DO HUMANS CAUSE DESERTS? AN OLD PROBLEM THROUGH THE LENS OF A NEW FRAMEWORK: THE DAHLEM DESERTIFICATION PARADIGM

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ABSTRACT

Desertification is a term associated with land degradation in drylands, and is presumed to result in a reduction in the biological and, hence, economic potential of the land to support human populations, livestock, and wild herbivores. However, others vigorously contest such an interpretation and the debate goes on. What exactly is desertification? Are 17 % or 70 % of global drylands 'desertified'? There is an urgent need to lessen uncertainties that paralyze action, and for new thinking beyond regional and disciplinary concerns. Towards this end, we present the Dahlem Desertification Paradigm (DDP), a new, interdisciplinary framework for tackling the complex issues of desertification developed at the 88th Dahlem workshop, *An Integrated Assessment of the Ecological, Meteorological and Human Dimensions of Global Desertification*.

At the core of the DDP is the recognition that desertification cannot be framed in terms of single measures alone but must simultaneously involve both *biophysical* and *socio-economic* factors. These factors, together with their implications for action, are determinable because a limited number of 'slow' variables determine the dynamics of linked biophysical/socio-economic systems at different scales. The DDP observes how important it is to keep the evolution of each subsystem in balance with that of others through the development of appropriate local environmental knowledge, and cuts through confusion using a well-structured approach that relates defined types of 'degradation' at finer scales to the emergent concept of 'desertification' at broader scales. The DDP framework has implications for research, monitoring, community development programs and policy.

1. INTRODUCTION

"*Drought and desertification threaten the livelihood of over 1 billion people in more than 110 countries around the world*."
Kofi Annan (as quoted on the UN Convention to Combat Desertification web page: http://www.unccd.int/main.php)

Desertification, which is intimately linked to global environmental change through climate, biodiversity loss, human dimensions, and land change, is viewed by many as one of the most critically important issues facing many countries. However, desertification is also a highly contentious issue usually evoking strong disagreement and controversy. In many areas, natural vegetation has clearly been eliminated or severely reduced through cultivation, overgrazing, and fuel gathering, and soils are eroding at accelerated rates. Many perceive that the capacity of these lands to support human populations, livestock, and wild herbivores has thereby been substantially reduced (i.e., *desertified*). Others (e.g., Leach and Mearns 1996), however, vigorously contest this interpretation. The problem is twofold: *first*, desertification is often triggered or exacerbated by climate variability, mainly drought, so that the causes are not necessarily anthropogenic (at least locally); and *second*, not all such observed changes directly affect human welfare.

In spite of substantial international efforts to tackle this problem over the past 30 years, there are still substantial uncertainties and misconceptions. To illustrate this controversy, we present a simple example. Consider a visit to a large ranch where herds of cattle are grazing in open rangeland and a large number of erosion gullies are evident across the landscape. It is tempting to deduce that these gullies are due to overgrazing by cattle, which removes the protective vegetative cover, leading to soil erosion and lost beef productivity.

As logical as this may seem—and as true as it may be in some instances—alternative views are possible: (i) some erosion gullies are the result of *natural phenomena* (wind and water); (ii) in some landscapes a modest number of gullies, whether natural or induced by overgrazing, may have *no effect* on things that humans primarily value (i.e. secondary productivity of cattle in this case); (iii) although the erosion gullies may not cause a loss of meat production on this ranch *per se*, they may well be creating major salinity problems and production losses *downstream* from the ranch; and (iv) even if the gullies are the direct result of overgrazing, it is debatable whether the *root cause* is over-stocking by the local ranch manager, a fault of the land tenure system or broader institutional/political problems, or largely natural processes related to regional or global changes (or indeed any combination of these). Obviously, different segments of society will see this 'problem' with differing degrees of concern and interest. An ecologist might view the erosion gullies as an immediate breakdown in ecosystem function, e.g., the ability of the soil to retain water, nutrient cycling, long-term soil stability, forage production. However, as noted, such ecosystem 'breakdowns' will resonate with the rancher only if they have a demonstrable, local impact on animal performance.

The Convention to Combat Desertification (CCD) (http://www.unccd.int/main.php, United Nations 1994) defines land degradation in terms of a number of ecological factors, e.g., productivity and erosion. As noted above, *the problem is that humans are often concerned only with that subset of this broad definition that affects some human activity* (whether at the local land use level or through feedbacks at a wider scale). For example, farmers in many regions of the world are generally only prepared to accept that they may need to change their management if land degradation (i) is a direct consequence of their activities; and (ii) if it affects them (or other members of society). Of course, all opinions are affected by the scale and purpose of the interpretation. Consequently, there is disagreement concerning the causes and processes of land degradation and its importance; issues include the extent to which land changes are natural (climate-driven) vs. anthropogenic, the role of 'grass-roots' abatement efforts vs. scientific and technological ones, how to determine the amount of land affected or at risk, and whether or not desertification is reversible.

We think that the only way to resolve the tangle of issues, disagreements, and misinterpretations surrounding desertification is to come up with a new synthetic framework. In the absence of such a framework, the answer to most questions is: "It depends!" This leads to endless and relatively unproductive debates, which have been one of the legacies of desertification research, and which have resulted in negligible impacts on policy and on the programs intended to help people living in these lands. In this paper we provide a brief overview of a new synthetic framework for desertification.

2. THE DAHLEM DESERTIFICATION PARADIGM (DDP)

2.1 New Ideas for the "Old" Problem

In an effort to address this challenge, the GCTE (Global Change and Terrestrial Ecosystems) and LUCC (Land-Use and Cover Change) programs of the International Geosphere-Biosphere Programme joined forces on a new initiative on desertification. The intent was to bring together researchers representing various global change programs on natural and human-influenced systems to stimulate new ideas to bear on this 'old' problem. One of the first activities was to conduct a Dahlem Conference (http://www.fu-berlin.de/dahlem/), which was entitled "The Meteorological, Ecological, and Human Dimensions of Global Desertification." The key product of the meeting was the development of a new synthetic framework for global desertification, which we call the Dahlem Desertification Paradigm (DDP). As is the case for many paradigms, the constituent ideas themselves are generally not new, but bringing them together reveals a fresh view of an 'old' problem, providing a new depth of insight. The DDP focuses on the interrelationships within coupled human-environment systems that cause desertification. It draws heavily from the chapters of our Dahlem book, Global Desertification. Do Humans Cause Deserts? (2002), and considers non-linear processes, resilience, vulnerability, traditional range ecology, human perceptions, panarchy theory, social structures, economic factors, and so on.

2.2 The Dahlem Desertification Paradigm (DDP*)*

The DDP is composed of 9 assertions (Table 1). The first three relate to the working framework while the remaining focus on implementation, limitations, and potentials of the paradigm. Details are given in Stafford Smith and Reynolds (2002), and we provide a brief summary here.

2.2.1 Assertion 1: Desertification Always Involves Human and *Environmental Drivers*

At the core of the DDP is the unequivocal affirmation that desertification is a phenomenon that encompasses both biophysical and socio-economic dimensions (Reynolds 2001) - neither dimension can be universally regarded as the sole predisposing factor (Figure 1). For instance, the presence of erosion gullies *per se* in a rangeland does not necessarily constitute land degradation. Similarly, the presence of sedentary pastoralists, which is often used as a correlate of land degradation in grazing lands in northern China (Ellis *et al.* 2002), does not alone constitute land degradation.

Consequently, any effort to detect a 'decline' in the condition of some parcel of land by measuring soil fertility and grain production, with the intent of assigning 'risk' or designing an 'intervention' strategy, is meaningless unless one is also monitoring appropriate socio-economic factors such as household debt ratio, local land use goals, and labor issues.

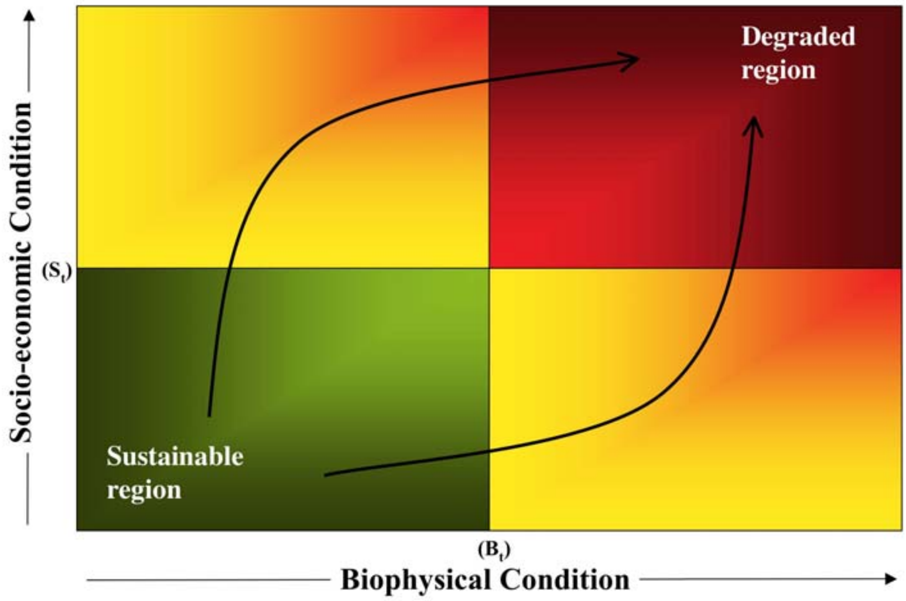

Figure 1. Conceptual representation of degradation framework. Desertification must simultaneously include *both* biophysical and socio-economic dimensions (x and y-axes respectively here). The various states of a system are shown as sustainable (green, with boundaries at Bt and St), unsustainable (yellow), and permanently-degraded (red); these boundaries are often fuzzier than shown here. Although a 2-dimensional representation is an oversimplification, there are a limited number of ways in which local factors interact to create a 'syndrome of desertification'. Modified from Fernández *et al.* (2002).

2.2.2 Assertion 2: 'Slow' Variables are Critical Determinants of System Dynamics.

There is a growing acceptance that a small number of 'slow' variables act as the critical determinants in human-environment systems (Holling, *et al.* 2002). Hence, the axes in Figure 1 should display 'slow' variables, in contrast to 'fast' ones that are very sensitive to short-term events and are thus not much use in characterizing the state of human-environment systems. Of course, the terms 'slow' and 'fast' are relative and depend upon the scale at which a system is being studied. Whereas 20 years of using a particular management approach may seem a more than adequate proving time in human terms, it may be insufficient to cause changes in many slow ecological variables. To an individual farmer, bank interest rates are slow variables that affect net disposable income after debt repayments (his fast variables); however, at the national scale, interest rates are fast variables driven by slower structural factors such as export efficiency. Likewise, shrub encroachment may slowly impact the forage production of one paddock, but on a regional scale it may be a fast variable in terms of a nation's total carbon budget, driven by 'slower' land tenure system constraints.

2.2.3 Assertion 3: Thresholds are Crucial, and May Change Over Time.

Another key feature of the conceptual model is the presence of thresholds (Figure 1). Thresholds represent critical points in the slow variables (whether biophysical or socio-economic), beyond which the system moves into a new state or condition. These thresholds, which are not fixed, are a function of the system's internal dynamics. For example, from a biophysical point of view, thresholds of grain production may be the result of long cycles of above- and below-average rainfall; from a socio-economical perspective, they may result from changes in the social capital of a community or its taxation environment. Some thresholds are amenable to intervention so that they can be deliberately expanded or contracted. It is important that we focus on efforts to expand the range of conditions in which people can operate before a threshold is reached, that is, that we seek to build and maintain the adaptive capacity of the human-environment system as a whole (Assertion 7).

2.2.4 Assertion 4: The Cost of Intervention Rises Non-linearly with Increasing Degradation.

As the state of the linked human-environment system described by the slow variables 'declines,' the cost of intervention to 'recover' the system increases. This increase may be steady or sudden, but in general it creates another type of threshold, this one related to the cost of recovery. This may be because of a fundamental biophysical (e.g., switch from overland water flow to gully erosion) or socioeconomic non-linearity in the system. For example, the latter commonly result from the necessity to call on resources from higher (e.g., provincial, state or international) or broader (e.g., other households or communities) scales in order to reverse the change (see examples in Fernández *et al.* 2002, Robbins *et al.* 2002). This results in significantly increased transaction costs for negotiating new levels of help; this effect alone normally creates thresholds in the cost of intervention. These relationships are potentially predictable and, in a general sense, quantifiable, although research is needed to better identify the nature of thresholds under a wide range of biophysical and socio-economic conditions.

2.2.5 Assertion 5: Desertification is a Regionally Emergent Property of Local Degradation.

We accept the CCD definition of desertification as the most institutionally enshrined version, noting simply but importantly that it should be applied at a broad but not local scale (Chasek and Corell 2002, Prince 2002).

By comparison, 'degradation' must be assessed at the household to community social scales and comparably modest spatial scales. Land degradation must be viewed as occurring on a timescale that can be explicitly stated for a given human-environment system, such as 50 years or perhaps two generations of management.

As Fernández et al. (2002) indicate, it should be seen "as a decrease of (a specified aspect of) biological productivity under current human use that (i) reduces potential options for foreseeable uses in the future and (ii) is not reversible to a specified level in the temporal scale relevant to the decision-makers with the current resources available to them." In taking this line, we accept that the term 'desertification' is a practical but 'loose' term for the emergent outcomes of degradation at broader scales but stress that it becomes less useful or operational at increasingly finer scales. It is comparable to 'sustainable development' or 'biodiversity conservation', which serve as valuable communication devices but are equally ill-defined concepts if applied, for example, at the scale of 10 hectares of rangeland (see discussion in Chasek and Corell 2002). This is because degradation is the local expression of regional desertification but there is no general concept of land degradation that is uniformly applicable to all situations: it will always be necessary to define what factor is degraded, thereby providing guidance as to what to measure, and how to direct management and remediation efforts.

Table 1. The nine assertions of the Dahlem Desertification Paradigm, and some of their implications. These assertions are not all-encompassing but provide the framework for a new paradigm.

Assertion 1. Desertification Always Involves Human and Environmental Drivers	Always expect to include both socio-economic and biophysical variables in any monitoring or intervention scheme
Assertion 2. 'Slow' Variables are Critical Determinants of System Dynamics	Identify and manage for the small set of 'slow' variables that drive the 'fast' ecological goods and services that matter at any given scale
Assertion 3. Thresholds are Crucial, and May Change Over Time	Identify thresholds in the change variables at which there are significant increases in the costs of recovery, and quantify these costs, seeking ways to manage the thresholds to increase resilience
Assertion 4. The Costs of Intervention Rises Non-linearly with Increasing Degradation	Intervene early where possible, and invest to reduce the transaction costs of increasing scales of intervention
Assertion 5. Desertification is a Regionally Emergent Property of Local Degradation	Take care to define precisely the spatial and temporal extent of and processes resulting in any given measure of local degradation. But don't try to probe desertification beyond a measure of generalized impact at higher scales
Assertion 6. Coupled Human-Environment Systems Change over Time	Understand and manage the circumstances in which the human and environmental sub-systems become 'de-coupled'
Assertion 7. The Development of Appropriate Local Environmental Knowledge (LEK) must be Accelerated	Create better partnerships between LEK development and conventional scientific research, employing good experimental design, effective adaptive feedback and monitoring
Assertion 8. Systems are Hierarchically Nested (Manage the Hierarchy!)	Recognize and manage the fact that changes at one level affect others; create flexible but linked institutions across the hierarchical levels, and ensure processes are managed through scale-matched institutions
Assertion 9. A Limited Suite of Processes and Variables at Any Scale Makes the Problem Tractable	Analyze the types of syndromes at different scales, and seek the investment levers which will best control their effects – awareness and regulation where the drivers are natural, changed policy and institutions where the drivers are social

2.2.6 Assertion 6: Coupled Human-Environment Systems Change over Time.

At any particular point in time, a dryland system is the product of a set of complex interactions between biophysical factors (biogeochemical cycles, population dynamics, climate variability, etc.), social factors (conflict resolution, role of culture in shaping attitudes, etc.), and economic factors (supply-demand, economic stratification, work force, etc.). Hence, these systems are not static but are constantly changing in response to dynamic drivers, both external (e.g., climate) and internal (e.g., soil nutrient-plant growth feedbacks, or farmer responses to declining soil nutrients). The implications of this dynamism are significant. In the past, there has been a tendency for some external observers to conclude that what 'used to work' in drylands is necessarily correct and must therefore be returned to, regardless of evidence to the contrary (Ellis *et al.* 2002); the debate about pastoral mobility is tinged by this view (Batterbury *et al.* 2002).

On the other hand, overly-optimistic free-marketers tend to overlook the presence of natural, internal constraints that limit the ability of dryland systems to change in certain directions: for example, while a donor-supported program to supply a new drought-resistant strain of millet to farmers is well-intended, it may be folly in the face of constraints like low soil fertility and the lack of an adequate labor base.

2.2.7 Assertion 7: The Development of Appropriate Local Environmental Knowledge (LEK) must be Accelerated

The application of knowledge to better manage arid and semi-arid systems must ultimately occur by practitioners, whether these are individual farmers, or policy-makers (in the broadest sense) who create the context within which the individual managers operate. No amount of scientific knowledge or external hectoring can be effective unless it is put to use by these practitioners. However, these practitioners operate on the basis of their own mental models (Robbins *et al.* 2002), which are modified from a community-level set of norms generally termed "local environmental knowledge" (LEK). Traditional ecological knowledge, defined as knowledge that has evolved over long periods of time, served long-persisting nomadic pastoral groups or aboriginal peoples (e.g., in Australia or North America) well in the past (Mauro and Hardison 2000). The ability to develop LEK depends on feedback from outcomes of actions coupled with an appropriate attribution of impacts, and is developed over generations through trial and error, at a cost of great individual human suffering. Usually most LEK is acquired experientially, which is a double-edged sword: on the one hand it is the source of the intimate knowledge that individual farmers have about their own land, but on the other hand it is often un-replicated and localized (making its value for generic use questionable). Some researchers too readily dismiss its credibility, whilst others overstate its value. In reality, the key to successful change in human-environment systems is an appropriately-validated body of LEK, where the human community has some degree of common vision about how to best interact with its environment given the constraints of the social circumstances (Turner *et al.* 2000).

2.2.8 Assertion 8: Systems are Hierarchically Nested (Manage the Hierarchy

How does land degradation affect processes at specific levels or scales of concern—defined here as household/farm, community, regional/national and international—and how are these effects translated to higher (or lower) levels of the hierarchy? Scaling questions such as these arise because of the hierarchical nature of systems and greatly complicate how we investigate the response of human-environment systems. There are numerous linkages or connections between the different levels in the hierarchy (the strength of which may change with time), there are feedbacks or constraints imposed by one level on another, and multiple interactions within and between levels are constantly occurring; as a result we will always have an imperfect and uneven understanding across the hierarchy. Although there has been some success in developing effective solutions for a variety of environmental problems based solely on observations on small-scale systems (Young 2002), the challenge of extrapolating across multiple temporal and spatial scales of interest is enormous. Differing objectives, perspectives, and attitudes of various stake-holders inevitably cause them to focus on different measures; hence, a useful framework must encompass all these and enable people to see why their perception might be at odds with that of a player acting at a different scale of concern. The day-to-day concerns in a household, as impacted by local social context and structure, biophysical drivers, and relevant spatial and temporal scales, seem vastly different than those in the international arena. As issues are filtered upwards and downwards within the hierarchy, changes occur in their interpretation, in the level of urgency and concern with which they are viewed and, ultimately, in political action.

2.2.9 Assertion 9: A Limited Suite of Processes and Variables at Any Scale Makes the Problem Tractable

The foregoing assertions could sound terrifyingly complex! How is it possible to elucidate explanations that are useful but also pragmatic, general and simple? Holling *et al.* (2002) argue that to understand the interactions of ecological, economic, and social systems we must be able to distinguish what is understandable or predictable (even if uncertain) from that which is inherently unpredictable. How can this be accomplished? In truth, there are a limited number of ways in which all of these factors interact. We discuss several here but there are others. First, everything is not equally important.

In Assertion 2, we argue that the slow variables in coupled human-environment systems are crucial to understanding their operation and that, for any given system, a limited number of these variables are essential to a particular issue. Second, not every problem need be viewed as encompassing all scales of concern. Rather, we need to develop a hierarchy of understanding, each suited to a particular scale yet drawing upon the insights and relevant information from other scales. In our opinion, this is the most effective way of accounting for interactions of ecological, economic, and social systems.

3. ARID*NET:* AN INTERNATIONAL DESERTIFICATION NETWORK

As a follow-up to the Dahlem conference we established ARID*net*[1], an international network of collaborators. We envision ARID*net* serving as a mechanism for providing the intellectual leadership for critical thinking about the causal factors of land degradation in drylands of the globe, ranging from socio-economic factors to ecological impacts to policy response strategies and their interactions, and spanning a wide range of temporal and spatial scales, from small geographical units to larger regions. This will be accomplished by a critical evaluation and refinement of the Dahlem Desertification Paradigm (DDP).

General objectives of ARID*net* are (i) to foster international cooperation and exchange of ideas about desertification as summarized in the DDP; (ii) to open communication channels to foster more practical, field-level interactions with stakeholders in sustainable land management; and (iii) to use the concepts, experiences, and applications developed by group members to support on-going international discussions on the principles, criteria, and policies related to global desertification, especially the Convention to Combat Desertification (CCD).

The specific tasks to be conducted by ARIDnet include the following:
Task #1: *Paradigm-building*. Conduct workshops to present the DDP to the international desertification community of researchers, stakeholders, and policy-makers for a round of critical feedback, evaluation and refinement;
Task #2: *Case studies*. Formulate working groups to develop case studies to test the DDP in a well-stratified, international, and comparative manner. These case studies will be based on existing data and specific stakeholders, and will represent a range of biophysical/socio-economic types from around the world;
Task #3: *Synthesis*. Conduct a quantitative assessment of findings from Tasks #1-2 in terms of what matters in desertification, when and where it matters, and why.
Task #4: *Network-building*. Foster the participation of a diversity of researchers in the activities of ARID*net*. This is to include the formation of collaborative teams that will submit coordinated research proposals to test hypotheses that emerge from the synthesis papers, in partnership with local stakeholders.

ARID*net* is an open, international network and we actively seek interested groups and individuals to participate in the activities of the network (http://www.biology.duke.edu/aridnet/).

4. SUMMARY

We argue that the term *desertification* is only useful at higher levels of aggregation, while *degradation* (appropriately refined) is applicable to lower levels (see Table 1 and associated text). The Dahlem Desertification Paradigm (DDP) framework embraces all these levels of concern. For example, at the international level, implementation of the Convention to Combat Desertification must be framed in terms of changes in coupled human-environment systems that matter to humans, which dramatically changes the meaning of the "extent of desertification" and both the timing and distribution of funding for intervention. Similarly, at the household or community level, where concern is focused on the specific type of land degradation that is occurring and its local socio-economic consequences, the DDP channels resources towards identifying those essential biophysical and socio-economic slow variables that really matter in terms of quantifying current and future risk.

The Dahlem Desertification Paradigm recognizes the simultaneous roles of—and complex feedbacks among—the meteorological, ecological, and human dimensions of desertification. It incorporates our state-of-the-art knowledge about risks, detection, processes, and consequences of desertification, and is able to capture emerging ideas, data, and conceptual schemes for exploring quantitative, as well as qualitative, interactions between the various dimensions of desertification. However, the DDP represents only a preliminary framework. It must be refined to represent the degree of uncertainty in our knowledge of the desertification puzzle and to propagate these uncertainties in the analyses, thus reflecting them in the conclusions. We hope to meet some of these challenges with the activities of ARID*net*. This network's success will be measured by how many scientists, stakeholders, and policy-makers develop a degree of 'ownership' in the DDP. We are optimistic that this can happen via open dialogue designed to encourage input about and refinement of this tool for meeting this major global change challenge.

[1] Assessment, Research, and Integration of Desertification network

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