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DESERTIFICATION AND CLIMATE CHANGE

ARE THEY PART OF THE SAME FIGHT?

BERNARD BONNET, JEAN-LUC CHOTTE, PIERRE HIERNAUX,
ALEXANDRE ICKOWICZ, MAUD LOIREAU, EDS

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Contents

Foreword 5

What is the nature and extent of desertification? **7**

Does desertification only involve the expansion of deserts? 7
Does climate change exacerbate the desertification process? 9
Which regions and populations are affected by desertification? 13
Can we adapt to desertification? 16
According to the UNCCD, why is it important to combat desertification and who should be involved? 22
Learn more 24

What are the causes and consequences of desertification? **27**

What are the processes, how do they interact and where do they occur? 27
How do certain practices lead to desertification? 31
How do economic and land institutions engender desertification? 35
How does desertification affect soil ecosystem services? 39
How does desertification affect biodiversity? 42
How do desertification and water resources impact each other? 45
How does desertification affect the atmosphere and climate? 48
What are the economic effects of desertification? 51
How does desertification make populations vulnerable and what are the repercussions? 55
Learn more 59

How and why should we combat desertification? **63**

What does it mean to "combat desertification"? 63
Why do we need a holistic and systemic approach? 67
Why do we need a territorial approach? 70
Why do we need an interdisciplinary, multistakeholder approach? 72
Why are agroecology-based solutions important? 76

Why should we foster complementarity between local, regional and global scales? 80
How does adapting to climate and environmental variations help combat desertification? 83
What are the different techniques for rehabilitating land affected by desertification? 87
What impacts and results have efforts to combat desertification had to date? 92
Learn more 95

What support mechanisms exist to combat desertification? 97

What legal provisions exist in this area? 97
What support is available for territorial stakeholders to combat desertification? 101
What research is being done to combat desertification? 105
What specialized training is available? 111
Learn more 115

Contributors 117

Foreword

The term "desertification" was first used in the early twentieth century. Its use spread quickly throughout colonial Africa, reinforced by the powerful image of the encroaching desert. From the outset, the causes of desertification have been linked to climate aridification ("desiccation") and environmental degradation, particularly that related to vegetation cover (deforestation, savannization, etc.) and soil (wind erosion, run-off, loss of fertility, etc.).

It was later mainly associated with poor environmental management by rural populations. This devaluation of rural environmental management techniques continued after countries gained their independence, mainly because the productivity levels of family farming did not meet the productivist and modernist aspirations of the new states. But the 1969–1973 and 1983–1984 droughts tipped the balance once again towards climatic causes – a view that has since gained traction with the impacts of climate change.

The severity of the environmental, social and economic crisis triggered by the droughts of the 1970s and 1980s led to widespread media coverage of the term "desertification", bringing it into the mainstream vernacular alongside "climate change" and "biodiversity".

This book answers questions about the nature of desertification, its geographical extent and its connection to deserts, climate variations and climate change (chapter 1). It also examines the causes of vegetation and soil degradation and the repercussions on ecosystems, biodiversity, water resources and the climate, along with the impact of those repercussions on human societies and the economy (chapter 2). This book also looks at adaptation strategies and methods for combating desertification (chapter 3) and delves into the history of these adaptations and struggles, the mechanisms deployed at local, national and international levels, and the efforts of specialized research and training programmes to tackle the issue (chapter 4).

Throughout the book, readers will see that desertification, and efforts to combat it, must account for the multifaceted complexity of the phenomenon, from its biophysical and socioeconomic aspects to the many stakeholders, scales of study and actions that are involved. Similarly, the spatial and temporal dynamics of causes and solutions are an essential part of the reflection process.

WHAT IS THE NATURE AND EXTENT OF DESERTIFICATION?

DOES DESERTIFICATION ONLY INVOLVE THE EXPANSION OF DESERTS?

Antoine Cornet, Pierre Hiernaux, Hélène Soubelet, Jean-Luc Chotte, Thierry Heulin

Originally, the word "desert" referred to an uninhabited area – in other words, devoid of people. Today, the word has a more climatic and biological meaning: it describes regions with scarce, irregular precipitation and very specific biodiversity made up of a few, highly adapted species, such as limited and sparse vegetation. Deserts are a particular biome mainly characterized by the absence or rarity of its living organisms as well as by the specific climate conditions that make these areas so arid. Desert ecosystems are remarkable examples of the ability of living species to adapt to extreme environmental conditions. The people who live in these areas have developed strong social and cultural innovations in harmony with the environment. Deserts have an internal dynamic tied to the geomorphology and climate. The theory of desert expansion – which suggested that the Sahara was expanding 5.5 km per year – has now been rejected by the entire scientific community, which has conclusively shown that deserts are not advancing significantly. As a biome whose ecological integrity has not been degraded, deserts are not typically considered part of the desertification process.

The term desertification has always been defined in various ways and subject to debate and even controversy. The United Nations Conference on Desertification in 1977 defined it as follows: "Desertification is the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems." However, this definition says nothing about the many causes of land degradation. To address the various debates and controversies on the issue, the United Nations Environment Programme (UNEP) formed a working group in 1991. A new definition recognized the harmful impact of people as the primary cause of desertification: "Desertification is land degradation in arid, semi-arid and dry sub-humid areas (drylands) resulting mainly from adverse human impact." While it involves various processes that lead to a decline in soil quality and vegetation, human activity drives the phenomenon. The concept of "land degradation" encompasses falling yields, declining vegetation cover, the exacerbation of physical mechanisms at the soil surface, the qualitative and quantitative loss of water resources, and soil degradation. But persisting controversies divide the scientific community. For some, desertification refers to an environmental state, i.e. the manifestation of desert conditions and the final stage of land degradation. For others, desertification characterizes the process of soil and vegetation degradation that gradually leads to a loss in productivity, which may or may not be reversible. These diverging definitions stem from differences in how the extent of desertification is assessed as well as in strategies to combat the problem. For instance, should priority be given to restoring degraded areas, or should preventive measures be adopted to reduce or eliminate the causes of desertification? Today, the scientific community considers that desertification, associated with the loss of total productivity and environmental resilience, is not a sudden phenomenon. On the contrary, it occurs at the end of a gradual process marked by different thresholds. It is based on this viewpoint that international bodies have adopted the term *desertification* as being equivalent to land degradation in dry areas. The United Nations Convention to Combat Desertification (UNCCD) has proposed a new definition: desertification means "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities". These bioclimatic regions are determined based on the ratio of mean annual precipitation to mean annual potential evapotranspiration. The UNEP defines dryland as areas with a ratio of between 0.05 and 0.65. Hyper-arid desert areas (with a ratio of less than 0.05) are excluded.

Desertification has myriad impacts on the environment and on people. At the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, following a call from countries affected by desertification, the international community recognized that the issue is a global environmental problem that requires worldwide mobilization. This was the beginning of the UNCCD.

In general terms, desertification describes complex and interacting mechanisms and processes driven by a set of factors at different scales over space and time. While human activity is recognized as the main factor, the climate context is often considered to be an aggravating or triggering factor, as in the case of the series of dry years in the 1970s and 1980s in the Sahel. The desertification process does not cause ecosystems to become a desert in the ecosystemic sense of the word, but rather in the ecological sense: they experience a loss of biodiversity, functionality and ecosystem services (the area's capacity to produce biomass, retain water, be fertile, etc.).[1] New knowledge about the environments and societies in dryland areas should now be used to further refine the concept of desertification to establish a more nuanced definition of land degradation in dryland areas that accounts for the resilience of the environment and people. Knowledge and political action must converge to move forward.

DOES CLIMATE CHANGE EXACERBATE THE DESERTIFICATION PROCESS?

Pierre Hiernaux, Jean-Luc Chotte, Arona Diédhiou

A global phenomenon of anthropogenic origin

The link between the air temperature at the Earth's surface and the atmosphere dates back to 1824 and the work of French physicist Joseph Fourier. The greenhouse effect was described as early as 1856 by the American scientist Eunice Foote, and the role of carbon dioxide (CO_2) in global warming was suggested by the

1. See chapter 4, "How does desertification affect biodiversity?"

Swedish scientist Svante Arrhenius in 1896. However, measurements of the concentration of atmospheric CO_2 did not begin until the 1950s, and their upward trend was not confirmed until the 1970s. The term “global warming” was used for the first time by the American climate scientist Wallace Broecker in 1975.

The first atmospheric circulation models were then developed, and the Intergovernmental Panel on Climate Change (IPCC) was set up in 1988. The first IPCC reports, published in 1990, provided scientific evidence linking climate change to the greenhouse effect and established human responsibility for global warming. The first world conference on climate change was held in Rio de Janeiro in 1992 and led to the United Nations Framework Convention on Climate Change (UNFCCC).

Climate change is a global phenomenon of anthropogenic origin that must be distinguished from cyclical interannual climate variations (such as El Niño), whose extent increases with the dry conditions that characterize arid, semi-arid and dry sub-humid climates. The rising atmospheric concentrations of greenhouse gases – mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – is the driving force behind global warming. This warming then alters the general circulation of air masses and ocean currents, causing disturbances in wind patterns, air humidity and precipitation.

While CO_2 levels have increased more or less steadily around the globe, the rise in temperatures varies depending on the region and the season. This rise may be tied to the coldest or warmest seasons, or to daytime or night-time temperatures. In the sub-Saharan Sahel, for example, Françoise Guichard’s research has shown that the increase mainly concerns night-time temperatures at the end of the dry season (March to May), which is already the hottest season. However, the rise does not affect temperatures at the start of the dry season (November to February), which are cooler, or the monsoon rainy season (June to September). In Mediterranean climates, it is not only the temperatures during the hottest summer months that rise the most, but also night-time temperatures, leading to more frequent warm nights. In the continental climates of Central

Asia, which are characterized by very wide temperature ranges, Uzbek climatologist Alisher Mirzabaev has observed a greater frequency of extreme events. Rainfall pattern trends affected by climate change also vary between regions. Rainfall is more abundant and more intense in tropical drylands, such as the sub-Saharan Sahel, East Africa, the southern Arabian Peninsula, western India and Pakistan, and northern Australia. However, it is less abundant around the Mediterranean region and in the Middle East, Central Asia, Southern Africa, northern Latin America and north-western Mexico. In any event, it seems that the irregularity and intensity of rainfall events are increasing, making seasonal droughts and floods (or, in some regions, snow and hail) both more frequent and more intense.

The impact of climate change on desertification

The effects of climate change are compounded by those of climate variations that characterize arid, semi-arid and dry sub-humid regions. They include the effects of CO_2 enrichment of the atmosphere, rising temperatures, and changes in wind and rainfall patterns, whose direction and intensity vary from one region to another.

Precipitation

The strong interannual variations in seasonal rainfall that are typical in arid and semi-arid climates have always been factors that promote or exacerbate ecosystem degradation. The droughts of 1972–1973 and 1983–1984 in the Sahel, for example, substantially reduced vegetation cover, which caused wind erosion and, locally, the shifting of dunes that had been stable for decades. Paradoxically, these droughts also prompted or exacerbated water erosion from monsoon rains, causing more incidences of stronger and more intense run-off, which then contributed to an increase in the filling of ponds and worsened flooding and siltation of temporary rivers. These droughts changed the Niger River's regime, adding an early peak known as the "red flood" due to the water's colour. This phenomenon has been called the "Sahelian paradox" (less rainfall but more water in the discharges). These wind and water erosion phenomena are all the more pronounced locally when they occur on soil that has been disturbed (e.g., ploughed, weeded or trampled by livestock).

CO_2 enrichment of the atmosphere

The CO_2 enrichment of the atmosphere, for which the concentration is currently around 450 ppm (compared with 310 ppm before the 1950s) should accelerate photosynthesis, and thus plant production. Numerous experiments carried out in climatic chambers have confirmed this upturn in production and the efficiency with which plants use water. However, the results also depend on water, nitrogen and phosphorus constraints in the soil, and they differ according to the biochemical pathways of photosynthesis (C3, C4 or CAM, for crassulacean acid metabolism). Since the 1990s, scientists have used experimental systems employing CO_2 enrichment of the air at plot scale (known as free-air carbon enrichment, or FACE, experiments) to test the effect of several concentration levels (often up to 600 ppm), combined with rainfall, temperature, and nitrogen and phosphorus input scenarios, on most crops and in various forest and savannah biomes. Unfortunately, few of these trials – which are extremely costly to run – have been carried out in arid or semi-arid zones. The overall findings confirm the stimulation of photosynthesis and higher water-use efficiency in plants. Some of these experiments are conducted over the long term and offer indications of how vegetation adapts. They show a change in the flora, generally in favour of C3 plants (especially woody species), but this trend may be offset by the concomitant rise in temperature, which favours C4 plants (e.g. maize, sorghum).

Rising temperatures

Rising temperatures are accompanied by an increase in evapotranspiration (which can worsen drought episodes), but their impact on vegetation depends on their timing in relation to plant growth. For example, rising temperatures have little impact in the Sahel, where they occur during the dry season.

Wind and rainfall patterns

The impact of changes in wind and rainfall patterns varies from region to region. The trend towards more rainfall in the Sahel since the 1990s explains the "regreening" observed on satellite imagery, especially the increase in woody plant cover and density. Exceptions to this trend, such as in western Niger, are related to the local intensity of land clearing for farming and urban sprawl. In other regions where climate change is reflected in reduced rainfall, such as the steppe in southern Algeria, we are seeing a decline in vegetation cover, a change in floristic composition towards annual species and an increase in wind erosion and local silting, all exacerbated by rising agricultural and pastoral pressure on resources. In all events, whether rainfall rises or drops, the increasing irregularity of its distribution, combined with its greater intensity, will likely worsen degradation of the biome by intensifying soil erosion, unless the effect of CO_2 enrichment of the air on the vegetation cover suffices to reduce erosion and maintain if not enrich soil organic matter.

WHICH REGIONS AND POPULATIONS ARE AFFECTED BY DESERTIFICATION?

Antoine Cornet

Most continents are affected by desertification. The dry regions threatened by this phenomenon cover 40% of available land, i.e. 5.2 billion out of 13 billion hectares. Some 37% of the world's drylands are in Africa, followed by Asia (33%) and Australia (14%). Affected drylands are also found in the Americas and on the southern fringes of Europe. In terms of land use, 65% of these areas is used as pasture, 25% is farmland and the remaining 10% is allocated to other purposes (forests, urban areas, etc.).

In 2000, dryland areas were home to 35% of the world's population. More than 1.5 billion people live in arid, semi-arid and dry sub-humid regions in over 60 countries. These populations, at least 90% of whom live in developing countries, rank on average far behind the rest of the world on human well-being and development indices. Aside from those with mineral and oil wealth or providing industrial and service activities, these countries subsist essentially from their natural resources and thus from agricultural, pastoral and forestry activities, most often for domestic consumption. Population growth and persistent drought, as well as climate change in general, are intensifying pressure on these resources and on land. This pressure leads to questions about how societies in dry zones adapt,[2] how quickly they implement and disseminate adaptations, and their capacity to innovate, all of which can jeopardize the local environment, particularly biological diversity, and the very survival of populations.

Under the United Nations Convention to Combat Desertification (UNCCD), the States Parties must voluntarily declare themselves "affected" by desertification. This involves various obligations, including the establishment of national action programmes to combat desertification. Non-affected countries have only one obligation: to report on their cooperation activities every two years and pay their compulsory contribution. France, for example, has declared itself as non-affected. However, climate models unambiguously predict its aridification, which may eventually lead it to declare itself affected. Furthermore, many of the affected countries that are signatories to the UNCCD (196 in 2024) do not have drylands. This relativizes the UNCCD's focus on dryland areas.

Assessments of the true extent of desertification and estimates of the total surface area of drylands affected by desertification around the world vary significantly. The calculation method and the type of land degradation taken into account both influence the estimate. The Global Assessment of Soil Degradation (GLASOD, 1991, Wageningen University), which was based on expert opinions, reckoned that 20% of drylands suffer from soil degradation. Another estimate dating from the early 1990s (International Center for Arid and Semi-Arid Land Studies – ICASALS, Texas Tech University), drawing mainly on metadata, calculated that 70% of drylands are affected by soil and/or

2. See the following question, "Can we adapt to desertification?"

vegetation degradation. A 2003 assessment, based on partially overlapping regional databases and remote sensing data, put the figure of the world's degraded drylands at 10%.

Using the broad concept of biological productivity and degradation of ecosystem services, the study commissioned by the Millennium Ecosystem Assessment (2005) estimated that 10–20% of drylands were already degraded. According to these estimates, the worldwide total area affected by desertification could be between 6 and 12 million square kilometres.

Given the limitations and inherent problems of each of the databases on which this work is based, better evaluation is needed. After 2008, the UNCCD established indicators for assessing the extent and evolution of desertification. It also created a conceptual framework for integrating these indicators and mechanisms for reporting and managing the indicators at national and local levels.

In 2008, the European Environment Agency (EEA) conducted a study on desertification in southern, central and eastern Europe, covering an area of 1.68 million square kilometres. In 2013, the EU's Joint Research Centre published a new version of the World Atlas of Desertification. In 2017, a follow-up study based on the same methodology showed that the area exposed to desertification had grown by 177,000 km^2 (or 10.5%) in under a decade.

The indicators established by the UNCCD were included in target 15.3 of the Sustainable Development Goals (SDGs): combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world. Indicator 15.3.1 used by the United Nations is the proportion of land that is degraded over total land area, expressed as a percentage. Based on a binary quantification (degraded/not degraded), the indicator is calculated using available data for three subindicators that must be validated and reported by national authorities. The subindicators are changes in vegetation cover, land productivity and soil organic carbon.

Based on these indicators, the 2015 baseline figures[3] for several countries and regions are: Africa, 18% of land degraded; Asia, 24%; Europe, 10%; France, 12%; Kenya, 40%. The SDG Global Database includes 136 countries, many of which do not have drylands.

Given that the UNCCD covers only arid, semi-arid and dry sub-humid areas, should we conclude that the definition of desertification as given should evolve within the UNCCD framework? To answer this question we must examine both the scientific and technical aspects as well as the political angles and opportunities within the international debate. Do the particular characteristics and distinct features of drylands mean we should consider land degradation in these areas to be a specific phenomenon to which the term "desertification" should be attributed and differentiated from the very real land degradation in other biomes? The recent recognition of land degradation as an important factor in other conventions (the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity) might justify this extension to the entire phenomenon of land degradation. Amending this definition within the framework of the UNCCD would require opening negotiations on the text, which few parties wish to do given the difficulty of reaching a consensus.

CAN WE ADAPT TO DESERTIFICATION?

Emmanuel Chauvin, Pierre Hiernaux, Christine Raimond

Perceptions of desertification, its causes, extent and effects vary significantly depending on the viewpoints of the stakeholders involved, which in turn stokes controversy.[4] In Africa, the concept of desertification is a colonial construct based on a profound misunderstanding of dryland ecology and the associated rural

3. Sustainable Development Goals Global Database: https://unstats.un.org/sdgs/dataportal

4. See the first five questions in chapter 2.

activity systems. This construct has since been analysed by scientists, but is often employed as is by post-colonial states and international players to justify their environment- and development-related actions. Theories and definitions based on the essentially anthropogenic origin of desertification – and more specifically, blaming the supposedly “bad” agricultural and silvopastoral practices of local populations for causing soil degradation (e.g. overexploitation, shifting cultivation, transhumant livestock farming, wildfires) – are stubbornly persistent. They often still guide actions proposed to prevent or remedy the problem (e.g. sedentarization of livestock farming and agropastoral activities, reforestation, and establishing land reserves, which often involves excluding populations and reducing access rights).

Yet the rural and urban societies living in these regions have long since adapted to arid, semi-arid and dry sub-humid climates, often in ways that run counter to the actions suggested by development projects to curb desertification. The ecosystems of these regions have developed as an adaptation to a major seasonal water constraint and very high temperatures, while also offering benefits for vegetation and agriculture, since rainfall occurs during the period when days are longest and temperatures are highest. Spatiotemporal heterogeneity in rainfall distribution, run-off and subsurface run-off, as well as in the mineral fertility of soils (nitrogen and phosphorus availability for plants), explain the considerable differences in the distribution and production of vegetation in landscapes that have also been greatly shaped by human activities (oases, wooded parks, pastures, etc.).

When faced with the scarcity and spatiotemporal variability of resources, societies adapt in many ways. In Africa, adaptations revolve around five principles: extensive resource exploitation; mobility and migration; multi-enterprise farming; multifunctional areas; and regional complementarity between different agroecological zones based on product flows.

The main adaptation is due to the extensive nature of most agricultural, pastoral and forestry activities, and to the mobility of people and products associated with them. Depending on soil conditions and climate fluctuations, farmers grow a wide range of crops (species and varieties) and use ancient agroecological practices to make the best use of land with varying levels of fertility and rainfall (agroforestry parklands, hedgerows, crop associations, fallow land, flood recession crops near rivers, shallow tillage, organic matter recycling, manure, zaï,[5] assisted natural regeneration).

Daily and local (as well as seasonal and regional) pastoral mobility remains an effective solution to the variability of rainfall and grazing conditions, provided that it is safeguarded. Herd growth, the expansion of cultivated and allotted areas, hydro-agricultural development and land privatization can be obstacles to this solution. Mobility is also used for crops (crop rotations, fallow periods, cropland expansion) and farm labour (seasonal movement to areas with more water and fertile soil that can better support agricultural production). Migration is another solution adopted to deal with dwindling resources, such as during brief periods of drought or in the case of long-term environmental change. One example of this was when livestock farmers migrated from Sahelo-Sudanian Africa to Sudanian Africa and to the edge of the tropical forest during two major droughts in the 1970s and 1980s. Migration to the cities, which has accelerated urbanization, is also a form of adaptation. It can be a way for part of a family to continue their activity and for those who leave to find employment in a new place.

Multi-enterprise farming (combining crop and livestock farming, fishing, gathering, etc.) is another form of adaptation that can encompass seasonal movements and migration. It characterizes an increasingly frequent trend towards diversification of activities in rural areas (trade, transport, mining, etc.) as well as a major change in lifestyles. These changes strengthen the links between rural and urban areas while accelerating the urbanization process, especially in secondary cities where service activities are developing.

5. See chapter 3, "What are the different techniques for restoring land affected by desertification?"

The multifunctional nature of these areas, which describes the seasonal succession of agricultural, pastoral, fish farming and forestry activities in fields, makes it possible to adapt activities to the seasonal calendar and increase productivity per unit area. Complementary activities are organized within farms and between specialized players (crop and livestock farmers, fishers, etc.), requiring alliances between the different groups of players and negotiated access rights depending on the resource.

Food product flows between production areas with different agroecological characteristics and production levels (deficits and surpluses) help keep food available on the markets, especially as transport conditions improve, and avoid shortages, even in regions where environmental degradation is slow (excluding exceptional crisis situations). However, food availability does not guarantee that certain populations (especially those who are poor or impoverished) have access to a variety of foods in sufficient amounts to meet their needs.

Can all these practices be enough to counterbalance rapid population growth and climate change, which, depending on the region, are likely to contribute to soil degradation? It all depends. The initial situation and its evolution are very much contingent upon the local context. Moreover, demographic growth varies between continental areas and depends on population density. The consequences of global warming also vary in different parts of the world. The oft-advocated solution of agricultural intensification (increasing yields on the same unit of land) cannot be reduced simply by adopting theoretical models, with intensive agriculture with a high level of technical and financial capital on the one hand, and agroecological principles that can be transferred from one area to another on the other. Future solutions will depend on the choices made by producers as well as consumption patterns (water, food, energy) within a context of rapid urbanization. In Africa, intermediate, "small-scale intensification" is often adopted, with the use of inputs (mineral fertilizers, animal feed), new varieties, new plant associations, adapted mechanization, etc.

DISSEMINATION OF TRANSPLANTED SORGHUM AND RESTORATION OF DEGRADED LAND (*HARDE* SOILS) IN THE CHAD BASIN

In the Chad Basin, pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*), with a wide variety of local cultivars, are the staple food of the local population. Following climate deterioration in the second half of the twentieth century, long-cycle cultivars were replaced by short-cycle cultivars. It was also during this period that sorghum transplanted to the vertisols of the floodplains became widespread, with cultivars and cropping systems that were known locally but not elsewhere.

The success of this crop can be explained by land availability and timing. Transplanting during the flood recession period makes it possible to avoid the ups and downs of the rainy season (onset, intraseasonal droughts, length of the rainy season), while ensuring a second cereal harvest in the middle of the dry season. Demand among consumers and from urban markets is such that certain soils, particularly those that are hardened (known locally as *harde* soils, which have little to no vegetation), were restored by ploughing to reactivate the soil's vertical movements, and by installing a dense network of small dykes. Since the early 2020s, exceptional flooding has enabled farmers to extend this crop to floodplain areas that experience less frequent flooding.

The options for agricultural intensification are based on ecological niches that concentrate resources and depend on hydraulic societies that are interdependent and hierarchical with regard to irrigation, labour availability (examples of mountain farming in northern Cameroon) and peri-urban dynamics. Irrigated areas (large developments, market gardens) and flood recession agriculture have developed with the transition to capital-intensive, large-scale agriculture. The use of varieties selected by research is one form of intensification (increasing inputs), but it requires additional investments to be profitable. Short-cycle, non-photoperiodic varieties with high yield potential are only appropriate for more fertile soils, so mineral fertilizers are required. This is the case, for example, with millet varieties selected by the International Crops Research Institute for Semi-Arid Tropics

(ICRISAT), which have not been adopted in Niger but which are being planted by farmers in Nigeria who use state-subsidized fertilizers. Livestock farming is intensified by better linking pastoral mobility, which focuses on breeding, and sedentary farms located near markets that engage in finishing (rapid fattening of animals) or milk production. Strengthening these existing ties is a future adaptation solution. In both types of livestock farming, the use of feed (at least seasonally) and the production of fodder

THE 3M MODEL (MOBILITY, MULTI-ENTERPRISE FARMING AND MULTIFUNCTIONAL SPACE) IN EASTERN NIGER

Before the crisis triggered by the armed group Boko Haram, the economy of the Diffa region in Niger was based on regional complementarity of food and cash crop production, labour flows (seasonal and temporary) and agricultural and manufactured products within a regional system centred around Lake Chad, the Komadugu Yobe River valley and the major Nigerian urban centres. The rural populations around Lake Chad and the Komadugu Yobe River, where there are fewer natural resources, lived indirectly from the resources of the wetlands where agricultural and pastoral production was concentrated and where people moved for work (access to plots or pastures, seasonal labour), or from income sent by family members engaged in transhumance or living in the southern areas. The violence perpetrated by the Boko Haram group and subsequent emergency measures implemented in 2015 have profoundly disrupted this resilient system, which has a surplus of agricultural and pastoral production, by blocking the movement of people and herds, prohibiting access to the most productive wetlands and concentrating populations and activities in areas with the least natural resources. The shift in production activities towards gathering and petty trading strategies (which is typical during crises) and increased human pressure are leading to localized and accelerated overexploitation of natural resources. These changes are happening against a backdrop of significant uncertainty and climate variability, as can be seen in the recent years of drought (2014) and heavy flooding (2001, 2010, 2012, 2016, 2019, 2020, 2022) that have caused large numbers of people to suffer.

(locally irrigated for dairy and feeder livestock, or imported from areas with more resources) can boost the productivity needed to meet the growing needs of a rapidly expanding population.

ACCORDING TO THE UNCCD, WHY IS IT IMPORTANT TO COMBAT DESERTIFICATION AND WHO SHOULD BE INVOLVED?

Antoine Cornet, Maud Loireau

Land provides a series of goods and services that are necessary resources for economic and social activities as well as for the overall well-being of populations. Land degradation, which disrupts the structure and functioning of agricultural systems and ecosystems, diminishes or destroys ecosystem services and affects people's living conditions.

Current pressures on land are extremely high and are likely to intensify. There is ever-increasing competition between demand for all the functions land performs to provide food, water and energy and demand for the services that support and regulate all life cycles. A large share of managed and natural ecosystems are deteriorating, particularly in dry areas as a result of desertification.

Biodiversity loss and climate change are deepening these imbalances.

The rise in poverty and inequality in rural areas in arid and semi-arid regions, and the national and international implications of this development, make the combat against desertification a global cause. Concerted action is therefore needed at the global level. All efforts – local, national and international – must converge.

The 2018 report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) recognizes that combating land degradation is an urgent priority in order to protect biodiversity and ecosystem services. Timely measures to prevent, reduce and reverse land degradation can improve food and water security, contribute significantly to climate change adaptation and mitigation, and avert conflict and migration. Preventing, reducing and reversing land degradation is essential to achieving the Sustainable Development Goals (SDGs) set out in the 2030 Agenda. Investing to prevent land degradation, rehabilitate or even restore degraded land makes economic sense, as the benefits generally far outweigh the cost. This is essential from a social point of view to combat famine and poverty and reduce the geographical and social inequalities they can create.

The United Nations Convention to Combat Desertification (UNCCD) acknowledges the global scale of the problem. It also stresses that efforts to combat desertification must be supported by measures to address not only the effects of desertification but also its root causes. In other words, all efforts must align with the very process of sustainable development. The UNCCD's approach is based on obligations and the principle of solidarity between affected countries and those able to provide assistance. This approach encourages countries affected by desertification to tackle social and economic factors and promote collaboration with local populations, whether land users or land managers.

Several guiding principles advocated by the UNCCD provide a framework for strategies to implement in order to combat desertification:

1. Combating desertification and land degradation is part of a more global approach to environmental and development issues. An effective strategy to reduce or curb land degradation must take into account sustainable development criteria: environmental integrity, economic efficiency and social equity.
2. The participatory approach, i.e. the production of knowledge involving civil society stakeholders, is essential in designing strategies, action plans and projects to combat desertification. The population and its various forms of territorial organization are increasingly involved through forums for dialogue set up for this purpose. These stakeholders can also be a proactive source of ideas and innovation.
3. The UNCCD advocates a new role for states, one that involves coordinating international initiatives and implementing appropriate legislative and regulatory frameworks. This coordination enables the development of national consultation mechanisms

and strengthens the capacity of local communities to manage their natural resources for more sustainable development.
4. A strategy for preventing and combating desertification must be based on the implementation of specific projects that can provide appropriate solutions to the major problems encountered locally. UNCCD implementation is underpinned by national action programmes.
5. Monitoring and assessment are vital to programme effectiveness. The UNCCD requires countries to report on the progress they have made in implementing measures to combat desertification. It calls for a coordinated effort to collect, analyse and exchange information on the state of degradation and the impact of actions to combat it.
Science and technology are crucial to combating desertification, better understanding the processes and effects of desertification, and setting up projects based on reliable information to curb it and capitalize on the results. International cooperation in scientific research and observation needs to be enhanced.

Since 2015, the fight against desertification and land degradation neutrality have been included in the SDGs (specifically in SDG 15 and target 15.3). At the Twelfth Session of the Conference of the Parties to the UNCCD, the signatory countries agreed to a national neutrality objective by 2030, which implies its operational implementation in these countries.

LEARN MORE

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WHAT ARE THE CAUSES AND CONSEQUENCES OF DESERTIFICATION?

WHAT ARE THE PROCESSES, HOW DO THEY INTERACT AND WHERE DO THEY OCCUR?

Pierre Hiernaux, Jean-Luc Chotte, Maud Loireau

Land degradation is the result of an array of interwoven causes requiring a holistic approach.[6]

The processes and their interactions

The processes involved in desertification – i.e. the long-term degradation of land in arid, semi-arid and dry sub-humid areas – are numerous and interconnected. Those that lead to an extensive decline in vegetation cover are often cited as the initial causes, since they pave the way for wind and water erosion as well as declining soil fertility and biological activity. Pollution from mining, industry, urban development and agriculture lowers water and soil quality, which is also reflected in a local reduction in vegetation cover. Biodiversity loss, which often goes hand in hand with the spread of invasive species, is both a consequence and an aggravating factor in ecosystem degradation.

Soil fertility decline

Soil fertility decline is mainly due to the succession of cropping cycles, where the organic matter and minerals that are extracted from the soil are not offset by the addition of organic amendments (crop residues, manure, compost) or mineral fertilizers. Furthermore, leaving cultivated land fallow for short periods of

6. See chapter 4, "What support is available for territorial stakeholders to combat desertification"; chapter 3, "Why do we need a holistic and systemic approach?"

time does not allow a regeneration of soil fertility. This decline in agricultural soil fertility is the result of the extractive nature of crops, whether food or cash crops. Already in 1989, the agricultural researcher Christian Pieri published an assessment of thirty years of agricultural research and development in the southern Sahara, in which he concluded that there was an overall downward trend in both soil fertility and yields of food crops grown without fertilizer. Moreover, the expansion of cropland in response to rural demographic growth, which led to the cultivation of land with marginal potential, only amplified this process. With the exception of cash crops (groundnuts, cotton, peri-urban market gardening), the extractive nature of crop growing was not offset by increased fertilizer use. Organic inputs from livestock manure or stubble and crop residue left in fields are also showing a downward trend. Instead of being used on crops, they are exported to urban centres, or there is less available owing to smaller livestock herds in agricultural areas.

Biodiversity loss

The processes that lead to biodiversity loss are more difficult to characterize, as shrinking vegetation cover, erosion and soil fertility decline may occur together with changes in the composition quality of biological communities that do not necessarily result in impoverishment or loss of ecological services. However, cropland expansion, most often to grow only a few crop species, homogenizes the landscape and reduces biodiversity. Contributing factors in the declining diversity of forest stands include rising pressure on stands due to increasingly frequent felling for growing crops and supplying towns with wood fuel, selective felling of species prized for woodworking or pharmacology, and felling for the expansion of towns and infrastructure (roads, dams, communication masts, high-voltage lines, mines and pipelines). These biodiversity losses are often accompanied by the rapid expansion of endogenous or exogenous pioneer species, also known as invasive species. Increased wind erosion during the droughts of the 1970s and 1980s exacerbated the spread of bushy and shrubby species with seeds that get dispersed by wind. Such species include *Leptadenia pyrotechnica*, *Calotropis* *procera* and *Pergularia daemia*, which have invaded the sandy landscapes of the northern Sahel. On more superficial silty-clay soils, *Acacia ehrenbergiana* has spread with the help of ruminants, which eat the pods. On limestone soils and in peri-urban areas, a small thorny tree native to Central America, *Prosopis juliflora*, has become invasive. Herbaceous plants are also affected by the spread of invasive species, which can sometimes be helped along by livestock herds, as in the case of *Sida cordifolia*, *Senna oblongifolia* and *Diodella sarmentosa* in the southern Sahel, or by passing vehicles, as in the case of *Hyptis suaveolens*, which first colonizes roadsides in sub-humid areas. However, these invasive herbaceous plants cover the ground well and, because they are annuals, do not completely outcompete other species, even if such species may occur less frequently.

Seasonal variations versus long-term effects

The extent of seasonal and interannual variations in vegetation cover, which are characteristic of arid, semi-arid and dry sub-humid ecosystems, makes it difficult to determine the decline in vegetation cover. If the forester Edward Percy Stebbing, who alerted the scientific community to the southward advance of the Sahara as early as 1935 after visiting Maradi (Niger) during the 1930–1931 dry season, had returned a few months later during the rainy season, he would have been more alarmed by the risk of flooding. Thus, a diagnosis of overgrazing or degradation based solely on the state of the vegetation cover at the end of the dry season can only characterize transient effects. This is particularly true of Sahelian rangelands, where the herbaceous layer is dominated by annual plants that die at the end of the rainy season, remain as straw and litter during the eight to nine months of the dry season, and regenerate through seed germination at the first rains. In the perennial grass savannahs that dominate the wettest areas, it is fires – which sweep through in the dry season, burning away the mass of straw and blackening the trunks of the trees that generally survive – that contribute to a degradation diagnosis.

On an interannual time frame, while the variations in vegetation cover, its mass and its floristic composition observed from one year to the next in conjunction with fluctuations in the volume and distribution of monsoon rains can be spectacular, they are not always indicative of a longer-term trend. In the Sahel, the overall decline in vegetation cover and crop yields that accompanied the long period of rainfall deficits from 1968 to 1994, during which severe droughts occurred in 1972–1973 and 1983–1984, was followed by a recovery in vegetation known as the "regreening of the Sahel". The French ecologist Gabriel Boudet was alarmed by the gradual desertification of the Sahel just after the first of these droughts. Boudet, who was experienced in surveying and mapping Sahelian vegetation to quantify fodder resources for the former French Institute for Tropical Livestock and Veterinary Medicine (the IEMVT, now part of CIRAD as the French Agricultural Research Centre for International Development), wondered how the desert's encroachment could be stopped. But when he returned a few years later to the sites described during the drought, he found that the vegetation cover fluctuated widely and recovered in wetter years, raising questions about whether what was called "desertification" would be more accurately described as "biological recovery".

Processes that can be highly localized

The "regreening" observed in the Sahel following the droughts of the 1980s did not occur in a uniform way. The regions of Niamey and Tillabéri in western Niger, for example, are exceptions.

Indeed, the scale of agricultural clearing due to an annual 3.3% rural population growth rate since the 1950s without any intensification of cultivation techniques, combined with the pressure on local resources from Niamey's urban growth (9% annual population growth since 2012), has tended to reduce the vegetation cover despite more abundant rainfall. Elsewhere, exceptions to regreening are even more localized and often linked to soil erosion, which has prevented or limited vegetation recovery following the loss of the loose surface horizon or soil crusting. In the Sahel, this phenomenon has produced the "Sahelian paradox": less rainfall, but more water in low-lying areas and ponds.

A similar phenomenon occurs with wind erosion in the Sahel–Saharan region. As wind erosion resumed following years of drought on long-stabilized sand dunes, it created fields of micro-dunes (*nebkra*) and deflation hollows or blowouts. These formations were recolonized by herbaceous vegetation within a few rainy seasons. However, when the deflation zones give way to a subsoil that is either rocky or clay-loam, recolonization slows. These desertification processes, which remain highly localized, are sometimes perpetuated by nearby structures (roads, buildings, mines, etc.) that promote erosion.

This local desertification is still possible even with a global trend towards regreening.

HOW DO CERTAIN PRACTICES LEAD TO DESERTIFICATION?

Bernard Bonnet, Maud Loireau, Yves Travi, Hélène Soubelet

Different practices for using, developing and managing natural resources in dryland areas can disturb the balance of established ecosystems and cause land degradation. Four types of practices are described here, along with the processes responsible for vegetation, soil and water degradation.

Agricultural clearing in the drylands to the north and south of the Sahara

The dryland areas to the north and south of the Sahara are fragile ecosystems due to the aridity, irregularity of rainfall and type of soils, which are sensitive to water and wind erosion. As a result of population growth, changes in consumer behaviours and shifts in the markets (from local to global), the need to produce more has very often led to the cultivation of land that had previously been farmed as a common good for its wood resources (wood fuel, timber, etc.) and for grazing. Mechanized land clearing wipes out the natural vegetation and immediately exposes these fragile soils to run-off and wind. The dry matter that is produced is exported, and because it is not offset by substantial additions of organic matter, the superficial soil horizons are stripped in just a few years. Rainfall on these soils leads to crusting, which prevents water from infiltrating.

If this type of farming continues without a radical and costly change in practices, the land will become barren. The original natural vegetation cannot be re-established without managed intervention using costly restoration or rehabilitation techniques, which must be tailored to the context to avoid unnecessary investment. In any event, restoration takes time. This phenomenon of desertification can be seen in sub-Saharan Africa and North Africa with the ploughing of pastoral land or uncontrolled clearing during the preparation (annually or after a fallow period) of rain-fed crop fields. In Niger for example, farmers traditionally practised what they call "controlled clearing", which consisted of leaving trees in the fields for the ecosystem services they provided (shade, fodder, soil fertility, non-timber forest products, etc.). This practice was abandoned under the combined pressure of increasing food requirements and the decline in agricultural land at farm level. Since the end of the 1980s, the practice was reintroduced, sometimes under the new name of "assisted natural regeneration".

In Europe, America and North Africa, intensification practices involving the ploughing up of permanent grasslands to grow specialized forage crops or rain-fed cereals can also degrade the soil and reduce plant diversity, resulting in a drop in fertility and productivity well below their initial levels.

Dryland forest exploitation

In many dryland areas, wood is still widely used for domestic energy consumption when other fossil or renewable energy sources are lacking. Without a development and management plan in place, wood cutting in urban areas, which are major consumers of wood and charcoal, engenders the degradation of vast areas of silvopastoral land. Combined with the successive droughts of 1973 and 1984, these practices led to the disappearance of the characteristic tiger bush (vegetation that naturally forms "stripes" running perpendicular to the slope) found on the plateaus around Niamey (Niger). These areas then became large impluvia devoid of vegetation, with crusted soils accelerating erosion and run-off into the valleys below. Without management measures to support the costly work required to restore these ecosystems, it will be difficult to use these degraded lands.

Extensive grazing of natural rangelands

In semi-arid ecosystems with a short vegetation period, grazing livestock is responsible for three more or less concomitant processes: grazing, trampling and the deposit of manure. Livestock also contribute to gas and heat exchanges (via their respiration, enteric emissions, etc.). The type of grazing plays a decisive role: depending on its intensity and pace, it can either exacerbate land degradation or improve the performance of ecosystem functions and the renewal of natural resources. The impact of the type of grazing is contingent upon the season and, to a lesser extent, the relief and texture of the soil. Only grazing in the rainy season affects short-term herbaceous plant production. The impact may be positive or negative, depending on the grazing schedule, grazing frequency and stocking rate (animals per hectare). Dry-season grazing allows at least two-thirds of the herbaceous forage mass to be recycled through trampling, in addition to the faeces deposited by the animals during grazing. It therefore has a very positive effect on carbon storage and soil fertility, and can contribute to carbon neutrality.

Hydro-agricultural development in wetlands

The Ramsar Convention[7] is an international treaty to protect the world's wetlands. It defines wetlands as areas that are saturated with water or flooded, either temporarily or permanently. Within arid, semi-arid and dry sub-humid environments, inland wetlands include aquifers, lakes, rivers (permanent or temporary) and floodplains; coastal wetlands include coastlines, estuaries, and coastal and atoll lagoons. All over the world, they are a source of fresh water, and their capacity to store water (by absorbing rainwater and reducing the impact of floods) acts as a bulwark against drought. Wetlands are a source of nourishment for many living creatures, and are used for livelihood activities such as growing rice, fishing and aquaculture. These reservoirs

7. https://www.ramsar.org/

of biodiversity and plants can support a multitude of uses by humans (medicinal plants, timber, animal fodder, etc.). This biodiversity also acts as a sink for atmospheric carbon, helping to reduce greenhouse gas emissions and mitigate climate change.

Hydro-agricultural developments designed to promote agricultural irrigation in dryland areas have the unintended effect of destroying the hydrological and ecological complexity of these areas. Using water for irrigation can defeat the multi-use and multi-resource purpose of these developments. For example, in Morocco, the shifting cultivation of developed areas and irrigation deplete water resources. In West Africa, this use of water often causes the salinization of groundwater. Developing land upstream of areas can lead to draining, as in Uzbekistan, where some of the rivers that feed the Aral Sea have been diverted.

This specialization of use is typical in intensive farming practices (monoculture, mechanization, chemical fertilizers, tree grubbing, etc.), the profitability of which is often overestimated and unsustainable due to excessive water abstraction, soil and groundwater pollution, deforestation and the collapse in product prices (e.g. cotton). In Niger's Goulbi de Maradi dry valley, for example, certain structures that capture alluvial groundwater in irrigated plots have been shown to have high concentrations of potassium, fluoride and calcium due to the use of chemical fertilizers (NPK).

Soil pollution and degradation of water resources

Industrial or artisanal and small-scale mining operations set up in arid, semi-arid and dry sub-humid areas generally cause major soil degradation, with the levelling of surface layers and the removal of large volumes of earth and rock. Mining operations also consume considerable amounts of water for ore processing or mine dewatering. Whether the groundwater is not replenished or the fossil water is not recharged, this can lead to water shortages that then trigger population displacement (e.g. copper mining in the Atacama region of Chile). Not only does mining physically degrade the soil and impact water resources, but it can also pollute the soil and water with chemicals. This is mainly due to the leaching of spoil tips and ore processing products (e.g. cyanide and mercury pollution at the Koma Bangou gold panning site in Liptako, Niger). Restoring these polluted transformed areas is very costly.

Finally, irrigated market gardening tends to use significant amounts of chemical fertilizers and pesticides (often unregistered and banned), which pollute the groundwater that supplies drinking water to villages and towns. The pollution of the dry valleys in the Maradi region of Niger is a case in point.

Users are also not sufficiently involved in local environmental management, especially to the north and south of the Sahara. Most countries have been influenced by centralized models of natural resource management, established and implemented by the State and its various departments, without any real consideration for the users and inhabitants of the areas in question. While the responsibility for managing natural resources in areas prone to desertification is a recurring theme, rural populations have for too long been excluded from the process to develop measures to manage and preserve natural resources. Until the end of the 1990s, rural populations regarded environmental authorities with substantial mistrust, as they were perceived as repressive of the rural world. Following the great Sahelian droughts of the 1970s and 1980s, approaches to combating desertification began including local people in efforts to manage their land.

HOW DO ECONOMIC AND LAND INSTITUTIONS ENGENDER DESERTIFICATION?

Charline Rangé, Patrice Burger, Jean-Michel Salles

Analyses of the causes of desertification often point to “unsustainable land use” as a central factor. But behind this tidy label lie a plethora of dynamics, both involuntary and deliberate, which lead crop and livestock farmers to expand their activities beyond the land’s capacities. Without going back over the previously discussed criticisms levied by past colonial powers characterizing certain farming practices as “bad”, or more recent efforts by national authorities wishing to legitimize their population control policies, it is reasonable to assume that crop and livestock farmers with extensive experience of their environment do not deliberately choose unsustainable practices. Instead, the circumstances and conditions that prompt them to do so must be examined.

The general phenomenon known as desertification refers to various situations that depend on history and context. It would be patronizing and questionable to say that local stakeholders are "irrational". In each situation, the behaviours seen generally have a social and historical basis. As such, these practices reflect both the socioeconomic strategies of players with multiple and distinct resources, approaches and interests on the one hand, and institutions (as in established ways of doing things) related to land and other resources on the other.

To understand situations of desertification, the following must be considered:

- Unequal access to resources (land and natural resources, labour, capital) and decision-making authority, and the political economy of these inequalities (and therefore the ability to shape the role of the market, the State and international aid);
- Economic flows between rural areas and cities, and migration, especially internal or seasonal migration;
- Economic diversification beyond activities linked solely to natural resources;
- Precarious livelihoods and ways of living, in contexts where the State is too weak to provide social security, which can compel users to adopt short-term solutions.

Land tenure is subject to many types of land and natural resource uses that depend on a combination of individual prerogatives, collective regulations and various modes of access. It is rarely a question of private property rights in the Western legal sense, but rather of a plurality of individual and collective rights of use and control, which have been superimposed over space and time.

As a product of a long history of settlement and power, land rights are most often attached to identities. Finally, land tenure practices draw on a variety of institutions and registers of norms (customary, religious, legal, development and conservation projects, etc.).

While our aim is not to provide an exhaustive typology, we can highlight different land and socioeconomic arrangements that lead to desertification in certain contexts.

Lack of economic incentives to invest in land

Sustainable development practices that require investment in equipment or labour, are neglected due to inadequate economic incentives. A lack of a deliberate policy to support family farming is a determining factor in this case, with the result being that the populations concerned are better off migrating than investing in land. An example of this type of situation was studied in the Mandara Mountains in northern Cameroon, where several factors have led to the abandonment of anti-erosion practices with the emigration of the male workforce since the 1970s.

Land tenure and land insecurity issues

The ability and interest of users to implement soil conservation practices are directly linked to land tenure security, which cannot be associated with a particular type of ownership (public, collective or private). Rather, it is an issue of trust and thus of institutions capable of guaranteeing land rights.

Users may also not have the ability to prevent land degradation due to a mismatch between the historical (unequal) distribution of land and changing social relations based on labour and capital. This inability is an even bigger issue where land policies and clientelism between the state and local companies tend to make the lending or leasing of land an uncertain venture. This is the case, for example, of the ouadis (sometimes referred to as wadis), or dry river valley ecosystems, in the Kanem region of Chad.

Government interventions that undermine local regulatory systems

Government intervention, whether in the form of proactive development strategies or attempts to change modes of governance, legitimizes new land rights for new stakeholders, who can then be unencumbered by local land regulation systems. Pastoral hydraulic works, where access to water is made public, are one example. By increasing the availability of water, these developments can lead to overgrazing and challenge the regulations established by the age-old Sahelian pastoral system.

Resource grabbing through lawless access and land markets

Certain actors, whether national or international, may be able to get around local land regulation systems because of their involvement in powerful networks or through the use of violence. They can also make use of multiple forms of appropriation legitimized by the land authorities to appropriate resources that were previously under shared access. Examples of this include land grabs – including by governments – and the development of private ranches in Sahelian pastoral areas, for which some analyses show that they tend to lead to lower productivity and less resilience when hazards arise.

Unregulated resources made accessible by technical improvements

Sometimes new techniques provide access to previously unused resources for which there was no regulatory system. This creates situations where those who have the means to implement the technique in question can freely access these resources. These situations can then be maintained by state representatives as a result of political cronyism. This brings to mind investments in oases which, by allowing faster exploitation of the water tables, lower their level and make traditional, regulated forms of gravity-fed development more difficult or impossible.

Regulatory system failures that allow for rent seeking

Such situations are widely described in regard to forest resources, both in terms of public management and so-called community management of resources. Without an appropriate monitoring and accountability system, legal bans create a situation in which those responsible for enforcing them (forestry officers, management committee members, etc.) can turn a profit to the detriment of the goals of resource preservation. These practices fuel inequalities in access and create major territorial disparities between areas where regulations are effective and those where they are not.

Land evictions

Land evictions, triggered by development or conservation projects with a strong hold over the land, are the most emblematic case of the problems posed by short-term development strategies seeking to attract capital. The allocation of vast areas to agribusiness or conservation projects forces people who live there to retreat to smaller areas and overexploit resources to survive. An example of this includes the development of large-scale, more industrial farming projects that aim to achieve good financial returns for investors to the detriment of not only local economic and social organizations but also protected areas.

Our analysis thus echoes the conclusions of Adeel et al. (2005) in the Desertification Synthesis from the Millennium Ecosystem Assessment: "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." From this very general ambition – no doubt politically negotiated – and beyond the many situations and their causes, we can attempt to distinguish cases according to whether the causes are primarily endogenous or exogenous. In the first case, public policies must help people adapt and react, based on a detailed understanding of the various stakeholders' capacities and interests. However, it is important not to assume that solutions can only come from international aid, when the answer lies in building social consensus at local level. This presupposes that local institutions have land authority and decision-making powers. In the second case, the question is how political trade-offs set priorities, and what the underlying interests are.

HOW DOES DESERTIFICATION AFFECT SOIL ECOSYSTEM SERVICES?

Jean-Luc Chotte, Jean Albergel, Thierry Heulin, Hélène Soubelet

Soil is an invaluable natural asset. All living beings on Earth, including human beings, depend on the soil. Many ecosystem services are built on functional soils. Home to around 25% of the world's biodiversity, soil is the site of interactions between a multitude of organisms (bacteria, fungi, protozoa, earthworms, plant roots, etc.). These food chains underpin biomass production and the major biogeochemical cycles. They help mitigate climate change, purify the air and water, and supply innovative compounds for human health. Ecosystem services can be divided into several types:

- Provisioning: services such as agricultural production and the supply of wood, fodder and drinking water;
- Regulating: these include climate and water cycle regulation (infiltration, purification, flood buffering);
- Cultural: recreational areas, religious areas such as sacred forests, etc.;
- Supporting: services that help ecosystems function (carbon, nutrient and water cycling, biodiversity).

Desertification, which is associated with the degradation of many ecological functions and a sharp decline in vegetation cover, leads to a loss of ecosystem services. For example, desertification goes hand in hand with soil degradation, which occurs when the soil structure, organic matter and nutrient content, and the soil's ability to hold water, are altered. As the soil loses its ability to hold water, it becomes less productive for agriculture and more susceptible to erosion.

Agricultural production service

Dryland farming systems, particularly in sub-Saharan Africa, very often combine crop and livestock production. Millet, sorghum, maize and fonio are the main cereals grown here. Legumes such as cowpeas and groundnuts are both subsistence and cash crops, and the grains and tops (leaves) can be sold. Crop residues left in the fields can be grazed by domestic animals roaming during the dry season. They stimulate biological activity in the soil, improving its structure. These residues can also be composted and then spread on fields to improve soil fertility. The productivity of livestock, rangelands and arable land are thus inextricably linked. Without mineral fertilizers, primary productivity relies almost exclusively on natural resources and soil fertility. Efforts to produce more often create a vicious circle: as these resources are depleted, the land is degraded, which then lowers productivity. Maintaining a balance between food and feed production and nutrient inputs and outputs is vital for sustainable land productivity and for combating land degradation. This balance is all the more crucial if we are to meet the needs of a growing population.

Climate regulation service

Dry regions, which cover around 47% of the Earth's land surface, have a specific feature. Their soils are low in organic carbon, present in the form of leaves, crop residues, and decomposing roots and organisms. During rainy spells, this organic matter is rapidly mineralized. However, these soils are also very rich in inorganic carbon, found in the form of carbonates. While it is estimated that the soils of these regions hold 15% of global organic carbon stocks, these same soils account for around 97% of inorganic carbon stocks. In these regions, the amounts of inorganic carbon can be two to ten times greater than the organic carbon stock. These two forms of carbon are strongly influenced by land use, temperature and the concentration of atmospheric CO_2. This means soils in dry regions can be both sources and sinks of CO_2. As a result, they have a strong capacity to regulate the climate.

Desertification is estimated to have caused a loss of almost 12% of the organic carbon stock. However, with the right management practices, more than two-thirds of these losses could be restored (sequestered). Researchers have documented the organic carbon dynamics in these soils in great detail. However, it is only more recently that they have turned their attention to inorganic carbon dynamics, whose processes are governed by chemical equilibria and influenced by agricultural practices (irrigation, fertilization). This is a research priority.

Ecosystem support and functioning services

The physical soil structure

Desertification also causes soil degradation, which occurs when the soil structure, organic matter and nutrient content, and water retention capacity are altered. When soils are degraded, their capacity to retain water is reduced, making them less productive for agriculture and more vulnerable to erosion.

Water and wind erosion

Desertification can increase soil erosion, as wind and water can more easily strip away the top arable and fertile layer. The result is lower soil productivity and a reduced capacity to support plant growth and agriculture.

The water cycle

Soils in desertified areas often have a diminished water retention capacity, which can lower the availability of water for crops and spontaneous vegetation.

Bare soil develops an impermeable film due to crusting, which increases run-off that can cause flooding. This causes what some authors have called the "Sahelian paradox", where very large amounts of run-off have been observed in ponds during periods of drought. Desertified soils lose their ability to filter and purify water.

Biodiversity above and below ground

In the same way that a decrease in biomass from vegetation cover affects the soil organic matter content, biodiversity loss also impacts the micro- and macroorganisms in soil. This loss of soil biodiversity has consequences for ecosystem functions and exacerbates the loss of services such as soil fertility, soil detoxification, nutrient and organic matter recycling, and the supply of innovative compounds for human health.

HOW DOES DESERTIFICATION AFFECT BIODIVERSITY?

Hélène Soubelet, Patrice Burger, Antoine Cornet, Jean-Luc Chotte

Species diversity is lower in drylands than in wetlands. That said, the rate of endemism is especially high in dryland areas. Climate variability and soil diversity have helped shape specific biomes, such as oases, over time. Genetic diversity is extremely high in these biomes, where species have adapted to specific conditions. As a result, these biomes are a genetic reservoir supporting adaptation and subsistence strategies to cope with environmental change.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has declared combating land degradation as an urgent priority to protect biodiversity and essential ecosystem services. In drylands, this would protect not only the future of ecosystems but also the sustainable development of the human societies that are so heavily dependent on them.

OASES: RESERVOIRS OF AGROBIODIVERSITY

Based on the principle of agroforestry, an oasis has three levels of vegetation: date palms, the fruit trees (apricot, pomegranate, etc.) that grow underneath them, and market gardening or fodder crops on the lowest level. This three-layer principle is a way to manage natural resources (water, soil), adapt to the climate (lower temperatures, conservation of soil moisture), and ensure food security for people living in drylands. The oasis system is a source of income and acts as an "economic hub" that helps to keep people in the area. In this way, oases serve as incredible reservoirs of agrobiodiversity, with local species that are essential for adapting to climate change. However, they are under pressure from misuse (conversion to perennial date palm cultivation) and dwindling water resources.

Desertification causes ecosystems to become desertified in an ecological rather than ecosystemic sense: biodiversity, functionality and ecosystem services (soil fertility, biomass production, water retention capacity, etc.) decline or disappear. Scientists speak of biotic homogenization, which refers to the loss of genetic (genes), specific (species), functional (interactions between species), ecosystemic (ecosystems) and landscape (landscapes) diversity, leading to an ecological desert, with very little life and very few interactions.

The proxies to highlight the consequences of desertification on biodiversity are:

- the decline in living species (disappearance or collapse of animal species, population loss). As climate change and anthropogenic pressures worsen, the risk of extinction should vary between regions from 5% to almost 25%, depending on the endemic species with a small distribution or the ecosystem vulnerability. Some projections for 2090 suggest an 18-fold increase in estimated extinction rates compared with natural extinction rates without any human influence;

- the transformation of ecosystems (bare soil, reduced vegetation cover, etc.). Desertification contributes to the emission and long-distance transport of fine mineral particles, which can harm ecosystems ranging from lowlands to mountain glaciers;
- the loss of ecosystem services (loss of soil fertility and the ability to disperse seeds, lower ecosystem productivity, extinctions of hunted, gathered and harvested species, reduction in soil carbon stocks), with contrasting effects. For example, the net primary productivity of ecosystems could fall due to a warmer, drier climate and yet also increase due to rising atmospheric CO_2 concentrations. This could mean that woody vegetation cover, particularly in dry regions, might increase.

Since 1988, the IUCN Red List Index of threatened species has indicated that threats to migratory birds are increasing. In 2008, more than half the migratory bird species populations were in decline, and especially raptors with an unfavourable conservation status, including 51% of African-Eurasian species and 33% of Central, South and East Asian species. The 2018 IPBES regional assessments showed that one of the explanatory factors is the decline in the extent and condition of their habitat in non-breeding areas, particularly in the drylands of tropical Africa.

According to the IPBES regional assessment for Africa, wild mammals have not been spared. For example, in the protected areas of Siwa (north-western Egypt), 28 wild mammals have been recorded, including seven rare species that are under threat of extinction (cheetah, Striped hyena, Egyptian gazelle, white gazelle, red fox, wild cat and Fennec fox). The Northeast African cheetah is currently extinct in the wild in Egypt and Libya.

Desertification affects soil in different ways, through water and wind erosion, salinization, changes to water resources, compaction and organic matter loss. These processes lead to a decline in the biological integrity in the soil ecosystem, with the degradation of structural and functional characteristics and the deterioration of biological communities. Desertification can drive down plant production and therefore agricultural yields. Soil bacterial and fungal communities are affected to varying degrees by desertification, and their responses are highly dependent on the type of vegetation in place and the climate conditions.

SOIL MICROORGANISMS ARE NOT ALL EQUAL DURING A DROUGHT (A STUDY IN TIBET)

In 2015, 15.1% of the total surface area of the Tibetan Plateau was degraded. This amounts to 392,000 km^2 of land. A great deal is at stake in terms of restoration in this area, and studies on biodiversity responses can provide solutions to help restore degraded desert grasslands. Studies have shown that the degree of desertification in mountain grasslands in Pakistan can be measured by the reversal of the plant ecological succession and the loss of the soil's physical properties. Studies have also shown that the greater the number of species, the greater the capacity of the ecosystem to resist desertification, and that fungal communities are more resistant to drought than bacterial communities because of their enhanced capacity to capture water through their mycorhizal network.

HOW DO DESERTIFICATION AND WATER RESOURCES IMPACT EACH OTHER?

Jean Albergel, Yves Travi, Christian Leduc

Desertification and water resources are closely linked. Often, the connection is obvious, but sometimes the interactions are complex and even surprising, especially when groundwater is involved. This is why some regions in the world with abundant groundwater, such as the Sahara or north-western China, are still affected by desertification. Accordingly, the relationship between desertification and water resources must generally be addressed simultaneously on several spatiotemporal scales. Changes in land use and vegetation cover, soil degradation and climate change are having a major and rapid impact on the availability and quality of surface water. The impact on groundwater may be slower and more gradual, but may last well beyond the return to milder surface conditions. Natural or human-caused damage to water resources in terms of both quantity and quality affects vegetation cover and soil, and can exacerbate desertification.

Impact of desertification on surface water

The decline in vegetation cover and the sealing of bare soil are changing the balance between evaporation, infiltration and run-off, with run-off nearly always winning out. The increase in run-off and erosion on slopes, and the sedimentation of eroded materials in rivers and low-lying areas, at times worsened by wind erosion and transport, significantly affect local geomorphology and alter the water distribution across the landscape. Infiltration is reduced on slopes, so diffuse groundwater recharge is lessened locally. In addition to these purely physical changes, farming practices and biological activity in the soil, which are often linked, also have a major influence on the distribution of water on the surface and in the soil; these phenomena all evolve simultaneously during desertification.

Complex interactions with groundwater

When run-off water accumulates at low points in the topography (such as ponds[8]), it increases focused recharge. Desertification can thus affect the regional water balance by increasing groundwater resources, as in the case of the spectacular rise in the water table around Niamey (Niger). This "Sahelian paradox" is mainly due to the expansion of cultivated fields at the expense of natural vegetation. This development has led to a considerable increase in run-off on slopes and water accumulation in low-lying areas, with a high level of infiltration in the phreatic aquifer, even during the severe droughts of the 1970s and 1980s. Groundwater recharge in this area is around ten times higher than it was in the 1960s. Meanwhile, there are other cases where water resources increase in dryland areas for completely different reasons. Most often, this happens following water transfers for irrigation or

8. See chapter 2, "How does desertification affect soil ecosystem services?"

drinking water (horizontal from other regions, vertical from deep aquifers), which interact, positively or negatively, with desertification.

Rising groundwater levels are not always good news. When they are due to greater rain infiltration, the unsaturated zone where the salts carried by rain and wind have accumulated over hundreds or thousands of years is washed away. This higher recharge will then increase the salinity of the water table and the rivers it drains into, as in the huge Murray-Darling Basin in Australia. This more mineralized water, which is harder for plants and humans to use, can exacerbate desertification. A water table that is closer to the ground surface also becomes more sensitive to evaporation; this can lead to increased water mineralization and soil salinization, to the point of rendering soil sterile. This has happened in the Ouargla and El Oued oases, in south-eastern Algeria, where the increase in urban and agricultural discharges – the result of the uncontrolled exploitation of the groundwater – has turned these oases into vast "salt marshes". The two towns, located at the bottom of depressions with no outlet and where the water table is often near ground level, have seen the salt-sterilized areas grow ever larger and closer.

Desertification and water resources

Diminished water resources, whether caused by natural phenomena (less rainfall and/or increased run-off) or human activities (e.g. significant groundwater pumping), can also lead to or worsen desertification. The lower water availability for tree and shrub root systems is an obvious issue, but other consequences can arise when streams are not refilled by alluvial aquifers whose flow and duration are reduced. This means that in addition to quantitative deterioration, rivers and water bodies are also exposed to qualitative risks. Firstly, erosion transports materials that become trapped by dams or are deposited downstream. Secondly, insufficiently diluted pollution and physicochemical alterations (e.g., temperature, oxygen content) can increase the mineralization of surface water, rendering it unsuitable for the needs of ecosystems and human activities. As water resources become scarcer, competition rises between different uses (especially agriculture, drinking water and industry). The first to suffer is generally the environment, as its demands for water can go unheeded to some extent as it is wrongly considered less of a priority. In such situations, wetland preservation becomes even more difficult, despite their major importance, in both hydrological (flood buffer, groundwater balance) and biological (biodiversity preservation) terms.

The multiplicity and complexity of the interactions between desertification and water resources underline the significance of considering all the human, biophysical and technical components and forces involved. Overly piecemeal approaches are sometimes very counterproductive; more often than not, they simply displace the problems rather than solving them. A holistic approach to the sustainable use of all resources (land, water, biodiversity) is the only way to effectively combat desertification.

HOW DOES DESERTIFICATION AFFECT THE ATMOSPHERE AND CLIMATE?

Arona Diédhiou, Pierre Hiernaux, Jean-Luc Chotte, Luc Descroix, Benjamin Sultan, Gilles Boulet, Yves Tramblay

Temperatures, atmospheric humidity, rainfall and rainstorms

Albedo is a measurement of the sunlight reflected by a surface. Dark surfaces have a low albedo, which means they absorb more solar energy and heat up more quickly. Lighter surfaces have a high albedo, meaning they reflect more of the sun's energy. The albedo of land without vegetation or snow cover varies from 0.1 to 0.6 (10–60% of light is reflected), while the albedo of forest areas varies from 0.08 to 0.15. Desertification, which reduces vegetation and exposes bare soil that is often very light in colour, increases albedo. As a result, the average surface temperature of the ground decreases, which in turn reduces fluxes of heat (sensible and latent) emitted by the surface. According to Charney (1975), this flux reduction would lessen the activity of rain-generating atmospheric convections, and would explain a self-amplifying tendency towards drought and hence increasing desertification. However, this explanation was later contradicted by changes in the Sahelian climate after the droughts of the 1970s and 1980s. During the 2000s, soil–plant–atmosphere measurement campaigns were carried out at sites located along the climate gradient of the African Monsoon Multidisciplinary Analysis international research project. The analysis and use of those measurements in general circulation models showed that the convective precipitation from the monsoon was highly dependent on local soil moisture and temperature contrasts associated with soil moisture regimes due to recent rainfall, vegetation and geomorphology. This dependence, which is quite significant at the start of the rainy season, diminishes over the course of the season as the vegetation cover becomes more generally established.

The degradation of vegetation cover and soils due to desertification reduces the land's capacity to retain moisture, which affects the hydrological cycle. Less vegetation also means less evapotranspiration, a process by which water evaporates from the soil and is released into the atmosphere by plants. At a local level, as evapotranspiration falls, atmospheric humidity and, ultimately, precipitation both decrease. However, at the scale of a watershed, the decline in vegetation cover exacerbates contrasts in soil moisture and temperature. For example, rather than infiltrating the ground on a slope, water may instead run off, ending up in a plain or pond downstream. These contrasts reinforce the triggering of convective rainfall locally, as demonstrated in 2022 by Christopher M. Taylor and colleagues. The rising intensity of convective storms since the 1990s has been established by analysis of rainfall data in the arid and semi-arid Sahel as well as in the sub-humid and humid regions further south, thus confirming the results of global models. On a regional scale, global warming is increasing the atmospheric water content through greater evapotranspiration. This higher water content fuels rainstorms, which are not necessarily more frequent but are more violent.

Wind and dust

Desertification affects atmospheric convection, the process by which warm air rises and cold air sinks and a source of instability in the atmosphere that is the basis of cloud development and precipitation. The range of diurnal temperature variations is also very high due to the lack of vegetation and the increase in albedo, which fosters the development of areas of high atmospheric pressure (anticyclones). These high pressure areas can influence local wind systems and precipitation patterns, contributing to weather phenomena such as sandstorms and droughts.

Desertified areas regularly experience dust storms, which have a major impact on the atmosphere and regional climate, particularly on the Earth's energy budget, cloud cover, temperature and rainfall. As vegetation declines and soils become drier, the soil surface is exposed to wind. Dust storms develop as the wind picks up fine particles of dry soil and transports them over long distances. These dust storms become more frequent and more intense when vegetation cover is reduced and the soil is dry and friable. Once these storms occur, dust particles suspended in the atmosphere block the amount of solar radiation reaching the Earth's surface, which cools the air at higher altitudes. This inhibits convection as well as cloud development and precipitation, thereby exacerbating drought and desertification. Thus, desertification, reduced rainfall and more frequent and intense dust storms are closely connected.

These phenomena are often linked in a negative feedback loop, where each amplifies the effects of the other. In the Sahel, dust storms – the spectacular haboobs that precede convective storms – occurred much more frequently during the droughts of the 1970s and 1980s, which saw a sharp reduction in vegetation cover. But the frequency of these dust storms later subsided with the "greening" of the Sahel in the 1990s. Desertification also has little impact on desert dust, such as that from the Bodélé Depression in northern Chad or the Azaouad Depression in northern Mali. These desert areas are swept by strong winds moving towards the south-west that add to the atmospheric dust that periodically blankets the Sahel in the dry seasons and carry minerals to the Atlantic Ocean and as far as the American continent, from the Amazon to the plains of the southern United States. Whether dust comes from Sahelian haboobs or the Sahara, it increases the density of aerosols in the lower atmosphere, which reflects some of the sun's rays back into the atmosphere. But these dust particles also amplify the greenhouse effect through their infrared emissions. Although solar radiation interception by suspended dust lowers the warming of the ground surface, this does not reduce the greenhouse effect.

Soil organic matter and atmospheric CO_2 concentration

Soil is one of the main carbon reservoirs: it holds two to three times more carbon than the atmosphere. Carbon is stored in soil in the form of organic compounds produced by plant photosynthesis. As such, vegetation abundance and the size of this reservoir are correlated. However, the amount of carbon stored also depends on another key factor: the type of soil. Soils in dry regions have little organic matter due to their very sandy texture. Even so, these soils account for almost 30% of the organic carbon stocks in the world's soils. If soil degradation continues at a similar rate as today, by 2030 there will be almost a billion hectares (9,750,000 km^2) of degraded land, which will contribute to rising atmospheric CO_2 concentrations and thus to greenhouse warming. Soils in dryland areas are also very rich in inorganic carbon (carbonates). Documenting the extent to which they are involved in CO_2 emissions is a research priority.

In sum, desertification can have complex and interconnected consequences on the atmosphere and climate, particularly on rainfall, by increasing the albedo and the CO_2 source function of the land.

WHAT ARE THE ECONOMIC EFFECTS OF DESERTIFICATION?

Mélanie Requier-Desjardins, Jean-Michel Salles

Assessing the costs of desertification comes with a number of challenges, not least of which involves determining the situation to which the current condition is being compared. First, a list of impacts linked to desertification must be agreed upon. This list varies depending on the regions under consideration and the way in which they are used by human societies. The economic costs must also be determined. These costs may relate to productive, residential or even recreational activities, both private and public, and whether or not they can be measured in monetary terms.

At the Rio Summit in 1992, the first global economic assessment of desertification (Dregne and Chou, 1992) was used as an argument for the decision to create a specific treaty on desertification in drylands. The economic assessment of natural capital could be useful in decision-making and public action to support sustainability.

In line with the official definition of desertification in the UNCCD, this initial assessment is limited to countries with arid, semi-arid and dry sub-humid regions. It is based on the results of studies (mainly in Australia and the United States) carried out at the research-project scale. This assessment measures in monetary terms the per-hectare productivity losses associated with land degradation for three main types of land use: irrigated agriculture, rain-fed agriculture and livestock farming. It is based on an estimate, by country and then worldwide, of irrigated agricultural land, rain-fed agricultural land and grazing land affected by desertification. The authors put the annual losses due to desertification at a total of USD 42 billion (at 1990 exchange rates). In this assessment, only agricultural uses are considered, and so the estimated losses correspond solely to the provisioning ecosystem service for food.

In the 2000s, a number of national assessments were carried out, particularly in Africa. They include new calculations associated with land desertification: the loss of wood, non-timber forest products and biodiversity as well as indirect costs such as the silting up of dams due to wind erosion and even some social costs.

In 2005, the Millennium Ecosystem Assessment established a new framework for the economic assessment of ecosystems and the services they provide, known simply as "ecosystem services". This framework was used for the second global assessment of land degradation, published in 2016 (Nkonya et al., 2016). This assessment applies to the entire surface of the Earth. It is based on land mapping – not by land use, but rather the observation and measurement of changes in biophysical characteristics in the main terrestrial biomes and major ecosystems. To do this, economic values were assigned to the main terrestrial biomes, based on several hundred regional studies compiled by The Economics of Ecosystems and Biodiversity (TEEB) initiative. By mapping changes in vegetation cover or the transition from one biome to another, researchers can estimate the per-hectare economic losses relating to these changes or conversions on the basis of the values calculated for each biome. Examples of such changes include the degradation of vegetation cover, conversion from a natural area to a grazed or cultivated area, or an area that has become unusable for plant and food production. This assessment also takes into account the issue of degraded areas used for crop and livestock farming. To this end, specific bioeconomic modelling was developed for land with no change in use (or occupation) in order to estimate the annual value of the observed productivity losses. In this global assessment, recommended by the Millennium Ecosystem Assessment, the total value of degradation corresponds to the sum of these two main methods of calculation, and adds together the loss of areas where change is under way and the loss of areas still used for crop and livestock farming. The results indicate a total annual cost of land degradation of USD 297 billion for the 2001–2009 period. Losses linked to provisioning services (crops and livestock) account for only 38% of this amount.

Although the two assessments carried out in 1992 and 2016 (Dregne and Chou, 1992; Nkonya et al., 2016) rely on different conceptual frameworks (food use in one case, ecosystem services and the total economic value of these services in the other), they combine per-hectare monetary estimates with a mapping assessment of the areas occupied and affected by land degradation. Despite obvious limitations, mainly linked to the extrapolation of regional data to national and global scales, they are objective assessments of the economic losses related to desertification. That said, they are clearly focused on the food use of land, as opposed to a quality-based vision regarding natural and cultivated ecosystems.

Stakeholders' perceptions can also be used to gain deeper insights into the value they place on the various non-market services that land provides. While a financial approach based on variations in production and induced productivity as well as on production losses is feasible for market provisioning services, estimating the value of non-market services linked to land requires reporting-based methods. An experiment was conducted in Burkina Faso in a region where anti-erosion and agroecological structures (stone lines, zaï holes, semi-circular bunds, gabions, etc.) had been implemented. The aim was to estimate the value of the non-market services provided by these structures, based on producers' perceptions. The findings are shown in the table below. First, the absence of agroecological infrastructure ("business as usual") results in a significant loss of utility per hectare for producers, estimated at almost a year's minimum income (at the local level). This calculation method shows the value placed on these types of developments. In consultation with local producers, each priority non-market service is assessed in monetary terms on a per-hectare basis according to their perceptions. The grand total of the non-commercial provisioning services of water, additional straw for the animals, trees (for biodiversity) and local solidarity (mutual aid is essential to maintaining these infrastructures) amounts to XOF 110,000 (around EUR 160) per hectare per year, or more than three months' minimum wage. As a point of reference, the minimum monthly wage in Burkina Faso in 2020 was XOF 33,130.

Assessments of this kind are important tools for guiding decisions on funding actions to combat land degradation, and more generally for making a case backed up with figures to public decision makers.

Table 1. Illustration of the methods used to assign a value to the effects of land degradation (adapted from Traoré and Requier-Desjardins, 2019).

Service	Calculation method	Value in XOF/year/ha
Harvest increase	Cost–benefit analysis on a representative sample CBA	52,250 (1)
Straw increase	Choice experiment method Evaluation of producers' willingness to pay on a self-reported basis WTP	27,400
Water	Choice experiment method Evaluation of producers' willingness to pay on a self-reported basis WTP	36,100
Biodiversity	Choice experiment method Evaluation of producers' willingness to pay on a self-reported basis WTP	16,800
Mutual aid	Choice experiment method Evaluation of producers' willingness to pay on a self-reported basis WTP	29,700
Total		162,250
Business as usual with no new developments		–330,303

(1) This amount was calculated by multiplying the surplus by the average price of cereals in 2018 (250 × XOF 209 = XOF 52,250).
CBA: cost–benefit analysis; WTP: willingness to pay

HOW DOES DESERTIFICATION MAKE POPULATIONS VULNERABLE AND WHAT ARE THE REPERCUSSIONS?

Isabelle Droy, Maud Loireau

Analysing the links between land degradation and population vulnerability requires an approach that accounts for the complexity of the specific situation, particularly with regard to three issues:

1. What are the demographic, socioeconomic and environmental changes that trigger the dynamics of desertification?
2. How does land degradation specifically affect rural populations and exacerbate inequalities?

3. Are there groups at greater risk depending on their status, gender, age and livelihoods?

Living conditions that are often difficult in dry areas

According to the 2021/2022 Human Development Report by the United Nations Development Programme (UNDP), the Human Development Index (HDI) is low for a significant share of the population living in dryland areas. This index takes into account income, life expectancy and length of schooling. Moreover, due to a relatively undiversified economy, a majority of the population lives in rural areas and depends directly on the condition of the ecosystem and its natural capital for their livelihoods.

Many of these countries experienced sharp population growth during the twentieth century as infant and child mortality decreased and the birth rate declined much more gradually. The demographic transition is happening unevenly. In West Africa, the rural population has continued to grow despite a rural exodus that has fuelled urbanization. Farming and agropastoral systems are evolving accordingly: they are being diversified but rarely intensified, and land is left fallow less often or for shorter periods due to insufficient space, even though doing so supports soil fertility. Without employment opportunities outside the rural sector, population growth is driving a "hunger for land[9]", resulting in the development of marginal and often more fragile land, the expansion of "pioneer fronts" where they still exist, and the encroachment of agriculture on pastoral areas. Pressure on trees and shrubs for wood and pressure on grazing land are further reducing vegetation cover, increasing the soil's exposure to water and wind erosion. The population's living conditions are deteriorating, thereby exacerbating poverty and food crises.

Without training and investment in soil conservation practices (such as agroecology), the degradation process continues. This scenario feeds Malthusian arguments, in which population growth

9. See chapter 3, "Why are agroecology-based solutions important?"

faces limited subsistence means, in turn triggering sometimes irreversible economic, social and ecological crises.

However, there are counter-examples that show the capacity of farming systems and societies to adapt, even in a context of poverty. In Niger's Maradi region, in Kano State in Nigeria and in the Machakos region in southern Kenya, demographic pressure has led to the innovation or adoption of farming techniques that increase agricultural production while protecting and restoring the soil. The correlation between poverty and environmental degradation is complex, and the historical, social, institutional, political and economic contexts are all factors that must be considered to fully understand the link between them.

Family farms must contend with various shocks

Family farming remains the dominant form by which production is organized. The family's domestic economy is organically linked to that of the production unit, and family labour is a key component. What all types of family farming – which includes agricultural, pastoral and fish production – have in common is the role played by the family in managing the activity and providing labour. Apart from this common trait, situations vary greatly, depending on the economic, agroecological and institutional contexts as well as on the kinship structures specific to the societies concerned.

In low-income countries, rural populations in remote and poorly equipped areas are not protected by formal insurance systems. Public agricultural policies are also not very supportive (little support for food production, exposure to price fluctuations, unsuitable agricultural advice). As such, their exposure to shocks (drought, floods, cyclones, price drops, input price rises) is particularly high, and the consequences can be dramatic. Given these shocks, endogenous solidarity and mutual aid mechanisms are less and less effective due to population growth, the monetization of the local economy and the weakening of customary or community authorities. Without institutionalized social protection and accessible public services, production losses or health shocks (illness or death of a family member) lead to a process of structural decapitalization or a debt cycle that is difficult to reverse.

Land degradation and growing inequalities

For the most vulnerable populations, land degradation has wider consequences than just a decline in soil fertility. Water resources, plant diversity (gathering plants, pharmacology) and wood resources (trees and shrubs) are all affected. The livelihood system is being changed, so alternative solutions must be found. Great ingenuity in adaptation can often be seen in the diversification of activities to compensate for diminishing agricultural or livestock farming resources. But some of these activities exacerbate the land degradation process, such as charcoal making, removal of straw from pastures for sale or mining activities (artisanal gold mining), which is characteristic of maladaptation. As local opportunities become scarce, people are increasingly reliant on more frequent and longer seasonal migration, sometimes including new household members (young girls in towns, children in gold-mining areas). Another consequence is the worsening of inequalities both between socioeconomic groups according to their status and means of existence, and also within these groups, according to place in the lineage, birth rank and gender. Women and young people face the most discrimination. In rural areas, young people are often not part of collectives or receive little support; illiteracy rates are high and they have very limited access to land. Their employment prospects are often bleak, and the only solution is to migrate to other parts of the country, to neighbouring countries or even farther.

Women and desertification

One of the basic features of the economic and social organization of rural societies is how rights, activities and responsibilities are differentiated by gender. These differences vary according to ethnicity, social group and level of wealth. Generally speaking, women are restricted in their access to land, trade, finance and mobility. Their rights to material and immaterial resources – respect, representation on decision-making bodies, access to positions of power, education – are not recognized. They also carry out most of the tasks associated with social reproduction, such as domestic work, collecting water and firewood, and caring for children and other dependants. These time-consuming tasks have little social value and no economic recognition.

This is why desertification affects men and women differently. Women have less room for manoeuvre to deal with the impacts of desertification, and are less represented than men in decision-making and power structures.

When competition for resources rises, women are the first to see their rights eroded. For example, their access to land is often denied or they are offered only the most degraded land.

Yet women are key players in the fight against desertification, and their activities, such as home gardening, help to maintain biodiversity. They also set up women's organizations that try to influence public policy in terms of collective management of resources, recognition of land rights and institutional consideration of gender issues. Women are key players in defending their own rights, despite the constraints, social norms and representations of their roles.

LEARN MORE

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HOW AND WHY SHOULD WE COMBAT DESERTIFICATION?

WHAT DOES IT MEAN TO "COMBAT DESERTIFICATION"?

Antoine Cornet, Bernard Bonnet, Jean-Luc Chotte, Maud Loireau, Yves Travi

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities".[10] Desertification has consequences for both the environment (soil erosion, water scarcity, loss of flora and fauna, etc.) and humans (poverty, famine, migration, conflict, among others). Combating desertification has been on the international agenda since 2015, and it is one of the 17 Sustainable Development Goals (SDGs) set by the United Nations and adopted by nearly 200 countries. By 2030, the aim is to move towards land degradation neutrality; for dryland areas, this means achieving neutrality in terms of desertification. Land degradation neutrality would be considered achieved if any new degradation is offset by the restoration or rehabilitation of the same type of degraded land. This land degradation neutrality is based on three pillars of action: avoiding degradation, reducing degradation and restoring/rehabilitating degraded land.

In addition to the actions to be implemented (see the other key questions in this chapter), combating desertification is part of a broader, multi-pronged framework. To make actions more effective, optimize their impact on communities and promote their sustainability, efforts to combat desertification must factor in some crucial points.

10. See chapter 1, "Does desertification only involve the expansion of deserts?"

Acting in the right place at the right time and on the right scale

There is no single, one-size-fits-all solution that can be applied ad infinitum. Successfully combating desertification requires tailoring actions to each context. Knowledge about the state of the land, how degraded it is and the factors causing degradation must be considered to decide the objective to be achieved – i.e. to avoid or reduce land degradation or, wherever possible, to restore degraded land – and choose the most effective and appropriate methods of intervention. The social and economic context and human capital ultimately determine the implementation and success of these initiatives. To go beyond local successes and develop projects that are truly transformative, efforts to combat desertification must be part of a territorial framework that supports local development plans.

Considering water resources as both a source of potential and a constraint

Having enough water of good quality is vital if forestry, pastoral and agricultural areas are to be maintained or rehabilitated. Combating desertification thus also entails understanding the potential and vulnerability of water resources, properly managing hydraulic structures (dams, rainwater collection points, village wells, boreholes, irrigation systems), and preserving groundwater resources through sound management. Preserving groundwater involves considering whether the resource is renewable or not. For example, the overexploitation of fossil groundwater supplying oases could soon cause them to disappear.

Factoring in human needs and aspirations

Efforts to combat desertification requires the involvement of various stakeholders to ensure the lasting success of any actions undertaken. Implemented measures must be developed based on the needs of the population, their priorities and their know-how. People must gain the skills required to implement and manage sustainable land management actions as well as increase and diversify resources to raise their income levels and reduce their vulnerability.

The expected outcomes of land restoration and rehabilitation

Given the extent of land degradation and its impacts, restoration is vital and is becoming essential to both increase productivity and restore ecosystem functions and services. Restoring an ecosystem does not necessarily mean attempting to return it to its pre-degraded state. Rather than achieving a prior state, the aim is to set the ecosystem on a path designed to make it resemble a "reference ecosystem" in terms of the composition and structure of its biotic community while adapting it to cope with current constraints. For agricultural systems, the main goal is to make the soil healthy again and set targets for a "desirable" future for people.

To be successful, efforts to rehabilitate or restore land must strive to enhance biodiversity and strengthen ecological functions enabling the provision of several ecosystem services. Restoration cannot be the simple application of a corrective technique, however useful such techniques may be. The goal is to take a gradual approach towards a land development trajectory that will improve productivity, biodiversity and other services (water storage, fertility, etc.).

Restoration efforts must also remove pre-existing degradation factors. Rehabilitated or restored land must be integrated into viable production systems as well as territorial conservation and development plans, taking into account the social conditions, constraints and aspirations of the local population.

Using indicators to assess the impact of initiatives

The aim of monitoring and evaluation systems is to record the effects of projects, programmes and policies to measure how successful they are, identify failures and make it easier to capitalize on them in the future. While monitoring and evaluation systems are necessary to understand the impact and effectiveness of actions undertaken and to guide ongoing actions, they are beset with difficulties. Challenges are related not only to the complexity of desertification processes and the interweaving of biophysical, human, social and economic aspects but also to the many stakeholders involved. These challenges are compounded by the different scales and users of these evaluations.

From 2008, the UNCCD set out its strategic objectives and indicators designed to track progress. At the Twelfth Session of the Conference of the Parties to the United Nations Convention to Combat Desertification (2015), the parties adopted the indicators of target 15.3 of the Sustainable Development Goals for 2030 (land cover, land productivity and the carbon stock from above- and below-ground biomass) to understand the state of land degradation and the potential for land restoration. The need to draw up a report for each country on changes in the state of the land based on these three indicators was also agreed. These three indicators, which are common to all countries, can be supplemented by specific indicators that each country is free to choose. The data for these indicators is most often provided by global observing systems (mainly satellite-based). While these systems make it possible to quantify overall changes in land degradation or regeneration, the impact of projects cannot be assessed. Monitoring systems at these broader scales are important, but impact monitoring systems are also important for the stakeholders and users of the areas in question as they are responsible for the management and restoration/rehabilitation measures taken. Different methods of rigorous observation of these dynamics at the field and landscape level thus need to be developed in conjunction with stakeholders. In Mauritania, methods have been developed to monitor vegetation cover in order to measure the impact of transferring responsibility for managing common areas. These methods show the usefulness of these systems for steering more sustainable management of arid areas exposed to desertification.

Combating desertification and land degradation is part of a global approach to environmental and sustainable development issues: increasing and diversifying resources to raise people's standards of living; stabilizing the balance between resources and use; restoring degraded land; re-establishing viable social and policy frameworks for natural resource management; and intensifying agriculture through agroecological practices to limit land clearance, overgrazing and deforestation, which worsen desertification.

WHY DO WE NEED A HOLISTIC AND SYSTEMIC APPROACH?

Alexandre Ickowicz, Christine Raimond, Pierre Hiernaux, Maud Loireau

The previous chapters have described the many causes of desertification, often due to changes in local human activities (unsustainable exploitation, unsuitable practices, dysfunctional territorial governments) as well as natural climate events (e.g. droughts and floods), migration movements and agricultural development. Drivers of these changes are both socioeconomic (subsistence farming, unsustainable agricultural sectors, unsuitable production models, etc.) and biophysical (deforestation, declining soil fertility, water resource depletion). Similarly, the consequences of desertification affect not only the various ecosystem compartments (soil, water, atmosphere, biodiversity) but also those of the sociosystem (value chain, governance, land tenure, etc.) at different scales, from the field to the landscape to the global scale of Earth.[11]

This means that actions to combat and prevent desertification and restore desertified land must reflect the different spatial and temporal scales involved in desertification processes. This requires a prior assessment of the causes and potential origins of local desertification as well as the various compartments affected (soil, water, atmosphere, fauna and flora, human societies). This global approach determines the holistic approach by taking into account the interactions between the different spatial and temporal scales. It complements the systemic approach, which describes these different compartments and the interactions between their components. Holistic and systemic approaches can be used together to understand how desertification works and its dynamics, and to assess the effects of actions to combat it.

The complexity of the phenomena involved

Whether the aim is to restore degraded land or prevent degradation altogether, a holistic approach is warranted, as the types of degradation (decline in vegetation cover, soil erosion, loss of

11. Also see chapter 3, "Why should we foster complementarity between local, regional and global scales?"

soil fertility and biological activity) often occur simultaneously and are interdependent, as are the management methods that caused them. While soil fertility can be improved on a field-by-field basis, practices are usually applied to all the fields and activities according to a farm- or community-wide strategy, such as collecting livestock manure from grazing land. Similarly, schemes to restore eroded land or prevent erosion are only effective if they extend to the catchment area or territory. Finally, vegetation cover must consider both herbaceous plants (including crops) and woody plants, which implies a territorial approach that considers land use and the role of trees in landscapes, and their contribution to meeting food, fodder, timber and fuel needs. These interventions cover a range of economic activities involving many stakeholders, thus justifying this holistic and participatory approach.

By addressing the different scales and compartments, these two approaches, developed jointly, can help stakeholders steer clear of the pitfalls of analyses and actions that are too local or too global, as well as those that overlook interactions and remain too focused on one compartment to the detriment of others. Two examples illustrate this point.

The misleading causes of major droughts in the Sahel

The major droughts in the Sahel in 1972–1973 and 1984–1985 caused significant degradation of steppe ecosystems (especially grazing lands) and substantial mortality of trees and domestic animals, not to mention human casualties in vulnerable human populations. Following these droughts, pastoral livestock farming in West Africa was pointed to as the main cause of the degradation and desertification of the Sahelian steppes. In the late 1980s, the reason given was excessive livestock density in the Sahel and an unsuitable and under-productive extensive management system that consumed large quantities of natural resources and was based on seasonal livestock mobility and rangeland fodder availability. It was not until the late 1990s (and even between 2000 and 2010) that multidisciplinary studies across the Sahel demonstrated that it was not the extensive system and pastoral mobility that were responsible for this environmental degradation. Rather, decadal climate variations had played a significant role in the degradation of vegetation and the spread of bare soil observed in the 1970s and 1980s. The years of greater rainfall that followed led the vegetation to recover, at least partially and in certain landscape units. Furthermore, areas frequented by livestock did not show any greater degradation of the soil or vegetation: in fact, regeneration of the grass cover and certain shrub species was greater than in the areas without livestock (experiments over several decades). This clearly demonstrates the importance of considering all the factors (anthropogenic, biotic and abiotic) influencing social-ecological systems, the various temporal and spatial scales, and the interactions between ecosystem components.

The social consequences of planting trees

The second example of an overly sectoral vision is the uncoordinated decision by forestry services to plant trees to combat desertification. Certain species are selected to fix nutrients and regenerate the soil, such as *Acacia* spp. (including *Acacia senegal* for gum arabic), which are leguminous plants that fix atmospheric nitrogen in the soil. Planting has often been carried out in recent decades by forestry services or non-governmental organizations, with the aim of regenerating ecosystems. When carried out by public services, rehabilitation/restoration work involves implementing deferred grazing of the areas so they are not damaged by grazing herds.

Rather than having any real impact on desertification, these planting activities have often triggered more social problems. By excluding local people from being involved in the interventions (choosing the areas, species replanted, implementation methods) and the management of these areas (deferred grazing, establishment of sustainable practices such as seasonal rotations), these activities have had very little lasting impact on a local or global scale. Because of the many conflicts of interest between stakeholders over the relevant areas and resources and their small spatial footprint, these plantation activities have often failed, with low regeneration rates and unsustainable uses. Conflicts over use between the various stakeholders (crop and livestock farmers, market gardeners, loggers) have often led to the degradation of resources and facilities by people and herds on seasonal and traditional rangelands, and to coercive measures by the forestry services (fines, confiscation of livestock, imprisonment, etc.).

Today, new strategies to combat desertification, such as those implemented for the Great Green Wall (GGW) initiative in the Sahel, seek to involve local populations in both determining and implementing activities, taking into consideration their practices and customs, their land-use rules and rights, and their needs in terms of access to resources and services. The challenges of territorial governance and cooperation at the various local, national and international levels remain significant and are the main impediments to this ambitious international project.

These new holistic and systemic approaches involving all stakeholders from the local to the international level, their uses and their interactions within a territory to decide on how to rehabilitate degraded land and the sustainable management of social-ecological systems are certainly more conducive to positive results. However, such systems are more complex to implement because of the number of players involved and the many interconnected mechanisms to be considered.

WHY DO WE NEED A TERRITORIAL APPROACH?

Maud Loireau, Patrice Burger

The territorial scale encompasses all the economic, social and environmental variables that have an impact on the target territorial area, regardless of their origins and whether short or long-distance, within the relevant territorial area or beyond. The resulting principle is to adopt options tailored to each context for a given area, whatever its size (for example, in the Sahel, this could range from a field to the area around a village or even the entire Sahel).

The nature, speed and intensity of land degradation (as opposed to aggradation) vary and are the result of a combination of factors:

- The initial state and intrinsic quality of the land and its ecosystem, the resources it shelters and can renew, and the services it

can provide and produce via the ecosystem's ecological functions and in response to human expectations;
- The activities (or lack of) that people (e.g. rights holders, managers or local users) have historically carried out there, and those that they are carrying out or plan to carry out in the future. Activities (individual or collective) may involve the simple removal of natural resources for consumption, processing or marketing (e.g. roots, foliage, fruit from naturally occurring trees, dead or cut wood, etc.). They may also include the use of natural resources (soil, water, flora, fauna, etc.) for production (agricultural or industrial). They may be focused on the land with a view to protecting it (e.g. planting a hedge of woody species to protect a cultivated field from wind or wind erosion), repairing it (e.g. building semi-circular bunds in an agricultural field) or reallocating it (e.g. urbanized agricultural land). Lastly, activities may entail regulating all these actions when they are carried out in the same area (e.g. a forest resources management plan);
- The direct and indirect pressures on the land, whether climatic (e.g. water scarcity in certain places, due to the high spatial variability of rainfall, which is a direct pressure), demographic (e.g. fragmented land ownership, due to the cumulative process of land distribution between descendants, which is an indirect pressure), social (e.g. the abandonment of the territory or, on the contrary, the arrival of displaced people or migrants or the move from a rural to a peri-urban area), cultural (e.g. a sacred space, such as a sacred grove, that becomes a peri-urban area, which is an indirect pressure), or political (e.g. an area designated for a particular development or use, a protected area).

All these considerations (or factors) establish the territorial context of land degradation (as opposed to rehabilitation) in a given area. When one of them changes, the general dynamics of degradation (as opposed to rehabilitation) may also change. Accordingly:

- To understand and assess the spatial and temporal dynamics of degradation (as opposed to aggradation) in a given area, all of these factors must be considered and various elements of the local context identified;
- To combat desertification and take concrete action to reduce or stop degradation, it is important to understand each context

and its main parameters to determine the most appropriate options (technical or social) in each case;
- To disseminate, replicate or adapt to other territorial areas the actions to combat desertification that have already proved successful in certain territorial areas, their respective territorial contexts must be considered and any such actions tailored to the new context.

WHY DO WE NEED AN INTERDISCIPLINARY, MULTISTAKEHOLDER APPROACH?

Alexandre Ickowicz, Patrice Burger, Maud Loireau

Whether at local, regional or global level, understanding and taking action on desertification phenomena requires considering different scales (from microorganisms and the soil to the field, region, country, continent and even planet) and the compartments of social ecosystems (soil, water, atmosphere, flora, fauna, human societies) with their interactions and the timescale. A wide range of skills provided by various stakeholders are needed to understand the issues and implement measures to prevent or restore degraded land. Developers and researchers from different fields can combine their expertise by working together to rigorously analyse the phenomena to be managed or find innovative technical and social solutions. Additional territorial stakeholders at different levels must also be involved as they have a direct or indirect impact on the practices implemented: farmers and other rural stakeholders, local decision makers, industrial players and other private individuals, national policymakers and more. It is important for both of these groups of stakeholders to understand why they need to work together.

An enriching scientific outlook

For scientists, analysing these complex processes requires collaboration to leverage a full range of disciplinary skills. Climatologists, soil scientists, ecologists, biologists, hydrologists, geologists, physicists, chemists, agronomists and more must all work together to analyse the various biophysical processes and identify solutions to reverse the dynamics of degradation. Similarly, sociologists, geographers, economists, anthropologists, environmental lawyers and others must combine their skills to analyse social processes and put forward solutions to regulate relations between people and between people and their environment. In addition to this type of interdisciplinary collaboration between major fields, it is crucial for the biophysical sciences and the social sciences to join forces. It is also important to draw on both academic and local knowledge from people, which has been proven by years of experience and often passed down through the generations, and to integrate the expectations and perceptions of local people into the innovation process. For example, how can we make a reliable assessment of the impact of a farming practice without knowing the detailed processes at work in the soil and what drives a farmer's actions?

While these collaborations may be vital, they can be quite challenging to put into place. Beyond the difficulty of bringing all these disciplines together around the same objective, collaboration itself between these experts from different disciplines can prove tricky. This is because each expert is often specialized in a particular research subject (root systems in soil, household income, landscapes, territorial identity, etc.) and a particular scale of work (e.g. the plant, plant population, landscape or family, village, nation, etc.). Experts also have their own disciplinary view of the subject being analysed and therefore of the evolutionary processes under way. As a result, all the scientists involved must be willing to listen to their colleagues and their assessments, and be able to carry out collective, interdisciplinary studies to produce joint assessments and proposals. They must all make an effort to speak a language that everyone can understand, admit that the same term can have different meanings from one discipline to another, and be prepared to develop or broaden the concepts and methods of their science.

When these collective processes are developed, they require lengthy discussions, analysing the problems and issues at stake, developing diagnostic methods, and ultimately reaching compromises between disciplines on the measures to be implemented and the objectives to be achieved in order to stay within a reasonable intervention framework. Disciplines other than those mentioned above – including data science and scientific modelling, knowledge engineering and cognitive science – can help with these processes of exchange and interdisciplinary co-construction. These disciplines showcase knowledge so that it can be better shared, and integrate it and connect it to generate new knowledge: spatialization of the phenomena studied; prediction of their spatial and temporal evolution; social appropriation and acceptance; dissemination of proposed solutions; decision support systems, etc. However, even when scientists do engage in interdisciplinary collaborations, the knowledge produced or the developed solutions may not be acknowledged or used (or only to a limited extent) by the local populations or stakeholders, because they are only partially or not at all suited to the different territorial contexts.

Territorial stakeholders must overcome divisions

When it comes to territorial stakeholders, they vary greatly depending on their activity (farmers, artisans, community organizations, tourism and industrial players, government officials who manage the area, local political authorities, etc.) and the social and professional category to which they belong (women, men, young people; entrepreneurs and employees; etc.). Everyone has their own point of view and makes their own assessment of the situation, influenced by their own interests, aims and experience; everyone has their own methods of analysis, intervention and communication. But their shared challenge is to find compromises in order to take action in the same territory and to reach consensus on the desired objectives. They must also find common ground and ways to work together so they can fully address the issues at stake. Whether a compromise is found (in the best of cases) or a solution is imposed by one or a minority of stakeholders, they are generally able to implement the necessary levers of action to achieve the set objectives (change in practice, regulations, investment, natural resource management, etc.). However, stakeholders sometimes lack tangible, reliable information on which to base their decisions, especially since the actions they will take following these negotiation processes may have negative impacts that were unanticipated or with an intensity they had not measured over the medium and long terms. Such actions may be carried out with full knowledge of the impacts, based on demands or short-term choices, for example, to the detriment of the sustainable management of land and natural resources.

The pragmatic virtues of dialogue between all parties

It is crucial for scientists and territorial stakeholders to work together, from identifying problems to resolving them and following up through monitoring and evaluation in the short, medium and long terms to adapt actions as necessary. Dedicated systems (e.g. so-called multistakeholder and science–society interface platforms, field schools, exchange programmes and training courses, etc.) can bring together scientists and territorial stakeholders to promote the exchange of viewpoints, knowledge, methods and capacities for action, and in so doing encourage collective intelligence. The process of arriving at a consensus on the assessment of the desertification situation, operational objectives for preventing or combating it, and realistic methods of action that often involve many stakeholders – all with an outcome that meets their multiple priorities – can be participatory, collective or collegial. The choice depends on whether the co-construction aspect applies partially (to certain issues or at certain key moments in the overall process) or fully. These mechanisms and approaches are complex and sometimes difficult to manage, especially over the long term, and more often than not require greater investment in time and human and financial resources. But they do have the advantage of not sidelining key stakeholders involved in critical issues, solutions and decisive means of action. These approaches can also save resources, such as when a solution existed but was unknown or had not yet been evaluated by most stakeholders. Regardless, leadership and mediation efforts are required to ensure that all viewpoints are taken into account, but also to spark a more collective dynamic, without which actions in this area have little chance of succeeding.

WHY ARE AGROECOLOGY-BASED SOLUTIONS IMPORTANT?

Jean-Luc Chotte, Patrice Burger, Maud Loireau, Sylvain Berton, Éric Scopel

Agroecology emerged in the early twentieth century and has developed within a rural context across the world. It has become more visible over the last twenty years and more widely accepted in scientific, agricultural and political discourse. The meanings, definitions, interpretations and approaches of this dynamic are ever evolving, making it difficult to establish a single, precise explanation of what agroecology is. But recent efforts have sought to better define the various aspects of this extensive approach, which seeks to better harness ecological processes for agricultural production and lessen dependence on chemical inputs in ways that are economically and socially sustainable and equitable. The FAO's ten elements of agroecology or the thirteen principles of agroecology described by the High Level Panel of Experts on Food Security and Nutrition (HLPE-FSN) illustrate the array of technical, organizational and sociopolitical actions and scales of application that agroecology can leverage. Agroecology is relevant to efforts to combat desertification in many ways.

Making efforts to combat desertification a key part of sustainable development

The holistic approach – which assumes that ecosystem health underpins human well-being, production system performance and social ecosystem resilience – makes agroecology a powerful lever at the point where many sustainable development objectives overlap. Applying agroecological practices and techniques to better manage resources and ecological processes through biodiversity has consequences not only for the three indicators used to assess land degradation (i.e. soil carbon stock, land productivity, vegetation cover) but also for the fight against poverty, hunger, biodiversity loss, desertification, climate change mitigation and adaptation, and the availability and quality of water resources.

Organic matter management, for example, is a key part of agroecology. In dryland areas, good management helps to reduce wind and water erosion by improving soil structure, reducing evaporation by storing water in the soil, increasing bacterial life by improving fertility, etc. Similarly, diversifying cultivated species supports better use of available resources through their complementarity, and facilitates the natural regulation of pests and diseases by stimulating biodiversity.

Agroecology also resonates at the community level in the proposals made by the people and managers of areas affected by desertification who are exploring innovative agroecological solutions. In Niger, agroecological practices have helped to combat land desertification by attempting to create urban–rural complementarities that did not exist before (e.g. recycling household waste in cultivated fields) or by giving more land rights and access to women farmers and agricultural processors.

A step-by-step transformation of production systems to fully address needs

Agroecological practices and techniques support an incremental transformation of production systems, avoiding the difficulties often encountered with disruptive change. Pathways that lead to a complete conversion of current systems towards entirely agroecological systems are possible, such as those described in Steve Gliessman's (2016) work. These transitions then go through a series of levels of change, each enabling the transformations to be targeted and monitored, and supported by clear actions.

In dryland areas, these steps must be adapted to conventional systems where chemical inputs are not a major issue, since low water availability limits their effectiveness. This intensification is based on the gradual adaptation of practices to better control soil degradation, capture rainwater, reintroduce biodiversity and stimulate ecological processes.

Agroecology does not offer a generic, universal solution that can be applied to any situation. It is above all an approach where ecological, economic and social principles are applied to support the sustainability, viability, resilience and coherence of the system as a whole. Agroecological systems are developed progressively, depending on the context and needs or urgent issues to address. Each of the principles may be favoured to a varying degree so as not to upset the balance of the entire system. In farming systems, agroecology leads to the participatory design, creation and adaptation of complex cropping systems that are productive and therefore attractive despite an unfavourable environment and very low input use.

Easier said than done

Agroecology practitioners face resistance and conflict throughout the value chain in production, processing and marketing systems.

At each stage of the transition, they decide which changes to implement and at which scale with a view to making the new systems compatible with a number of constraints, knowing that not all of them can be perfectly resolved at once. This means that producers must prioritize limitations and make compromises in dealing with them. These compromises are often related to the degree to which the different principles of agroecology are applied, which must be adapted to the resources available to producers. Each stage should enable simultaneous changes to be made to the internal or external conditions of farms, so that the next stages of adaptation can be put in place. It is an arduous process, requiring continuous collaboration with different producers who do not all have the same conditions or resources. Getting women, young people and the most marginalized populations involved is often crucial to ensuring an effective and equitable transition. Stakeholders must also work with the institutions that influence the economic, social and political context in which these producers work, in order to create more favourable conditions for agroecological transitions on farms.

Knowledge-based solutions

The joint production and sharing of information play a central role in the development and application of agroecological innovations. Science has joined the field of agroecology to provide valid options for the agricultural transition. However, the critical mass of existing know-how has mainly been produced in farming environments. Building on this foundation, the key challenge is to continue producing new knowledge through joint efforts by the various stakeholders to adapt new agroecological systems to the wide range of conditions faced by small-scale family farmers. It is also extremely important to be able to make a better scientific assessment of the potential of existing agroecological systems so they can be improved by the players involved, and thus share useful insights with institutional decision makers and policymakers. Similarly, it is vital to capitalize on all this knowledge and share it as broadly as possible, especially with stakeholders in dryland areas who are sometimes isolated and powerless to find suitable solutions to the issues they face.

USING EVALUATION TO SUPPORT ADVOCACY

"There is sometimes a degree of scepticism about the relevance of agroecology in meeting today's challenges. This reticence runs through the agricultural world as well as that of decision makers. [...] Systematic references produced using a solid, common methodology are still lacking. Yet there is a growing demand for reliable, 'aggregatable' data on the effects and development conditions of agroecology from policymakers, farmers and development support stakeholders" (Levard, 2023; translation by the authors).

Three methods for evaluating agroecology, its agroenvironmental and socioeconomic effects, and the conditions for its development have been recently designed and tested by development practitioners, researchers and teacher–researchers in different areas in the Global South: the method presented in the FAO's Tool for Agroecology Performance Evaluation (TAPE), the method proposed by the Working Group on Agroecological Transitions (known by its French acronym, GTAE) and the method developed by the AVACLIM[12] project. These methods help fill this gap.

12. https://avaclim.org/le-projet

WHY SHOULD WE FOSTER COMPLEMENTARITY BETWEEN LOCAL, REGIONAL AND GLOBAL SCALES?

Maud Loireau, Alexandre Ickowicz

According to the strict (cartographic) sense, the term "scale" in geography refers to the relationship between a real distance, measured in terrestrial space, and its representation on a map. The larger the scale, the smaller the area represented on a document (e.g. A4 size). This is why a map with a 1:1,000 scale (1 cm = 10 m) is at a larger scale than the 1:100,000 map (1 cm = 1,000 m) and shows a smaller area on the same A4 document. In other disciplines, scales measure the intensity of a phenomenon (e.g. the Richter scale for the magnitude of an earthquake, the Beaufort scale for wind speed). In interdisciplinary contexts, the term "scale" most often refers to the spatial level at which a phenomenon is analysed: scales may be local or regional in a subnational sense, national or regional in a supranational sense, continental or global, from the smallest (a field, village, municipality, etc.) to the largest (planet Earth) area being discussed.

Desertification (and efforts to combat it) is a phenomenon whose climatic and anthropogenic causes, land degradation (and rehabilitation) mechanisms and ecological and social consequences operate on different scales or apply to several scales (multiscale processes).

Wind erosion as a case in point

Fighting wind erosion is a perfect example to illustrate the importance of considering the different levels of scale involved and their interactions and complementarity in combating desertification. Wind erosion refers to the action of the wind on bare or sparsely vegetated surfaces in dryland areas resulting in the horizontal and vertical movement of part of the soil. The horizontal movement of this sediment leads to redistribution on a local scale, with areas of loss and areas of accumulation. The vertical flow of soil due to wind erosion transports desert dust over long distances (regional, continental and global scales). This loss of the finest, most fertile fraction of the soil degrades it (local scale). The African continent, for example, is depleted of fine particles exported in suspension by wind transport towards South America, Greenland and Europe. However, soil is also redistributed more regionally to the tropical rainforest of the Gulf of Guinea, which helps fertilize the forest soil (continental and global scales). The biophysical consequences of wind erosion are thus multiscale. They are also social, as evidenced by the problems wind erosion causes for the respiratory and cardiovascular systems of humans on a local, regional and continental scale.

The causes of this erosion may be local (e.g. unsuitable practices, tornadoes) or regional (e.g. geomorphological position of the eroded land, lack of policies to protect vulnerable land). To combat wind erosion, solutions can be sought at local scale (e.g. planting hedges, grouping fallow fields together under a village agreement) as well as at regional, national or continental scale (e.g. subsidies or training/awareness-raising to help farmers plant tree hedges and stabilize sand dunes; regional dissemination of effective practices identified at local scale). Finally, the ultimate purpose of interventions must be considered: why make changes in an area losing sediment that people do not use, when the area where it accumulates is – and benefits from – receiving the most fertile fraction of the eroded soil? Similarly, could potential tensions between land users in areas of loss and areas of accumulation be avoided (on a local as well as regional scale if necessary) by organizing consultations and collectively seeking compromises in terms of development linked to the effects of wind erosion? Wind erosion is a natural phenomenon people have long benefited from, such as by being able to farm the large fertile plains of sedimentary basins. Should we fight or slow down this phenomenon if the costs are reasonable, or let nature take its course and adapt to change? Of course, if the actions undertaken are too intense, too fast or unsuitable, they can accelerate natural dynamics that will need to be limited, especially if demographic pressure leads to new land being developed. Considering local actions within a global dynamic raises questions of a paradigm shift: should we consider the world as fixed and try to preserve the current equilibrium, and at what cost (economic and social)? Or should we adapt to the Earth's ever-changing dynamics?

Which innovative solutions should we draw from to do so without worsening inequality?

The degradation of woody plant species

The degradation of woody plants (trees and shrubs) in the Sahelian drylands is another illustrative example. The density and diversity of trees across much of this area (on a regional scale in the supranational sense) have declined sharply, particularly since the major droughts of the early 1970s and 1980s, with consequences on soil degradation (e.g. erosion, reduced fertility), biodiversity loss and less food for humans and animals. The consequences have also been social: for example, the loss of trees in fields (local scale) may have encouraged women who process non-timber forest products (fruit, leaves, bark, etc.) or men deprived of their extremely degraded land to change jobs and move to an urban area or another region, country or continent to make up for lost income (migration at regional to continental scale).

Some areas (local or regional scale in the subnational sense) in the Sahel have been regreening, starting in the 1990s and again from 2000. The vegetation (woody, grassy, etc.) and causes (climatic, anthropogenic) involved in this regreening are still being debated in the scientific world, but likely stem from multiple reasons, including improved rainfall in recent decades and regeneration practices, such as the assisted natural regeneration of trees in cultivated fields in Niger. Regreening linked to assisted natural regeneration in one or more village areas (local scale) can encourage locals in one or more regions to adopt this technique or to practise it again (regional-scale dissemination).

This type of practice is now being promoted at regional level in the Sahel as part of the Great Green Wall (GGW) initiative, which aims to coordinate efforts to restore and rehabilitate Sahelian ecosystems from Senegal to Ethiopia. This initiative addresses both local issues of participatory regeneration practices engaged in with local populations and the transnational harmonization of programmes, funding and legislation on the management of these ecosystems. Acting on these regional scales also means potentially being able to influence water cycles, erosion phenomena and the heat contexts that affect desertification processes on a local, regional and continental scale.

The causes and consequences of these desertification phenomena are thus multiscale (global/local climate, regulations, regional and local practices). The mechanisms differ from one context to another depending on the homogeneity or heterogeneity of the biophysical and social conditions (contexts can be highly localized, where regional heterogeneity is significant, or regionalized, where there is considerable regional homogeneity). Acting at all levels to ensure that actions are complementary rather than contradictory is the best way to implement sustainable, equitable and fair actions.

HOW DOES ADAPTING TO CLIMATE AND ENVIRONMENTAL VARIATIONS HELP COMBAT DESERTIFICATION?

Pierre Hiernaux, Alexandre Ickowicz, Christine Raimond

Despite major water constraints, people have been able to develop extremely resilient livelihood systems that are adapted to the ecosystems of arid, semi-arid and dry sub-humid areas through specific agroecological practices, the diversification of crop and livestock species and activities, and the mobility of goods and people. These systems revolve around crop and animal species that thrive in the local bioclimatic conditions, with farmers selecting those that best meet their needs and environmental changes.

Crops and animals suited to the climate

These crop species have a phenology adapted to a rainfall regime that is generally seasonal with high inter-annual variability and a temperature regime characterized by very high peaks in the middle of the day, particularly at the end of the dry season. Along the north–south, Saharan–Sahelian–Sudanese gradient, C3 photosynthetic plants (which produce sugars with three carbon atoms) account for the greatest number of species. There are fewer C4 photosynthetic species (which produce acids with four carbon atoms). They include cultivated cereals, which are diet staples for the local populations (millet, sorghum, maize). CAM (crassulacean acid metabolism) plants are also well suited to these specific conditions, but there are not so many of these species; unlike in other dry regions, succulent plants are uncommon in the Sahel. These various ways that plants adapt to the climate could play a role in climate change. In addition to seasonality, there is considerable spatial heterogeneity related to rainfall or its redistribution via surface or subsurface run-off, which affects the spatial distribution and availability of vegetation.

Animal species, both wild and domesticated, are also characterized by their ability to withstand heat, drink sporadically and feed opportunistically, while easily drawing from their body reserves during difficult periods.

The "3M" model: mobility, multi-enterprise farming and multifunctional space

Adapting subsistence systems to the environmental variability of resources is based on the species and varietal diversity (long or short cycles) of cultivated plants to make the most of the edaphic heterogeneity, the practice of fallowing, and the complementarity between less fertile areas that get little water and areas with more resources (e.g. oases, flood plains and rice paddies, manure-fertilized and watered gardens). With regard to livestock farming, animal breeds have been selected over millenniums, and mobility – daily and local pastoral mobility as well as seasonal and regional – remains the main mode of adaptation. This mobility is combined with community or public land tenure, which enables adaptive management of an area according to the inter- and intra-annual resource availability based on negotiated rights of access for specific uses: watering of animals, grazing, gathering, felling of wood.

These practices tend to renew soil fertility and mitigate land degradation processes, sometimes even encouraging regeneration, mainly due to the extensive nature of the resulting resource use. Soil nutrient exports drop along with falling crop yields. Pastoral mobility lowers the forage harvest at one place and in one season by grazing that is always selective and opportunistic. Fruit and wood gathering is also partial, as it is selective. Fallowing, the management of livestock effluents via composting and manure pits, and the spreading of manure and household waste all contribute directly to restoring soil fertility. This is also the case for agroforestry practices, which include the establishment and maintenance of agroforestry parklands and hedgerows. Diversifying their activities and moving to less densely populated areas with more favourable agroclimatic conditions or near urban centres are among the strategies adopted by farmers in areas where land is saturated. These strategies help strengthen regional complementarities to increase food security and reduce human pressure on local natural resources.

An uncertain balance

Global change (which encompasses climate change, population growth, urbanization and globalization) is having a major impact on rural areas in arid, semi-arid and dry sub-humid zones. Rising anthropogenic pressure, resource extraction and the reduction or elimination of fallow periods are degrading the soil. Until now, farmers have been able to adapt by planting new species and varieties of seeds, sometimes from far away and which they source through markets or the movement of people (e.g. replacing long-cycle varieties with short-cycle varieties during periods of drought). They have also diversified their crops and activities to ensure their own food security and supply local towns. However, the extent of climate change means that farming adaptations (photoperiodic varieties, field management, agricultural extension services) must go well beyond previous adaptations and require support. Rising livestock numbers adds to the pressure on natural resources. The speed and pattern of urbanization also play a major role in land degradation due to the ensuing sharp increase in demand for food, energy and building materials.

In this context, certain long-standing practices, depending on their nature and intensity, can degrade the vegetation cover or soil, such as fires used to clear Sahelian annual plants or tree felling, which affects species prized for their timber (e.g. *Prosopis africana*, *Dalbergia melanoxylon*, *Sclerocarya birrea*, *Hyphaene thebaica* in the Sahel, and *Pterocarpus erinaceus*, *Khaya senegalensis* and *Borassus aethiopum* farther south). New practices, such as collecting cereal stubble from the field and raking straw from rangelands, are becoming increasingly common. Because they reduce the organic matter and minerals returned to the soil, they worsen the slow decline in soil fertility and hence desertification. Fallowing is only effective if done for a long enough time. The number of years depends on the intrinsic soil properties (at least three to five years in the Sahel), but this leaves a large part of the landscape unusable, which is often incompatible with the rising need for agricultural land. Similarly, sources of animal manure may be sufficient to maintain soil fertility on a cultivated field, but they are often not enough to maintain the fertility of agricultural soils on a village or territorial scale.

The limitations of technical solutions and the need for a new model

Development projects offer a range of practices to tackle these soil degradation processes, with varying degrees of success. Anti-erosion measures such as terraces, filter dykes and semi-circular bunds to control surface run-off and limit water erosion are widely recommended and supported by international funding to rehabilitate land damaged by water erosion. The same applies to techniques for stabilizing dunes and bare loose sands by building dead hedges in a chequerboard pattern. Forestry-type afforestation projects, where seedlings are planted in rows in fields protected from any other use, are recommended to combat desertification (such as in the Great Green Wall initiative). Along with the use of mineral fertilizers to boost cropland productivity and increase yields, all these new practices are aimed at rehabilitating degraded land. However, farmers do not use them as strategies for adapting to climate variations and climate change. Rather, they reflect a desire to increase soil productivity, which can be seen as an indirect means of adapting to climate change by making better use of scarce water resources. The use of supplements to improve livestock feeding during the leanest periods at the end of the dry season and the beginning of the rainy season is an indirect adaptation by livestock farmers to keep their livestock in better condition to deal with the climate and related changes.

As a result, the solutions proposed by development projects are out of step with ancestral resource and ecosystem management practices when it comes to adapting to seasonal and interannual variations in resources in these heterogeneous environments that vary over time. While traditional practices place limited pressure on ecosystems over time through adaptive domesticated species, seasonality and mobility, development projects offer technical solutions. These solutions are based on agricultural intensification and increasing soil productivity along with land management (anti-erosion systems, reforestation, soil rehabilitation) and are limited to technical approaches. These field-centred solutions are not innovative in any way. Given the scale of the changes to come and the multiple crises affecting food security and governance systems at different levels, new practices are needed. Such practices will depend on the development of services (crop and livestock insurance, medical and social insurance), agroecological intensification and the creation of appropriate supply chains to improve the social, environmental and economic sustainability of these social ecosystems while also combating desertification.

WHAT ARE THE DIFFERENT TECHNIQUES FOR REHABILITATING LAND AFFECTED BY DESERTIFICATION?

Bernard Bonnet, Patrice Burger, Jean Albergel, Thierry Heulin, Maud Loireau

Combating land degradation is a major challenge in dryland areas for the development of vast territories whose economies mainly revolve around renewable natural resources. The productive capacity of these areas depends on the ongoing interaction between seasonal work and transhumance movements, which free up agricultural areas for the growing season.

Reducing land degradation means:

- Combating water and wind erosion;
- Expanding the woody and grassy cover of grazing areas and crop fields;
- Increasing the stock of soil organic matter for the long-term intensification of existing agricultural land;
- Managing flows and exchanges between ecosystem compartments and between regions;

- Establishing and enforcing land-use planning and management policies.

For dryland areas, soil and water conservation, soil defence and restoration, and agroecology (including agroforestry) encompass a diverse range of land rehabilitation techniques. These technical measures have generally been developed to adapt to biophysical realities, such as soil infiltration (e.g. loose, sandy soils or hardened, crusted soils). They have rarely been designed to adapt to the complex social and ecological contexts of the areas where they will be implemented. This is why desertification persists despite land rehabilitation efforts. Moreover, these techniques are only useful if they are used as part of a management approach to ensure they are sustainable and in conjunction with a legal framework that will give the people who manage the "treated" areas greater responsibility in doing so.

Sustainable land management encourages, facilitates and seeks to maintain land-use systems that respect the culture and expectations of users. It must maximize the economic and social benefits of the land, while maintaining or improving the ecological functions of ecosystems for the benefit of all. It must also ensure that land resources are shared between users while preserving private and public property. Land rehabilitation techniques must be integrated and combined within this general framework, and adapted to the social and ecological context of the land in question. The "technical" measures for land rehabilitation, which are complementary and necessary, can be divided into the following four categories.

Remedial measures to mitigate risks to infrastructure and people

One example of this is where the infrastructures of inhabited areas are often directly threatened by flooding or silting in large areas subject to desertification. The protection and remedial works that would be required in such a situation aim to stabilize the banks of rivers that can cause devastating damage as a result of the massive run-off that concentrates downstream of watersheds that have lost their grassy and woody vegetation cover. These measures rely on costly construction techniques such as gabions or rock armour, dams and weirs, which remain quite vulnerable without more extensive works to slow run-off across the entire watershed. As in this example, protection and remedial works often involve major investment that can be difficult to obtain and may prove unsustainable if the root causes of the problem are not addressed.

Techniques to make better use of natural resources

In the Sahel, for example, a range of techniques has been developed to adapt to the local conditions: stone lines, dykes, micro-dams on ravines, riverbank seeding, terraces, mulched strips, dune fencing, vegetation planting, direct sowing, etc. In soils with hardened, impermeable surface horizons, such as the Plateau-Central Region in Burkina Faso or the Ader in Niger, zaï holes are an example of a technique that improves the retention of water and nutrients in the soil and helps regulate nutrient flow. Zaï is a traditional technique of growing crops in small pits to break up the soil crust, concentrate water infiltration and stimulate soil life by applying organic fertilizer. Sorghum and bean seeds are sown when the rains arrive. This simple technique can enhance bare or abandoned areas and reduce run-off and water erosion by encouraging infiltration into bare soil. Collecting rain in a localized way can protect harvests in areas with at least 400 mm of rainfall. It is an inexpensive way to increase the area available for crop farming and is best applied to degraded land, valley walls and laterite plateaus. It also regenerates woody plants through applications of stockyard manure[13] containing the seeds of grazed trees, such as various acacias.

In North Africa, particularly in central and northern Tunisia, heavy earthworks have been carried out to systematize the large-scale development of anti-erosion earth banks to limit run-off and collect excess water in hill reservoirs.

In the vast, densely populated sandy plains of central-eastern Niger, agroforestry has helped support the development of agricultural forests (around 120 trees per cultivated hectare). In these areas, which are subject to continuous cultivation, the

13. A mixture of soil, urine and dried dung collected from livestock pens during the dry season.

development of dense agroforestry parklands dominated by leguminous plants such as *Faidherbia albida* and *Piliostigma reticulatum* has made it possible to protect the soil and crops, while improving soil fertility by stimulating biological activity and recycling mineral elements. These developments help increase income through the sale of poles and fodder from trees, and the sale or processing, especially by women, of non-wood forest products such as fruit, bark and honey.

ASSISTED NATURAL REGENERATION IN NIGER: AN EXCEPTIONAL DYNAMIC IN SATURATED AREAS

As early as 1985, in the densely populated regions of Maradi and Zinder in southern Niger, farmers began to protect and return to assisted natural regeneration of trees in their fields (sometimes through what was called controlled land clearing) by encouraging the growth of well-adapted local tree species with high added value (such as *Faidherbia albida* and *Acacia sp.*). By 2005, the area covered some 5 million hectares, with 15 to 20 times more trees than in 1975.

These trees were not planted; instead, they were able to grow following farmers' efforts to protect (through deferred grazing) and manage spontaneous regeneration. Farmers clearly recognize the multiple impacts of bringing trees back to their land, noting benefits such as "trees are like millet for us", "trees act as windbreaks", or "without trees, our animals would have nothing to eat". Trees are part of the production system and have improved the integration of agriculture, livestock farming and forestry.

Preserving trees in the fields, protecting nature and engaging in assisted natural regeneration are the least expensive and easiest techniques to adopt over large areas to ensure the sustainable management of forest resources and, more generally, to rehabilitate land.

Schemes and rules for managing shared resources

The use of common resources requires schemes and rules for the shared, equitable and "non-degrading" use of resources, as well as the monitoring of their application. For example, water abstraction rights, procedures for regulating the collection of firewood and rules for managing communal grazing land lead to the rational use of resources. A number of concerted schemes for the local management of common resources have been successfully developed in various countries, such as local agreements and rural timber markets in Niger and intercommunal pastoral charters in Mauritania and Chad. These consultation processes between the users of these areas facilitate the development of local management rules and the planning of developments to promote sustainable management of the commons.

CONSOLIDATING THE ECOLOGICAL BENEFITS OF PASTORAL MOBILITY

The strip of land between the 400 mm and 100 mm isohyets for average rainfall is an area heavily dominated by transhumant pastoral activities and rain-fed agriculture. The pastoral areas – which are saturated with a growing population – are facing pressure from expanding agricultural fronts.

The woody vegetation in the area is being regenerated, following its deterioration during the great droughts of 1973 and 1984. This vegetation, dominated by annual grasses, is of high pastoral quality (for milk production and breeding).

It covers patches of large areas with many temporary ponds (natural and artificial), which is what drives major transhumance movements that enable pastoralists, agropastoralists and livestock breeders to use this land for a few months of the year, before moving further south to areas with more rainfall.

Pastoral and agropastoral livestock farming are key activities in these areas and make the most of natural resources that vary from year to year depending on rainfall. Human settlements are only possible under such constraints if there are permanent water sources during the dry season and herd mobility is maintained, as this is crucial to adapting to the irregular availability of pasture.

Safeguarding this mobile, transhumant livestock farming, which is particularly well adapted to the variability of arid ecosystems, is an important action in the combat against desertification. It involves concerted planning and development of the agropastoral area so as to combine investment in diversified and appropriate pastoral water sources as well as concerted demarcation of grazing areas and sections of threatened passageways in dense agricultural areas.

Favourable institutional and policy mechanisms

This involves developing policies to secure land ownership in order to incentivize local stakeholders to invest in various developments or management techniques that require a longer payback period. Involving users in land management is therefore particularly crucial. Often, over-centralized management by governments can contribute to practices that lead to the degradation of land and the common resources it supports. The effective transfer of land management responsibilities to recognized user organizations opens up favourable avenues for reducing the dynamics of degradation and regeneration. Land policies therefore need to be drawn up and revised with approaches that combine legality and legitimacy, favouring negotiated rights and strengthening responsible governance. Such approaches must guarantee the broad, inclusive and informed participation of users in policy development, through bottom-up multistakeholder consultations (from local to national level), with the assurance of compliance with international agreements on the combat against desertification, on climate change and on biodiversity protection.

WHAT IMPACTS AND RESULTS HAVE EFFORTS TO COMBAT DESERTIFICATION HAD TO DATE?

Jean-Luc Chotte

The most tangible proof of the impact and results of the combat against desertification is arguably to be found on the political agenda and in international initiatives. While numerous regional initiatives to combat desertification have been in place for many years, their impact is rarely documented over the medium and long terms.

One of the 169 targets of the Sustainable Development Agenda

The concept of zero net land degradation was first officially mentioned in 2011 by Luc Gnacadja, the former Executive Secretary (2007–2013) of the UNCCD, ahead of the Rio+20 summit. At this summit, the heads of state adopted the concept of a world that was neutral in terms of land degradation, thus establishing a global political framework. The states then asked the UNCCD Science-Policy Interface (SPI) to refine this conceptual framework and provide a solid scientific basis for understanding, implementing and monitoring progress towards achieving the target of land degradation neutrality.[14] To date, 129 countries have committed to establishing voluntary land degradation neutrality targets and relevant measurements to achieve this goal by 2030. The Global Mechanism was created to facilitate the mobilization of financial resources to implement the UNCCD. It is the operating body of the UNCCD. It works with developing countries, the private sector and donors to marshal substantial resources within and outside a country to implement the UNCCD at national level. As such, it supported the creation of the Land Degradation Neutrality Fund (LDN Fund), a private-sector-led initiative to raise funds for projects to combat desertification. In 2015, achieving a land degradation-neutral world became one of the 169 targets (target 15.3) of the Sustainable Development Goals (SDGs). Including land degradation in the SDGs illustrates the growing awareness of decision makers outside the states affected by desertification.

A wide range of initiatives that go beyond the scope of the UNCCD

The Great Green Wall initiative, launched in 2007 by the 11 states across the Sahel in Africa, is a major initiative for the UNCCD, especially considering that the UNCCD has hosted the Great Green Wall Accelerator since May 2021. The Accelerator acts as a platform for strengthening, coordinating and monitoring the implementation of projects to combat desertification. However, there are many other initiatives that share the aim of making land a lever for sustainable development.

One such initiative is the Bonn Challenge[15], launched by Germany in 2011 through its International Climate Initiative (IKI). It is being implemented as part of a collaboration between the

14. See chapter 3, "What does it mean to 'combat desertification'?"

15. https://www.bonnchallenge.org/about

International Union for the Conservation of Nature (IUCN) and the World Wide Fund for Nature (WWF). At a global level, this initiative aims to restore 150 million hectares of degraded and deforested landscapes by 2020 and 350 million hectares by 2030. In 2017, the milestone of 150 million restored hectares was reached. This initiative is active in 61 countries. In Africa, 10 countries joined forces to launch the African Forest Landscape Restoration Initiative (AFR100), with the goal of restoring 100 million hectares of degraded land by 2030.

The United Nations Decade on Ecosystem Restoration

On 1 March 2019, the United Nations General Assembly unanimously adopted a resolution proclaiming the period 2021–2030 as the United Nations Decade on Ecosystem Restoration. Its two main goals are to "suppor[t] and scal[e] up efforts to prevent, halt and reverse the degradation of ecosystems worldwide and raise awareness of the importance of successful ecosystem restoration". The resolution seeks to bring stakeholders together, both in terms of the types of stakeholders involved and the diversity of the parties concerned. The resolution targets a very wide range of stakeholders, inviting "governments, international and regional organizations and other relevant stakeholders, including civil society, the private sector and academia, to actively support the implementation of the Decade". The resolution also "stresses the importance of the full involvement of all relevant stakeholders, including women, children according to their evolving capacities, young people, older persons, persons with disabilities, indigenous peoples and local communities".

The emergence of knowledge-sharing networks dedicated to combating desertification

All those involved quickly became aware of the need to share knowledge in order to scale up successful actions to combat desertification. The World Overview of Conservation Approaches and Technologies[16] (WOCAT) network was launched in 1992 to address this need. This global network facilitates knowledge-sharing at local, national, regional and global levels through an innovative forum for

16. https://www.wocat.net/en/about-wocat

sharing best practices to combat land degradation, climate change and biodiversity loss. It thus makes it easier to analyse best practices that work (where, how and why) and their costs and benefits. This platform describes more than 2,000 practices and techniques for combating desertification from over 130 countries around the world. In five of the 36 decisions taken at the Conference of the Parties in Abidjan in May 2022, it was recognized by the Member States for its role in training and knowledge-sharing, and as a lever for strengthening collaboration between all the stakeholders involved. It has over 400 users and data contributors.

Impact of practical actions that are rarely documented

The WOCAT platform collects data on the impact of actions to combat land degradation, climate change and biodiversity loss. The services it provides (knowledge-sharing, training, decision support) are extremely useful. However, it must be acknowledged that the limited number of practices listed (2,000) compared to the many initiatives, actions and programmes actually implemented curtails its influence. Indeed, only a tiny fraction of possible actions are documented. There are several reasons for this:

- Some of the effects of actions to combat desertification can only be measured over the medium term (10 years) or longer, such as soil organic matter stocks;
- The duration of projects (and their funding) is unsuitable for medium- and long-term monitoring;
- The lack of a precise framework setting out the indicators to be measured;
- Indicators that are too often established by research and too often inaccessible to stakeholders or unsuited to local conditions;
- A lack of support for training stakeholders on data acquisition and related methods and on the storage of those data.

LEARN MORE

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WHAT SUPPORT MECHANISMS EXIST TO COMBAT DESERTIFICATION?

WHAT LEGAL PROVISIONS EXIST IN THIS AREA?

Philippe Billet

Few available legal instruments

There are very few legal provisions relating to desertification. Those that do exist generally fall under soft law, a flexible legal approach in which states are bound only to develop ways to meet objectives, and not to achieve results. Initially, the Plan of Action to Combat Desertification (1977) only included material options: maintenance of woody vegetation cover, forestry and agroforestry programmes and projects, ecological management of rangelands to develop and improve arid and semi-arid grazing lands, etc. The United Nations Convention to Combat Desertification (UNCCD, 1994) does not draw on legal instruments, leaving Member States free to decide how they will meet its objectives. The aim of the UNCCD is "to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through effective action at all levels" (Art. 2). This "effective action" is based in part on various guiding principles, including:

- "ensur[ing] that decisions on the design and implementation of programmes to combat desertification and/or mitigate the effects of drought are taken with the participation of populations and local communities";
- "develop[ing], in a spirit of partnership, cooperation among all levels of government, communities, non-governmental organizations and landholders to establish a better understanding of the nature and value of land and scarce water resources in affected areas and to work towards their sustainable use."

Some references to legal frameworks ask Member States to work together to conclude agreements to fulfil their obligations; to implement "long-term integrated strategies"; "promote cooperation among affected country Parties in the fields of environmental protection and the conservation of land and water resources, as they relate to desertification and drought" and "determine institutional mechanisms".

Affected countries are also called upon to strengthen relevant legislation or adopt new laws, and develop new long-term policies and action programmes.

Legal protection for land and woodlands

Provisions adopted by Member States mainly focus on afforestation efforts to stabilize, protect and restore land. In Burkina Faso, Law No. 003-2011/AN of 5 April 2011 relative to the Forestry Code makes restoration and reforestation areas subject to the forestry regime and related protection, and severely punishes those who destroy them. In Mauritania, Law No. 97-007 of 20 January 1997 takes a similar approach, protecting "forests and woodlands, reforestation or restoration areas[17]", as well as "land that was covered by forest, recently cut, burned or degraded, but which will be subject to natural regeneration or reforestation". This law governs land clearing, which is subject to authorization where it is not expressly prohibited, and specifically in "protected dune areas" and "deferred grazing areas" as well as on "a 100-metre strip from the boundaries of reserved forests" and "mountain slopes subject to erosion and gullying risks". It also specifically prohibits the "grazing and moving of livestock in classified forests, reforestation or restoration areas, forest areas undergoing natural regeneration, or artificial restocking zones". Finally, it regulates use rights, which are subject to the condition of the forest stands and vegetation. These rights may be restricted or suspended to safeguard forest resources and withdrawn without compensation when it is in the public interest to do so. Texts adopted in other African countries (Niger

17. Translation by the author

and Côte d'Ivoire, among others) enshrine more or less the same principles.

The development of legal provisions relating to desertification is not limited to Africa. In China, for example, the 1982 constitution states that "the State shall organize and encourage tree planting and reforestation, and protect trees and forests[18]", with numerous provisions encouraging reforestation and combating sand encroachment and soil degradation.

Challenges with application

While the law can be a useful tool in combating desertification, it can also act as a hindrance to policies to combat and remedy it. This is mainly due to social structures and customs, land tenure systems, land-use policies and patterns of land ownership and use that limit tree planting (FAO, 1989). Overexploitation of land can also "be a result of excessive fragmentation of holdings, due to existing land tenure and succession laws. Overgrazing may stem from traditional rights of land use insufficiently adapted to changing economic and demographic circumstances" (Sand, 1977). This means contending with local laws, most of which are based on customary rights.

THE GREAT GREEN WALL FACES MYRIAD REGULATIONS

The Great Green Wall must account for myriad regulations, both formal and spontaneous, because garnering support among local populations for the project assumes respect for their traditional rules and social structures. The desire of financial partners for legal guarantees can come up against the reality of land-use rights that are granted on a temporary and personal basis through oral agreements by customary chiefs. This means that endogenous law that is not only far removed from property titles and other "reassuring" documents but also difficult to change must be taken into account.

18. Translation by the author

Contending with "peripheral" regulations

Regulations that address desertification specifically are supported by texts on climate change because the two phenomena are linked, even if desertification is exacerbated by certain human practices. The IPCC's 2019 Special Report, "Climate Change and Land", covered this in detail. Efforts must also be made to move closer to the commitment agreed by Member States to "combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world" by 2030 (SDG target 15.3).

A lesser-known aspect of desertification relates to human rights: people may be forced to leave their homes because they cannot live in a continuously deteriorating environment. Without a consensus on what constitutes an environmental "refugee" or similar term, people find themselves without rights when they cross the borders into another country. The same is true of certain Indigenous populations living on the margins of a state. When not registered at birth, their stateless status deprives them of the most basic rights (food, water, housing, health care, etc.), thus worsening their living conditions.

Legal mechanisms in Europe

The European Union is not immune to desertification. The EU Environment Action Programme to 2020 called for the implementation of the UNCCD after noting that: "The degradation, fragmentation and unsustainable use of land in the Union is jeopardizing the provision of several key ecosystem services, threatening biodiversity and increasing Europe's vulnerability to climate change and natural disasters. It is also exacerbating soil degradation and desertification." But, as the European Court of Auditors has noted, the aim is merely to encourage Member States to take measures "to ensure that by 2020 land is managed sustainably in the Union" and to apply the 2013 EU Forest Strategy given that "forests play an important role in combating land degradation and desertification." However, the adopted measures lacked consistency (European Court of Auditors, 2018).

The proposal for a directive on soil monitoring and resilience of 5 July 2023, which formalizes the EU Soil Strategy for 2030 published in 2021, considers desertification as a factor in soil degradation, but, in the interest of the subsidiarity principle, does not include measures relating to soil use, as this is a competence shared between the European Union and the Member States. It merely sets out objectives, including climate neutrality and resilience to climate change, as well as compliance with international commitments to land degradation neutrality (COM(2023) 416 final).

Combating desertification and its effects is legally based on an array of provisions, ranging from the international to the local level, oral and written, traditional and formalized. But rights, whether on paper or in words, are only effective if they are exercised, which means contending with both the public authorities and the public. There is still a long way to go.

WHAT SUPPORT IS AVAILABLE FOR TERRITORIAL STAKEHOLDERS TO COMBAT DESERTIFICATION?

Patrice Burger, Maxime Thibon, Sylvain Berton, Jean-Luc Chotte

Combating desertification and land degradation is inextricably linked to development issues. There are many stakeholders involved, operating at levels ranging from the very local to the national and global. Each of these levels is matched by modes of action that are linked to one or more supporting frameworks. These frameworks are specific to donors, ministries, local authorities, states, and scientific and international organizations. As a result, support systems should take this diversity into account and include elements of public policy, technical input or recommendations from those involved in implementation as well as funding from a variety of sources. They should also provide a medium- and long-term vision of what needs to be done, and encourage the development of forward-looking scenarios. To achieve this, these support systems must fulfil a number of roles.

Creating third places to bring all stakeholders together

Public policymakers are among the various stakeholders to be involved. National governments and local authorities have a key role to play in implementing policies and programmes to combat desertification. They can also marshal financial resources to support these types of initiatives.

International and regional organizations involved in combating desertification, such as the United Nations (UNEP, UNDP, FAO, IFAD, etc.), the World Bank and the Global Environment Facility, can provide funding and technical advice and coordinate various stakeholders' efforts.

Civil society organizations, trade associations and community organizations, which are key players in initiatives to combat desertification because of their steady involvement, are very often an essential link in the coordination and synergy between national and territorial policies.

Local communities play the most direct role in combating desertification by adopting sustainable agricultural practices, planting trees and managing natural resources responsibly. They are also sources of local knowledge and are stewards of the investments that are made.

The private sector, through businesses, must also play a major role in combating desertification by adopting sustainable business practices and financing projects to protect, rehabilitate and restore degraded land.

Finally, academic players such as national and international research centres and universities must hybridize their knowledge within these third places through their expertise, skills and student training systems (curricula, doctoral schools).

Developing and implementing multistakeholder consultation tools

Participatory approaches should be promoted not only to implement actions to combat desertification, but also to develop a medium- and long-term vision and anticipate the resulting choices.

Building the skills and capacities of all stakeholders

Training and awareness-raising programmes focus on capacity-building, especially among local stakeholders, to adopt sustainable land and water management practices. These local stakeholders include:

- Agricultural sector players (farms, trade associations, companies upstream and downstream of production);
- Support players in the agricultural sector (extension services, private consulting firms, civil society organizations, national research bodies);
- Land managers (local, regional and national authorities, traditional and customary authorities).

Encouraging the application and sharing of all types of knowledge: consultation and co-management

Setting up consultation frameworks enables intervention strategies to be co-constructed on the basis of a shared vision of the state of the area, the issues at stake and the actions to be taken. Setting up co-management platforms enables action plans to be drawn up that consider the roles, skills and resources of each of the stakeholders involved. While consultation frameworks are generally fairly easy to promote and run, the process is much more difficult with co-management platforms. Yet they are ultimately responsible for implementing and evaluating action plans and ensuring that development initiatives are sustainable.

Promoting inclusive development and improving resilience during crises from the local to the global level

Effective action at the territorial level must be specific, with targeted local solutions for combating desertification. It must also involve multiple stakeholders from different sectors to reflect a shared vision of the territory and its development trajectories and encourage synergy between actions.

The measures that are implemented aim to take action on the agricultural-environmental front to rehabilitate, restore and safeguard agricultural areas and ensure better natural resource management. In economic terms, the goal is to support the development of sectors that create food security, added value and jobs. In sociocultural terms, it facilitates access to information, advice and training. At the political level, institutional frameworks need to be adapted to remove constraints, secure the economic environment and promote social equity.

Strengthening public–private partnerships

In some cases, special initiatives exist such as the Ankara Initiative, the Changwon Initiative, the Abidjan Legacy Program or the Great Green Wall of the Sahara and Sahel initiative (which includes 11 states along the southern edge of the Sahara and currently extending into Southern Africa). The latter initiative benefits from an "accelerator", with the commitment of a large number of financial backers. These initiatives require support from private-sector partners. Such partnerships should lead to the development of a risk management strategy, which today relies on stakeholders who are active on the ground through the implementation of appropriate tools.

Implementing a framework policy to encourage major programmes

Land conservation policies must take a long-term approach and include key measures such as regulating land use, protecting areas vulnerable to degradation and promoting sustainable agricultural practices. Such policies would be advantageous for the following types of programmes:

- Soil conservation, as these programmes promote sustainable agricultural practices to protect soils from erosion and degradation. These include initiatives to restore/rehabilitate degraded land through sustainable land management practices such as tree planting, agroforestry, assisted natural regeneration, pasture management and soil conservation;
- Reforestation, as they encourage the planting of trees to improve soil quality, reduce erosion and provide wildlife habitats;
- Water management, because they work to improve the availability and quality of water for crops, animals and humans, while reducing erosion and soil degradation;
- Strengthening links between rural and urban areas, and between nature reserves and areas modified by human activities.

WHAT RESEARCH IS BEING DONE TO COMBAT DESERTIFICATION?

Jean-Luc Chotte, Christine Raimond, Hélène Soubelet, Maud Loireau

Improving knowledge of land degradation and rehabilitation/restoration

Combating desertification draws on expertise from a wide range of scientific fields, including the humanities and social sciences (geography, sociology, management), environmental sciences (climate, ecology, soil hydrology, agronomy, forestry) and data science and modelling (remote sensing). While the excellence of this research must be sustained, it is also essential to run experiments, make observations and create models where these scientific fields connect. Approaches that focus solely on one of these areas do not provide a broad enough perspective to understand the full causes of desertification, nor the severity or speed of degradation, and especially whether or not the phenomenon being observed is irreversible. As a result, a single approach cannot provide appropriate and effective solutions. Land degradation is the result of several interconnected causes:

- Choice of production and consumption models;
- Natural resource availability against a backdrop of climate change and the rising needs of a growing population;
- Conflicting land uses to address challenges that are at odds with each other (farming, conservation, restoration, reforestation);
- Social exclusion (young people, women);
- Local, national and global governance;
- Security concerns in certain regions.

Many links are difficult to establish, such as those between desertification and land-tenure systems and migration, or between biodiversity and climate. Research must provide insights on the synergies and trade-offs between the solutions to be found in this changing and complex context by producing multidisciplinary knowledge and associated data.

For many years, the research community in the countries affected as well as the international scientific community have been deeply involved in studying the causes of desertification. They have also been working to produce knowledge to prevent and curb desertification and restore/rehabilitate degraded land in arid, semi-arid and dry sub-humid areas. An analysis of recent publications listed in the main databases shows that, over the last 10 years, nearly 400 articles have appeared on these subjects in scientific journals. Numerous research programmes have also been deployed in arid, semi-arid and dry sub-humid areas. We believe that future research efforts should focus on the following points.

Complex systems science

It would be useful to invent, consolidate and generalize approaches, models (symbolic knowledge representation models, digital simulation models, data models, etc.) and tools to:

- Understand, simulate and monitor changes in the causes, mechanisms and consequences of land degradation in arid, semi-arid and dry sub-humid zones from different viewpoints and levels of decision-making and action;
- Shorten the assessment time before taking action to combat desertification, without compromising on quality;
- Facilitate iterative loops between formalizing enhanced knowledge and adapting models/tools (better connecting humans and machines);
- Produce longitudinal analyses of slow degradation and regeneration processes;
- Analyse the vulnerabilities induced and the technical and institutional frameworks to be implemented at different levels to reduce land degradation.

Social and cognitive sciences

Rules for organizing societies and their local areas could be established so they:

- Acknowledge the voices and rights of all;
- Organize action (scientific, political, civic) at different scales (of time and space) and different levels of organization;
- Are interconnected (and sustainable), based on cultural reference points regarding ethics and quality of life;
- Account for the power relations, conflicts and negotiations inherent in democracy and its principles.

It would also be useful to invent, consolidate and generalize the approaches, mechanisms and tools that enable them to be identified and respected in order to:

- Facilitate and improve appropriate and equitable management and governance, etc.;
- Organize synergies and skills (scientific, political, public) relating to the adaptation, restoration and rehabilitation of a site.

Sciences covering the interfaces between societies, environments and spaces

To better connect people to "nature", we need to learn more about the mechanisms that bind people to the land and its ecosystems, on which they depend for clean air, food and health.

OBS-SOMAGE OBSERVATORY IN MARADI, NIGER

The Dan Dicko Dankoulodo University of Maradi (UDDM) in Niger is leading a project to set up a society and environment scientific observatory that supports sustainable land management in Maradi (ObS-SoMAGE Maradi). This multidisciplinary observation and data-collection project complements observatories such as AMMA-CATCH[19] and the Health, Population and Environment Observatory – OPES) in Niakhar.[20] Its specific objectives, particularly in the context of the "4 per 1000" initiative,[21] are to contribute to the development of a scientific reference framework for drylands that includes socioeconomic aspects and demonstrates the potential of soil health for carbon sequestration.

Ecological sciences

Further research should be conducted on the following:

- Ecological functions that are key to proper ecosystem functioning;

19. http://www.amma-catch.org
20. https://lped.info/wikiObsSN/?Faidherbia-Flux
21. https://4p1000.org

- Characterization of the ecological integrity of arid, semi-arid and dry sub-humid zones;
- Ecological dynamics on all timescales, from interactions to evolution and the adaptation of communities to anthropogenic pressures, including actions to protect, rehabilitate and restore land;
- Dynamics of the ecosystem services that people benefit from in arid, semi-arid and sub-humid zones and the trade-offs between these services, especially between the services of regulation, climate, water quality and quantity, pathogens, and food and energy production;
- Evaluation of nature-based solutions or ecosystem-based approaches as alternatives to a purely technological approach, which is often more costly and less sustainable;
- Solutions for the sustainable use of biodiversity in arid, semi-arid and sub-humid ecosystems;
- Fair and equitable sharing of benefits from biodiversity and ecosystem services between and with local populations.

Promoting new ways of doing research

To support efforts to acquire new knowledge in these different scientific fields, new research methods must also be promoted.

Transdisciplinarity: driving innovation by joining forces with other stakeholders

Discovery-driven basic research is often contrasted with applied research associated with innovation. However, the two are not mutually exclusive. The most noteworthy example is Louis Pasteur. Thanks to his work on pasteurization and microbial growth, he not only advanced our understanding of the nature of disease, but also contributed to a technology that is still used today: vaccination. Pasteur's work was both innovative and fundamental. Pasteur approached scientific questions with the desire to solve a mystery. He illustrates the convergence between basic and applied research. To understand the interconnected causes of land degradation and devise ways to solve sustainable development challenges, researchers must combine their knowledge with that of other players involved in combating desertification. We feel it is important for all involved stakeholders to be able to listen to each other, to understand the many views of the causes and solutions, and to consider the possible constraints on the deployment of these solutions in the relevant territory. Bringing a variety of voices together is the only way to be successful and fully address needs in both urban and rural areas. This is also a way to promote innovations that meet these needs. Notable examples include the establishment of a multistakeholder partnership to inoculate cultivated plants with microorganisms, the success of which depended on a solid scientific foundation and the building of trust between researchers and farmers working together at research and demonstration sites (namely in Senegal).

Another example of innovation, based on ecosystem functions and biodiversity, is the use of assisted natural regeneration to promote an approach to restoration that is more sustainable, more robust and more resilient to climate change, because it more closely resembles the natural dynamics of ecological succession. Since the mid-1980s, experiments have been carried out in Niger, Mali and Kenya. Subsequent scientific assessments have shown, for example, that natural regeneration has increased millet and sorghum yields by 30% in Mali, and that the return of trees has boosted income from maize, honey and milk by between 170% and 900%.

Interdisciplinarity and the creation of permanent scientific networks and scientific observatories

The need to break down the boundaries between scientific disciplines is a response to the growing need to document all aspects of the way social-ecological systems function. Insights regarding the interactions between environmental, social and economic factors and their dynamics over time are essential and are underpinned by interdisciplinary research. The term "interdisciplinarity" describes the cooperation of researchers from several scientific disciplines working together on common projects. Working in this way opens up research prospects outside the scope of the individual disciplines involved. Data, methods, tools, theories and concepts from different disciplines are pooled and compared. Scientists – who are very often trained in a single scientific field – should be encouraged to engage in interdisciplinary research in order to better integrate different viewpoints. Targeted funding, training in interdisciplinarity and recognition by peers can all help.

Combating land degradation is a long-term undertaking. Collaboration between researchers themselves and between researchers and other stakeholders is already happening in projects. Beyond these projects, such collaborative efforts must become the norm through the creation of permanent scientific networks and scientific observatories rooted in the regions to support land and territorial management. Experimenting, observing, modelling, co-constructing solutions, informing policymakers, encouraging interdisciplinarity and intersectorality cannot all be achieved within the specific time frame of a project. Establishing relationships between sites and building and supporting scientific networks over the long term is crucial for:

- Supporting local stakeholders in designing and adapting innovative sustainable land management systems;
- Collecting multidisciplinary data that can be used to support decision-making and forecasting;
- Training young scientists.

Several systems, such as international joint laboratories,[22] platforms in partnership for research and training[23] and international research networks, are already operational. We believe it is important to strengthen these systems.

Consolidating the interface between science and decision makers

In recent years, decision makers have become more aware of the role of science in informing decisions. In the health sector, the setting up of a scientific advisory board in France to support efforts to manage the Covid-19 pandemic is one example. These types of mechanisms, which enable science to provide options for solving complex problems, exist at international level, but also at the very operational levels of the stakeholders involved. For example, at international level, the UNCCD signatory states have

22. https://en.ird.fr/international-joint-laboratories-lmi

23. https://www.cirad.fr/en/about-us/our-partnerships

pledged, based on the proposal of the UNCCD Science–Policy Interface, to use soil organic carbon as the essential criterion for evaluating progress in the combat against desertification. Farmers, who are decision makers in their own right, also need to be able to leverage the latest research findings. In Senegal, for example, a climate data portal lets farmers make decisions on the best crops to suit the weather conditions. This portal was developed using growth models for the main crops and climate models at very local levels, and was designed to meet the specific needs of farmers.[24]

These examples demonstrate the effectiveness of engaging in co-construction when developing solutions for the benefit of public policymakers and stakeholders on the ground. Research is still needed, not only to understand the processes involved and improve the solutions put forward but also to monitor the needs of users and managers, their own understanding of the phenomena under consideration and the solutions they envisage on their own scale.

WHAT SPECIALIZED TRAINING IS AVAILABLE?

Jean Albergel, Valérie Le Dantec, Quirico Migheli, Philippe Billet, Antoine Cornet

The improper use of the term "desertification", often as a synonym for "drought", goes hand in hand with the spread of preconceived ideas in need of correcting. For example, desertification:

- Refers to more than just the transformation of land into desert;
- Occurs in the desert regions of Africa as well as in other areas;
- Is not just a natural phenomenon linked to the climate;
- Is not inevitable.

These ideas show how important it is to educate not only the next generations of students and teachers but also the societies that are increasingly confronted with the issue. Efforts must be aimed at combating these common assumptions, developing a

24. http://geoportail.anacim.sn:8000/climap

precise understanding of the phenomenon and communicating effective and appropriate behaviours and measures to combat desertification.

Preventing and combating desertification involves sharing knowledge between different types of stakeholders:

- Experts on the current and future challenges of desertification, to continue scientific research in this field and inform the actions to be taken;
- Well-informed individuals (e.g. journalists, representatives of associations and NGOs, extensionists) at the interface between the scientific community and the general public and who are capable of using complex information to strengthen the ability of local stakeholders to analyse and consider desertification-related issues in combating desertification;
- Citizens, local elected representatives, decision makers and young people.

There are three main ways in which knowledge can be shared.

Raising public awareness and disseminating information to the general public

Awareness-raising can be achieved through dedicated campaigns, educational programmes in schools, community workshops and local media, conferences, exhibitions and special day-long events.

The World Day to Combat Desertification and Drought, on 17 June, is an example of these types of events, which aim to raise public awareness of the problems of land degradation, desertification and drought around the world. This one-day event highlights initiatives and projects to combat desertification, restore degraded ecosystems and strengthen the resilience of populations facing desertification.

A range of desertification awareness packs are available online in several languages. They contain essential information on the causes and consequences of desertification as well as solutions, and take the form of case studies, documents and videos from different regions of the world. They can be found on various websites such as:

- United Nations Convention to Combat Desertification (UNCCD), https://www.unccd.int
- United Nations Environment Programme (UNEP), https://www.unep.org/
- Global Environment Facility (GEF), https://www.thegef.org/
- French Facility for Global Environment (FFEM), https://www.ffem.fr/fr
- French Scientific Committee on Desertification (CSFD), https://www.csf-desertification.eu/
- Permanent Interstate Committee for Drought Control in the Sahel (CILSS), https://www.cilss.int
- Centre d'actions et de réalisations internationales (CARI), https://www.cariassociation.org/en/

Educational activities at elementary and secondary level

At elementary school level, the emphasis should be on raising awareness of desertification, using educational approaches tailored to children's ages. Educational tools should be specially designed to raise awareness of desertification and sustainable land management among children in primary schools. They help children learn about environmental issues and the actions that can be taken to combat land degradation in a fun and educational way. They can take a variety of forms, such as books, interactive games, educational videos, teaching kits, practical classroom exercises, outdoor activities and so on.

Some teaching resources are better suited to classroom learning, such as the education kit produced and made available by UNESCO.[25]

By combining different teaching approaches, teachers can help young people to develop an environmental awareness and become actively involved in protecting our planet. Young people can explore documents and dedicated publications such as this book and CSFD[26] features. Education kits developed specifically for secondary school teachers are available to raise young

25. https://www.unesco.org/en

26. https://www.csf-desertification.eu/

peoples' awareness of desertification (presentations, activity sheets, role-playing games and practical exercises designed to deepen understanding of the issues surrounding desertification; see the UNCCD and UNEP websites given above).

Training in higher education and e-learning

Those in higher education need more in-depth and specific training on desertification that covers such topics as the underlying scientific mechanisms, climate change models and large-scale land management practices. International masters degrees in desertification are generally offered by universities, research institutions and international organizations that specialize in sustainable development.

Some dedicated courses have been set up in the countries directly concerned, such as the highly reputable international master's degree in Desert Studies (Ben-Gurion University of the Negev, Israel),[27] the PhD in Land Degradation and Desertification at the University of Sassari (Sardinia, Italy) under joint supervision with the UN University for Peace (UPEACE),[28] or the DNI Academy initiative recently promoted by the international network DesertNet International.[29]

E-learning can also play a crucial role in training on this subject. It offers many benefits in terms of accessibility, scheduling and location flexibility, collaboration and individualized learning. As a result of the specialization of initial training courses and the fragmentation of concepts in current educational courses, company directors, senior managers, decision makers and scientific and political leaders have not always fully grasped all the dimensions and associated issues, despite the high quality of university teaching.

Given the limited availability and range of continuing education courses on offer, podcasts could be a possible solution.

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27. https://in.bgu.ac.il/en/akis/pages/desert_studies/about-desert-studies.aspx

28. https://agrariaweb.uniss.it/it/post-laurea/curriculum-desertification-and-land-degradation

29. https://www.desertnet-international.org

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What causes vegetation and soil degradation? What are the consequences for ecosystems, biodiversity, water resources and the climate? What are future impacts on human societies and the economy?

Desertification is often wrongly perceived as a remote issue for our European countries. As a result, efforts to combat it are struggling to gain footing as an environmental priority. Yet desertification is not inevitable. In this book, the authors show that this phenomenon is not always linked to climate change, and that it is not only an issue in dryland areas, although they are most exposed. They clarify the various geographical, biological and socioeconomic aspects of desertification and draw on the most recent research to explain the methods and expected benefits of combating desertification and land degradation. This book, which is aimed at scientists, NGOs, journalists, students, decision-makers, etc., deconstructs several preconceived ideas to contribute fully to national and international debates.

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