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# The Interplay between International and Local Processes affecting Desertification

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## ABSTRACT

There are few direct linkages between the biophyscial and socioeconomic drivers of desertification at the international scale, but desertification clearly has many international dimensions. International agreements, insitutions, and socioeconomic processes all frame the problem, and some large-scale biophysical processes such as climate, soil, and hydrological patterns set essential boundary conditions. At this scale, the critical importance of cross-scalar interactions among biophysical and social factors becomes particularly apparent. These extend to multiple levels of episodic events in the climate, market, political, and other spheres. Case studies, such as that of the long-term support and recent removal of winter fodder schemes in Kazakhstan, suggest that episodic events in the socioeconomic domain tend to arise from scales that extend beyond the region in which desertification may result, while the biophyscial episodes tend to be more local or subnational. This has important implications for targeting mitigation and adaptation strategies at appropriate levels for differents triggers. The syndrome approach is one of the possible ways to focus attention formally and comprehensively on the key socioeconomic and biophysical variables and processes that characterize the various archetypal forms which regional desertification takes. Using such analyses to identify the critical indicators of different desertification syndromes formally would move the international community a step closer to being able to quantify desertification across regions in more operationally targeted ways.

## INTRODUCTION

This Dahlem Workshop was organized around a hierarchy of scale, from the household to the international level, and from the local to the global scale (Figure 20.1). Desertification primarily impacts land at the local scale and alters the productivity patterns that provide the goods and services that humans derive from the land (Sala and Paruelo 1997). The impacts of desertification (as for most other global changes in the environment, with the exception of

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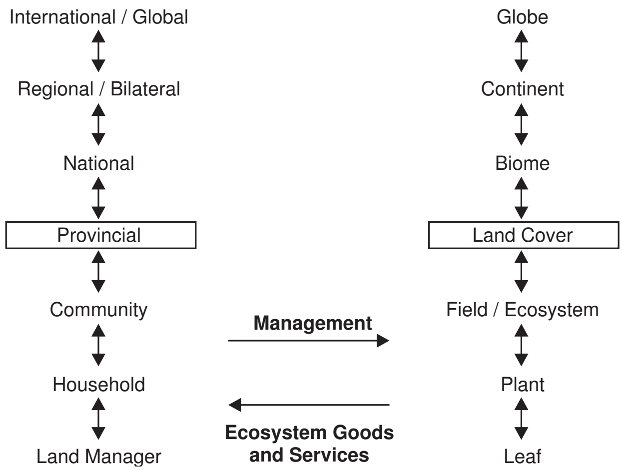


**Figure 20.1** Levels of interactions between biophysical and social factors of desertification. The biogeophysical processes that occur at the scales indicated in the righthand arm of the figure include climatology, vegetation production, species diversity, soil erosion, and soil chemistry. At the larger scales, the emphasis is on the global atmospheric circulation and its anomalies, large-scale aerosol from wind erosion, and reduced carbon sequestration in the vegetation and soil. At the finer scales, local plant production, soil erosion, and rainfall are relevant. At the scale that desertification occurs, the mesoscale climate, landscape to provincial crop and animal forage production, unpalatable and exotic plant invasion, sediment loads of rivers and dust storms need to be considered. The lefthand arm of the figure represents the socioeconomic factors of desertification. The locus of decision making is at the household/community level — balancing survival against resources and markets. Links to the national level are mediated by trade and development. Regional or global impacts mainly take place via multinational companies, generally responding to international markets and international insitutions.

climate change) only become globally significant through cumulative effects. We recognize that all levels shown in Figure 20.1 are important. This does not mean, however, that there are equally strong linkages between these levels. In fact, for the desertification issue, most of the relevant interactions between socioeconomic and biophysical systems occur at the lower level (Provincial/Land Cover, Figure 20.1) (see Prince 2002). Figure 20.1 shows that relationships up and down the human and biophysical sides are hierarchical and that interactions relevant for desertification mainly take place at the provincial level. It is at this level that major links occur in the form of an ecosystem's capacity to provide goods and services, and that human efforts to manage, improve, and sustain that capacity take place. Definitions of desertification and concrete measurements should also focus on the levels where interactions occur, thus simplifying the vast complexity involved in environment–human relations. Describing linkages between the socioeconomic and biophysical drivers at the international level was therefore inappropriate for this group, working as it was without considering the finer-scale drivers.

International agreements, institutions, and socioeconomic processes are important in framing the desertification problem. Moreover, large-scale biophysical processes such as climate, soil, and hydrological patterns define important boundary conditions for the functioning of local and regional land-use systems in drylands. In this report, we discuss the interactions between desertification and international factors, such as international conventions, trade, and climate. Through an example from Central Asia, we illustrate the interplay between different processes acting at different temporal scales and originating from different geographic levels. This complexity makes the analysis of the causes of rangeland modifications difficult. We then discuss a conceptual model that attempts to express the multiple dimensions in an integrated way. Finally, we identify research priorities for, and major gaps in, assessing the international dimensions of desertification.

## DESERTIFICATION: AN INTERNATIONAL ISSUE

Environmental issues may be recognized as being international when (a) they are truly global since they affect everyone, which is the case when common property resources are involved (e.g., climate change and ozone depletion); (b) they need international recognition for funding, technology transfer, and capacity-building (e.g., desertification); (c) the international community perceives it as being important, but the resource being degraded relates to national sovereignty concerns (e.g., vegetation and water resources).

Desertification is a global problem due to its extent and the nature of some factors responsible for its causation and its impact. It is linked to issues of drought and famine, climate change (via surface–atmosphere feedbacks and impacts on carbon sequestration), loss of biodiversity, loss of secondary production (e.g., livestock products), markets, human outmigration and refugee problems following environmental disasters and conflicts, public perception via the media, etc. If it is true that desertification is affected by and also affects global-level factors, then international institutions (including organizations within the United Nations' system and nongovernmental organizations [NGOs]) can be instrumental in promoting and funding policies aimed at combating desertification, setting political agendas, and building consensus. International institutions are thus major players in combating desertification.

International-level factors contributing to desertification tend to act at a slow pace and are not always easy to detect (e.g., feedback of land-surface changes on climate, growing public concern for the environment). It is particularly difficult to link a specific driver, such as a change in international markets, to a specific locality, where the effects of the change would most probably be felt (e.g., increased rates of land degradation or a reduced capacity to cope with environmental perturbations). The hidden character of the international dimensions of desertification stems from the complex causal chains leading to the process, the synergy between drivers, and the role of the nation-state as a mediator between international forces and local-scale processes.

The list of potential international-scale drivers of desertification is long and includes the environment (water, climate), technological change (e.g., demographic impact of vaccines or funding for family control programes), finance and trade (investment regimes, e.g., multilateral finance mechanisms, the World Trade Organization (WTO), and private trade through multinational corporations), and governance (legal systems; power relations; civil society; security, war; and organizations, e.g., UN/multilateral, bilateral, national/local, NGOs). The characteristics of international linkages influencing desertification include physical exchanges, economic relations, information and knowledge as well as global commons regulation and enforcement, and private enterprise. For each potential driver, one needs to identify the mechanisms that could lead to an increase or decrease of desertification under certain circumstances, as well as the empirical evidence that documents the cases. There is also a need to understand the hierarchies and linkages between these international-scale drivers. Three examples of interactions between desertification and international factors are discussed in the next section.

## INTERNATIONAL FACTORS INTERACTING WITH DESERTIFICATION

### Impact of International Institutions on Desertification

Can we measure the impacts of international conventions and organizations on drylands? It is possible to argue that international organizations or institutions do not have much to do with the actual local-scale management of arid land systems, but that they do have a lot to do with the process of getting the subject and issues addressed. An inventory of the institutions involved and money spent by the World Bank and others for desertification-related programs does not provide an assessment of the impact of these programs on desertification. Although international conventions do not manage the land at the local scale, they do create constraints and incentives for management. Conventions are only effective if there is a strong commitment at the national level and from any international donors who may be involved. Their success also largely depends on good governance. Coordination and effectiveness in the use of funds dedicated to the fight against desertification by the governments of nation-states leads to tangible results on the ground. However, it must be admitted that numerous projects in the past failed because they were based on scientific misconceptions about both rangeland ecology and local (including traditional) institutions. On the other hand, some projects have indeed brought benefits to the countries involved.

One can argue about the usefulness of the United Nations Convention to Combat Desertification (UNCCD 1994) (see Chasek and Corell 2002). However, since its adoption, the UNCCD has triggered several other international institutions to review their own activities related to combating desertification, to ensure that they are aligned to support the goals and objectives of the UNCCD. The UNCCD has also had the effect or function of justifying projects at the national (see Mtimet et al. 2002) or community scales and has galvanized funding for these projects. Moreover, international organizations have played a major role in the gathering and disseminating of valuable information about desertification, including data, satellite imagery, and maps. Note that an overall evaluation of the impact on desertification of multilateral and bilateral aid programs aimed at social and economic development in dryland regions has not yet taken place. Many of these programs affect the human–environment system and can either enhance or impede parallel efforts to combat desertification.

It is difficult to assess the impact of the UNCCD on the actual state of desertification in different countries given the short period of time since its inception, large climate-driven interannual fluctuations in conditions, and the absence of appropriate metrics to compare the current situation with the situation that would have prevailed without the UNCCD. The last point shows the difficulty inherent in monitoring implementation compliance in the case of desertification. Some questions to be raised in this context include: What is the relative importance of desertification to the agency's mandate and goals? Who holds the funds? How are the funds generated and invested? Is it required to link desertification with issues from different international domains to reduce desertification, for example, with climate change, multilateral environmental agreements, WTO and trade, poverty and international development targets? At what level of decision making do the international actors operate?

Parties of international treaties such as the UNCCD are sovereign states. Representatives from these states are responsible for negotiating the text of the treaty and for determining its operationalization, implementation, and future direction. As a result, the UNCCD, like any treaty, is only as strong or effective as the states party to the treaty want it to be. The relative weakness of many environmental treaties comes from the fact that countries are usually represented by their Ministries of Foreign Affairs at meetings of the treaty bodies (i.e., Conference of the Parties). In many countries, environmental issues are not priorities for their Ministry of Foreign Affairs. As a result, these issues tend to be marginalized. Until environmental issues (including desertification) are mainstreamed within national Ministries of Foreign Affairs, they are unlikely to receive the attention they need or deserve. Similarly, treaties can only be implemented as much as parties are willing to and capable of implementing them at the national and local levels. Finally, one should note a major difference between the UNCCD and the United Nations Framework Convention on Climate Change (UNFCCC 1992) in the use of scientific information. Both conventions have ad-hoc scientific bodies that provide direct advice on matters immediately relevant to the negotiations. The bodies use expert meetings and external consultancies, in a highly politicized advisory process. While the UNFCCC is based on indisputable scientific evidence, quantitative and reliable data are crucially missing for the UNCCD. This stems from the lack of a clear, operational definition of desertification (Reynolds and Stafford Smith 2002), the difficulty of quantifying desertification (Prince 2002), and the diversity of human–environment interactions worldwide.

## Impact of Trade on Desertification

Macroeconomic policies, such as structural adjustment programs, have an impact on the environment. In fact, through trade liberalization, countries with planned economies experience major changes in prices and therefore in the management goals of resource managers. In some cases, this may lead to an overuse of resources and a disregard for environmental impacts (Harou 2002). These environmental effects are particularly important in countries with fragile semi-arid lands. Trade liberalization involves the removal of quotas, subsidies, and taxation on imports, and leads to an economic specialization on a few activities. In developing countries, exports tend to be dominated by primary products, which need to be managed properly in order to avoid negative environmental impacts. Economic policies generally make the choices that are right for the economy, and only afterward consider measures to mitigate the environmental impacts. Other macroeconomic factors that have an impact on the environment include debt, food aid, and development assistance.

International trade can also improve environmental conditions through increase in connectedness, green certification and eco-labeling, improved communication infrastructure, wider and more rapid spread of technologies, better media coverage allowing international pressures on states which degrade their resources, etc. Opportunities for economic diversification toward environmentally friendly activities that do not degrade the environment are also opening, such as ecotourism and high-value products for foreign market export.

International courts of justice are also concerned with sustainable development and have already referred to the precautionary principle in their rulings (Sands 2002).

Trade-related measures, including sanctions implemented by national governments to protect the environment, can be useful for managing domestic consumption and catalyzing international action in the absence of appropriate binding international environmental standards. However, with the expansion of trade policy coverage and enforcement within the WTO context, there has been a series of cases in which trade rules have been used to challenge efforts of governments and civil society to address environmental, health, and safety problems. WTO rules must recognize the value of unilateral trade measures under clearly defined conditions that acknowledge equity concerns and other concerns of developing countries (Center for International Environmental Law and Greenpeace International 1999).

Another area of concern is the relationship between multilateral environmental agreements (MEAs) and the WTO (Sampson 2000). When negotiating MEAs, WTO members are free to forgo their WTO rights and ratify the use of trade restrictions to enforce environmental standards. Problems can arise, however, when the memberships of the WTO and of MEAs are not identical. In these cases, a trade-related measure implemented under an MEA could violate WTO obligations. Under which of the two bodies of law would the conflict be resolved? More broadly, the objectives of MEAs and the WTO may not always be mutually supportive. Some argue that the potential for conflict between MEAs and the WTO has been overstated, since few MEAs authorize trade restrictions and no trade dispute has arisen to date over an enforcement measure imposed under an MEA. However others, noting the growing commercial and political importance of MEAs, assert that appropriate measures should be put in place before conflict between the environmental and trade law regimes occurs.

### Large-scale Climatic Effects of Desertification

Climate and land surface can be viewed as a system with multiple, quasi-stable states (Prince 2002; Leemans and Kleidon 2002). In a region dominated by natural vegetation, the impact of human land use on land–surface functions (e.g., evapotranspiration) will be local, possibly affecting the microclimatic conditions only where the land-cover change occurred. With increased extent and/or intensification of land use, these small-scale effects will add up, potentially affecting the larger-scale climate system. At the extreme, where large areas are transformed by land use, experiments with numerical simulation models have shown that such large-scale changes can result in reduced precipitation, increased surface temperature, low soil moisture, and changed runoff (e.g., Xue and Fennessy 2002). Through the atmospheric circulation interactions, the effects could extend beyond the areas where the desertification originally occurred. Furthermore, these simulated climate changes are consistent with the observed decadal climate anomalies (Zheng and Eltahir 1997). Note however that, due to uncertainties in model simulations, further model development and intercomparisons of model results are necessary (see Nicholson 2002).

The climate/vegetation status relation can be visualized as two dimensions, with the extent/intensity of human land use forming one dimension and biogeophysical variables leading to reduced goods and services forming the other dimension. Figure 20.2 illustrates the linkage of the human and biogeophysical dimensions (see Fernandez et al. 2002). Some

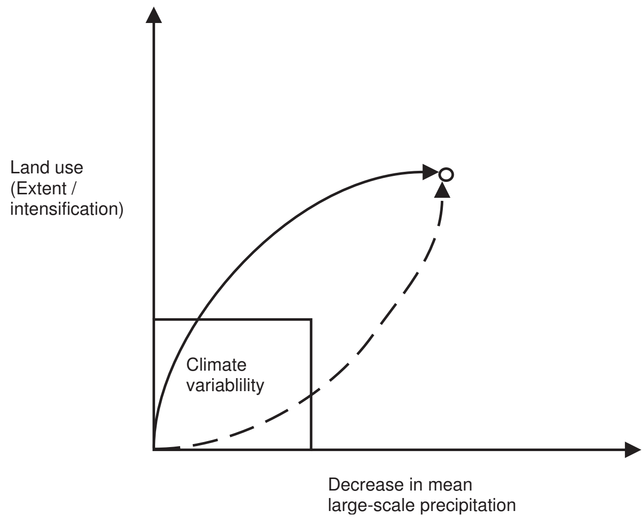


**Figure 20.2** Potential desertification trajectory in the land use versus precipitation space. The solid line indicates mainly unsustainable land use and the dashed line mainly reduced natural potential for production (e.g., NPP). The circle is desertified land. The lower left box indicates natural variability in nondesertified land. Whenever the trajectory leaves the lower left box as a result of inappropriate land use (solid line), it inevitably affects the biogeophysical system and leads to the desertified state. Similarly reduced natural productive potential, caused perhaps by drought, leads to extensification of land use and possibly unsustainable practices that also lead to the desertified state (cf. Figure 17.4, Fernandez et al. 2002).

studies have shown that there can be multiple states of the atmosphere–biosphere system for the Sahel region (Claussen 1998; Wang and Eltahir 2000).

Desertification can be caused either by drought or by an inappropriate intensity or type of land use, or both, although it should be noticed that the terms "drought" and "inappropriate land use" will often not mean the same thing for all susceptible lands. Hence desertification may be set in motion either with a change in land use or with a change in rainfall, but not necessarily both. If rainfall is reduced but adjustments in land use are not made or, conversely, if a change toward more intensive land use is made with no change in rainfall, the biogeophysical system may be perturbed sufficiently to start the changes that lead to irreversible or very slowly reversible change, which we call desertification (Fernandez et al. 2002).

## IMPACT OF EPISODIC EVENTS ON DESERTIFICATION

In most regions susceptible to desertification, one finds a combination of different temporal patterns of change: interannual variability due to biophysical factors (e.g., aperiodic fluctuations in rainfall); linear incremental and slow processes (e.g., human or livestock population growth); and episodic events with, sometimes, catastrophic impacts (e.g., civil war, currency devaluation, new policies, severe drought). Our next example of cold temperate rangelands in Central Asia illustrates the interplay between these three patterns of change and their impact on rangelands.

## Rangelands Degradation and Regeneration in Central Asia

The arid and semi-arid regions fall into warm and cold temperature regimes, with a transitional zone (see Nicholson 2002; Leemans and Kleidon 2002; Ellis et al. 2002). In the warm regions, short-term variations in net primary production (NPP) are mainly a function of seasonal and interannual rainfall variability. In the cold temperature regions, there is less interannual variation in rainfall, but an additional impact on NPP of cold temperatures, causing plant productivity to cease over winter. Seasonal plant dormancy due to lower precipitation or cold temperatures is the principal limit to herbivore populations. Episodic climatic fluctuations in snow depth and cold temperatures have a further effect on livestock populations, as animals are unable to forage. This is a similar effect to drought in precipitation-limited rangelands.

The natural checks on livestock populations resulting from these regular as well as irregular climatic patterns reduce grazing pressure. When livestock is decoupled from the impacts of climate through human interventions such as winter feeding, livestock populations can and do rise. Supplementary feed effectively buffers livestock from the winter feed deficits. This occurred in the Soviet Union rangelands of Central Asia (Kerven 2002). By overcoming the climatic checks to grazing resources, an increased number of livestock surviving the cold winter can overexploit the vegetation resources during spring, summer, and autumn. This can lead to loss of NPP and degradation, as has been widely reported in the former Soviet Union and in China.

When livestock populations are no longer supported by supplementary winter feed, population crashes reoccur, as recently happened in Kazakhstan, for example, largely due to the removal of state subsidies on feed (Kerven 2002). These livestock population crashes release grazing pressure and thus reverse desertification trends by raising NPP. But the cost has been massive loss of human livelihoods, leading to impoverishment and outmigration from the livestock-producing areas. Both the rising livestock population in the Soviet period and the crash in the post–Soviet period — with attendant impacts on degradation and regeneration — have resulted from the interactions between policy and economic processes within a cold temperature climatic regime.

In this example, rangeland modifications were driven by the interplay between processes of a different nature (climatic fluctuations, policies, and geopolitical factors), acting at different temporal scales (interannual variations, decadal-scale trends, and episodic events) and originating from different geographical levels (ecosystem, national, and international levels). Do episodic events always originate at the higher levels? For socioeconomic factors, it may often be the case (e.g., abrupt changes in prices on the international market, new international conventions, trade sanctions, changes in political regimes), even though there are exceptions (e.g., local conflicts). By contrast, episodic events that are biophysical in nature are more likely to be local or subnational (e.g., natural hazards).

## Buffering and Dependency

Interventions on an international and/or national scale provide buffering capacity against extreme events by providing external resources in times of crises (e.g., food aid, price stabilization schemes, etc.). For example, food aid during droughts buffers the population and helps to maintain local productive systems. A number of international organizations, including the

World Food Programme, and NGOs, such as Oxfam, have been providing food assistance to developing countries suffering from drought-induced famine for decades. The biggest challenge is knowing when assistance should cease or be reduced. When buffering provides more food than the natural environment can provide in the medium term, the food aid has the potential to result in overexploitation of the land rather than in buffering. Food aid can also create dependency, placing the population at risk of arbitrary, or unanticipated removal of the intervention. Both international organizations and NGOs need to know where to draw the line before a good buffer becomes a bad one. This cannot be done at the national scale, but rather must be dealt with on a case-by-case basis, possibly at the provincial scale.

Another example is provided by the Soviet system of winter feed in cold deserts, which was production-oriented and thus removed the natural regulation of livestock numbers. In less-developed nations, buffering has rarely reached the level of creating dependency. Dependency on crop production also occurs when fertilizers are subsidized, creating an expectation of yields that cannot be sustained in the absence of the cheap fertilizers. In this situation, farmers may bring marginal land into cultivation leading to desertification.

Mobility provides an internal mechanism to create buffering capacity. In regions in which transnational transhumance has been prohibited, or where a policy of sedentarization has been adopted (either forcibly or by a provision of water wells and other desirable services), movement to follow the spatially variable vegetation and hence fodder has been inhibited. This leads to increased vulnerability and, in some cases, to impoverishment and overutilization of land resources.

### Intercountry Differences

Large differences in the interplay of driving forces that lead to desertification exist between countries. For example, Zimbabwe and South Africa have a system of land tenure that has forced overpopulation in "communal lands." Botswana has a small proportion of large commercial land holdings and a much lower population, hence some of the effects of inequitable land tenure on desertification have been averted; however different problems, such as significantly lower rainfall and overutilization around water points, have serious effects. The cold desert situation during the Soviet era (e.g., in Kazakhstan and Mongolia) discussed above, in which winter feed was supplied to prevent winter losses of livestock, resulted in desertification because the livestock populations rose far above the carrying capacity during the summer period when supplemental feed was not supplied, and mobility of livestock was also curtailed.

## INTEGRATED FRAMEWORK TO MODEL INTERNATIONAL INFLUENCES ON DESERTIFICATION

Several conceptual models of desertification that are relevant to the international scale have been described (e.g., Prince 2002; Reynolds 2001; Oldeman et al. 1990). Also, each working group of this Dahlem Workshop (Fernandez et al. 2002; Robbins et al. 2002; Batterbury et al. 2002) developed conceptual schemes of desertification that emphasize various scales. But, so far, no comprehensive framework for the systematic understanding of cause-effect relationships underlying desertification at multiple scales exist. Several approaches however, which deal in general with global environmental change, provide guidelines for the development of a framework to address desertification.

An example for such an assessment is the "Pilot Analysis of Global Ecosystems" (PAGE), organized by the World Resources Institute (WRI 2000). Here five global ecosystem complexes (agro, coast, forest, freshwater, grasslands) were assessed with respect to their present ability and trend to provide eight ecosystem services (food and fiber production, water quality, water quantity, biodiversity, carbon storage, recreation, shoreline protection, and woodfuel production). The integrating concept of "ecosystem services" allows the analysts to consider the complex interrelations in the natural sphere. This is a significant step forward compared to previous studies assessing, for example, agricultural ecosystems mainly with respect to their "dominant" function, i.e., the supply of food and fiber. However, PAGE provides only marginal information on the underlying causes of ecosystem degradation.

Other approaches provide a classification of the different situations in which environmental degradation occurs. Subsuming a particular case (e.g., the present situation and the history in a specified region) under one of these classes should allow for a restricted prognosis of the possible future development, which is the prerequisite for mitigation or adaptation. One example for such a framework was developed by Kasperson et al. (1995) in their study "Regions at Risk." Here several case studies of regions under environmental degradation were described qualitatively by their histories until present ("qualitative trajectories"). These were mapped in terms of qualitative development of two highly aggregated variables: the wealth of the inhabitants and the state of the environment. Different typical time courses of these variables could be identified and interpreted with respect to more or less problematic future developments of the regions.

Below, we discuss a recent concept and methodology for understanding global desertification in an integrated way, based on a qualitative analysis of regional to global-scale data and using a greater number of political, socioeconomic, and environmental variables (including global drivers such as international trade, international agreements and institutions, and climate change). These conceptual models are useful as graphical means to communicate the various aspects of desertification, its causes, and implications.

## The Syndrome Approach

The syndrome approach contributes to the design of conceptual models through a formal taxonomy of environmental degradation types and their components. The basic idea of the syndrome concept is to describe archetypical, dynamic, coevolutionary patterns of civilization–nature interactions (Petschel-Held, Block et al. 1999, p. 296). This taxonomy links processes of degradation to state variables (both changes over time and status). The approach is applied at the intermediate functional scales that reflect processes taking place from the household level up to the international level. The scale depends on the syndrome. Syndromes can be successional types, can act alone or in synergies, with feedback between them. The typology of syndromes reflects expert opinion based on local case examples. The syndrome approach aims at a high level of generality in the description of mechanisms of environmental degradation.

Desertification is a characteristic of several syndromes operating on their own, reflecting the internal dynamics of places, resources, economies, and populations. This is most notable for the following syndromes (Lüdeke et al. 1999; Cassel-Gintz and Petschel-Held 2000; WBGU 2000; Downing and Lüdeke 2002):

- Sahel: overcultivation of marginal land, overgrazing, fuelwood extraction/deforestation; smallholder and pastoralists, subsistence orientation, rural exodus/circulatory migration;
- Overexploitation: deforestation, commercial orientation, large scale;
- Dust Bowl: mechanized, industrialized agriculture, maximum yields;
- Aral Sea: centrally planned, large project failures, hydrosphere, irrigation schemes.

The syndrome concept is related to the conceptual framework as defined by Working Group 1 (Fernandez et al. 2002). Here the state space of the system is characterized by socioeconomic and natural variables. In this space different regions are defined with respect to reversibility and acceptability. While the conceptual framework proposed by Fernandez et al. (2002) classifies trajectories of the system, the syndrome concept typifies the mechanisms leading to these trajectories. Desertification is a "multi-syndrome syndrome" so, globally, desertification risk would be an interpretation of several syndromes (Petschel-Held, Lüdecke et al. 1999).

With the syndrome model, it should be possible to investigate the relative importance of the main international components of the dominant syndromes that relate to desertification (Table 20.1). Criteria would be: strength of linkage (direct or indirect), direction of the impact (e.g., always negative, indeterminate, or always positive) and regional importance — to generalize and compare between processes that may be unique to one region (in which case the syndrome might be divided into separate subsyndromes). Open questions are: How can the syndrome concept be used to identify when the system reaches a threshold beyond which

**Table 20.1** The syndrome concept uses a set of about 80 variables, grouped into 9 spheres. The table lists a few example of important variables (direct or indirect drivers or consequences of desertification) which are related to the desertification syndromes. For the full list of 80 variables, see WBGU (1999).

| Sphere | Example of Variables |
|---|---|
| Biosphere | Productivity, changes in functional types, standing biomass, conversion of ecosystems, introduction of alien species, loss of biodiversity, … |
| Atmosphere | Regional climate change, enhanced greenhouse effect, … |
| Hydrosphere | Terrestrial run-off changes, shift of oceanic currents, … |
| Population | Migration, fertility, mortality, damage to health, … |
| Pedosphere | Erosion, capping, fertility, bulk density, … |
| Economy | International indebtedness, increasing world trade, globalization of markets, increasing tourism, … |
| Psychosocial Sphere | Spreading Western lifestyle, consumption patterns, … |
| Social Organization | Increasing international social and economic disparities, increasing ethnic and national conflicts, democratization, increasing international agreements and institutions |

desertification will indeed become a major problem? How do syndromes represent the interplay between global and local driving forces?

## MEASURING GLOBAL DESERTIFICATION

No techniques exist that can measure desertification on a global scale directly and objectively. This is because of the ambiguities and complexity of the phenomenon (Reynolds and Stafford Smith 2002). A map based on expert opinion exists (Oldeman et al. 1990) but this is not suitable for monitoring. Current research is exploring the use of global satellite observations and meteorological data to measure processes closely related to the human–biogeophysical interaction that is at the heart of desertification. These include erosion (see Batterbury et al. 2002) and reductions in net primary production (see Prince 2002). The absence of a clear definition of desertification, and the inclusion of both biogeophysical and human dimensions and reversibility owing to rehabilitation efforts, make it a phenomenon that is difficult to measure globally. Moreover, many unrelated environmental and development issues have been attached to the concept, making it an unworkable concept. Appropriate indicators of desertification would relate to the intersection between biophysical and socioeconomic aspects of the use of rangelands at the landscape and community scales. An operational monitoring system should make quantitative measurements of facets of human–environment conditions. These indicators should represent the particular desertification syndrome taking place, and any diagnostic should be based on a convergence of evidence between different indicators.

One of the major successes of international institutions dealing with desertification has been the production and free distribution of global-scale data sets, which are necessary to monitor desertification (e.g., maps, statistics, remote sensing data). There is still an urgent need to provide easy access to national meteorological data. There are convincing cases where these data sets have had an influence on resource management at the national scale. For example, farmers who use climate forecasts have improved their crop yields (Hammer et al. 2000). The lack of a communication infrastructure, however, often leads to the poor dissemination of the relevant information to farmers and not all information is relevant for all levels. Moreover, depending on the resources they manage, not all land managers are receptive to a certain type of environmental information, perhaps when there is no window of opportunity to apply the new information.

International organizations should focus more on the production of globally consistent data sets, which can yield information on the status and consequences of desertification, and on the diffusion of this information. For these data sets and models to gain wide acceptance, they need both strong institutional support and positive validation at the national scale (Prince 2002).

## FUTURE RESEARCH PRIORITIES

Major research questions are: What are the international factors that impact country- and landscape-scale land use, and how do they operate? What are the feedbacks from the local to global scales? While there is general agreement that many international or global factors can be considered drivers of desertification, there is no agreement on how much of an impact these factors have. Resolving these questions poses two related difficulties: disentangling and measuring. Global-scale factors of a diverse nature are interconnected (i.e., the world economy, trade, debt, the role of the World Bank, the International Monetary Fund, and the UNCCD), and they interact with lower-level factors. One area for future research would be to design a methodology to measure these impacts. How can one identify the influence of a specific factor given this complex causality pattern? Is it possible to separate and quantify the relative importance of a given factor, e.g., through natural experiments? The problem is compounded by the fact that different factors act with different time frequencies and time lags. However, improved data sets and monitoring systems for biological and social systems (at the international scale, with greater reliability and better standardization) would be of great value in providing the metrics required for a better understanding of the driving forces of desertification.

Another series of future research questions revolves around the level at which desertification is addressed politically. Traditionally, one of the problems faced is that too many programs to combat desertification have been generated from the top down. While the UNCCD has tried to instill a more participatory approach in the formulation of National Action Plans, many national governments are reluctant to allow NGOs, community-based organizations, and individual stakeholders to participate. When examining policies that have originated at the national or international level (donor-driven or international organization-driven), we need to ask: what has gone wrong or right in translating a national or international policy into an implementation at the local or community level? What is the impact of top-down decision making from the international organization level or even the national level on drylands and on the people who live there? What are the costs and benefits? What are the appropriate levels of intervention?

## CONCLUSION

Desertification can be conceptualized as a cluster of processes that have coherence at the provincial and national scales. Interactions and feedbacks between the biophysical and social systems mainly take place at the lower, but not lowest, levels of the hierarchy, while local–global interplays tend to be restricted within the biophysical and social systems. Each variable and level impacts drylands at different time scales, making the analysis of interactions particularly difficult. This difficulty is compounded by the lack of a clear definition of desertification and the lack of appropriate data that capture the different facets of the problems at the proper scale.

The strongest links from the international level to (local) desertification are through: (a) scientific measurements and description of desertification, which require international cooperation for data collection and scientific analyses; (b) ameliorative impacts via agencies and development projects at the local or national scale (e.g., water management); and (c) regulating measures such as international conventions, which enforce and control actions that influence desertification. Equally, some local desertification processes have strong international and global linkages.

To strengthen the role of science in desertification policy, a better understanding and quantification of the relative impacts of international factors (including interventions driven by international organizations) on desertification is required. Better communication between policymakers and scientists should be promoted for this purpose.

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