Ecosystems and Human Well-being

Desertification Synthesis

MILLENNIUM ECOSYSTEM ASSESSMENT

Ecosystems and Human Well-being

Desertification Synthesis

A Report of the Millennium Ecosystem Assessment

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Foreword

Desertification is a concept used to grasp the more acute forms of the degradation of land-based ecosystems and the consequences of the loss of their services. Drought is the silent killer—the natural catastrophe that is only too easily forgotten. Experience shows that awareness of the implications of desertification and drought must be expanded and that policy orientation must be backed by robust monitoring systems and related findings.

The Millennium Ecosystem Assessment has made a significant and much appreciated contribution to this end. It carefully presents the critical importance of functional ecosystems for human well-being and sustainable economic growth. The case is particularly powerful for the drylands of the world. Populations in arid, semiarid, and dry subhumid climatic zones, which define the field of intervention of the UNCCD, are greatly affected by environmental vulnerability and poverty.

The Desertification Synthesis, based on a sound summary of scientific evidence, states that desertification must imperatively be addressed to meet the Millennium Development Goals of the United Nations. Desertification must be fought at all levels, but this battle must ultimately be won at the local level. There is evidence that success is possible. All the while, this report makes it now clearer that this phenomenon is embedded in a global chain of causality and that its impact is felt far beyond the boundaries of affected areas. Desertification contributes significantly to climate change and biodiversity loss.

Diverse views exist on the complex relationship between climatic and anthropogenic causal factors of desertification. Work remains to be done in order to enhance the knowledge base that should produce policy-relevant findings and facilitate informed decision-making. The Committee on Science and Technology of the UNCCD should be able to contribute in this respect. In the meantime, this assessment portrays the magnitude of the challenge and invites the international community to focus on needed action.

Bonn, 19 February 2005

Hama Arba Diallo
Executive Secretary of the United Nations Convention to Combat Desertification

Preface

The Millennium Ecosystem Assessment was called for by United Nations Secretary-General Kofi Annan in 2000 in his report to the U.N. General Assembly, *We the Peoples: The Role of the United Nations in the 21st Century*. Governments subsequently supported the establishment of the assessment through decisions taken by four multilateral environmental conventions. The MA was initiated in 2002 under the auspices of the United Nations, with the secretariat coordinated by the United Nations Environment Programme, and governed by a multistakeholder board involving international institutions and representatives of governments, business, NGOs, and indigenous peoples.

The MA responds to governments' requests for information received through four multilateral conventions—the Convention on Biological Diversity, the U.N. Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species—and is designed to also meet needs of other stakeholders, including business, the health sector, NGOs, and indigenous peoples. The objective of the MA was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.

This synthesis report was developed during the period 2003–05. The preparatory work for the report and selection of a writing team was initiated in Tashkent, Uzbekistan, in August 2003, during a joint international workshop organized by the United Nations University, the International Center for Agricultural Research in the Dry Areas, and the MA Secretariat. Production of the report was made possible through a team effort by a diverse group of experts, backstopped with logistical support by the MA Secretariat. The full writing team convened in Hamilton, Canada, in August 2004 and in Scheveningen, the Netherlands, in January 2005. An extensive external review was undertaken in coordination with the MA Board of Review Editors, which engaged external reviewers, government representatives, and the secretariats of key multilateral environmental conventions. The report was formally approved by the MA Board in March 2005.

The Desertification Synthesis is underpinned by the conceptual framework for the MA, which assumes that people are integral parts of ecosystems and that a dynamic interaction exists between people and other parts of ecosystems. The changing human condition drives—both directly and indirectly—changes in ecosystems, thereby causing changes in human well-being. At the same time, social, economic, and cultural factors unrelated to ecosystems change the human condition, and many natural forces influence ecosystems. Although the MA emphasizes the linkages between ecosystems and human well-being, it recognizes that people's actions stem also from considerations of the intrinsic value of species and ecosystems, irrespective of their utility for someone else.

This report presents a synthesis and integration of the findings of the four MA Working Groups (Condition and Trends, Scenarios, Responses, and Sub-global Assessments). It does not, however, provide a comprehensive summary of each of those Working Group reports, and readers are encouraged to also review those findings. It is organized around the core questions originally posed to the MA: How has desertification affected ecosystems and human well-being? What are the main causes of desertification? Who is affected by desertification? How might desertification affect human well-being in the future? What options exist to avoid or reverse the negative impacts of desertification? And how can we improve our understanding of desertification and its impacts?

31 March 2005

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Reader's Guide

This report synthesizes findings from the MA global and sub-global assessments on desertification and human well-being. All the MA authors and Review Editors have contributed to this draft through their contributions to the underlying assessment chapters on which this material is based.

Five additional synthesis reports were prepared for ease of use by other audiences: general overview, Ramsar Convention (wetlands), CBD (biodiversity), business, and the health sector. Each MA sub-global assessment will also produce additional reports to meet the needs of its own audience. The full technical assessment reports of the four MA Working Groups will be published in mid-2005 by Island Press. All printed materials of the assessment, along with core data and a glossary of terminology used in the technical reports, will be available on the Internet at www.MAweb.org. Appendix B lists the acronyms and abbreviations used in this report. Throughout this report, dollar signs indicate U.S. dollars and tons mean metric tons.

References that appear in parentheses in the body of this report are to the underlying chapters in the full technical assessment reports of each Working Group. Please see Appendix C for the tables of contents of those reports. To assist the reader, citations to the technical volumes generally specify sections of chapters or specific Boxes, Tables, or Figures, based on final drafts of the chapter. Some chapter subsection numbers may change during final copyediting, however, after this report has been printed.

In this report, the following words have been used where appropriate to indicate judgmental estimates of certainty, based on the collective judgment of the authors, using the observational evidence, modeling results, and theory that they have examined: *very certain* (98% or greater probability), *high certainty* (85–98% probability), *medium certainty* (65–85% probability), *low certainty* (52–65% probability), and *very uncertain* (50–52% probability). In other instances, a qualitative scale to gauge the level of scientific understanding is used: *well established, established but incomplete, competing explanations, and speculative*. Each time these terms are used they appear in italics.

Clay crust formed at an aquifer recharge location in the Fars Province, I.R. Iran.

ZAFAR ADEEL

Summary for Decision-makers

Desertification is defined by the U.N. Convention to Combat Desertification as "land degradation in arid, semiarid and dry subhumid areas resulting from various factors, including climatic variations and human activities." Land degradation is in turn defined as the reduction or loss of the biological or economic productivity of drylands. This report evaluates the condition of desertification in drylands, including hyper-arid areas, by asking pointed questions and providing answers based exclusively on the reports generated for the MA.

Desertification occurs on all continents except Antarctica and affects the livelihoods of millions of people, including a large proportion of the poor in drylands. Desertification takes place worldwide in drylands, and its effects are experienced locally, nationally, regionally, and globally. Drylands occupy 41% of Earth's land area and are home to more than 2 billion people—a third of the human population in the year 2000. Drylands include all terrestrial regions where water scarcity limits the production of crops, forage, wood, and other ecosystem provisioning services. Formally, the MA definition encompasses all lands where the climate is classified as dry subhumid, semiarid, arid, or hyper-arid. Please see Appendix A for more details about their geography and demography.

Some 10–20% of drylands are already degraded (*medium certainty*). Based on these rough estimates, about 1–6% of the dryland people live in desertified areas, while a much larger number is under threat from further desertification. Scenarios of future development show that, if unchecked, desertification and degradation of ecosystem services in drylands will threaten future improvements in human well-being and possibly reverse gains in some regions. Therefore, desertification ranks among the greatest environmental challenges today and is a major impediment to meeting basic human needs in drylands.

Persistent, substantial reduction in the provision of ecosystem services as a result of water scarcity, intensive use of services, and climate change is a much greater threat in drylands than in non-dryland systems. In particular, the projected intensification of freshwater scarcity as a result of climate change will cause greater stresses in drylands. If left unmitigated, these stresses will further exacerbate desertification. The greatest vulnerability is ascribed to sub-Saharan and Central Asian drylands. For example, in three key regions of Africa—the Sahel, the Horn of Africa, and Southeast Africa—severe droughts occur on average once every 30 years. These droughts triple the number of people exposed to severe water scarcity at least once in every generation, leading to major food and health crises.

Desertification is a result of a long-term failure to balance demand for and supply of ecosystem services in drylands. The pressure is increasing on dryland ecosystems for providing services such as food, forage, fuel, building materials, and water for humans and livestock, for irrigation, and for sanitation. This increase is attributed to a combination of human factors and climatic factors. The former includes indirect factors like population pressure, socioeconomic and policy factors, and globalization phenomena like distortions to international food markets and direct factors like land use patterns and practices and climate-related processes. The climatic factors of concern include droughts and projected reduction in freshwater availability due to global warming. While the global and regional interplay of these factors is complex, it is possible to understand it at the local scale.

The magnitude and impacts of desertification vary greatly from place to place and change over time. This variability is driven by the degree of aridity combined with the pressure people put on the ecosystem's resources. There are, however, wide gaps in our understanding and observation of desertification processes and their underlying factors. A better delineation of desertification would enable cost-effective action in areas affected by it.

Measurement of a persistent reduction in the capacity of ecosystems to supply services provides a robust and operational way to quantify land degradation, and thus desertification. Such a quantification approach is robust because these services can be monitored, and some of them are already monitored routinely.

Desertification has strong adverse impacts on non-drylands as well; affected areas may sometimes be located thousands of kilometers away from the desertified areas. The biophysical impacts include dust storms, downstream flooding, impairment of global carbon sequestration capacity, and regional and global climate change. The societal impacts relate notably to human migration and economic refugees, leading to deepening poverty and political instability.

Tailored to the degree of aridity, interventions and adaptations are available and used to prevent desertification and to restore, where needed, the capacity of the dryland ecosystems to provide services. Increased integration of land and water management is a key method for desertification prevention. Local communities play a central role in the adoption and success of effective land and water management policies. In this respect, they require institutional and technological capacity, access to markets, and financial capital. Similarly, increased integration of pastoral and agricultural land uses provides an environmentally sustainable way to avoid desertification. However, policies to replace pastoralism with sedentary cultivation in rangelands can contribute to desertification. On the whole, prevention is a much more effective way to cope with desertification, because subsequent attempts to rehabilitate desertified areas are costly and tend to deliver limited results.

Desertification can also be avoided by reducing the stress on dryland ecosystems. This can be achieved in two ways. First, by introduction of alternative livelihoods that have less of an impact on dryland resources. These livelihoods benefit from the unique advantages of drylands: round-the-year available solar energy, attractive landscapes, and large wilderness areas. Second, by creation of economic opportunities in urban centers and areas outside drylands.

Scenarios for future development show that the desertified area is likely to increase, and the relief of pressures on drylands is strongly correlated with poverty reduction. There is *medium certainty* that population growth and increase in food demand will drive an expansion of cultivated land, often at the expense of woodlands and rangelands. This is likely to increase the spatial extent of desertified land.

The MA scenarios also show that coping with desertification and its related economic conditions will likely fare better when proactive management approaches are used. Proactive land and water management policies can help avoid the adverse impacts of desertification. These approaches may initially have a high cost due to technological development and deployment and may also have a slower rate of environmental improvement. Their long-term implementation may be facilitated by globalization trends through greater cooperation and resource transfer.

On the whole, combating desertification yields multiple local and global benefits and helps mitigate biodiversity loss and human-induced global climate change. Environmental management approaches for combating desertification, mitigating climate change, and conserving biodiversity are interlinked in many ways. Therefore, joint implementation of major environmental conventions can lead to increased synergy and effectiveness, benefiting dryland people.

Effectively dealing with desertification will lead to a reduction in global poverty. Addressing desertification is critical and essential for meeting the Millennium Development Goals successfully. Viable alternatives must be provided to dryland people to maintain their livelihoods without causing desertification. These alternatives should be embedded in national strategies to reduce poverty and in national action programs to combat desertification.

Children from Serdah village at the Khanasser valley in Syria

ICARDA

Key Questions on Desertification in the Millennium Ecosystem Assessment

1. *How is desertification related to ecosystem services and human well-being?*

Desertification is potentially the most threatening ecosystem change impacting livelihoods of the poor. Persistent reduction of ecosystem services as a result of desertification links land degradation to loss of human well-being.

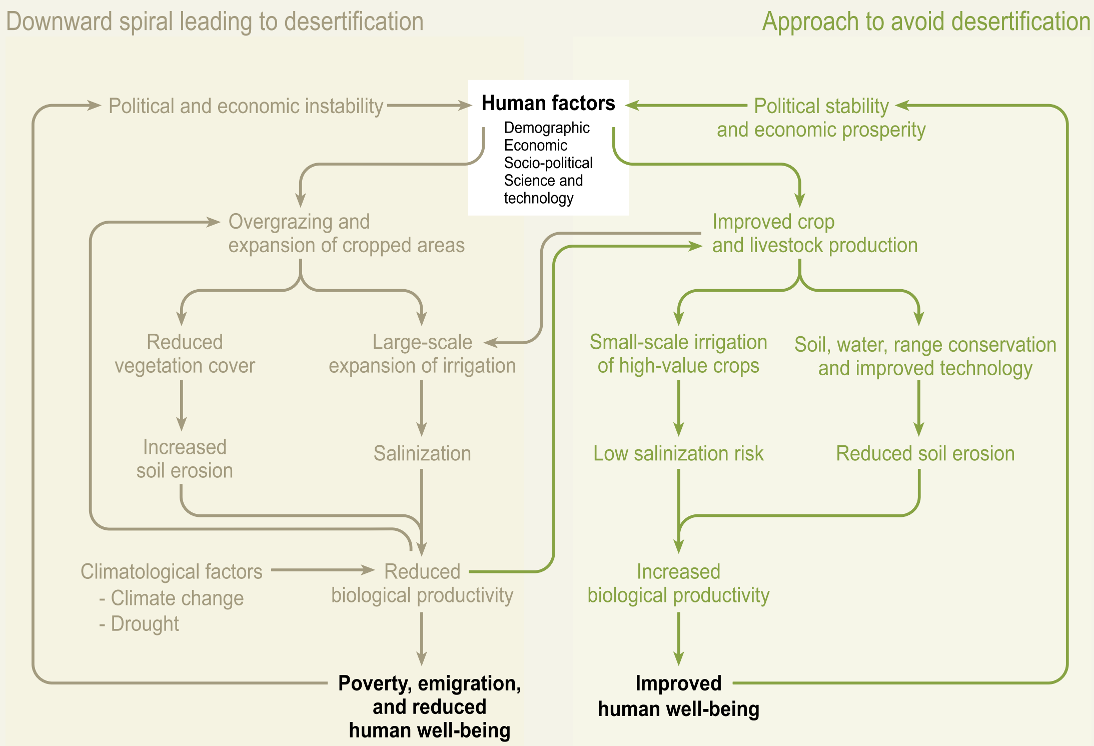
Interlinkages

The basic materials for a good life for most dryland people have their origin in biological productivity. More people in drylands than in any other ecosystem depend on ecosystem services for their basic needs. Crop production, livestock and dairy production, growth of fuelwood, and construction materials all depend on plant productivity, which in drylands is constrained by water availability. Thus it is the dryland climate that constrains viable livelihood opportunities. Practices like intensified cultivation in areas that do not have an adequate level of supporting services (soil fertility, nutrients, and water supply) thus require adjustments in management practices or costly imports of nutrients and water (C22.5).

Fluctuation in the supply of ecosystem services is normal, especially in drylands, but a persistent reduction in the levels of all services over an extended period constitutes desertification. Large inter-annual and longer-term climatic variations cause fluctuations in crop, forage, and water yields. When the resilience of a dryland ecosystem is impaired and it does not return to the expected levels of service supply after the stress is removed, a downward spiral of degradation—in other words, desertification—may occur. Many mechanisms linked to this phenomenon have been documented for drylands: excessive loss of soil, change in vegetation composition and reduction in vegetative cover, deterioration of water quality and reduction in available quantity, and changes in the regional climate system. A schematic description of the pathways that lead to desertification is provided on the left side of Figure 1.1. The intensity and impact of these mechanisms vary from place to place and change over time; they depend on the level of aridity and the varying pressure exerted by people on the ecosystem's resources (C22 Figure 22.7; SAfMA).

Figure 1.1. Schematic Description of Development Pathways in Drylands (C22 Figure 22.7)

This is a schematic graphic showing how drylands can be developed in response to changes in key human factors. The left side of the Figure shows developments that lead to a downward spiral of desertification. The right side shows developments that can help avoid or reduce desertification. In the latter case, land users respond to stresses by improving their agricultural practices on currently used land. This leads to increased livestock and crop productivity, improved human well-being, and political and economic stability. Both development pathways occur today in various dryland areas.



Source: Millennium Ecosystem Assessment

Measurement of persistent reduction in the capacity of ecosystems to supply services provides a robust and operational way to quantify land degradation and desertification. The international community, through the United Nations Convention to Combat Desertification, agreed to define desertification as land degradation in arid, semiarid, and dry subhumid lands. Land degradation is in turn defined as a persistent reduction of biological and economic productivity. It is therefore logical to measure productivity in terms of the "things that ecosystems provide that matter to people"—that is, ecosystem services. (See Table 1.1 for a list of key dryland ecosystem services.) Doing so makes degradation quantifiable in an operational way, since many of the ecosystem services are measurable and some are routinely monitored. Furthermore, such an approach is robust, because it is based on flow of services to a broad spectrum of people rather than a narrow range of beneficiaries (CF2, SAfMA).

The coping capacity of the affected population and the resilience of the ecosystem on which it depends determine the duration beyond which impaired services cause irreversible consequences. Dryland people have found ways of coping with periods of scarcity lasting up to several years. However, periods significantly longer than this can overwhelm their resources and adaptation strategies. Their capacity to cope with a shortage of services for extended periods can be increased by many factors, including demographic, economic, and policy factors (such as the ability to migrate to unaffected areas) and the time that has elapsed since the last stress period (C6).

A downward spiral of desertification may occur but is not inevitable, as shown on the right side of Figure 1.1. Understanding the location-specific interaction of socioeconomic and biophysical processes is critical. Some earlier explanations of irreversible desertification may have their origin in two fallacies. First, the time scale over which desertification evaluations are conducted is often too short, and reliable long-term extrapolations cannot be obtained. It is also important to consider continuous changes in dryland processes resulting from climatic factors and human intervention. Second, the spatial scale of assessments is either too large to effectively capture local phenomena or too local to provide a regional or global perspective. For example, desertification assessments rely on evaluation of national, regional, and continental soil surveys, on models of carrying capacity, on experimental plot studies, on expert opinion, and on nutrient balance models. While each of these methods is sound in its own right, the findings cannot simply be scaled up or down in time and space (C22.4.1).

Degradation is possible and observed in hyper-arid areas, which are not formally included within the UNCCD. The hyper-arid zone does not fall within the scope of the convention based on the argument that deserts are naturally low in productivity and cannot be further desertified. However, even hyper-arid areas have measurable levels of ecosystem service provision and support a human population with low density but significant numbers. Desertification has also been observed in hyper-arid areas, where mechanisms of degradation are similar to those in other dryland areas (C22.4.1).

Inland water, urban, cultivated, and other systems are integral parts of drylands and thus are critically linked to desertification processes. There are many systems embedded within drylands that are essential for the viability of the system as a whole and for livelihoods based on drylands. (In the MA, "system" is used to

Table 1.1. Key Dryland Ecosystem Services (C22.2)

Provisioning Services *Goods produced or provided by ecosystems*	**Regulating Services** *Benefits obtained from regulation of ecosystem processes*	**Cultural Services** *Nonmaterial benefits obtained from ecosystems*
■ provisions derived from biological productivity: food, fiber, forage, fuelwood, and biochemicals ■ fresh water	■ water purification and regulation ■ pollination and seed dispersal ■ climate regulation (local through vegetation cover and global through carbon sequestration)	■ recreation and tourism ■ cultural identity and diversity ■ cultural landscapes and heritage values ■ indigenous knowledge systems ■ spiritual, aesthetic, and inspirational services

Supporting Services *Services that maintain the conditions for life on Earth*
■ soil development (conservation, formation) ■ primary production ■ nutrient cycling

describe reporting units that are ecosystem-based but at a level of aggregation far higher than usually applied to ecosystems. The system also includes the social and economic elements. For example, the MA refers to "forest systems," "cultivated systems," "mountain systems," "urban systems," and so on. Systems thus defined are not mutually exclusive, and are permitted to overlap spatially or conceptually.)

In particular, the inland freshwater ecosystems within drylands—rivers, lakes, impoundments, wetlands, and so on—with their high potential for providing ecosystem services are of critical importance. Cultivated lands are a substantial part of the dryland landscape; about 44% of all cultivated systems worldwide are located within drylands, especially in the dry subhumid areas. (See Figure 1.2.) Conversion of rangelands to cultivated lands, especially in arid and semiarid drylands, leads to trade-offs in long-term sustainability of services and livelihood generation for people. Although urban systems occupy a relatively small fraction (about 2%) of the area of drylands, they contain a large and rapidly increasing fraction (nearly 45%) of the dryland population. Significant fractions of coastal (9%) and mountain (33%) systems are classified as drylands, highlighting the need for integrated land and water management that gives due consideration to dryland perspectives (C26.1.2., C27).

Manifestations of Desertification

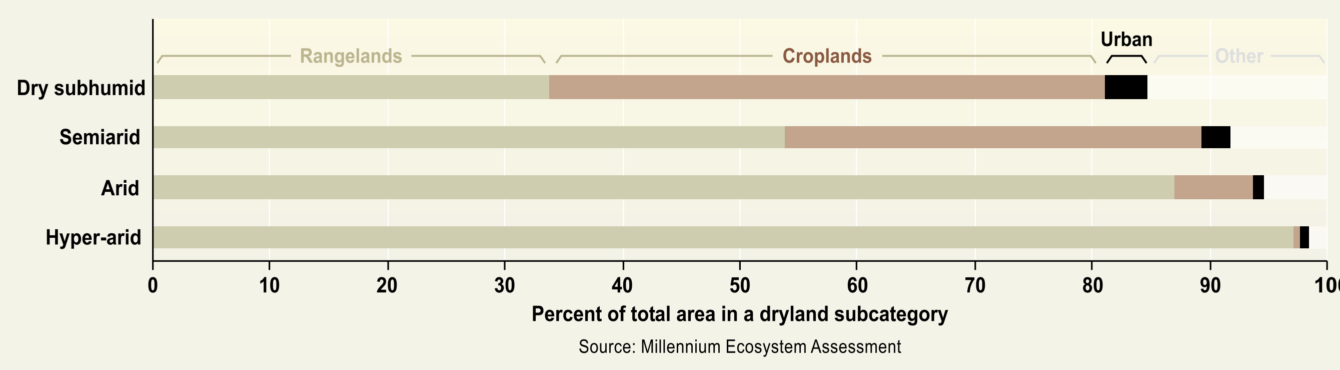
The manifestations of desertification are apparent in all categories of ecosystem services: provisioning, regulating, cultural, and supporting. Some of these services are typically measured and quantified, such as food, forage, fiber, and fresh water; others may be inferred or implied through qualitative analysis. As indicated earlier, management approaches that prevent, reduce, or reverse these manifestations of desertification are available and practiced (C22.2).

In desertified areas, people have responded to reduced land productivity and income by either increased use of other relatively marginal land (not yet degraded but having lower productivity) or by transforming more rangeland to cultivated land. Since policies to promote alternative livelihood opportunities are commonly not in place, migration to unaffected areas subsequently occurs. Initially it is from rural to urban areas, and then to locations of greater economic opportunity in other countries. These migrations sometimes exacerbate urban sprawl and can bring about internal and cross-boundary social, ethnic, and political strife (C22.3.1).

Transformation of rangelands and sylvo-pastoral dryland systems to croplands increases the risk of desertification due to increased pressure on the remaining rangelands or to the use of unsustainable cultivation practices. Although rangelands are resilient under traditional mobile grazing practices—commonly called transhumance—in response to seasonal changes, reduced transhumance leads to overgrazing and rangeland degradation. Removal of the rangeland vegetation cover takes place both by overgrazing of forage and by transforming rangelands to cultivated systems worldwide. Removal of vegetation cover when combined with unsustainable soil and water management practices in the converted rangelands brings about soil erosion, soil structure change, and soil fertility decline. Between 1900 and 1950, approximately 15% of dryland rangelands were converted to cultivated systems to better capitalize on the food provisioning service; a somewhat faster conversion has taken place in the last five decades during the Green Revolution (C22.ES, R6.2.2, C12.2.4).

In many semiarid areas, there is a progressive shift occurring from grassland to shrubland that exacerbates soil erosion. During the second half of the nineteenth century, large-scale commercial stockbreeding quickly spread over the semiarid drylands of North and South America, South Africa, and Australia. Both the kind of imported herbivore and type of grazing management (including fire prevention) were not adjusted to the semiarid ecosystems. The resulting disturbance was therefore a "transition trigger" that, combined with drought events, led to a progressive dominance of shrubs over grass (sometimes called "bush encroachment"). The transition from land fully covered by grasses to one covered by scattered bushes creates greater bare soil surfaces, which encourages increased runoff velocity, resulting in higher soil erosion (C22.4.1, R6.3.7).

Figure 1.2. Land Uses in Drylands



2. *Who is affected by desertification?*

Desertification occurs on all continents except Antarctica and affects the livelihoods of millions of people, including a large proportion of the poor in drylands. Assessments of the extent of desertification vary, but even by conservative estimates it ranks among today's greatest environmental challenges with serious local and global impacts.

Geographical Extent of Desertification

Desertification is occurring in drylands all over the world. Estimates for total global dryland area affected by desertification vary significantly, depending on the calculation method and on the type of land degradation included in the estimate (C22.4.1).

Despite the importance of desertification, only three exploratory assessments of the worldwide extent of land degradation are available. (See Key Question 7 for more on the specific limitations of each study.)

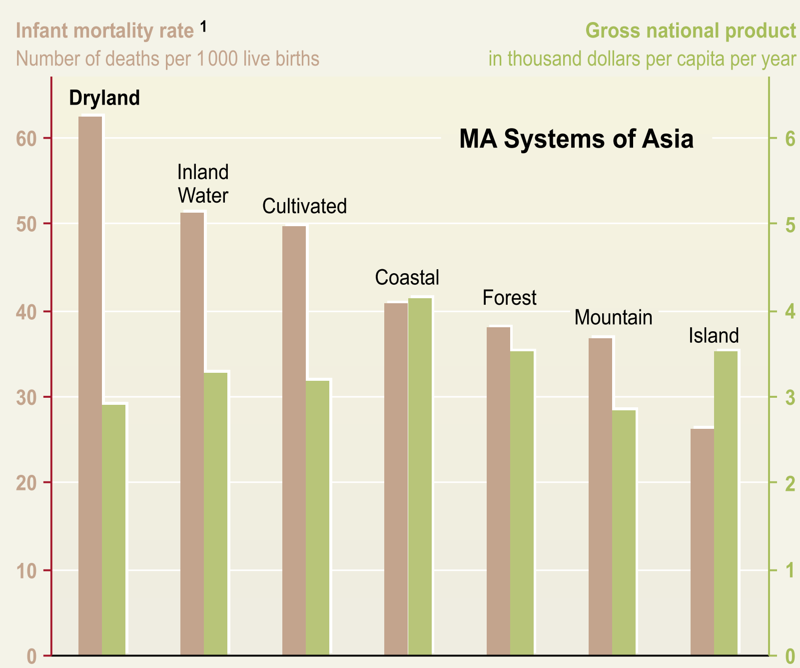
- The most well known study is the Global Assessment of Soil Degradation from 1991 that estimated soil degradation based on expert opinion. It reported that 20% of the drylands (excluding hyper-arid areas) were suffering from human-induced soil degradation.
- Another estimate from the early 1990s, based primarily on secondary sources, reported 70% of drylands (excluding hyper-arid areas) were suffering from soil and or vegetation degradation.
- A partial-coverage assessment from 2003, developed as a desk study from partly overlapping regional data sets and remote sensing data, estimated that 10% of global drylands (including hyper-arid areas) are degraded.

Given the limitations and problems with each of the underlying data sets, the need for a better assessment is underscored. The actual extent of desertified area may lie between the figures reported by GLASOD and the 2003 study. That is, some 10–20% of drylands are already degraded (*medium certainty*). Based on these estimates, the total area affected by desertification is between 6 million and 12 million square kilometers. It follows that based on the total number of people threatened by desertification, this ranks among the greatest contemporary environmental problems (C22.3.1, C22.4.1).

Poverty and Vulnerability of the Affected Population

Dryland populations, at least 90% of whom live in developing countries, on average lag far behind the rest of the world in human well-being and development indicators. Compared with other systems studied in the MA, dryland populations suffer from the poorest economic conditions. The GNP per capita of OECD countries exceeds that of developing dryland countries almost by an order of magnitude. Similarly, the average infant mortality rate (about 54 per 1,000) for all dryland developing countries exceeds that for non-dryland countries (forests, mountains, islands, and coastal areas) by 23% or more. The difference is even starker—10 times higher—when compared with the average infant mortality rate in industrial countries. Two key indicators of human well-being in Asia are compared in Figure 2.1, in which drylands have the lowest GNP per capita and the highest infant mortality rates among the MA systems. It is found that the relatively low rate of water provisioning in drylands limits access to clean drinking water and adequate sanitation, leading to poor health (C22.ES, C22.6).

Figure 2.1. Comparison of Infant Mortality and GNP per Person in Drylands and Other MA Systems in Asia (C22 Figure 22.12)



[1] Number of children less than one year old dying in a year, per 1000 live births during that year

Source: Millennium Ecosystem Assessment

Women often play a key role in water management in drylands (Mauritania)

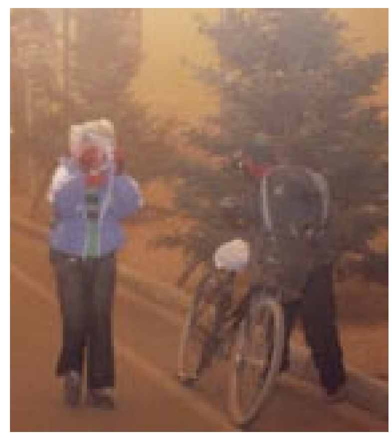
The low level of human well-being and high poverty of dryland populations vary according to level of aridity and global region. This is further exacerbated by high population growth rates in drylands. For example, the population in drylands grew at an average rate of 18.5% during the 1990s—the highest growth rate of any MA system. A number of policy factors also contribute to the poor human well-being, such as political marginalization and the slow growth of health and education infrastructure, facilities, and services. The uneven level of these driving factors in various locations and at different times has diverse societal impacts across drylands. The worst situations can be found in the drylands of Asia and Africa; these regions lag well behind drylands in the rest of the world. (C22.6.2, C6.6).

Dryland populations are often socially and politically marginalized due to their impoverishment and remoteness from centers of decision-making. This holds true even in some industrial countries. As a consequence, these dryland populations are frequently unable to play a significant role in political decision-making processes. Their marginalization leads to reduced human security and increased vulnerability to factors of change, like drought (C22.6).

Regional and Global Consequences of Desertification beyond Drylands

Desertification has environmental impacts at the global and regional scale. Affected areas may sometimes be located thousands of kilometers away from the desertified areas. Desertification-related processes such as reduction of vegetation cover, for instance, increase the formation of aerosols and dust. These, in turn, affect cloud formation and rainfall patterns, the global carbon cycle, and plant and animal biodiversity. For example, visibility in Beijing is often adversely affected by dust storms originating in the Gobi Desert in springtime. Large dust storms emanating from China affect the Korean peninsula and Japan and are observed to even have an impact on North American air quality.

An increase in desertification-related dust storms is widely considered to be a cause of ill health (fever, coughing, and sore eyes) during the dry season. Dust emanating from the East Asian region and the Sahara has also been implicated in respiratory problems as far away as North America and has affected coral reefs in the Caribbean. (Dust storms can also have positive impacts, however; for example, air-transported dust deposits from Africa are thought to improve soil quality in the Americas). Finally, reduction of vegetation cover in drylands leads to destructive floods downstream and excessive clay and silt loads in water reservoirs, wells, river deltas, river mouths, and coastal areas often located outside the drylands (C22.5.2, C14 Box 14.4, C12.2.4, R11.3.2, R11.1.3).



A couple walks home during a dust storm in Xinlinhot (Inner Mongolia), P.R. China

The societal and political impacts of desertification also extend to non-dryland areas. Droughts and loss of land productivity are predominant factors in movement of people from drylands to other areas, for example (*medium certainty*). An influx of migrants may reduce the ability of the population to use ecosystem services in a sustainable way. Such migration may exacerbate urban sprawl and by competing for scarce natural resources bring about internal and cross-boundary social, ethnic, and political strife. Desertification-induced movement of people also has the potential of adversely affecting local, regional, and even global political and economic stability, which may encourage foreign intervention (C22.ES, C22.1.3, C22.6.1, C22.6.2).

3. *What are the major causes of desertification?*

Desertification is caused by a combination of factors that change over time and vary by location. These include indirect factors such as population pressure, socioeconomic and policy factors, and international trade as well as direct factors such as land use patterns and practices and climate-related processes.

Desertification is taking place due to indirect factors driving unsustainable use of scarce natural resources by local land users. This situation may be further exacerbated by global climate change. Desertification is considered to be the result of management approaches adopted by land users, who are unable to respond adequately to indirect factors like population pressure and globalization and who increase the pressure on the land in unsustainable ways. This leads to decreased land productivity and a downward spiral of worsening degradation and poverty (as illustrated in Figure 1.1). Where conditions permit, dryland populations can avoid degradation by improving their agricultural practices and enhancing pastoral mobility in a sustainable way. On the whole, the interaction between climatic factors and human responses can create a range of different outcomes. (See the discussion of MA scenarios in Key Question 4.) To counter the problems effectively, it is important—but difficult—to distinguish between those resulting from the natural conditions of dryland ecosystems and those caused by unsustainable management practices as well as broader economic and policy factors (C22.3.1).

Social, Economic, and Policy Factors

Policies leading to unsustainable resource use and lack of supportive infrastructure are major contributors to land degradation. Conversely, this makes public policies and physical infrastructure useful intervention points. Thus agriculture can play either a positive or a negative role, depending on how it is managed. This in turn depends on the socioeconomic resources available, the policies adopted, and the quality of governance. Local institutions, such as community-based land-use decision-making bodies and social networks, can contribute to preventing desertification by allowing land users to manage and use ecosystem services more effectively through enhanced access to land, capital, labor, and technology (C22.6.4).

Policies to replace pastoralism with sedentary cultivation in rangelands can contribute to desertification. Policies and infrastructure that promote farming in rangelands that cannot sustain viable cropping systems contribute to desertification. The majority of dryland areas (65%) are rangelands that are more suited to sustainable pastoralism than crop production. For example, nomadic pastoralism is a rangeland management practice that over the centuries has proved to be sustainable and suited to the ecosystem carrying capacity. Sedentarization of nomads in marginal drylands and other limitations to their transboundary movement lead to desertification because they reduce people's ability to adjust their economic activities in the face of stresses such as droughts (R6.2.2, C22.3.2).

Land tenure practices and policies that encourage land users to overexploit land resources can be important contributors to desertification. When farmers and herders lose control or long-term security over the land they use, the incentives for maintaining environmentally sustainable practices are lost. Problems of water scarcity, groundwater depletion, soil erosion, and salinization have all been recognized as outcomes of deeper policy and institutional failures. Security of tenure does not necessarily imply private property rights; many long-established collective and community-based management practices have operated quite effectively. In successful communal systems, greater transparency and fairness in the allocation of resources to all stakeholders is essential. Private land tenure systems in drylands have been less successful in ensuring that pastoralists have access to various ecosystem services such as provisioning of water and pasture (C22.3.2, R17.3).

Globalization Phenomena

Many ongoing processes of globalization amplify or attenuate the driving forces of desertification by removing regional barriers, weakening local connections, and increasing the interdependence among people and between nations. Globalization can either contribute to or help prevent desertification, but it creates stronger links between local, national, sub-regional, regional, and global factors related to desertification. Studies have shown that trade liberalization, macroeconomic reforms, and a focus on raising production for exports can lead to desertification. In other cases, enlarged markets can also contribute to successful agricultural improvements. For example, a large share of the European Union flower markets is supplied with imports from dryland countries (such as Kenya and Israel) (C22.3.2).

Global trade regimes and linked government policies influence food production and consumption patterns significantly and affect directly or indirectly the resilience of dryland ecosystems. Improved access to agricultural inputs (like fertilizers, pesticides, and farm machinery) and export markets typically boosts productivity. Opportunities to gain access to international markets are conditioned by international trade and food safety regulations and by a variety of tariff and nontariff barriers. Selective production and export subsidies, including those embodied in the European Union's Common Agricultural Policy and the U.S. farm bill, stimulate overproduction of many food crops in those countries. Such distortions to international food markets drive down prices and have often seriously undermined the livelihoods of food producers in many poorer countries. In 2002, industrial countries spent more than $300 billion on their agricultural sectors—about six times the amount allocated to foreign assistance. Conversely, removal of international trade barriers without moderating national policies may also encourage unsustainable agricultural practices (C8.ES, C8.4.1).

Land Use Patterns and Practices

Land use changes are responses to changes in the provision of ecosystem services, and they also cause changes in this provision. Historically, dryland livelihoods have been based on a mixture of hunting, gathering, cropping, and animal husbandry. This mixture varied in composition with time, place, and culture. The harsh and unpredictable climate combined with changing socioeconomic and political factors has forced dryland inhabitants to be flexible in land use. Population pressure, however, has led to a growing tension between two main land uses: pastoral rangeland and cultivated land use. In some areas, this led to intercultural conflicts and desertification as herders and farmers claim access to and use of the same land. In other cases, it led to synergistic interaction and integration between the two land uses, with herders cultivating more land, farmers holding more livestock, and an increased exchange of services between the two groups. The synergistic behavior among pastoralists and farmers is driven by both governmental policies and favorable market opportunities; the two groups cooperate when it is in their own vested interests (see Key Question 5) (C22.5.1).

Irrigation has led to increased cultivation and food production in drylands, but in many cases this has been unsustainable without extensive public capital investment. Large-scale irrigation has also resulted in many environmental problems—such as waterlogging and salinization, water pollution, eutrophication, and unsustainable exploitation of groundwater aquifers—that degrade the drylands' service provisioning. In such irrigation approaches, rivers are often disconnected from their floodplains and other inland water habitats, and groundwater recharge has been reduced. These human-induced changes have in turn had an impact on the migratory patterns of fish species and the species composition of riparian habitat, opened up paths for exotic species, changed coastal ecosystems, and contributed to an overall loss of freshwater biodiversity and inland fishery resources. On the whole, there is a decline in biodiversity and services provided by inland water systems in drylands, which further exacerbates desertification (C20.ES).

Frequent and intensive fires can be an important contributor to desertification, whereas controlled fires play an important role in the management of dryland pastoral and cropping systems. In both cases, the use of fire promotes the service of nutrient cycling and makes nutrients stored in the vegetation available for forage and crop production. For example, dryland pastoralists use controlled fire to improve forage quality, and dryland farmers use fire to clear new land for cultivation. Conversely, fires can be an important cause of desertification in some regions when they affect natural vegetation. Excessive intensity and frequency can lead to irreversible changes in ecological processes and, ultimately, to desertification. The consequences of such changes include the loss of soil organic matter, erosion, loss of biodiversity, and habitat changes for many plant and animal species (C22.3.3, C22.4.2, C22.5.1).

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Water erosion and reduced soil conservation in semi-arid Burkina Faso negatively affects ecosystem services.

4. *How will different future development paths affect desertification?*

Population growth and increase in food demand will drive expansion and intensification of cultivated lands. If unchecked, desertification and degradation of ecosystem services in drylands will threaten future improvements in human well-being and possibly reverse gains in some regions.

Scenarios Approach

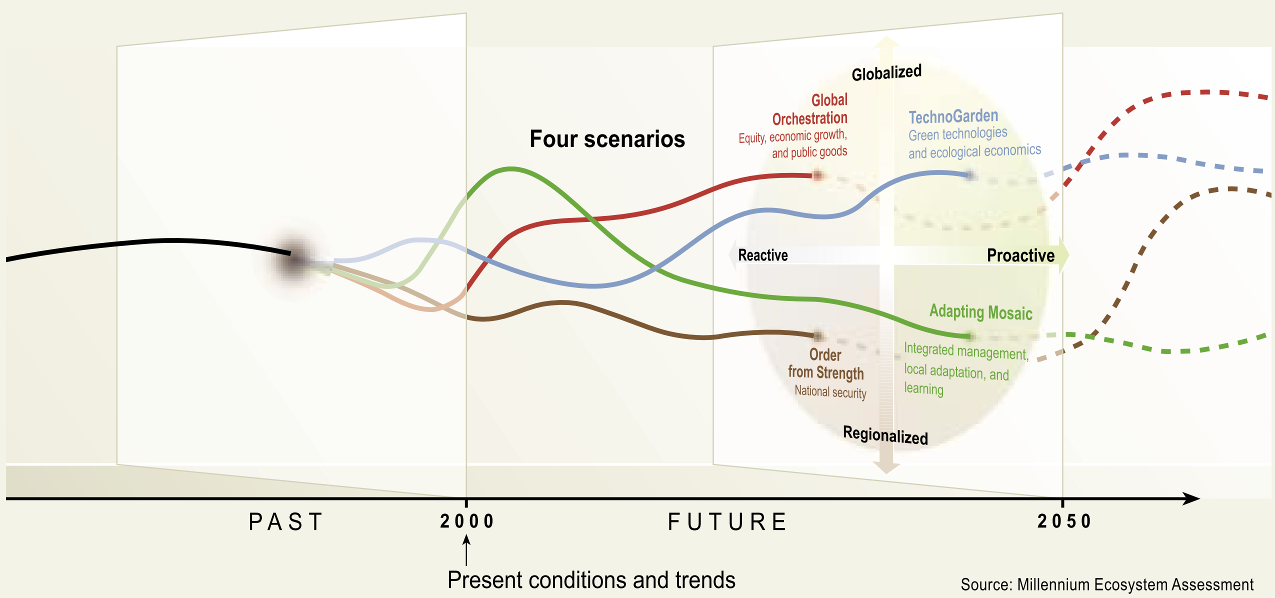
A better understanding of development options and management paradigms for the future can be achieved through scenario development. To make sound choices, we need to understand the consequences of alternative actions or inactions. This is facilitated by creating scenarios that are plausible and that tell stories about how the future might unfold, in both words and numbers. The MA scenarios were developed using established, peer-reviewed global models for quantitative projections (such as land use change, carbon emissions, water withdrawals, and food production) and qualitative analysis. The quantitative models did not address thresholds, risk of extreme events, or impacts of large or irreversible changes in ecosystem services. Scenarios are not forecasts, projections, or predictions. They are intended to provoke questions, widen perspectives, illuminate key issues, and therefore support better-informed and rational decision-making. In so doing, they attempt to reduce uncertainty about future outcomes of management approaches (S6, S2).

The MA generated four scenarios that explore how combinations of policies and practices may affect changes in ecosystem services, human well-being, and desertification. (See Box 4.1.) The scenarios were developed with a focus on the likely conditions in 2050, although they include some information through the end of the century. They specifically address desertification and human well-being in drylands. These four scenarios were not

Box 4.1. Millennium Ecosystem Assessment Scenarios

The MA developed four scenarios to explore plausible futures for ecosystems and human well-being. The scenarios explored two global development paths (globalized versus regionalized societies and economies) and two different approaches for ecosystem management (reactive and proactive). In reactive management, problems are addressed only after they become obvious, whereas proactive management attempts to maintain ecosystem services for the long term. These scenarios were selected to explore contrasting transitions of global society up to the year 2050.

- **Globalized world with reactive ecosystem management;** with an emphasis on equity, economic growth, and public goods such as infrastructure and education (also called *Global Orchestration*);
- **Regionalized world with reactive ecosystem management;** with an emphasis on security and economic growth (also called *Order from Strength*);
- **Regionalized world with proactive ecosystem management,** with an emphasis on local adaptations and learning (also called *Adapting Mosaic*); and
- **Globalized world with proactive ecosystem management,** and an emphasis on green technologies (also called *TechnoGarden*).



Source: Millennium Ecosystem Assessment

designed to explore the entire range of possible futures; other scenarios could be developed with either more optimistic or more pessimistic outcomes (S8 Figure 8.5, S9).

Key Findings from the MA Scenarios

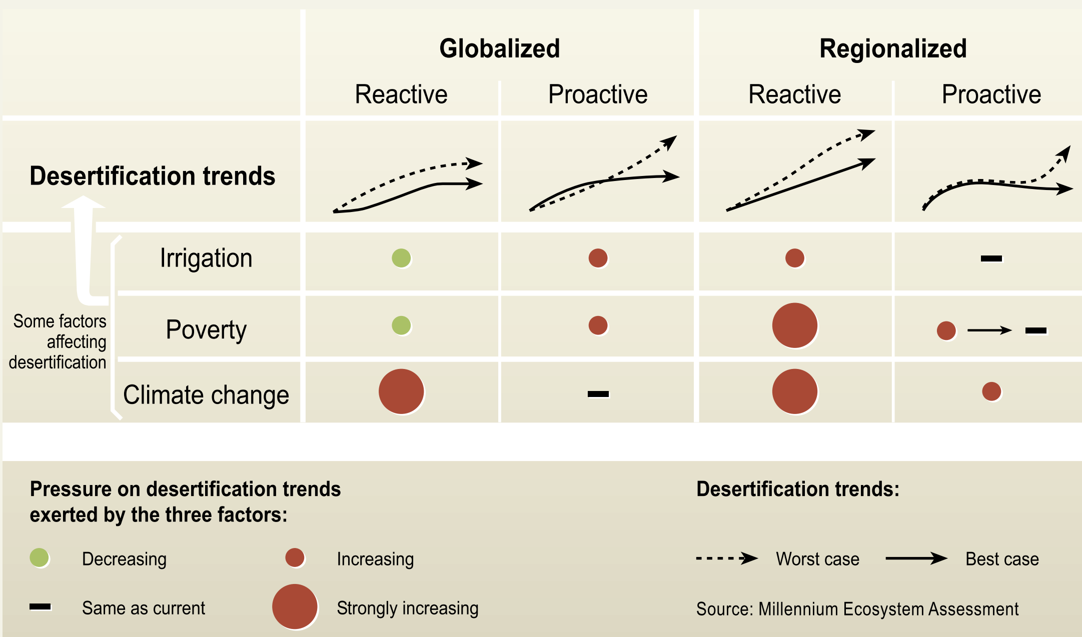
In all four scenarios, desertified area is likely to increase, though at different rates. Poverty and unsustainable land use practices continue to be the main factors driving desertification in the near future. The relief of pressures on drylands is strongly correlated with poverty reduction. Under all four MA scenarios, population growth and increase in food demand will drive an expansion of cultivated land, often at the expense of woodlands and rangelands. This is likely to increase the spatial extent of desertified land. No scenario indicates a reversal in the threat of desertification (S9, S8 Figure 8.5). (See Figure 4.1.)

In all the scenarios, climate change is linked to desertification, and the impacts of climate change vary according to region and the management approach adopted. Climate change is expected to affect the global hydrological cycle and local precipitation trends. The local manifestation of these global climate changes is strongly location-dependent. It is likely that extreme events will further intensify, bringing more floods and more droughts (S8 Figure 8.5, S14.4.4).

Coping with desertification and related economic conditions in drylands will likely fare better in a future where proactive management approaches are used. In a proactive approach, ecosystem management is aiming to be adaptive to changes and to make ecosystems more resilient, which is seen as also reducing the vulnerability of society to the disturbances caused by desertification. As a result, measures such as adaptations to climate change and non-expanding irrigation can jointly lead to

Figure 4.1. Key Desertification-related Findings of the MA Scenarios

Rates of change in the extent of desertified areas in the drylands: Solid lines indicate the best case; dashed lines indicate the worst case for desertification in each of the MA scenarios.



decelerated desertification rates. This approach might take some time to show its benefits, however, as the necessary changes in development and learning capacities first need to be further developed and improved. In contrast, under a reactive management regime, current pressures (climate change, overgrazing, and large-scale irrigation) on ecosystem services are likely to stay the same or intensify, leading to further desertification. The regionalized-reactive scenario demonstrates the greatest unsustainability of dryland development (S.SDM).

Globalization will not necessarily lead to increased desertification. Prospects for cooperation and resource transfers to support ecosystem management are better in this case due to the institutional reforms and the fast rate of technological development. In the globally proactive management scenario, policy reforms such as strengthening of property rights (either private or collective) as well as better integration of environmental issues lead to relatively less pressure in drylands. Market and policy failures can still pose risks of desertification, however. In contrast, in a fragmented world, the role of a global agreement is more limited either because of the diminished interest in resource transfers or because of the lack of interest beyond the national or regional boundaries (S14.ES, S14.4.3).

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A farmer in semi-arid Burkina Faso who works as a blacksmith during the dry season

Key Challenges for the Future

Persistent, substantial reduction in the provision of ecosystem services as a result of water scarcity, intensive use of services, and climate change is a much greater threat in drylands than in non-dryland systems. The greatest vulnerability is ascribed to sub-Saharan and Central Asian drylands. For example, in three key regions of Africa—the Sahel, Horn of Africa, and Southeast Africa—severe droughts occur on average once every 30 years. These triple the number of people exposed to severe water scarcity at least once in every generation, leading to major food and health crises. Unconditional, free supply of food or water to the vulnerable dryland people can have the unintended effect of increasing the risk of even larger breakdowns of ecosystem services. Local adaptation and conservation practices can mitigate some losses of dryland services, although it will be difficult to reverse the loss of food and water provision services and the supporting biodiversity (S.SDM, C20.6, C7.3.4).

The projected intensification of freshwater scarcity will cause greater stresses in drylands. If left unmitigated, these stresses will further exacerbate desertification. Water scarcity affects approximately 1–2 billion people today, most of them in drylands. This leads to overexploitation of surface and groundwater resources and eventually magnifies problems related to desertification. Freshwater availability in drylands is projected to be further reduced from the current overall average of 1,300 cubic meters per person per year. While this average figure masks great variations, it is already well below the lowest threshold of 2,000 cubic meters required for human well-being and sustainable development (C7.ES, C24.ES, C22.ES).

The prospects for implementing the UNCCD differ significantly under the four MA scenarios. Implementation will be the most difficult in a regionalized-reactive world, while prospects improve in a more globalized world and with proactive ecosystem management. The four MA scenarios give an indication of how effectively the UNCCD directives can be implemented by the affected countries when operating under broadly different management approaches. In a regionalized world with only reactive environmental management, the scope for global environmental agreements is rather poor. In this reactive management mode, desertification will likely increase further before its impacts—massive famines and environmental and hunger refugees—trigger a significant response. A globalized world provides a more favorable situation for implementation of the UNCCD at the global scale through facilitation in the flow of resources and technologies, but here too it will depend which kind of overall management approaches are favored (S14.4.3).

5. *How can we prevent or reverse desertification?*

Effective prevention of desertification requires both local management and macro policy approaches that promote sustainability of ecosystem services. It is advisable to focus on prevention, because attempts to rehabilitate desertified areas are costly and tend to deliver limited results.

Rationale

Major policy interventions and management approaches are needed to prevent and reverse desertification. Assessment of future scenarios shows that major interventions and shifts in ecosystem management will be needed to overcome challenges related to desertification. As recognized by the UNCCD, such interventions are to be implemented at local to global scales, with the active engagement of stakeholders and local communities. Improved information generation and access, as noted in the final section, will help create enabling conditions for this implementation (S14.4.2, C6.6).

Societal and policy responses vary according to the degree of desertification that a society faces. This intensity of responses needs to be reflected accordingly in National Action Programmes stipulated by the UNCCD and their subsequent implementation. In areas where desertification processes are at the early stages or are relatively minor, it is possible to arrest the process and restore key services in the degraded areas. The adverse impacts of desertification on dryland ecosystem services and limited success in rehabilitation demonstrate that it is more cost-effective to prevent desertification (C22.3.2, C22.6, R17).

Addressing desertification is critical and essential to meeting the Millennium Development Goals. The human well-being of dryland people, about 90% of whom are in developing countries, lags significantly behind other areas. Approximately half of the people worldwide who live below the poverty line live in drylands. The combination of high variability in ecosystem conditions in drylands and high levels of poverty leads to a situation where societies are vulnerable to a further decline in human well-being. Addressing desertification therefore facilitates eradication of extreme poverty and hunger, as envisioned in the MDGs. This also complements directly the policies to be included in NAPs to combat desertification (C22.ES).

Prevention

The creation of a "culture of prevention" can go a long way toward protecting drylands from the onset of desertification or its continuation. The culture of prevention requires a change in governments' and peoples' attitudes through improved incentives. Young people can play a key role in this process. Evidence from a growing body of case studies demonstrates that dryland populations, building on long-term experience and active innovation, can stay ahead of desertification by improving agricultural practices and enhancing pastoral mobility in a sustainable way. For example, in many areas of the Sahel region, land users are achieving higher productivity by capitalizing on improved organization of labor, more extensive soil and water conservation, increased use of mineral fertilizer and manure, and new market opportunities (C22.3.1).

Integrated land and water management are key methods of desertification prevention. All measures that protect soils from erosion, salinization, and other forms of soil degradation effectively prevent desertification. Sustainable land use can address human activities such as overgrazing, overexploitation of plants, trampling of soils, and unsustainable irrigation practices that exacerbate dryland vulnerability. Management strategies include measures to spread the pressures of human activities, such as transhumance (rotational use) of rangelands and well sites, stocking rates matched to the carrying capacity of ecosystems, and diverse species composition. Improved water management practices can enhance water-related services. These may include use of traditional water-harvesting techniques, water storage, and diverse soil and water conservation measures. Maintaining management practices for water capture during intensive rainfall episodes also helps prevent surface runoff that carries away the thin, fertile, moisture-holding topsoil. Improving groundwater recharge through soil-water conservation, upstream revegetation, and floodwater spreading can provide reserves of water for use during drought periods (C22.2.3, C22.4.3, C22.4.4, R6.2.2, R6.3.7).

Protection of vegetative cover can be a major instrument for prevention of desertification. Maintaining vegetative cover to protect soil from wind and water erosion is a key preventive measure against desertification. Properly maintained vegetative cover also prevents loss of ecosystem services during drought episodes. Reduced rainfall may be induced if vegetation cover is lost due to overcultivation, overgrazing, overharvesting of medicinal plants, woodcutting, or mining activities. This is usually coupled with the effect of reduced surface evapotranspiration and shade or increased albedo (C22.2.3, C22.2.2, C13 Box 13.1).

In the dry subhumid and semiarid zones, conditions equally favor pastoral and cropping land use. Rather than competitively excluding each other, a tighter cultural and economic integration between the two livelihoods can prevent desertification. Mixed farming practices in these zones, whereby a single farm household combines livestock rearing and cropping, allows a more efficient recycling of nutrients within the agricultural system. Such interactions can lower livestock pressure on rangelands through fodder cultivation and the provision of stubble to supplement livestock feed during forage scarcity (and immediately after, to allow plant regeneration) due to within- and between-years

climatic variability. At the same time, farmland benefits from manure provided by livestock kept on fields at night during the dry season. Many West African farming systems are based on this kind of integration of pastures and farmland (C22.2.6, R6.3.7).

Use of locally suitable technology is a key way for inhabitants of drylands at risk of desertification to work with ecosystem processes rather than against them. Applying a combination of traditional technology with selective transfer of locally acceptable technology is a major way to prevent desertification. Conversely, there are numerous examples of practices—such as unsustainable irrigation techniques and technologies and rangeland management, as well as growing crops unsuited to the agroclimatic zone—that tend to accelerate, if not initiate, desertification processes. Thus technology transfer requires in-depth evaluation of impacts and active participation of recipient communities (R.SDM, R17.2.4, R14.ES).

Local communities can prevent desertification and provide effective dryland resource management but are often limited by their capacity to act. Drawing on cultural history and local knowledge and experience, and reinforced by science, dryland communities are in the best position to devise practices to prevent desertification. However, there are many limitations imposed on the interventions available to communities, such as lack of institutional capacity, access to markets, and financial capital for implementation. Enabling policies that involve local participation and community institutions, improve access to transport and market infrastructures, inform local land managers, and allow land users to innovate are essential to the success of these practices. For example, a key traditional adaptation was transhumance for pastoral communities, which in many dryland locations is no longer possible. Loss of such livelihood options or related local knowledge limits the community's capacity to respond to ecological changes and heightens the risk of desertification (C22.ES, C22.6.4, R6.2.2, R17.3, R2.4.3).

Desertification can be avoided by turning to alternative livelihoods that do not depend on traditional land uses, are less demanding on local land and natural resource use, yet provide sustainable income. Such livelihoods include dryland aquaculture for production of fish, crustaceans and industrial compounds produced by microalgae, greenhouse agriculture, and tourism-related activities. They generate relatively high income per land and water unit in some places. Dryland aquaculture under plastic cover, for example, minimizes evaporative losses, and provides the opportunity to use saline or brackish water productively. Alternative livelihoods often even provide their practitioners a competitive edge over those outside the drylands, since they harness dryland features such as solar radiation, winter relative warmth, brackish geothermal water, and sparsely populated pristine areas that are often more abundant than in non-drylands. Implementation of such practices in drylands requires institution building, access to markets, technology transfer, capital investment, and reorientation of farmers and pastoralists (C22.4.4).

Desertification can also be avoided by creating economic opportunities in drylands urban centers and areas outside drylands. Changes in overall economic and institutional settings that create new opportunities for people to earn a living could help relieve current pressures underlying the desertification processes. Urban growth, when undertaken with adequate planning and provision of services, infrastructure, and facilities, can be a major factor in relieving pressures that cause desertification in drylands. This view is relevant when considering the projected growth of the urban fraction in drylands, which will increase to around 52% by 2010 and to 60% by 2030 (C22.5.2, C27.2.3).

Reversal of Land Degradation

The goal of rehabilitation and restoration approaches is to restore ecosystem services that have been lost due to desertification. This is achieved through a positive change in the interaction between people and ecosystems. Restoration is an alteration of a degraded site to reestablish a defined native ecosystem state and all its functions and services. Rehabilitation seeks to repair damaged or blocked parts or sectors of ecosystem functions, with the primary goal of regaining ecosystem productivity. Like the benefits of increased education or improved governance, the protection, restoration, and enhancement of ecosystem services tend to have multiple benefits (C2.2.3, CF.SDM).

Effective restoration and rehabilitation of desertified drylands require a combination of policies and technologies and the close involvement of local communities. Examples of measures to restore and rehabilitate include establishment of seed banks, restocking of soil organic matter and organisms that promote higher plant establishment and growth, and reintroduction of selected species. Other rehabilitation practices include investing in land through practices such as terracing and other counter-erosion measures, control of invasive species, chemical and organic nutrient replenishment, and reforestation. Policies that create incentives for rehabilitation include capacity building, capital investment, and supportive institutions. Community involvement in conceptualization, design, and implementation is essential for rehabilitation approaches. For example, many of the policies for combating desertification tried in the Sahel during the 1970s and 1980s failed because they did not involve local land managers (C22.3.2, R2.4.3).

ZAFAR ADEEL

Terracing prevents further gully erosion and stores surface runoff for olive production (Tunisia)

For desertified areas, rehabilitation strategies have a mix of positive and negative impacts on ecosystems, human well-being, and poverty reduction. The success of rehabilitation practices depends on the availability of human resources, capital for operation and maintenance, infrastructure development, the degree of dependence on external sources of technology, and cultural perceptions. Adequate access to these resources, combined with due consideration of the needs of local communities, can lead to successful rehabilitation of some ecosystem services and hence reduce poverty. Some success stories have been observed; for example, farmers in the Machakos (Kenya) restored degraded lands. This was achieved through access to markets, off-farm income, and technologies that increased land and labor productivity faster than population growth.

In cases where these conditions are not met, efforts to rehabilitate fail. For example, in response to the 1930s Dust Bowl in the United States, major policy interventions were introduced, including zoning laws for the most fragile areas, repurchases of submarginal private land, cash payments for leaving land fallow, and farm loans tied to approved land practices. These economic reforms, coupled with the migration of 1 million people in 1940–70, could not prevent the return of the problem as Dust Bowl II in the 1950s and Dust Bowl III in the 1970s. This demonstrates that restoring degraded dryland services may be difficult even with major policy and technological interventions (C5.ES, C5 Box 5.1, C22.3.2).

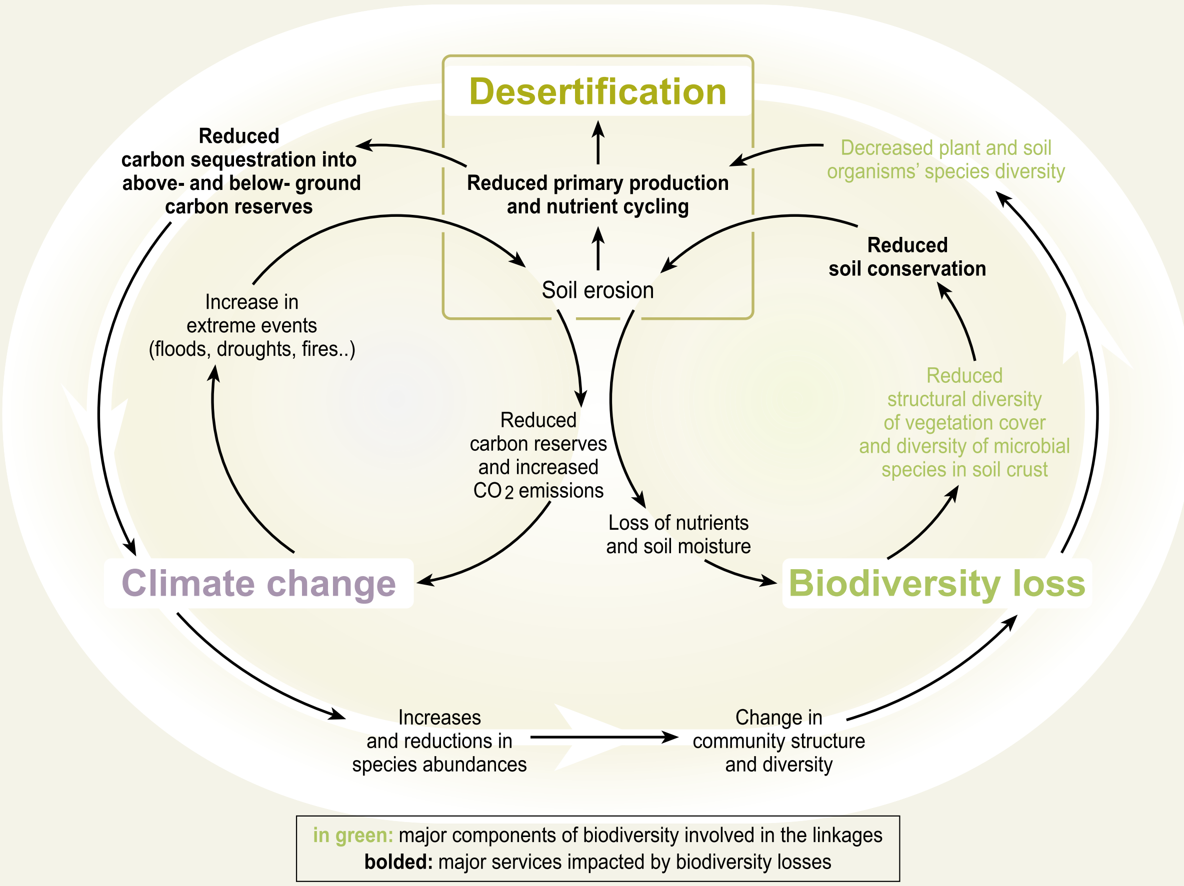
6. *What are the linkages among desertification, global climate change, and biodiversity loss?*

Desertification is associated with biodiversity loss and contributes to global climate change through loss of carbon sequestration capacity and an increase in land-surface albedo.

Biological diversity is involved in most services provided by dryland ecosystems and is adversely affected by desertification. Most important, vegetation and its diversity of physical structure are instrumental in soil conservation and in the regulation of rainfall infiltration, surface runoff, and local climate. Different plant species produce physically and chemically different litter components and, together with a diverse community of micro- and macro-decomposers, contribute to soil formation and nutrient cycling. The species diversity of vegetation supports both livestock and wildlife. All plants support primary production that ultimately provides food, fiber, and fuelwood and that sequesters carbon, thus regulating global climate. Excessive exploitation of vegetation leads to losses in primary production and hence also to reduced carbon sequestration. It is the disruption of the interlinked services jointly provided by dryland plant biodiversity that is a key trigger for desertification and its various manifestations, including the loss of habitats for biodiversity (C22.2.5, C4.1). (See Figure 6.1.)

Figure 6.1. Linkages and Feedback Loops among Desertification, Global Climate Change, and Biodiversity Loss

The major components of biodiversity loss (in green) directly affect major dryland services (in bold). The inner loops connect desertification to biodiversity loss and climate change through soil erosion. The outer loop interrelates biodiversity loss and climate change. On the top section of the outer loop, reduced primary production and microbial activity reduce carbon sequestration and contribute to global warming. On the bottom section of the outer loop, global warming increases evapotranspiration, thus adversely affecting biodiversity; changes in community structure and diversity are also expected because different species will react differently to the elevated CO_2 concentrations.



Source: Millennium Ecosystem Assessment

Desertification affects global climate change through soil and vegetation losses. Dryland soils contain over a quarter of all of the organic carbon stores in the world as well as nearly all the inorganic carbon. Unimpeded desertification may release a major fraction of this carbon to the global atmosphere, with significant feedback consequences to the global climate system. It is estimated that 300 million tons of carbon are lost to the atmosphere from drylands as a result of desertification each year (about 4% of the total global emissions from all sources combined) (*medium certainty*) (C22.5.3, C12.2.4).

The effect of global climate change on desertification is complex and not sufficiently understood. Climate change may adversely affect biodiversity and exacerbate desertification due to increase in evapotranspiration and a likely decrease in rainfall in drylands (although it may increase globally). However, since carbon dioxide is also a major resource for plant productivity, water use efficiency will significantly improve for some dryland species that can favorably respond to its increase. These contrasting responses of different dryland plants to the increasing carbon dioxide and temperatures may lead to changes in species composition and abundances. Therefore, although climate change may increase aridity and desertification risk in many areas (*medium certainty*), the consequent effects on services driven by biodiversity loss and, hence, on desertification are difficult to predict (C22.5.3).

Due to strongly interlinked issues and policies between desertification, biodiversity loss, and climate change, joint implementation of the UNCCD, the Convention on Biological Diversity, and the Framework Convention on Climate Change can yield multiple benefits. Environmental management approaches for combating desertification, conserving biodiversity, and mitigating climate change are linked in numerous ways. Typically, these issues were dealt with separately by different conventions and policy fora, which were negotiated and implemented independently of one another, often by different departments or agencies within national governments. Thus, joint implementation and further strengthening of ongoing collaborations can increase synergies and effectiveness (R13.2, R15.3.3).

7. *How can we better understand the significance of desertification?*

Understanding the significance of desertification is constrained by many uncertainties. Information gathering—long-term remote sensing and sub-national biophysical and socioeconomic data—enables development of a baseline and indicators of desertification. Such information helps us reduce uncertainties regarding the relationships among desertification, climate change, biodiversity, ecosystem services, and human well-being.

Monitoring, Baseline Development, and Assessment

Without a scientifically robust and consistent baseline of desertification, identifying priorities and monitoring the consequences of actions are seriously constrained. Three assessments of the global extent of land degradation give different figures: the UNEP/GLASOD report (1990), research work from Dregne and Chou in 1992, and a more recent assessment prepared for the MA by Lepers *et al.* in 2003 (C22.4.1). These assessments of land degradation all have major weaknesses. GLASOD was based on expert opinion only, with variability in quality and quantification. Dregne and Chou's assessment was based on secondary sources, which they qualified as follows: "The information base upon which the estimates in this report were made is poor. Anecdotal accounts, research reports, travelers' descriptions, personal opinions, and local experience provided most of the evidence for the various estimates." The most recent assessment by Lepers *et al.* has the benefit of combining multiple sources of information but it did not have complete spatial coverage and was limited to 62% of drylands, with some areas relying on a single data set. That assessment was qualified as "an exercise of compilation of data from a variety of sources, with different scales, legends, definitions, etc. We have done our best to standardize but, still, there are many inconsistencies and gaps." The shortcomings of these available assessments point to the need for a systematic global monitoring program, leading to development of a scientifically credible, consistent baseline of the state of desertification (C22.4.1).

Integrated use of satellite-based remote sensing or aerial photographs with ground-based observations can provide consistent, repeatable, cost-effective data on vegetation cover. Drylands lend themselves readily to remote sensing because they are mostly cloud-free and hence a wide range of images are available. Continuity of observations is required to account for the high interannual variability of dryland ecosystem services. Valid interpretation of remote sensing imagery for desertification requires careful calibration and validation against ground measurements (such as vegetation cover, biological productivity, evapotranspiration, soil fertility, and compaction and erosion rates). Access to affordable satellite imagery, particularly in developing countries, is critical for effectively undertaking such integrated uses (S7.3.3).

Long-term monitoring is needed to distinguish between the role of human actions and climate variability in vegetation productivity. Impacts of human activities (such as overgrazing or soil salinization) and climatic variables (such as interannual variability in rainfall and drought events) on vegetation productivity are difficult to distinguish. One example of this is the repeated droughts and famine in the Sahel region. (See Box 7.1.) Quantifying such impacts requires an established baseline of vegetation productivity against which changes can be assessed. Such a baseline is often not available and is further complicated by year-to-year and even decade-to-decade fluctuations (C2.2.1).

Understanding the impacts of desertification on human well-being requires that we improve our knowledge of the interactions between socioeconomic factors and ecosystem conditions. The combination of factors affecting human well-being varies by location and aspect, as demonstrated by the example in Box 7.1. Health outcomes, for example, are the combined result of ecosystem condition, access to health care, economic status, and many other factors. A small increase in food prices resulting from lower yields will affect the well-being of many people. Tracing such impacts is often difficult, particularly in macro-scale analyses where the impacts of ecosystem change are often hidden by aggregation of data or hampered by lack of information. Analyses linking well-being and ecosystem condition are most easily carried out at a local scale, where the linkages can be most clearly identified (C2.ES).

FAO

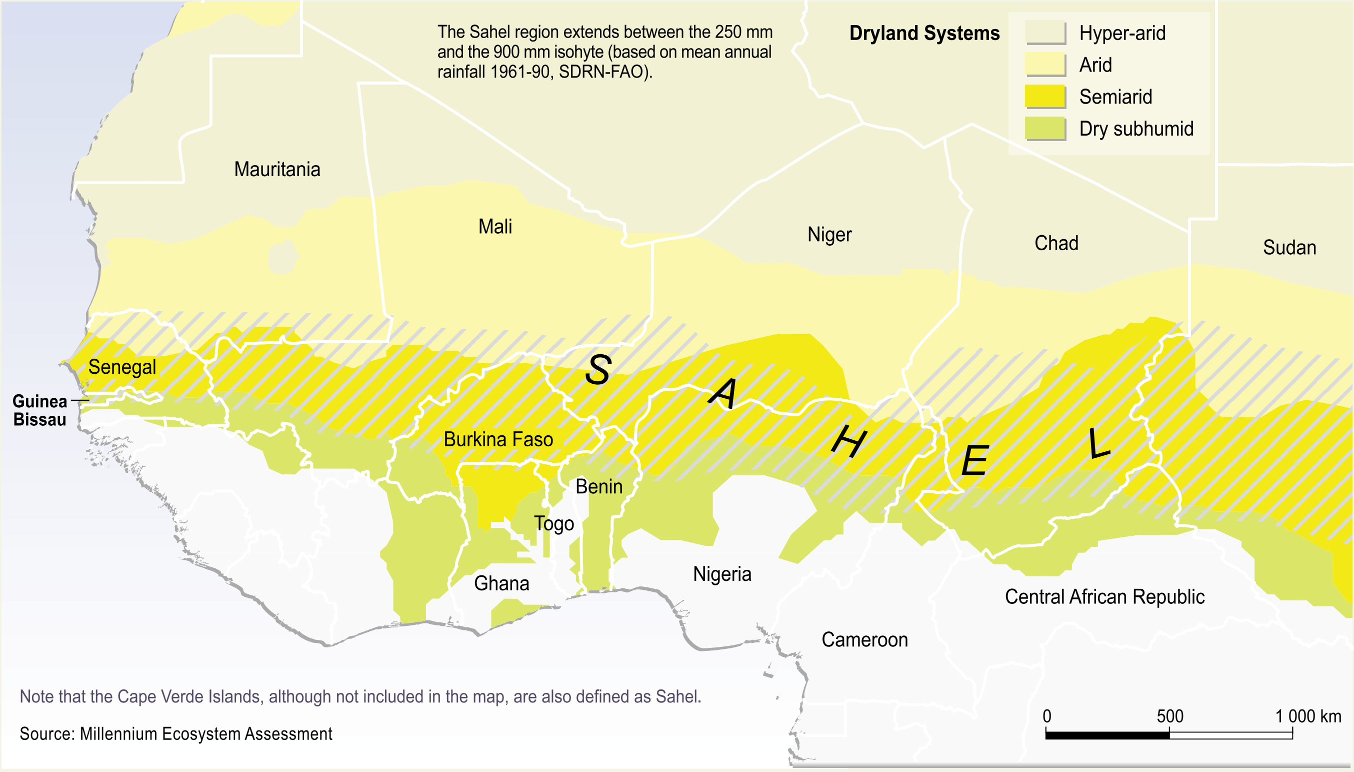
Serious erosion is eating away at the land of a Bolivian farmer and will threaten his crops; erroneous plowing techniques often cause such erosion

Box 7.1. Droughts in the Sahel Region: Lessons Learned and Knowledge Gaps

The Sahel region in Africa has been hit by a series of droughts and subsequent famines in the 1970s and 1980s (C5 Box 5.1, C22.6.4). These droughts are natural phenomena in the Sahel, and the consequent land degradation in the Sahel has further reduced regional rainfall (C13.6.1). More recently, the warming of the Indian Ocean is also thought to have contributed to these droughts.

Droughts in the Sahel reduced productivity, leading to low vegetation cover that increased albedo, reduced water recycling and monsoon circulation, thus decreasing precipitation. Reduced vegetation cover also led to soil erosion and further reduction of productivity. This vicious cycle further suppressed vegetation cover (C13 Box 13.1). Reduced vegetation cover could also be attributed to human activities such as unsustainable land use practices, including overstocking, overgrazing, deep ploughing, and monocropping (C5 Box 5.1). These practices—partly in response to droughts or increasing population density in the Sahel region—contributed to soil degradation, increased wind erosion, and higher levels of dust (C13.4.3). Thus it has been suggested that the combination of human and natural factors led to the severe loss of land productivity and subsequent famines. However, long-term remote sensing studies indicate extensive recovery of vegetation productivity after the droughts, suggesting that it was almost completely controlled by rainfall (C22 Box 22.2, C13.3.2, C19.2.3).

Because productivity was restored in many parts of the Sahel region, the relationship between famine, drought, and desertification is not clear. The complex interactions between regional and local biophysical conditions and human intervention make it difficult to determine cause-and-effect of desertification correctly. More reliable data in Sahel are needed to better understand the magnitude of desertification and to reduce uncertainties for policy-makers. It is clear, though, that the sustainability of livelihoods based on ecosystems experiencing serious droughts or desertification depends on appropriately tailored management approaches.



It follows that the gathering of information about socioeconomic factors related to desertification needs to be carried out at sub-national levels. The MA was able to gain specific insights into the correlation of human well-being to the level of aridity by disaggregating economic and well-being data like GNP per person, infant mortality, and the hunger rate in children under the age of five at the sub-national level. This enabled the categorization of these data according to the degree of aridity. National monitoring efforts that directly collect sub-national and perhaps household-level data are essential to our understanding of the impacts of desertification on human well-being (C22.6.1).

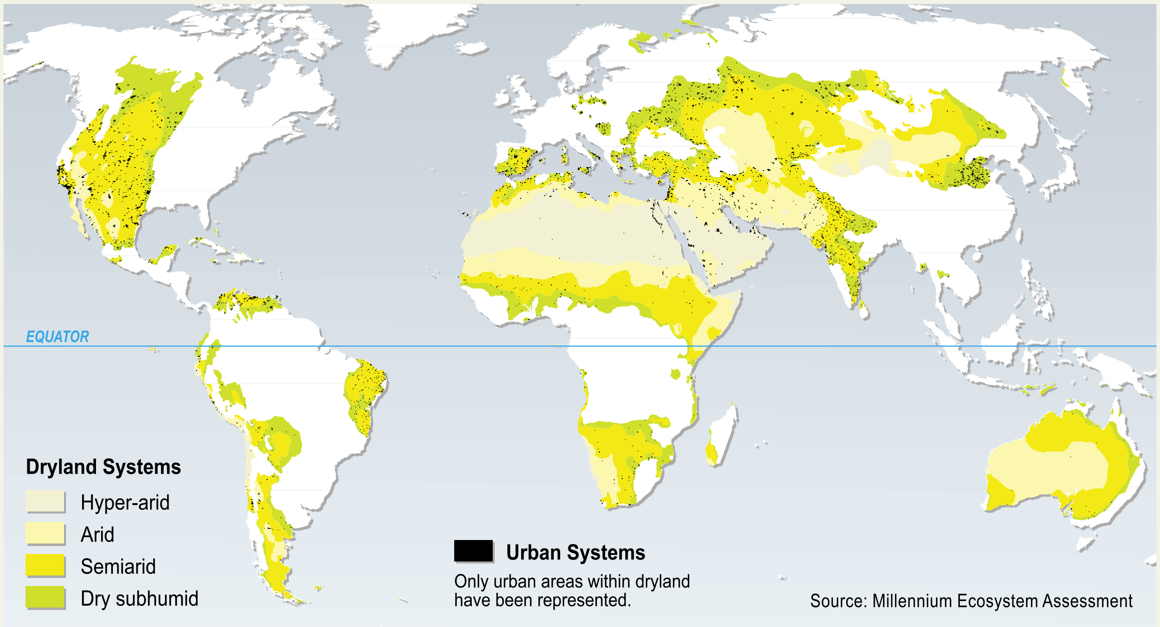
Reducing Uncertainty

There are considerable scientific challenges in detecting thresholds beyond which drylands systems would reach a critical or effectively irreversible change. This partly stems from our lack of understanding about the interactions between biophysical, social, and economic factors. Ecosystem conditions and factors affecting them are dynamic and change over time. This complicates accurate predictions of policy outcomes and detection of irreversible thresholds (C22.6).

The impact of poverty reduction strategies on ecosystem services and desertification has not been fully explored by governments and the international community. More information is needed to assess the linkages between the policies for poverty reduction and combating desertification. Poverty-ecosystem links are typically ignored in poverty reduction policies. Even when these links are included, only the economic values are considered. Successful responses should include broader notions of poverty and should try to mainstream the role of ecosystem services in the main poverty reduction programs.

The contribution of dryland urban areas to desertification may be significant but is not known. Figure 7.1 shows the overlap of urban areas with the four dryland categories. The dependence of these cities on ecosystem services from drylands versus non-drylands is generally not well known. Understanding this dependence will also help determine the degree to which cities may relieve pressure on desertified areas through economic opportunities (C22.4.4).

Figure 7.1. Overlap of Urban Areas with the Four Dryland Categories



A Chinese farmer walks home after work, Xinglungzhao forest station, P.R. China.

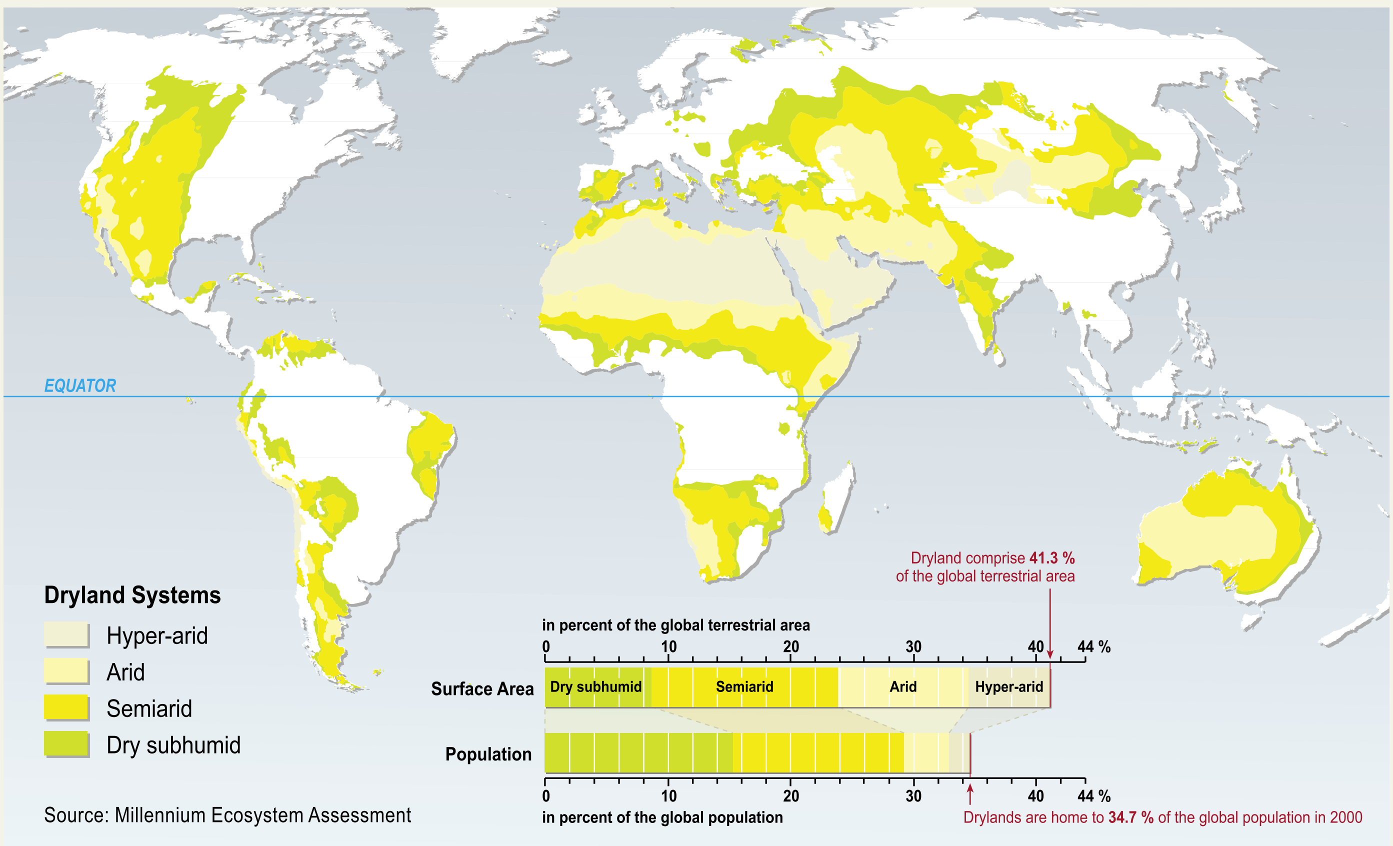
ICARDA

Appendixes

Appendix A

Present-day Drylands and Their Categories

Drylands include all terrestrial regions where the production of crops, forage, wood and other ecosystem services are limited by water. Formally, the definition encompasses all lands where the climate is classified as dry subhumid, semiarid, arid or hyper-arid. This classification is based on Aridity Index values†.



† The long-term mean of the ratio of an area's mean annual precipitation to its mean annual potential evapotranspiration is the Aridity Index (AI).

Notes: The map is based on data from UNEP Geo Data Portal (http://geodata.grid.unep.ch/). Global area based on Digital Chart of the World data (147,573,196.6 square km); Data presented in the graph are from the MA core database for the year 2000.

Appendix B
Abbreviations and Acronyms

GLASOD	Global Assessment of Soil Degradation
GNP	gross national product
MA	Millennium Ecosystem Assessment
MDG	Millennium Development Goal
NAP	National Action Programme
NGO	nongovernmental organization
OECD	Organisation for Economic Co-operation and Development
UNCCD	United Nations Convention to Combat Desertification

A jubilant Syrian farmer watering his field, with newly built water-delivery infrastructure in the background.

Appendix C
Assessment Report Tables of Contents

Note that text references to CF, CWG, SWG, RWG, or SGWG refer to the entire Working Group report. ES refers to the Main Messages in a chapter.

Multiscale Assessments: Findings of the Sub-global Assessments Working Group


P. CENINI/FAO

Secretariat Support Organizations

The United Nations Environment Programme (UNEP) coordinates the Millennium Ecosystem Assessment Secretariat, which is based at the following partner institutions:

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Back cover:
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Caption:

Use of solar energy for cooking and home lighting reduces reliance on firewood, and hence, reduces the threat of desertification (Tuareg village, Niger)

CBD

CMS

GEF

ICSU
International Council for Science

IUCN
The World Conservation Union

Ramsar
CONVENTION ON WETLANDS

UNITED NATIONS FOUNDATION

U N D P

UNEP

UNESCO

WORLD RESOURCES INSTITUTE

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