GLOBAL LAND OUTLOOK WORKING PAPER

THE LAND IN DRYLANDS:
Thriving in uncertainty through diversity

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September 2017

United Nations
Convention to Combat
Desertification

CONTENTS

1. THE IRREPLACEABLE DRYLANDS

It is June in Moroto, a dryland district in north eastern Uganda, and it is the peak of the rainy season. Agropastoralists from the Karimojong ethnic group have planted sorghum crops in fields near their homesteads and the young men have moved westwards with their herds of cattle, sheep and goats to graze seasonal pastures. Those pastures, available for a brief period during the rains, provide the most nutritious fodder of the year, and they can be accessed due to the presence of surface water along the migratory routes. The resilience of the Karimojong herders depends on using these rich resources for a period of time and then resting them until the following rains. Like millions of other dryland residents worldwide, they have adapted their lifestyle, their economy and their culture to the unique opportunities and challenges of their natural environment.

Rainfall in Moroto reaches over 800mm per year on average; higher than London (av. 750mm) or Paris (600mm). Drylands, however, are not determined by level of rainfall, but instead by potential water loss through evaporation and transpiration. Moroto's average annual temperature of 22 °C means that evapotranspiration rates are high. The region is classified as semi-arid because the potential water loss to evapotranspiration is two to five times greater than the actual mean precipitation (see box: Drylands). Water being the source of life, the capacity of dryland ecosystems to minimize evapotranspiration—namely to capture and store water— determines how well they function.

Drylands

Drylands are defined using an Aridity Index (AI), which is calculated by dividing mean precipitation by potential evapotranspiration. Drylands have an AI of 0.65 or lower, meaning that potential evapotranspiration is at least 50% greater than actual mean precipitation. Drylands with an AI of between 0.65 and 0.5 are classified as dry sub-humid. They are often naturally dominated by broad-leaved savannah woodlands, fairly dense tree canopies, and perennial grasses. Dry sub-humid lands account for 21% of all the drylands. Semi-arid areas (AI=0.5-0.2) account for 37% and their potential evapotranspiration is between 2 and 5 times greater than actual mean precipitation. These lands are often dominated by thorny savannahs with a great diversity of grass species. Arid lands (AI=0.2-0.05) have a potential evapotranspiration between 5 and 20 times greater than actual mean precipitation. They account for 26% of all drylands and are often comprised by annual grasslands, with the presence of grazing animals. The potential evapotranspiration of hyper arid lands (AI<0.05) is at least 20 times greater than actual mean precipitation. They support minimal vegetation and include many of the world's deserts. Hyper arid lands cover 16% of the world's drylands (UN, 2005).

Water scarcity has shaped dryland ecosystems and biodiversity, and dryland plants and animals show remarkable adaptations to periodic water stresses. Some plants have evolved the capacity to store water in roots or leaves, to root deeply in search of water, or to lie dormant through the drought season. Some dryland animals minimize water loss through physiological adaptations, some estivate during the driest season while others migrate to more humid regions (Bonkoungou, 2001).

Water scarcity, however, is not the only feature that defines the drylands. Many of the characteristics of drylands are determined also by extreme unpredictability in rainfall. As climates get drier they tend to become more uncertain, with high variability from one year to the next. Rainfall data over a thirty year period from the Zarqa Basin in Jordan's Baadia region show a mean precipitation of approximately 270mm per year, reaching as low as 50mm in the driest years and as high as 600mm in the wettest (Salameh, 1993). This twelve-fold difference between low and high is unremarkable in the drylands. Such variability in humid climates would cause catastrophic stress, but in the drylands it has driven further species adaptations, including the development of opportunistic behavior to take advantage of moisture as and when it is available.

Dryland soils differ from those in more humid areas. In savannahs, for instance, termites play a vital role in recycling organic matter and in maintaining soil porosity, particularly in the driest and most nutrient-poor soils. In many drylands, vegetation grows more vigorously and is more drought resistant around termite mounds, yet termites are often treated as pests that cause crop damage and efforts are made to exterminate them. Bacteria in the guts of large herbivores play a similarly vital role in dryland soil fertility, digesting vegetation and accelerating the process of nutrient cycling. Indeed, the intimate relationship and interdependence between plant-digesting, hoofed animals and grasslands is responsible for some of the world's most treasured landscapes, such as the Serengeti and the Asian Steppe.

Natural fires are another feature that sets drylands apart from more humid areas. Fire is a common natural phenomenon in many drylands and has driven many ecological adaptations, to the extent that suppression of fire, or changes in fire regimes, can lead to significant and often harmful ecological changes. Some dryland plants rely on fire to favor their growth or reproduction, including many grasses which recover more rapidly than shrubs after fire events. Where fire is restricted it can lead to an increase in woody biomass, often at a cost to productivity and overall biodiversity, and producing a large fuel-load that ultimately can result in a more severe and ecologically harmful fires: the kind of event that increasingly makes the news in Australia and the US. Fire is used as a management tool in many dryland production systems, for example to encourage fresh growth of pastures or to remove brush growth that can harbor parasites. In Uganda and elsewhere, efforts to suppress traditional practices of fire management led to extensive bush-encroachment and the return of the disease-bearing tsetse fly, which rendered large areas of grassland inaccessible to domestic herds.

It should come as no surprise to discover that societies which have thrived in the drylands for centuries are highly adapted to these local conditions and particularly to the twin challenges of water scarcity and climatic uncertainty. The Karimojong in Moroto rely on locally-adapted, drought and disease-resistant varieties of sorghum. They herd equally well-adapted livestock over large distances to take advantage of unpredictable and patchy grasslands. Jordan's Bedouin pastoralists have traditionally used herd mobility to track resources across the arid landscapes of the Baadia, taking advantage of different resource patches according to the prevailing weather, and using opportunistic strategies to capitalize on the most productive years. In other parts of the world dryland crop farming practices include innovations like agroforestry and land fallows that conserve both soil moisture and soil fertility. Research in the Sahel has shown how the practice of agroforestry creates micro-climatic variation within fields and farms, in otherwise vast and relatively homogeneous landscapes, creating diversity that can buffer against climatic risks (Brouwer, 2008).

There are a host of sustainable land management techniques that people in the drylands have relied on for centuries. Yet land degradation in the drylands is one of the most pressing environmental emergencies of our time. To understand land degradation we must therefore understand why proven local practices are either failing or being abandoned. To ensure that land is sustainably managed in the drylands and to understand the real reasons behind land degradation we must first learn how people have traditionally managed aridity and variability. Often the best way to address land degradation in the drylands is to support land users to revive, adapt and evolve, rather than replace, their tried-and-tested management strategies.

2. THE VALUE OF DRYLANDS

Although the name "drylands" can diminish people's appreciation of them, under different guises this land is often well-known and valued. Few doubt the importance to biodiversity of the world's savannahs for example, or the value of fine fibers such as cashmere and alpaca wool, which are produced on dry grasslands. In countries of Central Asia, southern Europe and in the United States the drylands are acknowledged for their important cultural heritage. Yet in some countries drylands are equated with low productivity and they are starved of investment.

Drylands cover 41% of all land and include unique ecosystems like savannahs and oases. Some of these are high-value but relatively small resource patches that are crucial for the survival of vast ecosystems. Whilst there is often a temptation to convert such high-value pockets of land within the drylands to alternative uses and effectively to excise them from the wider ecosystem, their value is greatest when they are managed as an integral component of a much larger dryland landscape.

Drylands contribute to national economies in many ways, although the principal land use is determined by aridity. Rangelands cover two thirds of the drylands (65%), a quarter of drylands are used for rain-fed and irrigated farming, whilst around 10% are either forest lands or are occupied by towns and cities (United Nations, 2011). An estimated 44% of croplands and 50% of livestock worldwide are found in the drylands (UNCCD, 2012). In dryland countries like Afghanistan, Burkina Faso and Sudan agriculture provides almost a third of GDP. Shrubland, savannah and grassland all support extensive livestock production, which also overlaps with croplands and forests in the drylands. In Mali, Kenya, Ethiopia and numerous other African countries the dryland livestock sector provides over 10% of Gross Domestic Product (GDP). In Kyrgyzstan and Mongolia the figure is closer to 20% (Davies and Hatfield, 2008).

However, food production represents only a fraction of the value to society the drylands provide. Dryland forests for example contribute to national economies directly through provision of fuel, timber and non-timber forest products, and indirectly through protection of watersheds and other ecosystem services. Overall the drylands support one third of the area within Global Conservation Hotspots: places that are both biologically diverse and seriously threatened (Davies et al., 2012). Dryland biodiversity regulates climate locally, through provision of shade and shelter, and globally, through capture and storage of carbon. Despite having relatively low plant biomass, and hence relatively low organic carbon (in vegetation and soil), inorganic soil carbon increases as aridity increases; overall dryland soil organic reserves represent 27% of the global total, whilst inorganic carbon reserves account for 97% (Millennium Ecosystem Assessment, 2005).

In spite of their name, drylands also include globally important watersheds that supply clean water to millions of people, and they regulate water flows and mitigate the risks of flood and drought. Over a third of the world's major river basins, as mapped by the World Resources Institute (WRI), fall at least 50% within the drylands. The mighty Yangtze River, the longest in Asia, rises in the drylands of the Tibetan Plateau, supplying water for irrigation, sanitation, transport and industry, including the world's largest hydro-electric power station, the Three Gorges Dam. The Yangtze Delta generates around a fifth of China's GDP, yet the river is increasingly polluted and silted with eroded soil from mismanaged land upstream, which reduces water quality and aggravates flooding. The Yangtze is one of several vast rivers that rise in the drylands of Tibet; others include the Yellow River, Mekong and Salween. Between them these rivers support humanity in the most populous region on earth, traversing, in the case of the last two, multiple national borders.

Drylands are home to about a third of humanity, or over two billion people. Many of these people rely on rural livelihoods, directly or indirectly managing land. However, drylands are also home to many of the world's megacities; places like Los Angeles, Cairo and Karachi. The way the drylands are managed directly affects life in these urban centers, and desertification can compromise the safe and regular supply of water, clean air, food and fuel, as well as opportunities for recreation. At the same time, population growth is placing ever-greater demands on the drylands, and increasing pressure on dryland biodiversity. The International Union for Conservation of Nature (IUCN)'s Red List of Threatened Species shows that cacti, the most quintessential of dryland plants, are among the most threatened taxonomic groups. Thirty one percent of the 1,478 evaluated species is threatened and their decline is linked with growing human pressure in arid lands (Goettsch, 2015).

The vast majority – some 90% – of the dryland population lives in developing countries and this affects how drylands are perceived. There has been a tendency to dismiss drylands as unworthy of investment and to categorize them as low-potential lands. Several countries have legally classified drylands as 'wastelands'. Research in India and China, however, has shown that the opposite can be the case; that drylands can give higher returns on investment than so-called high-potential lands. In China, for instance, a combination of agricultural reform and investment in agricultural research and development, education, roads and electricity stimulated growth in the non-farm rural sector, supporting development of agriculture as well as providing job creation for urban migrants (Fan et al., 2008). A similar pattern was observed in India where rural non-farm employment grew and poverty declined in response to infrastructure investment, particularly in places where literacy rates were raised (Ravallion and Datt, 1999).

In many cases it appears to be policy and investment failures that have led to weak development outcomes in the drylands; these failures should be addressed, rather than the drylands written off as an economic basket-case.

3. DESERTIFICATION: DEGRADATION OF THE WORLD'S DRYLANDS

History provides many stories of environmental mismanagement of drylands, from the collapse of the Mayan Civilization a millennium ago to John Steinbeck's "Grapes of Wrath" set in the American Dust Bowl of the 1930s. Yet the lessons that these stories teach continue to be ignored and drylands are being degraded at a rapid pace. Land degradation in the drylands is such a significant environmental concern that a global agreement has been established to prevent and reverse it: the United Nations Convention to Combat Desertification (UNCCD). Desertification has been described by some governments as the greatest environmental challenge of our time and a threat to global wellbeing, more severe and immediate than even climate change. A growing number of countries, particularly in the developing world, are voicing concerns about the closely related challenges of Desertification, Land Degradation and Drought.

Desertification

According to the UNCCD (1994) "Desertification" means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. "Combating Desertification" includes activities which are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development which are aimed at:

- prevention and/or reduction of land degradation;
- rehabilitation of partly degraded land: and
- reclamation of desertified land.

Estimates of the extent of land degradation in the drylands differ considerably, although figures are converging on somewhere between 25% and 30% of all land. Unfortunately the absence of a standard global assessment and monitoring system contributes to this variance and leads to divergent understandings of land degradation. This is particularly problematic in drylands where resources are most scarce and where there is the greatest misunderstanding over what constitutes degradation. One frequently cited study estimated that land degradation is occurring on about 24% of all land worldwide and about 13% of the drylands. However, this study does not reflect what the authors call "the legacy of thousands of years of mismanagement in some long-settled areas", which includes a number of the world's drylands (Bai et al., 2008).

A more recent analysis of long-term trends (25 year span) using remote sensing to measure inter-annual vegetation found land degradation hotpots covering about 29% of global land area, but with dryland-dominated biomes affected to an above-average extent (Le et al., 2014).

Many interrelated factors contribute to desertification, including population growth, changing demands for production, technology change and climate change. Desertification is driven by increasing demands on land to produce food, fuel and fiber combined with a decline in the total area of agricultural land available for production. As the global population grows and becomes wealthier, the demand for food increases, which in turn increases the pressure on land. At the same time productivity is threatened by declines in soil fertility and water access. It is estimated that increased water scarcity could lead to annual grain losses of 30% and that about 40% of the world's population, up to 2.8 billion people, currently live in water-scarce regions (UNCCD, 2014). Water and food insecurity are closely related threats that are greatly exacerbated by land degradation, and nowhere more so than in the drylands.

When desertification happens as a result of changing practices and efforts to increase productivity it is often related to a misunderstanding of dryland ecology and a failure to appropriately manage soil fertility and moisture. Considering that potential water loss in the drylands can greatly exceed the actual rainfall it is important to understand the full costs of farming practices that significantly increase evaporative losses, such as irrigation. Farming practices often have to be adapted to retain soil and soil moisture and to protect soil fertility in the drylands, and this requires innovative solutions.

Changing agricultural practices in the Sudan have led to serious declines in soil fertility and food production. The practice of leaving land fallow in Sudan's drylands has been widely abandoned due to rising population pressure and demand for food, whilst State policies have led to widespread clearance of land for mechanized farming under monoculture, removing trees from entire landscapes and replacing crop rotations and other more sustainable management practices (UNEP, 2007). When drylands are cultivated in this way it rapidly leads to loss in soil biodiversity—the fungi, bacteria and other organisms—that is so important for recycling nutrients and maintaining organic carbon in the soil. Declining organic carbon in the soil means a reduction in water retention, aggravating the impact on food production.

In Australia, in common with several dryland countries, one of the most significant causes of desertification is salinity which threatens the natural environment as well as reducing agricultural productivity. Salinity has been caused through land clearing, mainly for agricultural production, and occurs when the water table rises and brings natural salts to the surface. This has been the outcome of employing farming practices developed in the more humid lands of Europe, based on shallow-rooting crops and pastures. In the year 2000, 5.7 million hectares of Australia were assessed as having a high potential to develop salinity, with the area predicted to reach 17 million hectares by 2050 without remedial action (ABS, 2010).

There is a close relationship between poverty and desertification, and although dryland populations may have historically practiced sustainable land management, many are finding it increasingly difficult to continue to do so. There are many reasons for this, from rural population growth to breakdown in local governance to the imposition of foreign farming practices. However, poverty is complex and in the drylands it is rooted in the historical neglect of these so-called "low potential" areas. This has been a self-fulfilling diagnosis as resources have been channeled into humid lands, leaving drylands starved of investment, security and basic services. Poverty levels in the drylands, measured in terms of literacy rates and health indices, are above average in many countries. Adult female literacy rates in the humid lands of West Africa, for example, are around 50%, but they drop to between 5-10% in the drylands. In the drylands of Asia, infant mortality rates are around 50% above the mean (Middleton et al., 2011).

A closely related factor to poverty and marginalization in the drylands is weak land tenure and declining governance over natural resources. Tenure is particularly weak in communally managed drylands, such as grasslands and dry forests. However, these lands have historically enjoyed strong governance through local agreements and practices, for example the coordination of harvesting forest and rangeland products and establishment of rules to prevent malpractice. In many cases these institutions are weakening, often as the result of emerging state power that has undermined customary authority without providing an effective alternative.

Strengthening governance and tenure is therefore fundamental for sustainable management of the drylands. This often requires innovative and specialized approaches to accommodate the unique governance requirements of the drylands, where resource sharing, communal management and mobility are central management strategies. Hybrid governance arrangements, which combine elements of traditional governance with different roles of the State, may be essential and are often apparent in governance arrangements in the drylands of the industrialized world. Stronger governance can provide a platform for improved blending of local institutions and local knowledge with new science and institutions. Stronger governance is often also essential for equitable development of value chains and for connecting the many values of drylands with markets in ways that promote rather than erode sustainability (Herrera et al., 2014).

4. COSTS OF DESERTIFICATION

Desertification is a global threat that impacts heavily on the lives and livelihoods of millions of people both in and outside the drylands. The Bedouin inhabitants of Jordan's Baadia experience lower agricultural productivity, loss of biodiversity and decline in water supplies as a result of desertification. Production of vegetation on the Baadia has declined by half since the 1990s, directly impacting livestock production and contributing to a decline in biodiversity, including forty-nine medicinal plant species that have a significant market value, particularly for women. Desertification has led to declines in water infiltration and this cost is felt not only by Bedouin residents in the Baadia but also by downstream consumers, including a large part of Jordan's industry. There are other external costs of desertification in the Jordanian Baadia such as sedimentation of dams that supply power, or the release of greenhouse gases and loss of the capacity of soil to store carbon and mitigate climate change (IUCN, 2013). The true cost of desertification is frequently underestimated due to the large scale of these external impacts.

There are many challenges to estimating the cost of desertification at local and national scales, and as a result any attempt to identify a global figure must be treated with caution. Nevertheless, such estimates provide justification for action and a few examples have been published in recent years. The UNCCD published a White Paper on the Economic and Social Impacts of Desertification, Land Degradation and Drought in which it estimated the global cost of desertification as 1-10% of Agricultural Gross Domestic Product (AGDP) annually (UNCCD, 2013). A study in fourteen Latin American countries put the figure at between 8-14% of AGDP annually (Morales et al., 2011). The Global Mechanism of the UNCCD estimates the costs of land degradation at 3–5% of global AGDP (Berry et al., 2003).

Some studies differentiate between direct costs, as a result of lower land productivity, and indirect economic costs, such as environmental externalities. Direct costs have been estimated at 2% of AGDP for Ethiopia, 4% of AGDP for India, and up to 20% of AGDP for both Burkina Faso and the US (various sources cited in UNCCD, 2013). Indirect costs, on the other hand, may be felt farther afield from the source of degradation and can include disruption in water flows, contribution to climate change, dust storms and other phenomena. Annual indirect costs of soil erosion in the US have been estimated at US$17 billion, or 63% of the estimated direct costs, raising the total costs of soil erosion to 0.7% of GDP (Pimentel et al., 1995).

As illustrated in the Baadia example, land degradation can disrupt water cycles and diminish water quality, for example through siltation of rivers and reservoirs. Degraded landscapes are more prone to flooding as rainwater runs off rather than soaking into the soil. Run-off can lead to loss of top soil and biodiversity and in extreme cases can lead to inundation of downstream communities and land. Many degraded landscapes are simultaneously more prone to both flood and drought, since water is lost through run-off rather than retained within the system. Soil organic carbon—a key indicator of the health of land—plays an important role in water retention, and as it declines so does the capacity of soil to hold moisture. Additionally, the rate of infiltration of water can be reduced as a result of surface compaction, loss of soil invertebrates, and a number of other factors related to desertification, leading to drier soil, lowering of aquifers, and soil erosion. The result can be an increase in drought, independent of any change in rainfall, simply due to reduced capacity of the land to capture and hold onto water. It has been estimated that on severely degraded land as little as 5% of total rainfall may be used productively (Humphreys et al., 2008).

Dust storms are another major external cost of desertification that can have consequences throughout the economy. China, for example, is comprised of two-thirds dryland; half of this land is affected by desertification, and particularly wind erosion. Wind erosion causes dust and sand storms that affect 400 million people and causes direct economic losses that were estimated at US$ 7.7 billion per year in 2003 (Lu and Wang, 2003). Wind erosion causes loss of soil, loss of soil moisture and fertility, and in some cases leads to the formation of sand dunes, all of which reduce agricultural output. Wind erosion is exacerbated by farming methods, such as leaving soil bare, particularly in the case of sandy soils that are common in China's drylands. This form of erosion is also aggravated by the removal of trees that provide windbreaks, particularly during winter and spring when winds are highest and vegetational ground cover is minimal. Besides these visible impacts of desertification, society at large can be affected in less visible ways, for example through the increase in food prices when agricultural productivity is reduced, or when local impoverishment contributes to migration, both domestic and international. Desertification has also been implicated in conflict, through increased competition over scarce resources and through increases in the price of food. When desertification leads to lower food production it contributes to national poverty and to vulnerability of the poorest communities. This can create a vicious circle since the poorest farmers may also face the greatest challenges with regard to reducing or mitigating land degradation (Low, 2013).

Perhaps the least tangible cost of desertification is the loss of the cultural and aesthetic values of land, and yet in many cases this is the cost that finally drives people to act. Land is much more than a place to produce food or to supply water; for many people it is inextricably connected to their cultural identity and their dignity, and many rural communities feel a sense of responsibility towards the land. Assigning a figure to such costs is impossible, although methodologies have been used to estimate what people would be willing to pay, or to do, in order to avert the cost of desertification. As a result it is impossible to give governments an accurate estimate of the returns on investment, but this should not diminish the importance of such values. As an elderly Bedouin woman responding to the question of why she was investing her time in rehabilitating the rangelands put it, "I want to open my door in the morning and see the beauty of nature in front of me."

5. DESERTIFICATION AND CLIMATE CHANGE

Soils store more carbon than the combined total of the worlds' biomass and atmosphere, and a substantial part of this carbon is in the drylands. When land is degraded this carbon can be released into the atmosphere, along with other greenhouse gases like nitrous oxide, making land degradation one of the most important contributors to climate change. About a quarter of all anthropogenic greenhouse gas emissions come from the agriculture, forest and other land use sectors (Smith et al., 2014). As the most agriculturally productive lands are either exhausted or lost to urban development there is a risk that a growing proportion of future land use change will take place in the drylands, increasing their contribution to climate change.

Land users need to adapt the way they manage land to the changing climate, but in the drylands of many developing countries people's adaptive capacity is declining, as a consequence of desertification and impoverishment. In Karamoja, for instance, people are facing more droughts, flash floods, increasingly erratic rainfall, and prolonged dry spells. At the same time, the capacity of the land to absorb torrential rain, and to hold water for the following dry periods, is declining wherever the land is degraded. Simultaneously, the capacity of people to deal with these impacts has been weakened, through reduction in herd movements, loss of vital seasonal resources, poor access to markets, and low overall human development (Mubiru, 2010).

Like other dryland people, the Karimojong are highly adapted to the natural uncertainty of the drylands, not only through their land management practices but also through social and cultural adaptations. For example, many dryland communities have well-developed practices of resource sharing that help them to spread risk. In some pastoral communities this includes cultivating debts and obligations, over many generations and vast distances, so that in times of hardship they can call on support from people who may be less affected. Mongolian pastoralists have a long history of reciprocal arrangements that enable herding families to spread climate risks, such as blizzards and drought. However, there are signs that these institutions are coming under pressure from economic forces and changing institutional relationships between herders and the State (Upton, 2012). At the same time as the local institutions of dryland people are coming under strain, there are fears that the rate of climate change and the scale of its impact may leave dryland people more vulnerable to climate change (Davies and Nori, 2008).

The web of interactions between climate change, desertification and poverty is complex. Degraded land stores less water, leading to more severe effects of both drought and flood. In the drylands such consequences are more acutely felt due to the relative scarcity of water. Climate change is projected to reduce both the availability and the quality of water in the drylands over the next forty years by 10-30%, while extreme weather events (e.g., droughts, floods, blizzards, frosts) will increase in number and/or intensity (IPCC, 2007). The capacity of dryland soils to cope with inundation and to store water for subsequent drought is crucial.

Table1: **Role of dryland soils in storing carbon (UNCCD, 2015)**

	Biomass Carbon	Soil carbon		
		All Soil C	**Soil Organic C**	**Soil Inorganic C**
Global	576Gt	2,529 Gt	1,583Gt	946Gt
Drylands	83Gt	1,347 Gt	431Gt	916Gt
Portion in drylands	**14%**	**53%**	**27%**	**97%**

Naroo Plains ©Simon Nangiro

Desertification contributes to climate change, but climate change can also contribute to desertification, through the effect of changing weather patterns on land and biodiversity. Climate change can also exacerbate poverty and further undermine the capacity of people to manage land sustainably. The poorest people on earth are the most vulnerable to climate change (IPCC, 2001), and yet for the most part they contribute the least towards it. Since the drylands include a disproportionate number of the world's poor they are likely to be among the most affected by climate change.

This interconnectedness between desertification, climate change and poverty helps to focus attention on responses that deliver multiple benefits. Addressing these challenges together could create a virtuous cycle, by capturing atmospheric carbon in the soil to mitigate climate change, reverse land degradation, raise agricultural yields, and increase the overall resilience of the drylands. Higher agricultural productivity and increased resilience can contribute to greater food security and lower poverty. It is crucial to ensure that soil carbon is fully accounted for as a terrestrial carbon sink, and is monitored as an indicator of progress not only towards combating desertification, but also towards reversing both climate change and biodiversity loss (UNCCD, 2015).

6. MANAGING DRYLANDS SUSTAINABLY

Desertification is not the inevitable outcome of development and we are fortunate to have a wealth of experience at our fingertips illustrating better practices. There is growing awareness of the techniques for sustainably managing the drylands and there is increasing evidence that the most sustainable solutions not only protect the environment, but in some cases also produce more food, of better quality, and with lower dependency on fossil fuels. Interestingly, many of the large-scale solutions to this issue have their roots in the tried-and-tested practices of traditional dryland farmers. This is not advocating a return to historical agriculture, but moving forward with better innovations that build on, rather than replace, proven approaches. Above all, what is needed is a significant overhaul of the way we account for, protect and manage ecosystems.

Agroforestry in the Sahel illustrates how traditional approaches can be revived and improved upon. The technique underwent a decline in the 20th Century due to various changes in socioeconomics, policy and tenure, partially fostered by an alternative vision of agricultural development based on large-scale mechanization and mono-cropping, not dissimilar to the Sudanese scenario described further above. Today, however, agroforestry is experiencing a renaissance with over seven million hectares in Niger restored through revival of simple practices of selective protection of high-value trees within farming landscapes. The example of agroforestry in the Sahel provides a compelling example of what is possible when farmers are supported to better capitalize on their knowledge.

Fallows, which have long been integral to maintaining soil fertility and boosting soil moisture in the drylands, are showing some signs of revival despite a worldwide decline in recent years. The United States 1997 Census of Agriculture reports 85,000km^2 of summer fallow in the country: some 5% of all its cropland. Herd mobility, which has been the mainstay of pastoralist systems worldwide for centuries but has been greatly restricted in many countries, is also being revived in a number of countries. Spain's 1996 "Vias Pecuarias" Act has restored these movements through protection of an ancient network of 120,000 km of livestock tracks—a livestock corridor that could circumnavigate the earth three times—leading to considerable improvements in biodiversity and ecosystem services.

The key to unlocking sustainable management in the drylands is to understand the uniqueness of dryland ecology. It is understandable that communities have survived in the drylands by adapting to the conditions and it should therefore be no surprise that their practices are amongst the most sustainable and well-adapted to risk.

Nevertheless, the drylands are confronted with many new challenges that could overwhelm established practices, with new risks from sociopolitical pressures, globalized markets and climate change. Innovation is needed particularly in relation to management of soil moisture and soil fertility, but also with regard to securing tenure and strengthening governance over natural resources.

Management of water is central to the effective management of drylands, in particular maximizing infiltration and soil moisture content and managing run-off. In the Sahel, natural vegetation uses around 15% of rainfall; the balance either recharges aquifers, or is lost to evaporation and run-off. Land management practices can both reduce and capture run-off, they can reduce evaporation, they can boost the water retention capacity of soils, and they can increase the water-use efficiency of crops so as to reduce transpiration. Reducing run-off has the added benefit of similarly reducing the loss of soil and nutrients through erosion. However, run-off that represents a loss in one place may be relied on by people downstream. Decision-making, therefore, must take place at the right scale, based on adequate evidence, to ensure equitable and sustainable outcomes throughout the ecosystem and society.

One way of improving soil water management is to adjust the way soil is tilled - and there is growing interest in low or zero-tillage systems in the drylands as a way to conserve soil moisture. Since ploughing the soil can potentially lead to soil compaction, loss of organic matter, loss of soil biodiversity, and soil erosion, planting without ploughing could be a way to avoid these costs. No-till agriculture minimizes soil disturbance and maintains crop residues and other organic matter on the soil surface, where it may contribute to reducing evaporative losses and increasing infiltration. Evidence shows that no-till agriculture can lead to greater concentration of soil organic carbon near the surface which often translates into improved productivity. The impact on the overall soil carbon balance is less certain and the role of no-till agriculture in climate change mitigation has been questioned, but there is a clear positive benefit with regard to climate change adaptation (Powlson et al., 2014).

There are, however, potential barriers to the adoption of no-till agriculture. It requires substantial changes in farming practices, including changes in the management of weeds and pests and the use of fertilizer. Nevertheless, it can be more profitable than conventional farming and it may reduce the costs of labor, fuel, irrigation and machinery. No-till agriculture is practiced to the greatest extent in the drylands of the world's leading grain-exporting nations, such as Australia and Argentina, as well as in the US, where it accounts for 22.6% of all cropland areas (Friedrich et al., 2008).

The potential to support crop production with direct rainfall alone declines with aridity, leaving two options: either harvest water to boost crop production, or use land for other purposes such as livestock production. Both options have their advantages and disadvantages, each with plenty of good practice illustrations. In the former, water is collected, stored and moved where and when it is needed. In the latter, livestock are moved according to where and when water is available, to give access to vegetation. Although it is worth noting that there are numerous ways that water availability can be manipulated to influence either availability of or access to pasture.

A great diversity of water harvesting practices exists in the drylands, many of them known and practiced for centuries. Water harvesting is influenced by topography and soil type and can be practiced at very different scales. Small-scale measures, sometimes called micro-catchments, are used to capture run-off within farm fields and include practices such as planting-pits and contour bunds. These work by slowing down the rate of run-off and encouraging localized infiltration. Larger-scale measures are used for capturing run-off beyond individual fields and include dams and ponds. These macro-catchments usually require water storage; in drylands, where evaporative losses are great, this can include sub-surface storage, for example in cisterns. In some soils sand-dams are used to trap sand, which in turn holds water, thereby effectively creating sub-surface storage. When water is stored in macro-catchments, or harvested from rivers and aquifers, irrigation is then required to supply water to the land. This can include irrigation on a grand scale, although such schemes often face controversy, are challenging to manage and are high in both financial and environmental costs. Smaller-scale irrigation, however, can be more carefully controlled to supplement rainfall at critical times in the growing cycle, for example boosting growth at a key moment or extending the growing season.

The most widespread land use in drylands is livestock production, which is mainly carried out on natural or semi-natural grasslands and is highly attuned to the constraints of the dryland climate. Extensive livestock production of this type is often called pastoralism and revolves around the seasonal use of pasture, shrubs and other resources. Since the primary input is natural fodder pastoralism relies on vegetation that is naturally adapted to the limited water supply. Rather than trapping water locally, pastoralists use herd mobility to track resources as they are made available by the rains. In this way domestic herds mimic the behavior of wild ungulates and can, to some extent, replace wildlife in shaping and maintaining grassland ecosystems.

Management of rangeland vegetation is determined to a large extent by access to water. Pastoralists maintain both natural and artificial infrastructure for water supply, including deep wells, tanks and surface ponds; these are used to regulate access to rangelands. Land around these water points and oases is the most prone to degradation, particularly where people are encouraged to settle and graze livestock permanently. Pastoralists often have elaborate customs and institutions governing the use of water and pasture, which enable communal resource use over vast areas, and in some cases across international borders. These are vital for maintaining the herd movements that make their production system viable. Several countries are taking measures to strengthen and legitimize systems for local regulation of resource use. This includes legislating for hybrid governance systems that link customary and state institutions, equipping them to use modern tools such as remote sensing and telecommunications to enable more efficient rangeland planning and management at scale.

Although the livestock sector is frequently criticized for its contribution to global warming, the pastoral sector can contribute significantly to climate change mitigation. Rangelands contain more than a third of all the terrestrial above and below-ground carbon reserves, and with improved rangeland management they could potentially sequester a further 1300-2000 MtCO2e by 2030. Small increases in global soil organic carbon will have a high impact on the global carbon cycle and on atmospheric concentration of CO2. Reversing desertification and increasing soil organic carbon therefore provides one of the most effective ways to achieve multiple goals: climate change mitigation and adaptation, conservation of biodiversity, alongside an increase in resilience and productivity of food production (Wilkes and Tennigkeit, 2008).

Soil organic carbon is a crucial indicator of soil health; management practices that boost carbon in the soil contribute to both fertility and moisture. Carbon is captured by plants through photosynthesis and the proportion of this carbon that is returned to the soil has important consequences for soil fertility. Increased organic carbon in soil not only increases fertility but can also increase soil moisture: it has been estimated that each gram of organic carbon in the soil can hold up to twenty additional grams of water. The heroes of soil fertility are often the least noticed creatures: microbes, invertebrates like worms and termites, and fungi. Maintaining this biodiversity in soil can be challenging under conventional farming practices based on mechanization and application of chemicals, but it is often crucial for the management of soil fertility and moisture.

7. UNLOCKING SOLUTIONS FOR SUSTAINABLE DRYLANDS MANAGEMENT

In view of the ongoing process of desertification, combined with poverty and development barriers, the future of the world's drylands appears uncertain. Business as usual in the drylands will see continuing desertification and vulnerability, combined with increasing risks from climate change, contributing to greater social problems of poverty, migration and conflict. Adoption of the Sustainable Development Goals in 2015, and particularly target 15.3 on Land Degradation Neutrality, demonstrates a growing willingness to act to avert desertification. However, this willingness has to be matched by a capacity to act in the most suitable way. Understanding how to adapt investments to the drylands is constantly improving and offers cause for optimism. But the extent of deprivation in the drylands and the absence of many basic conditions for development ought not to be underestimated.

In most drylands the building blocks for sustainability are more fundamental, and at the same time more subtle, than those provided by technological innovation. In many countries the priority is to enable highly marginalized communities to become part of the development mainstream through provision of basic services and infrastructure; from schools and hospitals to roads and marketplaces. Promoting private investment in drylands depends on first creating enabling conditions through judicious use of public investments. There are particular challenges to growth in African drylands due to these fundamental development gaps combined with the frequency of drought and other shocks. These shocks put a strain on scarce government resources and divert resources from long-term development into more costly short-term measures.

The population of Africa's Drylands is projected to rise by 65% to 80% in the next fifteen years. Combined with increasing outside investment in large-scale agriculture and extractive industries, this rise in population has the potential to fuel natural resource degradation and competition. This would exacerbate conflict and increase the vulnerability of dryland people. Although resilience can be strengthened through agriculture-sector interventions - such as improvements in sustainable crop and livestock production - significant investment is required for broader poverty eradication. In the medium term it is anticipated that economic growth in the drylands will be significant, but it may not keep pace with population growth and climate change-induced vulnerability. As a result, many countries will need to establish social protection for the most vulnerable in the drylands (Cervigni and Morris, 2016).

Scientific knowledge of dryland ecology and sustainable management of land and ecosystems remains underdeveloped. The knowledge and evidence that exists is often side-lined in favor of management approaches that have been developed in humid lands. This is compounded by inadequate data on dryland environments and economies, which leave important decisions to be made in an information vacuum. The complexity of risk-adapted strategies for dryland management, and the value of local knowledge and practices need particular attention. Greater effort is required to combine local knowledge with emerging scientific knowledge through appropriate partnerships, participatory learning, and through more effective knowledge dissemination (Mortimore et al., 2009).

Learning how to capitalize on multiple ecosystem values is an area that needs particular attention. Dryland ecosystems provide many benefits to humanity beyond the obvious primary products of food and building materials. Rehabilitation of rangelands in the Jordanian Baadia showed modest improvements in livestock production and in marketable biodiversity like medicinal plants, but vastly greater benefits to groundwater flows, carbon storage, and reduced sedimentation of hydropower dams, all of which are enjoyed by people other than those responsible for their protection (Myint and Westerberg, 2014). Incentivizing the most sustainable land management practices in the drylands may depend on a shift from maximizing output of single commodities towards the optimization of a range of interconnected ecosystem goods and services. This shift may well be required worldwide, but in the drylands, where the absolute production potential for individual commodities may be lower, the attractiveness of multifunctionality may be greatest.

Moving towards an economy that is based more strongly on balancing multiple land-use values may imply additional challenges for developing profitable markets. In Kenya and other countries dryland communities generate substantial secondary income through ecotourism, which benefits particularly from the comparatively wildlife-friendly nature of traditional herding systems. Elsewhere, land managers tap into markets for natural products, like fruits and herbs, or receive payments for ecosystem services. All of these require multiple value chains, as well as new skills and sources of finance to enable dryland communities to capture a greater proportion of the value added (Davies and Hatfield, 2008).

Improving markets for sustainable management also requires greater attention to attracting the right investors. Drylands have been particularly at risk of large scale foreign land acquisitions in recent years, aided by the comparatively weak tenure and in some cases the weak political voice of the inhabitants. Smaller scale transfers of land are also taking place rapidly and leading to unplanned, or unregulated, changes in land use.

Governments can do more to mobilize private investments that support existing land users to improve their management of land and to develop land-use plans that are effective at the landscape-scale for integrating a number of practices including, but not limited to, crop farming, grazing, forest management, wildlife management, and protection of wetlands. Particular effort is required to mobilize local entrepreneurs and to develop small and medium sized enterprises in the drylands in order to simultaneously strengthen and diversify rural livelihoods. The growing urban population in the drylands is more likely to be culturally connected with the rural population and provides both a market for dryland products as well as a better-educated population that will become the future service providers in the drylands; for instance, health workers and educators that speak the local language.

Small scale investments by farmers are vital to the future of most sustainable practices. Development projects increasingly endeavor to harness the wealth of the private sector, yet sometimes overlook smallholder farmers as an existing sub-section of the private sector. Dryland farmers and herders invest in many ways on a relatively small scale that is multiplied thousands of times across a landscape. These investments can be hard to valuate but they essentially represent a diverse portfolio of capital, including labor and social capital, which yield a similar array of returns, including food, insurance and ecosystem services. The seven million hectares of agroforestry that have been recovered in Niger was achieved through thousands of individual acts by small-scale farmers across a vast landscape (WRI, 2008).

The revival of agroforestry in Niger provides another important lesson: the need to improve resource tenure security. A tipping point in the revival of agroforestry was a change in rights over trees, giving farmers the confidence that their efforts to protect trees would neither be wasted, nor would they lead to confiscation of farmland that was perceived to be misused. One of the most important steps in many countries is to ensure that drylands are under secure tenure so that land managers have the freedom and legitimacy to implement sustainable management strategies. This frequently needs innovative solutions that reconcile statutory law with customary rights. In several countries this is being facilitated by government decentralization, which allows greater participation in local-level decision making and greater respect for local rights and responsibilities. Stronger local institutions can provide a vital interface between customary and statutory systems and may be the key to combining improved local governance with improved access to markets and other services. In Mongolia and Kyrgyzstan, for example, public policy supports the establishment of Pasture User Groups for rangeland governance, forming a crucial mechanism for community representation, and coordination of management activities (Herrera et al., 2014).

Indigenous and Community Conserved Areas (ICCAs) are gaining ground as a tool for legally recognizing local tenure in the drylands and for promoting the compatibility between economic use of drylands and conservation. Many drylands are effectively protected through traditional land management practices, sustaining the biodiversity on which local livelihoods depend. These de facto protected areas, which could qualify under IUCN Protected Area Categories 5 and 6, are often overlooked by governments. Designating them as ICCAs could offer communities greater potential to capitalize on the environmental benefits of their production system and thereby further incentivize sustainable land management. Worldwide, about 9% of the drylands (or 5.4 million km2) are formally protected, which is below the global mean of protected lands, at 12.9%. Arid and semi-arid drylands are particularly poorly represented and yet are home to one of the most sustainable land use systems on the planet: namely mobile pastoralism. Formalizing these lands as ICCAs will help establish standards for sustainable management, improve monitoring, and also provide incentives to maintain sustainable practices (Davies et al., 2012).

8. A STRATEGIC AGENDA FOR SUSTAINABLE DRYLANDS

In 2011 the United Nations published a UN System-Wide report on the drylands in recognition that the drylands had become “investment deserts” where chronic underinvestment was driving under-development and poverty (UN, 2011). The report provides clear priorities for responding to the needs of the drylands: enhancement of economic and social well-being; sustainable management of dryland ecosystem services for global public goods; and increasing adaptive capacity to manage environmental change, including climate change. However, the UN Strategy does not go far enough in addressing the marginalization and rights of dryland communities or the deeply entrenched misunderstandings that are driving mal-investment in the drylands. It is essential to generate greater investment in the drylands, but that investment must not compound the failures of earlier interventions and policies.

Priority should be given to securing the resource rights of dryland people. Weakness in land tenure contributes to degradation through breakdown in local management practices. It also contributes to poverty and loss of resilience through degradation as well as through outright loss of land. In many cases the most suitable form of tenure is communal rather than individual. Securing tenure means legally upholding the right to use and to manage land; it does not necessarily mean allocating rights to alienate and sell land (Herrera et al., 2014). Countries increasingly understand the importance of secure tenure rights but many countries remain unable to pursue the necessary reforms.

The Voluntary Guidelines on the Responsible Governance of Tenure, produced in 2012 by the Food and Agriculture Organization (FAO), have been endorsed by over one hundred countries, providing an excellent platform for strengthening land rights.

However, a great effort is needed to build the necessary skills and mobilize resources for effective progress. This can only be achieved by placing secure land rights front and center in dryland development.

Stronger governance is needed for sustainable management of the drylands; key gaps are found in the institutional arrangements for coherent management of dryland ecosystems at scale. Divergent policy priorities between sectors can lead to harmful consequences, for example where land, water, trees, wildlife and other resources are managed for different goals. This is particularly problematic given the scale of drylands and also given the potential misunderstanding about the most suitable development pathways. Improved coordination is needed between sectors such as agriculture, wildlife, forestry, and water. This should be driven by high-level political leadership and guided by improved science and knowledge that supports improved integration.

Sustainable development of the drylands needs not only an enabling environment, but requires capable actors. Policies and investments can be mobilized but extensive efforts are often needed to upgrade the skills of professionals in the drylands. This includes professionals working in the public sector, providing advice to land users, as well as professionals working the land, who are the repositories of local knowledge that is vital for dryland resilience. The local knowledge of farmers and herders is an essential resource for sustainable development and must be capitalized on through more people-centered approaches to development, including participatory planning and a focus on training and awareness raising.

The positive trend towards widespread re-adoption of sustainable, risk-oriented land management strategies is to be encouraged. The scientific community must lead the way in validating sustainable land management practices, illustrating alternative development pathways for sustainable agricultural intensification. Emphasis should be placed on supporting land users to manage and adapt appropriately to the extreme levels of risk and to strengthen efficiency of water use through appropriate soil management practices. Focus is also needed on optimizing the production of multiple ecosystem services in the drylands, including supporting diversity of production, as well as the production and marketing of higher value goods and services.

The UN Global Drylands report mirrors the trend in dryland development by focusing on economic, and, to a lesser extent, social development without paying adequate attention to the ecosystem services that sustain both. At the heart of desertification is a weak understanding of dryland ecosystems and how they can be most effectively managed, particularly with regard to the intricate ecology of dryland soil. Basic assumptions over the harvesting and use of water, the management of soil fertility, and the management of spatial scale have been developed in humid lands and are often unsuited to the drylands. This reflects a shortcoming in research and education and requires a fundamental review of how knowledge is generated and used. This knowledge gap further highlights the importance of participatory approaches so as to benefit from the rich local and indigenous bodies of knowledge developed by societies that have been managing the drylands for centuries.

A strategic agenda for the drylands should revolve around the three established pillars of sustainability, paying equal attention to each pillar: social, environmental and economic.

1. Environmental sustainability in the drylands requires a substantial overhaul of the natural resource sector, integrating agriculture and environmental management, while ceasing to treat food production as a purely extractive industry. Soil is produced so slowly in the drylands that it is often portrayed as a finite, non-renewable resource; in future, agriculture must ultimately put back into the soil as much as it takes out. It is particularly important to broaden our understanding of biodiversity and to develop agriculture around the recognition that organic carbon, the prime indicator of soil fertility, is nothing more or less than biodiversity. Farmers, as stewards of soil carbon, are at the heart of the effort to address the biggest environmental challenges of our time: biodiversity loss, climate change and land degradation.
2. Social sustainability in the drylands must be strengthened through development of human capital, including improved access to basic services such as education, health and security. It should also include improved social protection as well as better management of demographic changes, such as urbanization, rural destitution, and the marginalization of women. Social sustainability requires effective institutions for governance of natural and economic resources. It will be achievable only when human rights are respected as a foundation for people-oriented development.

3. Economic sustainability must build upon, and ultimately contribute to, a strong foundation of ecological and social sustainability. It requires investment in value chains that reflect the essential diversity of dryland management systems, including capitalizing on environmental services and certification of sustainably produced goods. This includes supporting the development of small and medium sized enterprises that increase value addition locally and also create jobs for the growing urban poor of the drylands. It also requires an effort to overcome transaction costs, particularly those associated with access to information. Equally, it requires enabling investments from the public sector to overturn the legacy of sustained under-investment in order to unlock private sector engagement. Economic sustainability in the drylands must be built around sound risk-management, including efficient management of soil fertility and water, as well as reinforcement of locally-proven land management practices.

An important step is ensuring that global and national development targets, as well as sustainability goals, are monitored sub-nationally to give deeper insight into what is happening in the drylands. The Millennium Development Goals advanced global development in many ways, but places like Moroto in Uganda and the Zarqa basin in Jordan have been left behind in terms of both economic and human development. The values and importance of drylands means that sacrificing them to focus on development in more humid regions is not a viable option. The adoption of the Sustainable Development Goals in 2015 provides an opportunity to redress the balance, knowing that it will take time for drylands in many countries to catch up, but also recognizing that these are the very places where the benefits of investment can be highest.

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United Nations
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