warming severely influences the development of the water budget and its components, both at global and regional scales, and that this will have far-reaching effects on the availability of water resources. As already referred to, the general intensification of

the global water cycle will most likely lead to an increase of precipitation in high and mid-latitudes and a decrease in some regions closer to the equator, of course with consequences on surface runoff. The IPCC assumes an increase in the higher latitudes as well as in South-east Asia, and a reduction of runoff in most of the drylands. Smaller amounts of rainfall together with increased evaporation at higher temperatures should compound the general water shortage and thus the desertification hazard. In addition, problems of water quality should rise.

Hoff (2001) proposes that changes of surface runoff may be quite different from those of precipitation, as general warming will also increase evaporation. Thus, as calculated by Postel (1993, quoted by Hoff 2001) a warming by 1–2 °C combined with a decrease of precipitation by 10% could reduce surface runoff by as much as 40–70%. Increased rates of evapotranspiration will also affect infiltration and soil moisture, and thus the amount of plant-available soil water. In general it can be stated that the water budget of arid and semi-arid regions is particularly sensitive to variations of climate. There is thus a real danger of desertification processes being accelerated by climate change, which will be amplified by the potentially increased drought hazard.

…with regard to vegetation

The effects of climate change on the vegetation may mainly affect its metabolism, but also modify species composition and agriculture. Expressed in simple terms, in photosynthesis CO_2 and solar radiation are transformed into glucose and O_2. In this process CO_2 is assimilated through the stomata of the leaves. With a higher concentration of CO_2 in the atmosphere the stomata need not be opened as wide as before to take up the same amount of CO_2. This leads to a reduction of the plants’ transpiration. In times of water stress this would be an advantage, resulting in more efficient water use. As discussed by Osborne & Woodward (2002), this might partially balance the expected aridification. However, stomata reactions are largely site-specific and therefore can hardly be generalised. The reaction of vegetation to a CO_2 rise will be variable by season and from year to year, depending highly on the availability of soil water (Osborne & Woodward 2002). As the global pattern of vegetation (zones) is largely determined by climate, it has to be expected that climate change will also be reflected in vegetation patterns. Clausen & Cramer (2002) present some examples for the Holocene, such as the northward extension of tundra and taiga or the transformation of the Saharan deserts to savannas and subtropical grasslands about 11,000 years ago. They are explaining the feedback of vegetation change on climate modification. Plant communities will react to climatic change by succession; in turn, climate will be affected through changing plant-physiological processes, structural changes and the role of vegetation in the carbon cycle. In general, changes of the world's vegetation pattern, at constantly increasing emission rates of greenhouse gases, are thought to be quite likely (Clausen & Cramer 2001). Estimates of the effects of climate change on agricultural yields are mainly based on the spatially different development of temperatures and the availability of water. Hörmann & Chmielewski (2001) explain that cultivated plants, which in a certain region presently grow within an optimal temperature regime, may react with lower yields as soon as they loose their optimal thermal range. For drylands the availability of water is of utmost importance, being the main limiting factor for plant production. Of course also CO_2-fertilising effects, plant diseases or changes of the vegetation period will have additional effects. Their interaction and importance will eventually determine the agricultural productivity of a particular region. At the global scale, Hörmann & Chmielewski (2001) do not predict any major changes of yield. For higher latitudes yield increases are thought to be likely, whereas for the arid and semi-arid regions a negative trend with an increasing risk of famines is expected. The poleward increase of arable land due to higher temperatures will probably be balanced by losses in the subtropics and the increasing area of dry steppe and desert. This would certainly intensify the pressure on remaining arable lands in regions already prone to desertification. Desertification would thus be accelerated by climate change.

Conclusion

Desertification starts with degradation of vegetation and soils, with negative effects on the water budget, eventually leading to the development of desert-like landscapes. In turn, inappropriate land use triggering the desertification process is the result of political and socio-economic constraints. Among the effects of climate change on drylands it is primarily the effect of increasingly frequent and intense heat waves and droughts that will most likely accelerate desertification. More frequent and intensive heavy rainfall will advance degradation processes, in particular soil erosion, especially in subtropical regions like the Mediterranean. The effects of global warming on plant metabolism are difficult to assess, but it seems to be likely that the fertilising effect of higher atmospheric CO_2 and more efficient plant water use might have a positive effect. Increasing rates of evapotranspiration at reduced surface runoff will have a negative effect both on the amount and quality of available water. In concert with potentially decreasing crop yields this could have a negative effect on socio-economic conditions, which would be counter-productive to sustainable land-use and would thus shift the balance towards desertification.

Pilardeau & Schulz-Baldes (2001) have drawn attention to political aspects. If it can be supposed that the contribution of climate change to desertification is just as important as inappropriate land use in the affected regions, this would imply that the industrial nations, being the prime causers of global warming, would be directly responsible for desertification processes in affected countries. Therefore, it has to be asked whether the growth of deserts in response to the anthropogenic part of the greenhouse effect should still be called »desertification« in its traditional sense, as mankind does not directly interfere with the landscape balance of vulnerable drylands, but indirectly via its affection on the world's climate, thereby starting a quasi-natural process. Thus, it has also to be asked whether desertification inevitably depends on the direct interference of humans in those regions where it presently occurs. The significance of climate change for desertification is very difficult to assess. This uncertainty is well expressed by Seuffert (2001). He states that without effective countermeasures, desertification due to global warming is likely to increase and to affect increasingly large areas. But according to him, there is also hope that in response to regionally varying effects of climate change and accentuations even large tracts of land will experience the opposite development, i. e. leading to an improvement of their ecological as well as economic potential. The IPCC (2001), however, is convinced that with increasing climate change the negative effects will prevail. Referring to their interpretation, it has to be supposed that, although there are regions likely to benefit from global warming, there will be other regions which will suffer severely on accelerated desertification. As regions which are already subject to extreme climatic conditions, such as most of the present drylands, are regarded as being particularly sensitive to »environmental change«, their ecosystems might thus be the first ones to suffer from the expected change of the global climate♦