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Michael Mortimore *Editors*

The End of Desertification?

Disputing Environmental Change in the Drylands

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Contents

Chapter 1
Introduction: The End of Desertification?

Roy Behnke and Michael Mortimore

Abstract The opening chapters of this book examine something that never occurred but was widely believed to have existed—the late 20th century desertification crisis in the Sahel. Recent advances in climatology and changing weather patterns have effectively terminated further scientific debate about the existence of widespread Sahelian desertification, providing us with an opportunity to take stock and draw lessons. The logical and empirical shortcomings of the concept of desertification have been known for decades but the idea has been institutionalized at the global level and is remarkably resilient. The middle section of this book presents new reasons for concluding that the concept of desertification is no longer analytically useful and that we should instead struggle to better define and measure dryland degradation. The closing chapters of the book provide case studies from around the world that examine the use and relevance of the desertification concept. Despite an increasingly sophisticated understanding of dryland environments and societies, the uses now being made of the desertification concept in parts of Asia exhibit many of the shortcomings of earlier work done in Africa. It took scientists more than three decades to transform a perceived desertification crisis in the Sahel into a non-event. This book is an effort to critically examine that experience and accelerate the learning process in other parts of the world.

Keywords Desertification · Dryland degradation · UNCCD · Sahel · China

In *The End of Nomadism?* Humphrey and Sneath (1999) questioned the future of pastoralism in Inner Asia and challenged the analytical categories routinely used to characterize the world's mobile pastoral systems. The question in the title of the present book draws attention to the shortcomings of another, related scientific

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concept, that of desertification, which has become a political tool of global importance even as the scientific basis for its use grows weaker. We shall argue that the concept of desertification has ceased to be analytically useful and distorts our understanding of social-environmental systems and their sustainable development, particularly in poor countries with variable rainfall and persistent poverty. In the interests of better policy and governance, we need to reconsider the scientific justification and the institutionalized promotion of attempts to combat desertification.

There are three parts to our indictment:

Part I of this book examines something that never occurred but was widely believed to have existed—the late 20th century desertification crisis in the Sahel—the affair that ushered in the modern 'Age of Desertification' (Davis, Chap. 8). Science advances by failing as well as succeeding, and understanding the aetiology of a misconception can help to prevent its repetition. Recent advances in climatology and changing weather patterns in the Sahel have effectively terminated further scientific debate about the existence of widespread desertification in that region in the late 20th century, providing us with an opportunity to take stock and draw lessons. The chapters in Part I also exemplify the methodological sophistication and care with which current research investigates social, political, economic and environmental change in the Sahel, including the politicized nature of the desertification concept (Chap. 2), the changing paradigms in understanding social-environmental systems (Chap. 3), the relations between degradation and conflict (Chap. 4), re-greening through on-farm afforestation (Chap. 5), the combination of earth satellite data with ground observations (Chap. 6) and adaptation or resilience of agro-ecosystems (Chap. 7). This work has dispelled the very notion of widespread, catastrophic environmental degradation in the region, altered the recommended approach to environmental management, and underscored the need for scientifically informed governance.

The logical and empirical shortcomings of the concept of desertification have been known for decades (Chaps. 2 and 3; Mortimore 1989; Thomas and Middleton 1994; Warren and Agnew 1988; Swift 1996) but the idea has been institutionalized at the global level and is remarkably resilient. Part II of this book presents new reasons for concluding that the concept of desertification is no longer analytically useful and that we should instead struggle to better define and operationalize the admittedly difficult concept of dryland degradation.[1] The main planks in our argument are the pre-scientific and now indefensible set of ideas that generated the term 'desertification' (Chap. 8), the undefined and unquantifiable nature of the

[1]Drylands receive relatively low precipitation in the form of rainfall or snow and have an aridity index of <0.65. The aridity index is a measure of the ratio between average annual precipitation and total annual potential evapotranspiration. Drylands can be subdivided into: hyper-arid deserts (<0.05 index of aridity), arid (0.05–0.20 index of aridity), semi-arid (0.2–0.5 index of aridity) and dry sub-humid (0.5–0.65 index of aridity). A further defining characteristic of many (but not all) drylands is a strongly seasonal and sharply variable distribution of precipitation, both within and between rainy seasons (UN Environment Management Group 2011).

concept on a global or regional scale (Chap. 9), the need and opportunity to subsume desertification within a larger framework of global change (Chap. 10), and our current understanding of rangeland dynamics, which contradicts important aspects of desertification theory (Chap. 11).

Part III presents regional case studies that document dryland degradation and assess the efficacy of state policies to control degradation in different semi-arid environments. Chapters 12–14 and 16 examine the environmental impact of livestock production and crop agriculture in East Africa, South America and the Mediterranean. Chapter 15 looks at how journalists in three countries depict pastoralists, who are often viewed as one of the main agents of desertification. The final three chapters of the book, Chap. 17–19, document a worrying disconnection between policy formulation and environmental research on dryland issues in Central Asia and China. The use now being made of the concept of desertification in parts of Asia exhibits uncomfortable parallels to the history of the concept in the Sahel, suggesting that a reappraisal of Sahelian desertification is of more than regional or historical interest.

A final overview, Chap. 20, evaluates the contents of this book in terms of the 'drylands development paradigm', a recent and authoritative guide to investigating the complexities of dryland environments and societies.

1.1 Part I: Desertification in the Sahel: The Meaning of a Non-event

Given the complexity, imprecision and methodological opacity of desertification, the concept has lost its analytical utility for science and practice. Our argument begins in the Sahel, where a large literature has developed surrounding the widespread use of the concept, where the term itself was popularized, and where mainstream desertification orthodoxy has now been effectively dismantled by new scientific knowledge.

1.1.1 Crisis Versus Evolution

If desertification denotes an environmental crisis consisting of irreversible degradation on a sub-continental scale, then the most significant thing about desertification in the Sahel is that it never happened. Localized, even severe land degradation certainly exists in the region. Widespread, long-term degradation of some components of the environment may also be occurring (Herrmann and Sop on trees, Chap. 5), or not (Hiernaux et al. Chap. 6 on herbaceous and shrub vegetation in the northern Sahel). But the care with which researchers now work indicates the subtlety of these long-term environmental trends (Miehe et al. 2010) and, on occasion, the debatable nature of their existence (Hein and de Ridder 2006; Prince et al. 1998,

2007). While degradation is certainly a reality in the Sahel at some localities or with respect to certain components of the environment, there is no evidence of a catastrophic regional environmental crisis: 'Existing data do not support the claim that the African Sahel is a desertification hotspot' (Lepers et al. 2005: 122).

In the last century there was a Sahelian crisis, but not one of desertification. Beginning in the 1970s, a prolonged and severe drought caused tremendous human suffering. This drought was initially seen as 'a catalyst which exposed the deleterious effects of long-term degradation by people' (Thomas and Middleton 1994: 27). Recent shifts in rainfall patterns have witnessed the re-greening of much of the Sahel (Seaquist et al. 2009; Bégué et al. 2011; Olsson et al. 2005; Anyamba and Tucker 2005; Herrmann et al. 2005), and in retrospect it now seems that the mostly reversible effects of a persistent drought were simply confused with long-term degradation.

1.1.2 Blame and Response

Destructive land use practices by peasants and pastoralists—primarily primitive farming techniques and overgrazing—were blamed for causing Sahelian drought and desertification. In the late 1970s a renowned expert on the Sahel listed the causes of desertification as: overgrazing, overcultivation, uprooting woody species, borehole drilling and livestock vaccination campaigns (Le Houérou 1977); the UNCOD in 1977 identified overcultivation, overgrazing, deforestation and mismanagement of irrigated cropland (Thomas and Middleton 1994). It was argued that by removing vegetation, traditional agriculture exacerbated erosion and increased the reflectivity of the earth's surface, permanently shifting the regional climate towards more arid conditions (Charney et al. 1975). This argument was eventually refuted by climatological research summarized and discussed in detail by Giannini in Chap. 10. Climatological research demonstrated that the immediate cause of the great Sahel droughts had not even been terrestrial in origin, but resulted from variations in sea surface temperatures, and to the extent that these oceanic temperature anomalies had terrestrial causes, these could be traced to the changing composition of the air pollutants emitted in the northern hemisphere. Residents of the Sahel had not, as previously asserted, been the agents of their own misery.

The conclusive scientific demise of the Sahelian desertification paradigm only came about in the last decade or so, but serious reservations about the standard narrative emerged in the late 1980s (Mortimore 1989; Toulmin and Brock, Chap. 2). In the intervening decades this counter narrative coalesced into a compelling alternative explanation of the evolution of Sahelian landscapes and society (Mortimore, Chap. 3), and—in some parts of the Sahel—provided the rationale for innovative technical and political responses to the challenge of combining conservation with economic development (Boubacar, Chap. 7).

1.1.3 Institutionalization

Of the many things that the history of desertification in the Sahel can teach us, a lesson about the interaction between science and public policy is possibly the most important. The protracted Sahel drought that began in the early 1970s promoted widespread concern about desertification and sparked a global political response. As discussed in Chap. 2 by Camilla Toulmin and Karen Brock, desertification has for nearly half a century been a formal institutional process, a topic of occasional journalistic attention and the subject of an international convention and of environmental policy in individual nation states. Commitment to the concept of desertification goes beyond the scientific community and this has, in retrospect, complicated the attempt to objectively assess its status.

As a global institutional phenomenon, desertification has gone through two main phases. In the first phase, the United Nations Conference on Desertification (UNCOD), was convened in Nairobi in 1977 in the wake of the Sahel drought of the early 1970s, and gave rise to the nonbinding PACD or Plan of Action to Combat Desertification, coordinated by the United Nations Environment Program (UNEP). In the second phase, the PACD, which was supposed to run until 2000 but was widely perceived to be ineffective, was supplanted at a second UN conference, the Conference on Environment and Development (UNCED) or 'Earth Summit' held in Rio de Janeiro in 1992. The Rio conference set in motion negotiations to create a binding international convention on desertification, which eventually came into force in 1994 and continues to operate, the UNCCD or the Convention to Combat Desertification (Toulmin and Brock, Chap. 2).

In neither of these two time periods—from 1977–92 or from 1992 to the present—has the relationship between science and the international desertification bureaucracy been close or productive. In the initial phase under PACD, UNEP essentially ran an advocacy campaign that exaggerated the extent, severity and threat posed by desertification, making the official version of desertification a target for informed scientific criticism (Thomas and Middleton 1994; Helldén 1991; Tucker et al. 1991):

> UNEP limited the scope of knowledge communicated to policy makers through its exclusive choice of experts and having final say on how knowledge was presented….-favouring the policy domain over the science domain….The casualty of this trade-off was the credibility of scientific knowledge (Grainger 2009: 417).

As a result, "when the United Nations finally created the Convention to Combat Desertification (UNCCD) in 1994, policy was seriously disconnected from science" (Toulmin and Brock, Chap. 2, citing Andersson et al. 2011: 306).

If scientists require clarity in the concepts they employ, the politicians and administrators who create and manage large institutions have other, very pragmatic requirements. In the search for money and support, they need a problem that is dramatic enough to command immediate attention, simple enough to be quickly grasped, and general enough to satisfy diverse interest groups; they need what

Jeremy Swift has called a development narrative—a powerful story line with clear, broadly applicable policy implications and urgent funding needs (Swift 1996).

In Chap. 2 Toulmin and Brock explain how such a crisis narrative for the Sahel was assembled and subsequently challenged. The mainstream interpretation of desertification in the UN era initially replicated earlier colonial concerns about the rapid expansion of the Sahara as a result of native agricultural practices (Stebbing 1935, 1937). These predictions of environmental disaster were sufficiently apocalyptic to mobilize money, and the proposed solutions were technical enough to avoid the appearance of political involvement by international or bilateral development agencies in the affairs of newly independent African states. By the early 1990s scientific critiques were effective in blunting some of the more egregious elements of the crisis narrative, such as inflated estimates of the geographical expansion of the Sahara or the confounding of drought with permanent land degradation (Tucker et al. 1991; Helldén 1991; Olsson 1993). Following the Earth Summit in 1992, the definition of desertification adopted by the UNCCD reflected these adjustments. Dropping the desert metaphor and the insistence on either human causation or permanence, the official definition was sufficiently vague to encompass all kinds of environmental decline—including changes that did not mimic the onset of desert conditions or were only transitory—by almost any imaginable cause—natural or human:

> Desertification is land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities. (United Nations Convention to Combat Desertification, Bonn, Germany: Convention text).

In the decades since ratification, the broad UNCCD definition of desertification has permitted the perceived purpose of the Convention to evolve in step with changing policy concerns and shifts in development theory. In the 1990s official thinking on desertification began to reflect the fashion for participatory or bottom-up development, and to distance itself (though not entirely consistently, as discussed by Toulmin and Brock in Chap. 2) from the older rhetoric of coercion and centralization (Stiles 1995). Post-2000, desertification has been depicted as a potential security threat, reflecting the emergence of terrorism, state failure and forced migration as international policy concerns (Benjaminsen, Chap. 4). With the increasing prominence of climate change, desertification has recently been reframed as one part of land degradation 'in any climatic zone—not just in drylands' and linked to wider issues of resilience and adaptation in response to global warming (Reed and Stringer 2015: 27). Finally, as the only legally binding international agreement with 'a dual focus on environmental and developmental concerns', the UNCCD has also been depicted as a useful mechanism for promoting pro-poor economic growth (Middleton et al. 2011: 2).

In sum, the institutionalization of desertification within the UN system has fostered the conviction that the concept must be relevant to something important. Unconstrained by a precise definition of the phenomenon or by a credible system of scientific oversight (Grainger 2009) and driven by competition for international

funding (Toulmin and Brock, Chap. 2), what this relevance might be has been open to multiple interpretations.

1.1.4 Learning from the Sahel

Part I of this book provides an opportunity to reassess the utility of the concept of desertification from the perspective of contemporary research on the Sahel. Because it acted as the catalyst for the modern 'Age of Desertification' (Davis, Chap. 8), the Sahel has been subjected to unusually high levels of scientific scrutiny for a prolonged period of time. The focus of our argument is not, however, strictly on the Sahel itself but on learning from a protracted period of interaction between science and environmental policy, in order to make sense of what is happening now in parts of the world that may not be as intensively studied. It took science more than three decades of work on the Sahel to transform a perceived desertification crisis into a non-event. This book is an effort to critically examine that experience and accelerate the learning process.

Michael Mortimore (Chap. 3) provides an overview of what we now know about the state of the Sahel environment. He argues that there is little evidence across a broad range of indicators—forest cover, rangeland condition, soil fertility or overall biological productivity—for an irreversible decline in the Sahelian environment since the middle of the 20th century. There is, on the other hand, ample evidence for high and occasionally destructive levels of environmental variability, a reality that residents of the Sahel have adapted to with remarkable success despite poverty, political marginality and rapid population growth.

A reappraisal of the relationship between Sahelian society and its environment is therefore required, what Mortimore characterizes as a shift from a desertification to a resilience paradigm. In the desertification paradigm, humans cause irreversible degradation by disturbing the inherent stability of their natural environment. In response, technical solutions are externally imposed on local communities, which are perceived to be the source of the problem, and biophysical variables are used to measure success or failure. Alternatively, in the resilience paradigm, local resource users adapt to a variable environment that they cannot control, and their responses provide temporary solutions to a shifting set of problems and opportunities. Mortimore closes with a plea for a decentralized approach to development that respects the ingenuity and effectiveness of these responses and seeks to build on them.

Yamba Boubacar (Chap. 7) provides a concrete example of how Niger adopted and then implemented just such a decentralized approach. Innovation in Niger's case was a response to multiple crises—an extended drought (1972–84) that undermined the livelihoods and destroyed the working capital of rural households, accompanied by government indebtedness and currency devaluation. In response, in the 1980s government abandoned a centralized forestry strategy that was modelled on colonial policy and 'switched from protecting forest reserves to the overall

management and use of plant resources'. The technical centrepiece of this effort was a new method for clearing farmers' fields that encouraged the retention and natural regeneration of indigenous trees. Equally essential, however, were political changes at the national level, new land laws that recognized the property rights of rural people, and programmes to enhance the capacity of local institutions to manage natural resources.

Instead of a purely environmental crisis, the real challenge is to manage linked processes of political, social and environmental change. Chapters 5 and 6 provide examples of the methodological care with which current research addresses this challenge in the Sahel.

Stefanie Herrmann and Tene Sop (Chap. 5) document trends in Sahelian woody vegetation from multiple perspectives: satellite data, ethnobotanical studies, historical vegetation surveys, and the analysis of the size class distributions of current tree populations. While recent remote sensing studies suggest a regreening of the Sahel and a general increase in bio-productivity, the field studies reviewed in this chapter document the opposite trend for woody vegetation, including the loss of large trees, trees that require wetter conditions, or species that are economically valuable to local inhabitants. In contrast to the general trend, the good news about trees comes from farmers' fields where they are more intensively managed and have become more dense and diverse than before the great droughts, a consequence of the political processes detailed by Boubacar in Chap. 7:

> As farmer-managed natural regeneration has shown, human population growth and agricultural intensification do not have to entail losses in vegetation productivity and environmental degradation …. On the contrary, where sound management is practised, farmers' fields stand out by improved vegetation cover and diversity, while unprotected woodlands and unmanaged fields continue to degrade (Chap. 5).

Pierre Hiernaux, Cecile Dardel, Laurent Kergoat and Eric Mougin (Chap. 6) present an equally complex picture based on decades of ecosystem monitoring at two study sites, a sparsely populated pastoral area in Mali and a more densely settled agro-pastoral region in Niger. In the more arid pastoral study site, vegetation dynamics were erratic, complex, and unpredictable—largely driven by fluctuations in rainfall and unresponsive to the impact of grazing. At the more humid agro-pastoral site, the expansion of cropland and high concentrations of livestock increased the spatial heterogeneity of the ecosystem, pushed rangeland resilience to its limits, and left a long-lasting imprint on the landscape, an outcome that some observers might interpret as 'degradation'. Long-term monitoring in specific locations—Mali versus Niger, pastoral versus agro-pastoral areas—demonstrates the inadequacy of sweeping generalizations about the Sahel; ecological change is as varied and locally specific as the heterogeneous social and physical environments in which it takes place.

Tor Benjaminsen (Chap. 4) reveals, nonetheless, a continuing appetite in some quarters for broad generalizations—in this instance an alleged connection between increased conflict levels and a scarcity of natural resources. Benjaminsen argues that lack of evidence for widespread desertification in the Sahel makes it an unlikely

cause of conflict. In two case studies from Mali, he demonstrates that there was also no correlation between the timing of episodes of conflict and drought periods, making it unlikely that drought directly provoked increased levels of conflict. There were, on the other hand, compelling alternative political and historical explanations: state-sponsored agricultural encroachment on pastoral grazing resources, rent-seeking by government officials, the embezzlement of emergency aid, the temporary retreat of state control over rural areas, and the perceived para-military suppression of pastoral regions.

Stepping back from the individual chapters, a common message emerges from Part I. In considerable measure, science grows by making mistakes, acknowledging them, and moving on. With respect to the science on desertification in the Sahel, this process of rejection, invention and rejuvenation has been complicated because desertification is not simply a scientific concept. It also provides a basis for public policy and for the funding of global institutions, and concepts that are useful for this purpose often do not provide a convenient platform for the conduct of impartial science. Publicists, administrators and politicians active in the public arena thrive on crises and on unequivocal prescriptions for addressing crises. Careful science tends to deflate and moderate this rhetoric: Crisis degrades into evolution, environmental collapse becomes a problematic process of environmental change, local resource users are transformed from environmental villains into potential collaborators in conservation and development. There would seem to be an inherent tension, well illustrated by the history of ideas about desertification in the Sahel, between science that is flamboyant enough to be politically influential and yet cautious and complex enough to withstand scrutiny. Walking this tightrope is a recurrent challenge for research conducted in the service of public policy.

1.2 Part II: Challenging the Desertification Model

Several papers in this collection raise new questions about the continued relevance of the concept of desertification, both for the Sahel and for drylands more generally.

1.2.1 If You Can't Define It You Can't Measure It, and if You Can't Measure It You Can't Map It

Diana Davis (Chap. 8) and Stephen Prince (Chap. 9) address the same question from very different perspectives—'What is desertification?' Davis answers this question historically; Prince argues that the concept remains vague and cannot be defined operationally. Taken in combination, these chapters suggest that, despite a plethora of definitions and decades of discussion, we still do not know—and may never know—exactly what we mean by desertification.

The concept of desertification is not a 20th century invention; it was a product of early European scientific and prescientific thinking that survived virtually unchanged into the 20th century. Desertification is a variant of desiccation theory, 'the idea that deforestation causes the climate to dry out and diminishes rainfall', a theory that was widely accepted in European scientific and philosophical circles in the 18th and 19th centuries (Chap. 8). It was the French in their North African colonies who first applied desiccation theory to semi-arid environments and invented the concept and term 'desertification'—the creation or expansion of deserts by people. In North Africa the French colonial authorities invoked desertification to explain the impoverished condition of the natives in what appeared to be a degraded landscape. Avoidable environmental mismanagement by the natives helped rationalize the need for French imperial rule, for the reallocation of land to European settlers, and for the criminalization of native agricultural practices (Davis 2007). From their North African possessions, French administrators and scientists carried the desertification concept across the Sahara into West Africa. Chapter 8 traces these historical linkages, step by step, showing how colonial experts eventually provided the basis in the 1950s for UNESCO's Arid Zone Program, which in turn provided the background for the UN Conference on Desertification convened in 1977, and ultimately for the UNCCD, ratified in 1996.

As Davis makes clear in Chap. 8, the mid-20th century image or metaphor of desertification was perfectly clear, widely shared, and centuries old: It referred to what Bovill (1921) called the encroaching Sahara, a human-created desert where a desert did not naturally occur, 'a living environment becoming irreversibly sterile and barren' (Nicholson 2002: 51). The problem with this metaphor was that it had become scientifically indefensible by the early 1990s (Toulmin and Brock, Chap. 2). Driven by political expediency, the response to this impasse was not to abandon the concept as untenable, but to expand it. The negotiations that created the UNCCD were dominated by differences between developed and developing countries concerning the purpose of the new Convention (Corell 1999). Political support for the Convention 'rested on the diplomatic artifice of ambiguity' predicated on 'a consensus definition of the problem agreed in negotiations at UNCCD …[that] formalized the ambiguous roles of environmental degradation and drought [in the desertification concept]' (Grainger 2009: 419). If artful compromise trumped scientific clarity in the construction of the Convention, it continued to do so with its implementation. Writing in 2009, Grainger's estimation of the chances for improving scientific inputs into the official desertification regime was poor: 'Social order between developed and developing country Parties [is maintained] by means of [a] … combination of narratives compatible with both sets of discourses….Better scientific inputs could puncture the ambiguity on which the political viability of the CCD depends' (Grainger 2009: 425). As late as 2012, the UNCCD remained the only 'Rio Convention' without a functioning or proposed independent intergovernmental scientific body 'to guide policymakers' considerations of scientific evidence that is credible, relevant and legitimate' (Thomas et al. 2012: 123).

In Chap. 9 Stephen Prince documents the lingering scientific consequences of this political process: our inability to quantify and map either the global extent or

severity of desertification. In the mid-1990s desertification was characterized as a 'blanket term for a whole range of specific biological, chemical and physical changes in the environment' whose 'breadth rendered its actual use impractical, for example in terms of attempts to quantify desertification' (Thomas and Middleton 1994: 9). In Chap. 9 Prince argues that little has changed: Desertification remains 'a nebulous, all-encompassing concept' that 'is not a single phenomenon … and is therefore incapable of simple measurement' (Chap. 9). As a result, existing global maps of desertification are often based on subjective assessments by experts and cannot be replicated or used for monitoring. Moreover, there is no general agreement between different global map sets and there are no strong correlations between the levels of desertification depicted in the maps and the environmental variables that are generally thought to cause degradation: 'Consequently, unsupported statements about the extent and severity of desertification abound,' (Chap. 9). Prince concludes that 'Progress will be difficult unless the unitary concept of desertification is abandoned' in favour of measuring aspects of land degradation—changes in vegetative biomass, the responsiveness of the vegetation to rainfall, or rates of soil erosion, for example—that are each susceptible to quantification (Chap. 9). These scientific advances are, however, dependent on institutional reform, including 'independent organizations at national, regional and global scales to undertake routine monitoring' and 'technically credible leadership, free from external pressures … to address the issues of degradation at international-global scales and to harmonize policy-relevant research, monitoring and interpretation' (Prince, Chap. 9). As ever, desertification research remains enmeshed in global politics.

1.2.2 From Regional Desertification to Global Climate Change

Given the centuries of desiccation theory that preceded the 'Age of Desertification,' it may have been 'intuitive,' as Alessandra Gianinni notes in Chap. 10, for researchers in the 1970s to look to regional land use to explain regional climate change. At that time the attractiveness of a desiccationist interpretation was also reinforced by the emergence of a new mechanism that purported to explain how desiccation worked: the albedo effect. According to this theory, by reducing vegetation cover, desertification altered the reflectivity of the earth's surface and caused drought, which further reduced the vegetation cover, causing more drought—a degenerative biophysical feedback process (Charney 1975; Charney et al. 1975). At the bottom of this spiral of causation were the usual suspects—expanding numbers of local land users who were denuding the landscape—which set the stage for the standard remedies—population control, afforestation (Xue and Shukla 1996), and the reduction of livestock numbers (Otterman 1974). Desiccation theory had, in its essential features, been updated for the 20th century.

As Gianinni observes in Chap. 10, since the early work of Charney and his associates, regional models of land-atmosphere interactions have become increasingly sophisticated with the inclusion of more variables (such as soil moisture) and a more realistic depiction of these variables (Taylor et al. 2002). As a result, 'It has become increasingly clear that the processes by which anthropogenic land use change can reduce precipitation are physically plausible, and consistent with a natural positive feedback response of the land surface to precipitation' (Gianinni, Chap. 10). What the regional land-surface models could never explain, however, was the magnitude of the Sahel droughts, which were simply too big to be caused by observable levels of land use change in the region. A resolution to this impasse only occurred when climatologists turned to simulating the timing rather than the amplitude of rainfall fluctuations, and did so by looking at the Sahel climate from a planetary rather than a regional perspective.

As Gianinni explains, over the last century in the Sahel, alternating periods of high and low rainfall—such as the wet 1950s and 1960s followed by persistently dry conditions at the end of the 1960s, or the regreening currently taking place—are all correlated with global variations in sea surface temperatures. Dry periods in the Sahel are the consequence of elevated sea surface temperatures in the tropical oceans combined with cooler conditions in the north Atlantic (Palmer 1986; Folland et al. 1986). In the case of the great Sahel droughts at the end of the 20th century, the warming of the equatorial Indian Ocean and south Atlantic was caused by greenhouse gas emissions, while the cooling of the northern oceans was, aside from natural variation, caused by sulphate aerosol pollutants from the northern hemisphere (Gianinni, Chap. 10). Air pollution from greenhouse gasses continues, and so does the warming of the world's oceans; pollution from sulphate aerosols increased until the mid-1980s and has declined since the introduction of legislation aimed at controlling acid rain in North America and Europe. Both the great Sahel drought and current regreening trends reflect these pollution-driven shifts in oceanic temperature:

> As warming of the tropical oceans began to emerge in the 1970s, the reduced warming of the North Atlantic … starved the African continent of the moisture needed to trigger deep convection, causing persistent drought. Now that the North Atlantic has reversed its trend and is warming, a wetter Sahel has become possible, as manifest in a "partial recovery" of the rains since the mid-1990s (Gianinni, Chap. 10).

Droughts in the Sahel are primarily caused by oceanic temperatures, but may be suppressed or amplified by land use changes in the Sahel itself. This conclusion shifts the primary blame for the great 20th century Sahel droughts from local to global anthropogenic influence:

> In response to our best estimates of global sea surface temperature, state-of-the-art atmospheric models require no information on human-induced land cover/land use change to reproduce Sahelian drought. These simulations lead to the conclusion that drought was caused by large-scale, if subtle, shifts in oceanic temperatures, not by local anthropogenic pressure on the environment (Gianinni, Chap. 10).

1.2.3 Beware the Charismatic Story

Managed grazing systems—i.e., pastoralism broadly conceived—occupy about a quarter of the earth's land surface and are the most widespread form of land use on the planet, and dryland biomes—savannahs, grasslands, shrublands and deserts—contribute over three quarters of the world's total grazing area (Asner et al. 2004). Given the global importance of drylands and of grazing in drylands, if the concept of desertification is to have any utility, it must contribute to a better understanding of the impact of extensive livestock production on these environments. Reflecting this imperative, seven chapters in this book—Chaps. 6, 11–18—focus on rangelands and various forms of pastoralism and livestock farming.

In Chap. 11 Lynn Huntsinger re-examines the 'founding narrative' of the rangeland management profession in America—the widely accepted story of how human greed and uncontrolled resource exploitation degraded the 'pristine' rangeland ecosystems of the American West. Huntsinger argues that this 'declensionist' reading of Western history as a process of decline has been reinforced by an equally declensionist interpretation of Western range ecology, and that both are flawed.

Huntsinger limits her social and biological critique to a re-examination of the American experience, but her analysis has wider implications. In the 1970s when desertification was institutionalized globally, classical American rangeland management of the sort discussed by Huntsinger was influential far beyond the borders of the United States. In its classical form, the discipline was predicated on Clementsian theories of plant succession leading to climax vegetation, concepts of rangeland condition that identified good and bad plants, a paramilitary commitment to fire suppression, and an authoritarian approach to resource management. If these ideas have now been found inappropriate in their homeland, as Huntsinger suggests is the case, then a reappraisal of their global significance is overdue.

Effective story telling has been part of the problem. Stories, Huntsinger argues, are dangerous because they are such a powerful form of communication. The theories of rangeland ecology that dominated North American and much of the rest of the world for most of the 20th century were essentially stories—powerful simplifying narratives with moral implications. These stories were persuasive because they contained a considerable element of truth, but they were fundamentally misleading because their clear story lines excluded the complications, qualifications and exceptions that litter more balanced but less exciting accounts of reality. By the late 1980s, however, complications, qualifications and exceptions finally overwhelmed the simple Clementsian succession story, resulting in a more accurate and effective model of vegetation change—the states and transition format based on nonequilibrium theory. Alas, as Huntsinger emphasizes, this was an explanatory framework without a plot:

> Unfortunately, the "multiple stable states" model of vegetation change does not have the same simple, moralistic and appealing story as linear succession—there really isn't a beginning, end, or moral lesson. There is a site, it rains and things change or it doesn't rain

and things change. Changes may be permanent. Rainfall is unpredictable and not influenced by human actors. We need to watch, experiment, and record to learn what is going on.

The role of grazing in this scenario is one of many interacting dramatic changes, and changes without directionality. Removal of grazing may have little or no impact, and threshold dynamics may result in multiple stable states that have little to no relation to a "climax" or previously identified "potential" vegetation. There is no simple story here.

The state and transition format may be scientifically robust but it creates, in Huntsinger's words, a 'narrative vacuum,' a natural world populated by plants that lack a 'moral compass', plants without a human story to tell. In North America, Huntsinger argues that commercial interests purveying a mixture of story-telling and pseudo-science have filled the narrative vacuum created by the retreat of the Clementsian consensus.

If science is to regain the initiative and influence public policy, it must provide an interpretation of rangeland dynamics that is empirically adequate and yet simple enough to engage non-scientists. Drawing on research that provides the background to the present book, the following section argues that range science is moving towards such a synthesis.

1.2.4 Contemporary Range Science and the Desertification Paradigm

The following discussion examines the intellectual equipment—the concepts, theories and some of the field evidence—that can now be brought to bear on questions about the impact of extensive livestock production on rangeland environments. There are at least three practical questions that a non-specialist policy maker would want answered about the relationship between livestock and desertification:

- When livestock change vegetation, what kinds of changes should be characterized as 'degradation' or desertification?
- Under what circumstances is livestock grazing likely to cause changes in rangeland vegetation?
- How can rangelands be managed to limit degradation?

Contemporary range science provides answers to these questions that are different from those that prevailed in the 1970s and 1980s when desertification was first institutionalized in the UN system. In part these differences reflect scientific progress. Equally important, however, are the changes that have happened on the rangelands in the succeeding decades, particularly to pastoralists in developing areas. Subsistence-oriented livestock producers have been incorporated into commercial markets, increasingly adopting husbandry practices dependent upon purchased inputs and orientated to the production of commodities for sale. In some areas traditional migratory systems of livestock production are also in decline, for a variety of reasons including conversion of key pastoral resource areas to other forms of land use, the fragmentation and privatization of communal lands, the importance of markets and services that anchor families to settlements, and the

availability of new technologies—from water development, to feed supplementation or disease prevention—that render some kinds of movement unnecessary. These developments have blurred one of the standard dichotomies of desertification orthodoxy—the contrast between the primitive nomad and the modern, sedentary livestock producer. Taken in combination with advances in our understanding of rangeland ecology, these changes suggest new answers to the practical resource management questions enumerated above, answers that fundamentally challenge the concept of desertification.

The following three sections of this introduction outline some contemporary answers to our three management questions. We focus on grazing and rangeland issues because they have been central to the desertification debate since its inception, and clearly illustrate the relationship between science and environmental policy. It is important to note, however, that livelihood systems based on cropping or on mixed crops and livestock, routinely support larger human and animal populations than specialized livestock production and deserve consideration in their own right. With increasing market integration, dryland farming, like pastoralism, is also undergoing a transition to different and potentially higher levels of accepted risk. The land changes associated with these processes have been characterized as desertification in reports and publications targeted at policy makers and general readers. Equally, however, some recent policy-oriented analyses simply forgo the use of the term desertification, preferring to employ less prescriptive frameworks such as soil fertility management, resilience and agricultural intensification. While not reviewed here, these trends are fully discussed in a number of recent UN publications and development reports (Mortimore et al. 2009; UN Environment Management Group 2011; UNCCD/UNDP 2011; Davies et al. 2012).

1.2.4.1 When Is Vegetation Change Degradation?

'Desertification' connotes harmful environmental change, which implies an ability to distinguish between harmful and beneficial changes. In the 1970s, late succession grasses, especially perennials, represented both good livestock feed and the natural climax vegetation, and loss of such plants was routinely construed as evidence of degradation. Contemporary research suggests a more complicated situation in which the history of grazing in a region has an important influence on degradation processes (Milchunas et al. 1988). In areas that were not exposed to high levels of ungulate grazing prior to the introduction of livestock, such as parts of the south-western United States or Australia, degradation is often an unambiguous progression in which the later stages of environmental disruption become ever more expensive or time-consuming to reverse, or are irreversible (Schlesinger et al. 1990; Ludwig et al. 2004). But the situation is not always this clear-cut.

In much of Eurasia, Africa and North America, grazing by large hooved mammals—either domestic or wild—has contributed to creating the existing vegetation, and it would be misleading to characterize grazing as an unnatural disturbance. In these circumstances, the attributes that might be used to identify

rangeland condition—particular kinds of plants, high levels of plant productivity, livestock productivity or biodiversity—are not consistently linked to one another, or to grazing intensity. Three case studies from regions with a long evolutionary history of grazing—the rangelands of South Africa, the North American prairie, and the Mediterranean Basin—illustrate the complexities of environmental change in these environments.

In South Africa, a nation-wide study concluded that heavy grazing altered the composition of plant communities by increasing the proportion of annuals and favouring opportunistic, grazing-resistant species with low palatability and forage quality—weedy, grazing-induced degradation from the perspective of climax vegetation. Despite these changes in species composition, at none of the very heavily utilized communal rangeland sites was there a decline in species richness—degradation defined in terms of the loss of plant biodiversity (Rutherford and Powrie 2013).

The maintenance of an imagined 'climax' vegetation may also conflict with wildlife biodiversity. In the United States the most rapidly declining kinds of birds are those associated with rangelands, and these declines coincided with nationwide improvements in rangeland condition and health, as defined by Clementsian succession theory (Fuhlendorf et al. 2012). Many of the bird species that suffered were those that required disturbed ground and low vegetation structure caused by heavy grazing or fire. In terms of the habitat requirements of North American semi-arid bird populations, there was no single livestock stocking rate or type of vegetation that met the needs of all species. Instead what was beneficial was a diversity of different habitats—a high level of local, botanical variability caused by different levels of grazing intensity (Fuhlendorf et al. 2006, 2012; Fuhlendorf and Engle 2001).

In a wide-ranging review, Seligman and Perevolotsky concluded that 'grazing by domestic ruminants is seldom irreversibly destructive to landscape values' for winter rainfall regimes of the Mediterranean Basin (Seligman and Perevolotsky 1994: 93–4; Perevolotsky and Seligman 1998). Animal output per unit area was also higher under heavy grazing and primary production was not reduced (Crespo 1985; Gutman et al. 1990). As in South Africa, the herbaceous plant community formed under very intensive grazing was no less diverse or rich in species than less disturbed vegetation, but the composition was substantially altered (Hadar et al. 1999).

The preceding cases illustrate the difficulties of identifying botanical indicators of degradation in environments long exposed to grazing. In South Africa and the Mediterranean Basin heavy grazing produced changes in the composition of pastures as grazing-tolerant plants replaced ones that were grazing intolerant, but with no loss in diversity or species richness, and, at least in the Mediterranean, with no loss of livestock productivity. In North America, intense but localized grazing that would traditionally constitute overgrazing was essential to the survival of certain species of wildlife. Cases like this suggest that degradation cannot be identified with particular kinds of plants or assessed according to a single metric—be it biodiversity, primary or secondary production. A more realistic measure of environmental resilience may instead be the maintenance of diverse landscapes capable of sustaining different production systems, species and environmental services. Instead

of asking how drylands can be managed to limit desertification, we might instead ask how they can be managed to maximize this heterogeneity.

1.2.4.2 Under What Circumstances Is Grazing Likely to Cause Vegetation Change?

The threat posed by spreading deserts or 'desert edge displacement' (Veron et al. 2006) was a central component of the early desertification literature (Lamprey 1988; Aubréville 1949), as was the perception that drylands were fragile environments especially prone to degradation.

The non-equilibrium theory of grazing systems dramatically reversed this assessment (Ellis and Swift 1988). Part of the resilience of semi-arid rangelands can be attributed to the characteristics of the plants themselves. Some semi-arid grasses are robust to grazing because the evolutionary adaptations that promote survival to drought also equip them to evade, resist or tolerate large herbivores (Coughenour 1985). More important, however, is the response of livestock populations to severe droughts, which occur frequently in regions of low rainfall. Following droughts, herd sizes recover slowly and the vegetation has an opportunity to rebound in the absence of significant grazing pressure (Ellis and Swift 1988).

In areas subject to low and erratic rainfall, recurrent livestock population crashes also suppress livestock numbers over the long term. As a result, in the absence of feed supplementation, herbivore biomass per unit of plant biomass—i.e., the herbivore load relative to primary production—increases exponentially with average annual rainfall (Oesterheld et al. 1998; McNaughton et al. 1989; Fritz and Duncan 1994). Subjected to both more constant and increased grazing pressure, vegetation in high rainfall areas is more exposed than in low rainfall areas to the effects of grazing (Coppock, Chap. 12).

This conclusion is supported by a global meta-analysis that discovered no instances of widespread or zonal vegetation change—i.e. change on a spatial scale that might qualify as desertification—in non-equilibrium rangelands with sufficiently high levels of rainfall variability (von Wehrden et al. 2012). The same pattern emerges when grazing systems are examined along a rainfall gradient in a single region. As Hiernaux et al. explain in Chap. 6, grazing leaves little imprint on the vegetation in more arid areas of Mali but has a significant impact under more humid conditions in Niger.

Mongolia provides another well-researched example. In Mongolia, grazing pressure was of minor importance and weather conditions determined vegetation characteristics at the arid end of the rainfall gradient, but differences in grazing pressure had an increasingly marked effect on vegetation under more humid conditions (Fernandez-Gimenez and Allen-Diaz 1999, 2001; Zemmrich et al. 2010), and degradation became more of a concern as the level and reliability of rainfall increased (Wesche et al. 2010; Stumpp et al. 2005; Khishigbayar et al. 2015).

Similar results emerged from a long-term study in Senegal that substituted a temporal for a spatial rainfall continuum (Miehe et al. 2010). In an area that had experienced shifts in weather conditions, fluctuations in precipitation drove vegetation change and masked the effects of grazing during a run of dry years with variable rainfall. However, in a wetter phase when rainfall variability had declined, grazing caused changes in the species composition of the vegetation that might be construed as degradation (Miehe et al. 2010). Contrary to the anxieties about 'desertification' that typically emerge in times of drought, in Senegal the risk of grazing-induced vegetation change coincided with periods of higher rainfall.

There are exceptions to the association between aridity and reduced grazing impacts. Some of these exceptions can be attributed to the susceptibility of certain types of vegetation to grazing (Oliva et al. Chap. 13; Todd and Hoffman 2009; Hacker et al. 2006). Problems also occur when mobility is too successful at buffering migratory livestock populations from feed shortages. This possibility arises when mobile herds have access to large areas of grazing that are insensitive to heavy use during periods of feed scarcity—extensive marshes or floodplains, for example. The reliable food supplies available in these areas can mitigate the effects of an erratic climate and sustain livestock populations that are large enough to damage vegetation that is vulnerable to grazing in adjacent areas (Illius and O'Connor 1999).

By far the most common exceptions to the nonequilibrium model are caused by differences in the way livestock are managed (Briske et al. 2003; O'Connor 1995). With access to feed supplementation, water development and markets, commercial ranchers have an enhanced ability to suppress fluctuations in livestock populations caused by variable weather conditions, removing the periods of low grazing pressure that buffer arid rangelands from the impact of livestock. Under these conditions, episodic fluctuations in rainfall may produce the most visible vegetation responses, 'but these changes are unlikely to be directional provided there is no long-term rainfall trend. In contrast, the response of a species to heavy grazing is … generally unidirectional … and although year-by-year changes due to grazing are small, they are cumulative (O'Connor 1995: 59). While the immediate effects of grazing may not be dramatic, managers with sufficient resources at their disposal can override the climatic constraints that would otherwise protect arid rangelands from livestock-induced degradation (Ellis and Lee 2003).

Most livestock owners would like to reduce their exposure to climatic variability and there is increasing evidence that producers in developing areas are now acquiring industrial inputs that make this possible. The most important of these inputs are purchased or home-grown feed supplements, the construction of artificial water points, and enhanced disease prevention—all of which suppress livestock population crashes and increase livestock productivity. Unless these interventions are combined with management practices that ensure the periodic resting of rangelands, they also increase the risk of long-term resource degradation (Vetter and Bond 2012; Vetter 2005; Hary et al. 1996; Miehe et al. 2010; Müller et al. 2007; Li et al. Chap. 18).

Arid rangelands are not the fragile, degradation-prone environments of the orthodox desertification paradigm, but they are currently under stress, not from the nomadic menace of the older narrative, but from intensification and commercialization processes that are at once economically attractive and environmentally challenging.

1.2.4.3 New Approaches to Managing Extensive Grazing Systems

Since the 18th century, proponents of desertification have identified nomadism with environmental destruction (Davis, Chap. 8). By the 20th century, the standard antidote to nomadism, modelled on commercial ranching in developed countries and promoted by numerous donor-financed livestock development projects, was settled ranching and rotational grazing.

Designed to move livestock on a predetermined schedule through a sequence of fenced paddocks, rotational grazing schemes were promoted as the modern, orderly, and scientifically endorsed alternative to the presumed randomness and environmental destructiveness of migratory movement. Despite the lingering popularity of rotational systems among some commercial ranchers and rangeland professionals, research has repeatedly demonstrated that fenced systems of grazing rest and rotation do not reliably increase plant or livestock production in arid and semi-arid rangelands (Heady 1961; O'Reagain and Turner 1992; Briske et al. 2008). As scientific confidence in rotation grazing systems has eroded, there has been a steady advance in the understanding of the ecological processes that underpin wild animal migrations, which sustain some of the greatest concentrations of animal biomass on earth. Migration also has a measurable impact on the productivity and viability of free-ranging animal populations, both domesticated and wild, and on the state of the resources that they use (Milner-Gulland et al. 2011).

For our understanding of desertification, the significance of these findings lies in a revaluation of the implications of rangeland heterogeneity. By forcing livestock on a predetermined schedule through a sequence of relatively small fenced areas, often at high densities and for short periods of time, rotational systems attempted to suppress selective grazing and distribute animals evenly across a landscape, and made little attempt to exploit the temporal and spatial variability in forage quality and quantity that is an inherent feature of many dryland environments (Fynn 2012). Migratory systems—both in developing (Behnke et al. 2011; Butt 2010; Butt et al. 2009; Moritz et al. 2013) and industrial settings (Huntsinger et al. 2010; Huband et al. 2010; Baena and Casas 2010; Abreu et al. 2010)—take a different approach, seeking to exploit rather than suppress rangeland heterogeneity. These systems encourage livestock to track the best grazing areas available on a seasonal basis, to respond to unpredictable episodic variations in the location of favourable and unfavourable areas, and to exploit the distinctive features of individual localities. Benefits derived from this kind of movement include higher growth rates for mobile herbivore populations (Wang et al. 2006), the creation of grazing-induced lawns of highly nutritious forage (Hempson et al. 2014); mitigation of the effects of drought

(McAllister et al. 2006); higher sustainable stocking rates (Boone and Hobbs 2004); and facilitation of the co-existence of wildlife and livestock (Western et al. 2009).

Different criteria are also relevant for identifying harmful vegetation changes in migratory systems. The grazing gradients that occur around water points and settlements have for decades been central to the argument that pastoralism is a major cause of desertification (Sinclair and Fryxell 1985). Herbaceous plants in the heavily used 'sacrifice zones' adjacent to water points or settlements tend to be short, quick-growing annual species well adapted to defoliation and trampling, but providing small quantities of forage—unattractive grazing weeds in terms of a traditional Clementsian classification. However, these heavily grazed plant communities often provide forage of high nutritional quality (García et al. 2014; Vetter and Bond 2012), albeit for short periods of time (Anderson et al. 2010; Anderson and Hoffman 2007). While the ephemeral nature of these feed sources may render them unsuitable for permanent use, their transitory productivity is well suited to mobile systems that exploit resources during periods of optimal productivity and then move on to new areas and other kinds of resources (Bollig and Schulte 1999; Thomas and Twyman 2005). Increased spatial scale facilitates these migratory systems but is not an absolute requirement. Recent work has extended the principle of heterogeneous resource exploitation to private properties in which movement takes place over shorter distances (Fynn 2012; Bailey and Brown 2011; Hempson et al. 2014).

Mobile livestock production is not suited to all natural environments or to the needs of all producers. In some regions mobility is not a realistic alternative because resources are evenly distributed in space or fluctuations in their productivity are inappropriately timed. In other settings, the pressures of population growth or the advantages of agricultural intensification may render mobility impossible or make it unattractive. At the extensive margins, however, there are and will remain large dryland areas suitable only to low-input livestock production. Contrary to the desertification paradigm, for these marginal drylands, the scientific rationale for the environmental and economic benefits of mobility is stronger than ever.

1.2.5 Summing up the Challenge to Desertification

Nearly a decade ago Veron, Paruelo and Oesterheld undertook an assessment of desertification (2006). Their review noted many of the difficulties highlighted in this book—exaggerated journalistic accounts of the extent of the desertification threat, a plethora of competing definitions, and flawed attempts to measure the extent or severity of the problem. Despite these shortcomings, their appraisal concluded on an optimistic note:

> There are no reasons to believe that desertification ecology faces harder challenges than other disciplines (e.g. the definition of invasive species in invasion ecology, or of endangered species in conservation ecology) (Veron et al. 2006: 760).

According to this passage, desertification studies are like any other scientific sub-discipline: Growing pains are inevitable and temporary setbacks are to be expected and overcome. We are sceptical of this conclusion and the chapters in this book explain why.

When it comes to understanding and controlling desertification, scientists have not been the only interested party. From its inception to the present, desertification research has been targeted at and deeply involved in the formulation of public policy. The idea of desertification that was broadly accepted until the late 20th century labelled a clearly defined process: desert encroachment caused by destructive land use practices and population growth in dryland areas. This vision was sufficiently apocalyptic to capture the interest of policy makers, and had the added attraction of justifying the imposition of imperial control and pandering to European conceptions of their own technical superiority (Davis, Chap. 8). By the late 1980s, however, this portrayal of desertification had become difficult to defend against contrary scientific evidence and was replaced by a UNCCD definition that equated desertification with dryland environmental decline, irrespective of its permanence, cause, or similarity to desert conditions (Toulmin and Brock, Chap. 2 and Mortimore, Chap. 3). This omnibus definition has been effective in holding the UNCCD together institutionally, but the vagueness that made it institutionally effective has also rendered it unworkable as a basis for the objective quantification and mapping of desertification on a global scale (Prince, Chap. 9).

It is also becoming increasingly difficult for observers to attribute dryland environmental change to regional land use alone, as the concept of desertification implies, or to distinguish confidently between the effects of local and global influences. Our evolving understanding of the Sahel drought of the 1970s and 1980s is indicative of this shift in perspective. Unbeknownst to observers at the time, these droughts were a manifestation of global climate change, so much so that the ability of current climate models to replicate this event 'now constitutes a litmus test of our confidence in these models' (Gianinni, Chap. 10). But the Sahel is not an isolated case. Recent changes in the rangeland vegetation of Mongolia, for example, have been attributed to excessive grazing pressure or to rising temperatures associated with climate change, or to an unknown combination of these factors (Khishigbayar et al. 2015). Similar uncertainty surrounds the extent to which bush encroachment is caused by elevated levels of CO_2, changing rainfall patterns associated with global warming or by land use variables, such as the intensity of grazing or the suppression of fire (Buitenwerf et al. 2012; Lohmann et al. 2012; O'Connor et al. 2014). From Patagonia to Central Asia, the case studies in this book frequently cite a new source of uncertainty: the impact of climate change at local or regional levels. The pervasiveness of global change calls into question the concept of desertification as a distinct, regional form of dryland degradation that can be understood or managed in isolation from changes that are now rapidly taking place on a planetary scale.

The concept of desertification also contradicts current understandings of the complexities of dryland degradation. The UNCCD definition of land degradation assumes that a decline in biodiversity is consistently associated with declines in the economic and biological productivity of the land:

> Land degradation is defined by the United Nations Convention to Combat Desertification as the 'reduction or loss of the biological or economic productivity *and* complexity' of terrestrial ecosystems (our emphasis). That no provision is made in this definition for 'productivity *or* complexity' reflects a common negation of the possibility of finding an inverse or part-inverse relationship between the two… (Rutherford and Powrie 2010: 692).

The assumptions that underpin the UNCCD definition of degradation make sense in a simple Clementsian framework in which climax vegetation is assumed to be uniformly good; they make little sense in a state and transition framework in which different measures of degradation such as biodiversity, primary and secondary productivity are free to vary independently of one another, and have been shown to actually do so in numerous field studies. Field research also questions the attempt to identify and maintain uniformly good environments, however 'good' might be defined. Heterogeneous landscapes sustain diverse plants, animal species and environmental services, and the attempt to create homogenous environments can have negative consequences both for conservation and for mobile production systems that exploit heterogeneity.

The problems of evaluating vegetation change in positive or negative terms are indicative of a broader ambiguity. This dilemma corresponds to what Andrew Warren has called the contextual nature of degradation: 'simple, universal systems of judging land degradation … for precise criteria, or criteria based on economic performance are in vain. The evaluation of land degradation cannot be reduced to nutrient budgets, soil depth, soil water holding capacity, to economics or to politics' (Warren 2002: 457). If 'degradation' is situationally dependent, then desertification studies cannot characterize the condition of the earth's dryland environments by applying a uniform system of evaluation. At global and regional scales, a more realistic goal is the construction of maps or data sets, now heavily dependent on remote sensing, that summarize what we know about different measures of change in semi-arid environments: estimates of biomass production or rain use efficiency, changes in land cover, biodiversity or plant species richness, erosion rates, soil carbon levels, etc. (Prince, Chap. 9). Evaluation of the positive or negative implications of these attributes will remain, as the case studies in in this book demonstrate, subject to field documentation and local (sometimes contested) interpretation.

1.3 Part III: Regional and Country Case Studies

The opening chapters of Part III continue the discussion of pastoralism and rangeland issues, but pose additional questions about the broader socio-economic context in which environmental change takes place.