Conserving Dryland Biodiversity

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Citation: Davies, J., Poulsen, L., Schulte-Herbrüggen, B., Mackinnon, K., Crawhall, N., Henwood, W.D., Dudley, N., Smith, J. and Gudka, M. 2012. *Conserving Dryland Biodiversity*. xii +84p

ISBN: 978-2-8317-1541-4

Cover Photos: ***Background:*** Cashmere goats and fat tailed sheep (Piet Wit)

Thumbnails: Top- Iran Cenesta

EWC

Drinking horses with mountain background - Mongolia (Pichugin Dmitry)

Dracaena - Egypt (Scholte)

Design & layout: Gordon Arara (IUCN Publications Unit, Nairobi)

Illustrations by: Clara Herreros Murueta-Goyena

Available From: **IUCN (International Union for the Conservation of Nature)**

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Contents

Foreword

Dryland biodiversity is of tremendous global importance, being central to the well-being and development of millions of people in developing countries. In June 2012, at the UN Conference on Sustainable Development (or "Rio+20"), global leaders from governments and civil society reaffirmed the intrinsic value of biological diversity and recognised the severity of global biodiversity loss and degradation of ecosystems. Although drylands were implicitly recognised, there continues to be inadequate attention to this major biome that covers such a vast part of our world's terrestrial surface. Yet, as this book conveys, conservation and sustainable management of drylands biodiversity offers a viable pathway to deliver international conservation and development targets. This book is a global resource aimed to aide dryland management as it is the first comprehensive analysis of dryland biodiversity that is of global importance and significance.

Many people in the drylands pursue livelihoods that conserve biological diversity in innovative ways, and often with little recognition. Farmers in the Sahel for instance practice cultivation and agro-forestry techniques that not only improve productivity and strengthen resilience, but also provide family income and numerous environmental benefits. Mobile pastoralists in many dryland regions maintain herding strategies that mimic nature, thereby promoting ecosystem functions that not only underpin their livelihood but also provide global environmental benefits like carbon sequestration and species conservation.

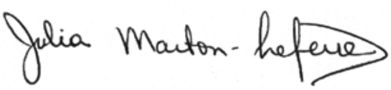
IUCN, the International Union for Conservation of Nature, is strongly committed to the conservation and sustainable management of drylands biodiversity. As a Union of more than 200 government organisations and over 900 non-government organisations, as well six Commissions of 11,000 voluntary scientists and experts, IUCN is strongly positioned to champion dryland biodiversity and to demonstrate and promote innovative ways to achieve the shared goals of biodiversity conservation and sustainable development.

The United Nations Convention to Combat Desertification, as the international legally binding agreement on desertification and land degradation, recognizes that actions taken to combat desertification/land degradation and drought, and actions taken to promote biological diversity are inextricably linked in both purpose and effect. Working to improve both the livelihoods of dryland populations and the conditions of such ecosystems, the UNCCD delivers on this mandate particularly by advocating the need, and demonstrating the ways, to maintain and restore land and soil productivity and to mitigate the effects of drought. Aware of the inter-linkages between biodiversity, land and soil productivity and human well-being, the Convention acts to raise awareness on drylands biodiversity and its value, including species diversity, habitat and ecosystems. Additionally, it takes action to offset land degradation through effective ways of conserving and restoring dryland biodiversity. And indeed, the world came out of the Rio+20 Summit with an international resolve to achieve a land degradation neutral world, to be pursued with the implementation and promotion of sustainable land management practices worldwide.

For the United Nations Environment Programme, drylands biodiversity is a cross-cutting priority throughout its work on ecosystem management, environmental governance, early warning and assessment, and beyond. UNEP chairs and hosts the Environment Management Group, a UN system wide coordinating body which catalyses and coordinates action on important environment and human settlement issues. In 2011 the UN released the EMG-supported Global Drylands: A UN System-wide Response, which commits the entirety of the UN system to step up their efforts to protect and revitalise drylands, and improve the well-being of drylands communities, through a pro-active drylands development and investment approach.

Conserving Dryland Biodiversity is intended to raise awareness amongst all stakeholders and galvanise wider action to boost drylands conservation and development. It is a call to action as well as a guide to how dryland conservation and development can be equitably pursued. The book is designed to inform and remind us of the beauty of dryland biodiversity and its intrinsic and instrumental value. It demonstrates the mutual dependency of dryland biological and cultural diversity. The book includes new analyses of drylands biodiversity and an overview of approaches that promote sustainable development as well as conservation goals. It strongly underlines the importance of indigenous knowledge and culture to dryland conservation, and demonstrates an unrivalled opportunity for sustainable growth and biodiversity protection.

The commitment of global leaders cannot be translated into reality if the drylands are neglected or continue to be misunderstood. If historic underinvestment in the drylands is addressed and knowledge gaps are closed then dryland conservation will enable us to greatly exceed our global expectations. We, as heads of our respective institutions, are proud of this effort and we are committed to working, together and with others, to realise the worthy and vital ambitions outlined in this book.



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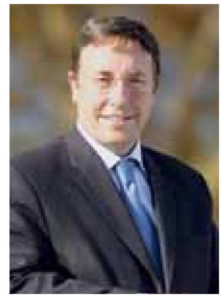


Mr. Achim Steiner
(Executive Director UNEP)

Acknowledgements

The authors are very grateful to the following contributors who enriched this book by providing experiences from their countries or regions and their fields of expertise.

- Abisha Mapendembe, UNEP-WCMC
- Aline Kuehl, Convention on Migratory Species (CMS)
- Cecilia Larrosa, UNEP-WCMC
- Edmund Barrow, IUCN, the International Union for Conservation of Nature
- Elena Maria Abraham, Consejo Nacional de Investigaciones Cientificas y Tecnicas (CONICET) and Instituto Argentino de Investigaciones de las Zonas Aridas (IADIZA)
- Fernando Spina, Convention onf Migratory Species (CMS)
- Dr. Gabriela Lichtenstein, INAPL/CONICET, Chair South American Camelid Specialist Group (GECS)
- Gidske L. Andersen, Uni Environment, Uni Research
- Hamid Sarfraz, IUCN, the International Union for Conservation of Nature
- Ishwar, N. M, IUCN, the International Union for Conservation of Nature
- Knut Krzywinski, Uni Environment, Uni Research, Thormøhlensgt. 49 B, 5006 Bergen and Department of Biology, University Bergen, Thormøhlensgate 53 A. 5006 Bergen
- Laura Cerasi, Convention onf Migratory Species (CMS)
- Laurens Geffert, UNEP-WCMC
- Maria Daniela Rodriguez, IADIZA-CCT-Mendoza-CONICET
- Mariam Akhtar-Schuster, Desert Net International
- Martin Nganje: IUCN, the International Union for Conservation of Nature
- Neil Cox, Conservation International
- Oraib Nawash, Royal Botanical Garden, Jordan
- Scott Perkin, IUCN, the International Union for Conservation of Nature
- Ute Schmiedel, Desert Net International

We are also very grateful to the following experts who dedicated their time to thoroughly peer reviewing the book.

- Anne Juepner, UNDP-Drylands Development Centre
- Bertrand Vincent, UNCCD
- David Coates, Convention on Biological Diversity
- Edmund Barrow, IUCN, the International Union for the Conservation of Nature
- Elizabeth Migongo-Bake, United Nations Environment Programme (UNEP)
- Emmanuel Chinyamakobvu, UNCCD
- Geoffrey Howard, IUCN, the International Union for the Conservation of Nature
- Jasmin Metzler, UNCCD
- Michael Mortimore, Independent consultant and member of the Commission on Ecosystem Management
- Sergio A. Zelaya-Bonilla, UNCCD
- Stephen Woodley, Parks Canada and IUCN
- Victor Castillo, UNCCD

Acronyms

AZE .... Alliance for Zero Extinction

CABI .... Capitania de Alto y Bajo Izozog

CBD .... Convention on Biological Diversity

CBNRM .... Community Based Natural Resource Management

CMS .... Convention on Migratory Species

CONICET .... Consejo Nacional de Investigaciones Cientificas y Tecnicas

CSO .... Civil Society Organisation

EBA .... Endemic Bird Areas

FAO .... Food and Agriculture Organization

FUGs .... Forest User Groups

GGWSSI .... Great Green Wall for the Sahara and the Sahel Initiative

IADIZA........... Instituto Argentino de Investigaciones de las Zonas Aridas

IBA .... Important Bird Areas

ICCA .... Indigenous and Community Conserved Areas

ICIMOD .... International Centre for Integrated Mountain Development

IIED .... International Institute for Environmental Development

IPCC .... Intergovernmental Panel on Climate Change

IUCN .... International Union for Conservation of Nature

IWRM .... Integrated Water Resource Management

KBA .... Key Biodiversity Areas

KIGC .... Kaa-Iya del Gran Chaco

NCRD .... Negev Center for Regional Development

NGO .... Nongovernmental Organization

NTFP .... Non-timber forest Product

OECD .... Organization for Economic Cooperation and Development

RLE .... Red List of Ecosystems

SBSTTA .... Subsidiary Body on Scientific, Technical and Technological Advice

TEEB.............. The Economics of Ecosystems and Biodiversity

TILCEPA .... Theme on Indigenous Peoples, Local Communities, Equity and Protected Areas

UNCCD.......... United Nations Convention to Combat Desertification

UNDP .... United Nations Development Programme

UNEP .... United Nations Environment Programme

UNESCO .... United Nations Educational, Scientific, and Cultural Organization

WCMC .... World Conservation Monitoring Center

WDPA............ World Database on Protected Areas

WHS.............. World Heritage Sites

WWF............. World Wildlife Fund

Executive summary

The Richness of Dryland Biodiversity

Water is an essential ingredient for life on Earth and its scarcity drives extraordinary biological, and often cultural, diversification. Drylands are defined by water scarcity and characterised by seasonal climatic extremes and unpredictable rainfall patterns. Yet despite their relative levels of aridity, drylands contain a great variety of biodiversity, much of which is highly adapted to dryland ecology. As a result there are many animal and plant species and habitats found only in drylands: some semi-arid and dry sub-humid areas are among the most biodiverse regions in the world.

Diversity is also great within drylands, for example between areas of different aridity, temperature or altitude. Species have adapted to these factors in many unique ways creating a variety of habitats that are essential to the survival of species as well as to the livelihoods of people. Wetlands, forests, mountains and other habitat types provide vital resource patches within the drylands. Species richness is generally lower in the drylands than in tropical forests but within-species diversity may be higher due to this diversity of habitats and the isolation of populations. Some drylands, however, such as North America's tall grass prairie, are among the most productive vegetation types in the world.

Biodiversity is vital to the livelihoods of many dryland inhabitants playing a central role in traditional risk management strategies, supporting food production and providing a multitude of other services. Dryland biodiversity also provides significant global economic values through the provision of ecosystem services and biodiversity products. Many cultivated plants and livestock breeds originate in drylands, providing a genetic reservoir whose importance is increasing as climate change drives the demand for new adaptations and extinctions of wild breeds. However, many dryland ecosystem services cannot be quantified or valued in monetary terms, despite providing some of the most important motives for conservation. These services such as cultural identity and spirituality are central to dryland cultures and can be integral to the protection of dryland ecosystems. There has been an observable correlation between land degradation and cultural degradation in drylands demonstrating their interconnectedness.

Managing and Conserving Dryland Biodiversity

Although the conservation status of dryland biodiversity is not well monitored, many known drivers of biodiversity loss are present in the drylands. These drivers include rapid demographic shifts and urbanisation, agricultural expansion, land use change, weakening of governance arrangements and the introduction and spread of alien invasive species. Accelerating dryland development is anticipated to increase the rate of biodiversity loss. The combination of habitat loss and fragmentation will reduce the opportunities for dryland biodiversity to adapt and survive, with the additional impacts of climate change further exacerbating the problem.

Despite approximately 9% of drylands receiving formal protection, the protected areas are not representative of all the dryland subtypes. For example, deserts are disproportionately represented whilst temperate grasslands have amongst the lowest level of protection of all biomes at 4-5%. To some extent this is because traditionally, areas with the lowest economic value were the ones designated as protected areas. Nevertheless, large areas of drylands are protected informally by the communities that inhabit the area, either consciously (for example as sacred sites) or as a by-product of sustainable management practices that evolved through generations (for example as seasonal grazing reserves). This indigenous protection is seldom recognised by government and is often undermined by government policies.

Many traditional land management practices have proven to be more economically viable than more 'modern' alternatives, whilst simultaneously providing conservation benefits. The ecological rationale of these traditional strategies developed through a deep understanding by the indigenous communities of their surrounding natural environment ensures both economic and environmental sustainability. The drylands perhaps more than any other biome offer opportunities for achieving both conservation and development objectives simultaneously and in many cases have shown to do so. The Aichi targets on protected areas could be more easily achieved, or even surpassed, in drylands by legitimising and supporting Indigenous and Community Conserved Areas, and traditional natural resource management strategies.

Conserving Dryland Biodiversity and Sustaining Life

The relationship between poverty and biodiversity loss can be easily misconstrued in dryland settings because of the higher proportion of drylands that appear to be in peril in developing rather than developed countries. However, it is important to avoid simply equating dryland biodiversity loss with poverty without first scrutinising the causal factors behind the poverty. Where the causes of poverty are social and political marginalisation, poorly planned conservation and development efforts can entrench poverty and generate conflict and this has implications for biodiversity.

A major factor in environmental degradation in drylands is weak or weakening governance, and particularly the undermining of customary institutions without replacing them with effective alternatives. Drylands may be particularly prone to weakening of governance due to political marginalisation and also the importance of common property regimes. Nevertheless, in many countries customary governance remains intact and can be rebuilt or reformed with appropriate support and sensitivity.

The drylands are different in a number of important ways from humid lands. However, development pathways for the drylands are often driven by a distorted idea of how drylands should or could exist, often modelled on more humid areas. Notions of "greening the desert" are developed on a misunderstanding of dryland ecology and have led to many harmful policies and investments. Furthermore, misrepresentation of drought and water scarcity in the drylands diverts attention away from sustainable and adaptive management, capable of being supported by limited resources, towards unsustainable practices that are ecologically harmful. Rather than adapting development strategies to fit the drylands, considerable effort is expended on trying to adapt drylands to fit development strategies.

A Future Vision for Drylands

A more nuanced vision of sustainably developed drylands is needed: one that reflects social and ecological realities and provides a framework against which policies and investments can be assessed. Such a vision should include at least four components based on the intersection between sustainable land management and biodiversity conservation:

1. Adapting green economic growth to the drylands;
2. Conservation and sustainable management of dryland biodiversity;
3. Land health as the basis for secure food and water provision; and
4. Resilience and risk management in uncertain environments.

Green Economic Growth in the drylands can play a prominent role in ensuring that ecosystems are protected as the foundation of life and prosperity, but Green growth strategies need to be tailored to the environmental conditions of drylands. In particular, strategies must reflect the uncertainty of dryland climate, the high levels of risk that this implies and the strategies of local resource managers to maintain resilient livelihoods. Government policies that encourage land use changes need to be better informed of the wider ecosystem and economic costs of such changes and a great effort is needed to valuate existing land use strategies in terms of productivity, resilience and wider ecosystem benefits.

Conservation strategies in drylands should reflect the important role that drylands play for agricultural development. They should promote ecologically-sensitive farming practices, such as agroforestry, pastoralism or conservation agriculture as an alternative to intensive farming practices. Indigenous knowledge and local institutions could support the effective implementing of such practices. Landscape scale biodiversity management in the drylands is only possible if farming systems are treated as tools for conservation and conservation becomes a tool for sustainable agricultural development.

Land health is an established concept in a few countries but lacks adequate government support in many others, particularly in the developing world. Improved integration of land and water planning at the level of government can provide the basis for dryland ecosystem management and protect the soil on which indigenous vegetation and agricultural development depends. It can also play a significant role in protecting ecosystem services and thereby mitigating the risks of drought. With greater respect for the value of soil, more sustainable farming practices can be widely incentivised, promoted or protected, which will in return lead to development and conservation benefits.

Resilience is at the heart of dryland livelihoods but is poorly reflected in public decision making or development investment. A greater understanding of resilience in dryland social-ecosystems is needed to inform policy making and institutions need to be strengthened to provide the foundation for resilience. Institutions are needed at multiple levels, to integrate planning and governance at a local level but also at the international level to enable negotiations, for example over transboundary resources. Improved coherence in planning will also help to reduce the harmful effects of emergency interventions.

Strategies for dryland biodiversity conservation

To realise such an ambitious vision in the drylands requires a strategic and broad suite of actions. Many drylands have received low investment for decades and often basic investment is needed to build infrastructure and strengthen human capital. Investment is needed to strengthen innovation, science and knowledge, including greater attention to local and indigenous knowledge and more collaborative research to allow mutual validation of different knowledge systems. Local innovations should be more strongly encouraged, through improvements in education, greater access to finance and other services and increased support for entrepreneurialism around new biodiversity-based business opportunities. Stronger science and knowledge are needed to make the case for green economic growth in dryland and there is a strong case for conducting a "State of the World's Dryland Biodiversity" assessment.

Innovation, knowledge and science

Research and investment need to be more responsive to new and evolving understanding of dryland ecology and there is need for greater consensus on how to protect and regenerate soil through land management. Greater investment is needed in extension services that provide relevant technical advice to land users in the drylands. An improved understanding of what constitutes land health in the drylands is also needed and should underpin improved monitoring systems. Similarly, monitoring of dryland biodiversity needs greater investment, including red-listing of species and ecosystems to provide better support to decision makers. Improved monitoring must also go hand in hand with improved communication and there is need for improved packaging and dissemination of information to be of greater value to land managers and other decision makers in the drylands.

Incentives and investment

Incentives and investment are required to promote sustainable land management and biodiversity conservation in the drylands, and this includes significant multi-sectoral investments to establish conditions for sustainable growth. Policies that favour less sustainable land use options need to be revised in many countries and incentives can be better oriented towards promoting environmentally-friendly land use options. Investments can also be better designed to capitalise sustainably on biodiversity, for example through tourism. Payments for ecosystem services and other incentives for environmental custodianship have an important role to play in conserving dryland biodiversity, but are often undermined by the lack of relevant institutions or capacities. Investment and incentive strategies should be developed that reflect the importance of diversity to dryland resilience and ensure broad-based investment in multi-functionality across ecosystems rather than narrow sectoral investments in a few isolated pockets of high value resources.

Governance and empowerment

Governance, from local to international levels, needs strengthening in many drylands in order to enable sustainable growth and conservation. The principle of subsidiarity should be better applied in drylands in order to strengthen governance, but should also reflect the large scale of ecosystems. Greater attention is needed to legitimizing customary and local institutions and addressing inequities in governance. Many dryland communities are undergoing profound demographic and social changes that have important implications for governance and equity and efforts to strengthen governance must take such changes into consideration. Indigenous Community Conserved Areas (ICCAs) have a particularly important role to play in dryland biodiversity conservation, since they recognise and build on traditional practices and capitalise on proven local governance arrangements that enable the use of indigenous knowledge. Conservation strategies are needed that combine a variety of protected area approaches so that exclusionary forms of protection are complemented by widespread community-conserved areas (e.g. ICCAs).

Mainstreaming dryland biodiversity

A concerted effort is required to mainstream dryland biodiversity and coordinate actions between all government sectors, and this poses particular challenges of scale in the drylands. Government institutions need to be tailored towards supporting and augmenting the skills of land managers and government staff often require new skills to conduct more participatory planning. Governments should increasingly look to champion the role of land managers as environmental stewards in “Green Community Landscapes” whilst the role of environmental authorities should be adjusted to ensure they have the mandate and capacity to play a mainstreaming role. As the Millennium Ecosystem Assessment and the Millennium Development Goals have underlined, a disaggregated approach to conservation and development in drylands serves the interests of neither.

Dryland Biodiversity and Sustainable Land Management


Kangaroo in Wilpena Pound Australia – ©CSLD

Biodiversity is the variety of ecosystems and living organisms on earth: animals, plants, microorganisms, their habitats and their genes. Biodiversity forms the web of life of which humans are part: it regulates the great ecological cycles of the earth and is responsible for our very survival[1]. One way or another, biodiversity affects us all, and the more we learn about the interconnectivity of ecosystems around the world, the more we appreciate the importance of global biodiversity.

Drylands from the Asian Steppe to the Australian Outback have provided countless millions with inspiration and spirituality. Many of the world's great religions emerged from the drylands of Asia and the Middle East and desert regions have long been a place of pilgrimage, meditation and hermitage. Dryland animals, like the African elephant and the lion, are globally known and cherished, while dryland plants include the ancestors of many of our staple food crops as well as the source of a growing number of medicines and cosmetics. Dryland cultures, like the Maasai or the Bedouin, pervade the popular consciousness. It is no coincidence that so much of our global heritage comes from the drylands; it is human adaptation to life in the drylands that gives this cultural heritage its uniqueness and value.

Maasai Warriors – ©Hector Conesa


Bedouin Women with their Camels - ©NRT

Drylands, including dry sub-humid, semi-arid, arid and hyper-arid lands, cover 41.3%[2] of the earth's land surface and dryland biodiversity plays a pivotal role in the global fight against poverty, climate change and desertification. Paradoxically, many people also consider the drylands to be barren with little value or interest. However, it is often what we do not see that is important for our lives – there may be more biodiversity in dryland soils than in a tropical rainforest. The cultural diversity, dramatic landscapes and iconic wildlife of the drylands contrast starkly with the negative attitudes that some people hold towards them.

Drylands are defined by water scarcity and characterised by seasonal climatic extremes and unpredictable rainfall patterns. In line with the definitions of IUCN, UNEP and the Convention on Biological Diversity (CBD), and inclusive of the definition of the UNCCD, this book considers drylands to be areas where the potential amount of water that is transferred from the land to the atmosphere is at least 1.5 times greater than the mean precipitation: a calculation known as the aridity index.

Despite their relative levels of aridity, drylands contain a great variety of biodiversity, much of which is highly adapted to dryland ecology. As a result there are many species and habitats found in drylands that are not found in more humid areas. Some semi-arid and dry sub-humid areas are among the most biodiverse in the world including, for example, the Mediterranean Basin, the Californian Chaparral, the Cape Floristic Kingdom, southern Madagascar and the Brazilian Cerrado. Flowering plant species are significantly more diverse in dry sub-humid areas than in temperate humid areas.

Dryland biodiversity is also central to sustainable development and to the livelihoods of many of the world's poor: the importance of biodiversity to poverty reduction and economic development in the drylands may be greater than in many other biomes[3]. This is because drylands are characterised by extreme climatic uncertainty and biodiversity plays a crucial role in traditional rural risk management strategies, and also because drylands are more widespread in the developing

Table Mountain in Cape Town, South Africa - ©Sculpies

world and have a comparatively high proportion of rural livelihoods. Dryland biodiversity also has global economic importance, providing a number of high-value products that fill important niche markets (such as gums and some medicinal plants). Furthermore, at least 30% of the world's cultivated plants and many livestock breeds originate in drylands, providing an important genetic reservoir that is becoming increasingly valuable for climate change adaptation[4].

Dryland biological diversification

In addition to being distinct from non-dryland ecosystems, there is also great diversity within the drylands. Dryland ecosystems include Mediterranean types, such as the Mediterranean Basin or the Cape Floristic Region of South Africa, as well as cold deserts such as the Gobi in Mongolia and hot deserts like the Sahara, where both climate and latitude strongly influence biodiversity. Dryland diversity is further influenced by altitude, which ranges from low lying areas like the Danakil Depression of Ethiopia to high altitude drylands in countries like Afghanistan or Bolivia. These diverse dryland ecosystems contain a greater variety of plants and animals that have evolved to colonise their unique habitats.

Water scarcity has played a major role in influencing biological diversity in the drylands, but variations in topography, geology, soil type and quality and in other resources have also been important factors in this process. Other drivers of biological diversification in drylands include the seasonal patterns of rainfall, fires and herbivore pressure as well as the influence of human management over centuries, and in some cases millennia. The outcome of all these drivers is that drylands consist of a patchwork of habitats, which determines the distribution of living organisms[5].

Species have adapted to these drivers in many remarkable ways. Short rainy seasons have selected for species that can complete their reproductive cycle in a very short period. Extended drought periods have selected for a variety of mechanisms in organisms, including the ability to escape, evade, resist and endure drought. Fire and herbivore pressures have led to the selection of plants that can withstand or even require such impacts for successful reproduction and propagation[6]. Water scarcity has led to extraordinary physiological and behavioural adaptations in many plant and animal species.

The diversity of habitat types within the drylands is essential to the survival of species as well as to the livelihoods of people. Wetlands, oases and other water resources in drylands, for example, are often small patches within vast landscapes, but their value to the wider ecosystem is frequently under-rated. In fact the reliance of many migratory bird species on these resource patches illustrates that their value may extend far beyond the boundaries of the drylands. Dryland forests and woodland patches play similarly important roles within wider landscapes, often providing seasonal refuge for migratory species as well as people, in addition to harbouring their own unique biodiversity. Although species richness in the drylands is generally lower than in tropical forests, within-species diversity is thought to be higher because of the variety of habitat types and the isolation of populations[7]. Furthermore, some drylands, including some temperate grasslands such as North America's tall grass prairie, are among the most productive vegetation types in the world[8].

Volcano in the Danakil Depression, Ethiopia – ©Matej Hudovernik

Saiga Antelope – ©Andriy Solovyov

Wetlands within drylands: Saryarka-Steppe, Kazakhstan[9]

The Saryarka-Steppe and Lakes of Northern Kazakhstan are part of the Kazakh Uplands and have been designated as a World Heritage site by UNESCO. Saryarka is a semi-arid landscape that includes wetlands of great importance for a number of migratory European bird species, including the globally threatened and extremely rare Siberian White Crane (*Grus leucogeranus*), the Dalmatian Pelican (*Pelecanus crispus*), and Pallas's Fish Eagle (*Haliaeetus leucoryphus*). These wetlands-within-drylands are key stopover points and crossroads on the Central Asian flyway of birds from Africa, Europe and South Asia to their breeding places in Western and Eastern Siberia. The area is also home to the migratory and critically endangered Saiga antelope (*Saiga tatarica*).

People have occupied Saryarka for some 10,000 years. Initial they were livestock keepers and as the area dried out from approximately 5,000 years ago people adopted more mobile husbandry practices: the short grass steppe of Saryarka becoming the summer grazing grounds. In the past century and a half people have also adopted more arable farming practices. However, after 1968 only conservation-related activities were permitted within the reserves, although some farming, hunting and fishing is permitted in buffer zones. The value of the wetlands to wider dryland livelihoods in the region is not strongly reflected in conservation strategies, yet the area is among the poorest regions of Kazakhstan. Evolving strategies for exploiting the complementarity between sustainable land management and conservation could benefit the environment of Saryarka as well as the livelihoods of local residents.

Individual species have not adapted in isolation in the drylands and relationships between species within plant and animal communities have evolved in response to dryland characteristics. For example, low soil moisture and nutrients have led to diverse symbiotic relationships between plants and micro-organisms. These relationships are central to some of the most important ecosystem processes in the drylands, such as nitrogen fixation or extraction of other micronutrients[10].

Status of dryland biodiversity

Data from the IUCN Red List[11] show that, across all biomes, over 32% of species (out of a total of 59,507 species that were assessed) are threatened with extinction. The drivers of biodiversity loss are complex and inter-connected, and include human population growth, conversion of habitat for expansion of farming and expansion of urban areas. Invasive alien species threaten indigenous biodiversity and frequently undermine ecosystem services. Furthermore, human-induced climate change and habitat fragmentation is altering species migration patterns, shifting the range that many species can occupy and accelerating the spread of invasive alien species[12].

The status of dryland biodiversity is perhaps not quite so clear, since many datasets are not typically differentiated into dryland and non-dryland biodiversity, although this book begins to address this. However, many of the drivers of biodiversity loss are present in the drylands, and if dryland development is poised to accelerate then biodiversity loss should be anticipated. Furthermore, as discussed later, climate change is likely to impact heavily on drylands and the combination of habitat loss and fragmentation will reduce opportunities for dryland biodiversity to adapt, particularly the ability of species to physically relocate to more suitable habitats as climate zones shift.

With a few exceptions, the drylands are poorly monitored and it can be difficult to disaggregate species that are exclusive to the drylands from species whose broader ranges overlap dryland habitats to some extent. This creates a challenge in understanding the link between the rate of biodiversity loss and the extent of land degradation[13] in the drylands. As the following chapter illustrates, the percentage of drylands that are formally designated as protected areas is close to the global average, but this global average is distorted by the presence of some very large protected desert areas, often chosen for political expediency rather than a careful analysis of biodiversity values.

On the other hand, some of the richer dryland ecosystems are under-represented in terms of protected areas. Temperate grasslands for instance have among the lowest level of protection of all biomes at 4%–5%, yet they may already be among the most altered biomes on earth[14]. It must be understood however that many dryland areas are informally protected by the communities that live there, either consciously (e.g. as sacred sites) or as a by-product of management (e.g. as seasonal grazing or forest reserves). In many cases this indigenous protection is not officially recognised and may be undermined by government policies that restrict traditional land-use practices such as mobility, or undermine customary governance. Additionally, areas may be 'accidentally' protected because

Loss of endemic biodiversity in the Thar Desert

Due to its unique location at a biological crossroads of the Indian subcontinent, the Thar Desert harbours spectacular biodiversity. However, since the 1960s human population increase has led to steady expansion of cropping even on the most marginal lands. This has been facilitated by an exponential rise in irrigation from boreholes and canals, especially from the Indira Gandhi Canal, during the last 30 years. Since the 1960s the area under irrigated crop fields has increased from 300,000 hectares to over 4 million hectares.

Changing land use has significantly affected biodiversity, with desert-adapted species being replaced by species that demand more water. Increasing irrigation in the Thar Desert is leading to loss of numerous shrubs such as *Calligonum polygonoides*, *Haloxylon salicornicum* and *Dipterygium glaucum*. Reptiles that are adapted to survive in extremely dry environments are likely to be affected by the transformation of desert areas to irrigated crop fields. These include the lesser known lizards such as *Eumeces taeniolatus*, *Acanthodactylus cantoris* and *Cyrtodactylus kachhensis*, and the snakes *Leptotyphlops macrorhynchus* and *Lytorhyncus paradoxus*. At the same time, land-use changes create conditions that are favourable to a number of invasive species and other weeds that further undermine indigenous biodiversity.

From a conservation perspective it is important to examine the presumed inevitability of agricultural expansion and the ways of mitigating the harmful impacts of land-use change. To some extent land-use changes can be moderated by greater recognition of the value of existing land-use practices. For example, studies in Kenya have shown that existing pastoral land use in the dry north of the country makes more efficient use of scarce water resources than irrigated crop farming[16]. Where land-use change is inevitable, different land-use options can be considered that impose less of an environmental cost, including more environmentally sensitive irrigation plans. Economic valuation of ecosystem services can be a strong tool for measuring such environmental costs in order to help planners avoid undesirable environmental outcomes.

Village in the Thar Desert, India – ©Oskana Perkins

they are military lands, or set aside for other purposes. Protected areas, as recognised by IUCN, give priority to nature conservation. Places where conservation outcomes are a beneficial secondary outcome of natural resource use, such as grazing or forest management, are therefore likely to be outside any official protected area system. Given the extent of such sustainable land management practices in the drylands it is likely that significant conservation outcomes are thus obtained without recognition[15].

Dryland biodiversity and resilient livelihoods

As later chapters will discuss further, biodiversity plays a strong role in dryland livelihoods, underpinning rural economies and providing safety nets during periods of climatic and other stress. Traditional land management practices that have often proved economically superior to so-called modern alternatives also often bring conservation benefits. This is not a coincidence since it is often their ecological rationale that confers both economic and environmental sustainability.

Conservation of biodiversity can be approached in different ways with different impacts on the lives of local communities. In some cases conservation offers not so much a route out of poverty as a safety net for local resource users. However, conservation approaches have changed substantially in recent years and now pay much more attention to the risks of inequity and impoverishment of rural communities. Furthermore, community conservation (such as Indigenous Community Conserved Areas as discussed later) is gaining credibility as a way to achieve conservation goals in parallel with economic and social sustainability[17].

Poverty is not a global characteristic of drylands and neither is it the only cause of dryland degradation. Industrialised countries such as Canada, the United States and Australia include large, affluent dryland regions which are nevertheless subject to degradation. Land-use changes that contribute to dryland degradation, such as conversion of rangelands to artificial pasture or clearance of forests and rangelands for crop cultivation, may accelerate with economic development. Nevertheless, a disproportionate number of the world's poor reside in the drylands, and a disproportionate amount of the world's drylands are found in the developing world. It is estimated that 2 billion people reside in the drylands and 90% of these are found in developing countries[18]. As a result, it is important to understand the specific relationship between poverty and conservation or degradation of dryland biodiversity.

Poverty, climate change, land degradation and drought are all reported to be important drivers of dryland biodiversity loss. However, the reverse is also true; loss of biodiversity contributes to land degradation, drought and poverty and can increase vulnerability to climate change. Food security is particularly compromised by the loss of provisioning ecosystem services and the loss of species that can be harvested for food. Conversely, protecting and restoring biodiversity can contribute to climate resilient livelihoods, sustainable development and climate change mitigation as well as reducing desertification and land degradation[19].

Poverty is multidimensional and in the drylands it is often closely linked to social exclusion and political marginalisation. Dryland populations are frequently ethnically distinct from those with political power, and they are often also geographically marginal and disconnected from markets as well as decision making centres. Policies that influence dryland development are often biased towards the needs of humid areas, and frequently need to be adjusted to the conditions of the drylands[20].

Traditional dryland strategies for natural resource management have commonly been found to be highly sustainable, although these strategies are repeatedly constrained by government policy. In many cases sustainability is compromised where decision making powers and tenure security have been weakened. Drylands may be particularly prone to weakening of governance due to their marginalisation but also to the importance of common property arrangements as the basis for many risk management strategies. However, in many countries customary governance remains strong or can be revived as the basis of resilient livelihoods[21].

The specific value of biodiversity for different natural resource user groups in the drylands is not just a matter of rich versus poor. Other socio-economic characteristics also play a critical role, especially gender, which cuts across social groups and wealth or livelihood profiles. The gender-division of household economies, particularly in rural areas in poor countries, means that women often have specific knowledge about local crops or biodiversity that plays a significant role in meeting families' food and medicinal needs. In developing countries, women are often particularly affected by biodiversity loss, for example by the impact of deforestation on availability of fuel wood. The relationship between biodiversity, gender and other socio-economic characteristics in non-poor and urban environments still demands further attention[22].

There is an important relationship between dryland biodiversity and land degradation that needs to be further examined. Conservation and sustainable land management strategies can protect soil from erosion and degradation and promote soil formation. Land degradation is a major global threat that undermines the ecosystem services on

Peruvian Woman carrying fuel wood - ©UROSR

which humans depend. It is estimated that 10%–20% of drylands are already degraded and the total area affected by desertification[23] is between 6 and 12 million square kilometres[24].

Dryland biodiversity loss and land degradation are influenced by, and contribute in turn to climate change. As land degrades and vegetation is lost, the land becomes less capable of absorbing or storing atmospheric carbon, although the albedo effect (reflectivity) may increase with denudation of soil, leaving the net outcome uncertain[25]. Biodiversity is central to the resilience of many dryland communities and therefore land degradation may play the dual role of increasing exposure as well as vulnerability to the effects of climate change. The relationship between biodiversity and prosperity is complex and diverse, and as a result much of this value is overlooked by government planners and investors.

Valuing dryland biodiversity

Dryland biodiversity has great value, both to local resource users and to the global beneficiaries of ecosystem services such as carbon storage and sequestration. However, ecosystem services are widely taken for granted, which is a major factor in their loss[26]. Methods exist for effectively quantifying such values, although these are far less well developed or applied in drylands as they are in forest or coastal ecosystems. Furthermore, it is not always possible or even desirable to put a monetary value on ecosystem services, particularly cultural and spiritual services. It is important to ensure that people, particularly those from outside the drylands, understand the values of the services they are enjoying, and that appropriate measures are put in place to protect against their loss.

Drylands provide local populations with food, fuel and water, but often these values are not well captured in government accounts, and are easily dismissed by government planners in pursuit of alternative capital investments. Other dryland ecosystem services have great value but are seldom accounted for and the cost of losing them may be felt too late. For example, when water regulation services break down and catastrophic floods cause costs that are measured in human lives.

Some types of dryland biodiversity have more immediately obvious value and are the basis of revenue generation. The aesthetic value of Africa's wildlife has generated significant revenue from tourism in recent decades, which has contributed to protection of some species[27]. More often dryland biodiversity is not subjected to formal valuation at all and government planners lack the necessary information to make the right decisions. By contrast, dryland resource users are often acutely aware of the values of their natural resources and enact strategies to protect them: strategies that may be dismissed or underestimated by government[28].

Grasslands alone contain major stores of carbon and estimates suggest that grazing lands, many of which are in drylands, could hold between 10% - 30% of the world's soil carbon. In total, grasslands are thought to hold in excess of 10% of total carbon in the biosphere. Temperate grasslands and steppes generally have lower carbon in biomass than temperate forests but can have higher levels of soil carbon. Savannah and tropical grasslands usually have higher rates of carbon storage than temperate grassland, ranging from less than 2 tC/ha for tropical grass and up to 30 tC/ha for wooded savannah. Grasslands are also one of the ecosystems where changes in human management can have the most significant impacts on carbon storage and sequestration[29].

Not all ecosystem services can be adequately quantified or valued in monetary terms, yet some of these services provide people with the greatest motivation for conservation. These services include cultural identity and diversity, cultural landscapes and heritage values, servicing knowledge systems, spirituality, aesthetics and inspiration, recreation and tourism. The diversity of dryland ecosystems leads to great diversity in dryland cultures that contributes to cultural identity, which in turn can be integral to the protection of those ecosystems. There has been an observable correlation between land degradation and cultural degradation in drylands.

Action to protect dryland biodiversity

Although we do not know the full extent of dryland degradation, we can identify factors that have been shown to contribute to biodiversity loss more generally and which are clearly present, and increasing, in the drylands. In particular, the long-term neglect of drylands combined with the emerging demand for a rapid acceleration in dryland development puts drylands at particular risk. Protecting dryland biodiversity and its considerable global value requires concerted action. An important starting point is to recognise the extent to which dryland peoples already conserve and protect their biodiversity, and the knowledge and institutions that enable them to do so. In the first instance a great deal can be achieved simply by recognising and rewarding conservation efforts that already exist. Further support, from government and investors, can be mobilised by raising broader public awareness of the value and interest of dryland biodiversity, which is one of the aims of this book.

The book highlights many unique characteristics of drylands biodiversity: features that have implications for the way drylands should be managed or conserved, as well as for the way they contribute to economic development. We present examples of how dryland biodiversity has been successfully conserved and emphasise the importance of dryland peoples to biodiversity conservation, and of biodiversity conservation to the livelihoods of drylands peoples. The book is written for a diverse audience – from dryland developers or planners who may be unaware of the value of biodiversity, to dryland conservationists who may overlook the importance of biodiversity for local livelihoods or the power of local communities to conserve their environment. The book is also written for economic planners and conservationists in general, who could allocate more resources to the drylands if they were aware of their value and the costs of underinvestment.

The book therefore targets an informed and semi-informed audience, and blends technical data with features of more general interest. We have included several new maps to present spatial data on dryland biodiversity along with numerous features on dryland species or habitats and examples of successful conservation and sustainable development initiatives. We also describe scenarios or visions of how we think the drylands could exist, and propose strategies that we believe will make progress towards those scenarios. However, while putting forward these strategies we are conscious of the inadequacy of knowledge on many dryland regions of the world and the lack of consensus between dryland resource managers, government planners and scientists, and this book is above all a call for action to address such knowledge and communication gaps.

The book is organised in three broad sections. The first is designed to illustrate the great variety and uniqueness of biodiversity in the drylands, the second focuses on ways that dryland biodiversity is managed and conserved, and the third outlines four scenarios and strategies. The book avoids focusing overtly on the economic opportunities of dryland biodiversity, since this has been written about extensively[30]. Nevertheless, conservation and sustainable land management strategies are discussed at length and these raise important questions of markets and market-based incentives.

The book places considerable emphasis on the role of local and indigenous knowledge for the effective management of drylands. This knowledge has evolved in response to local conditions and demands and is at the heart of local governance arrangements. We include examples of how successful conservation and development initiatives have placed local knowledge, and the empowerment of its users, at the centre of decision making. We also present examples of how local governance can be strengthened by ensuring that all stakeholders in dryland resource management are enabled to participate equitably in making and enforcing rules for the use and protection of resources.

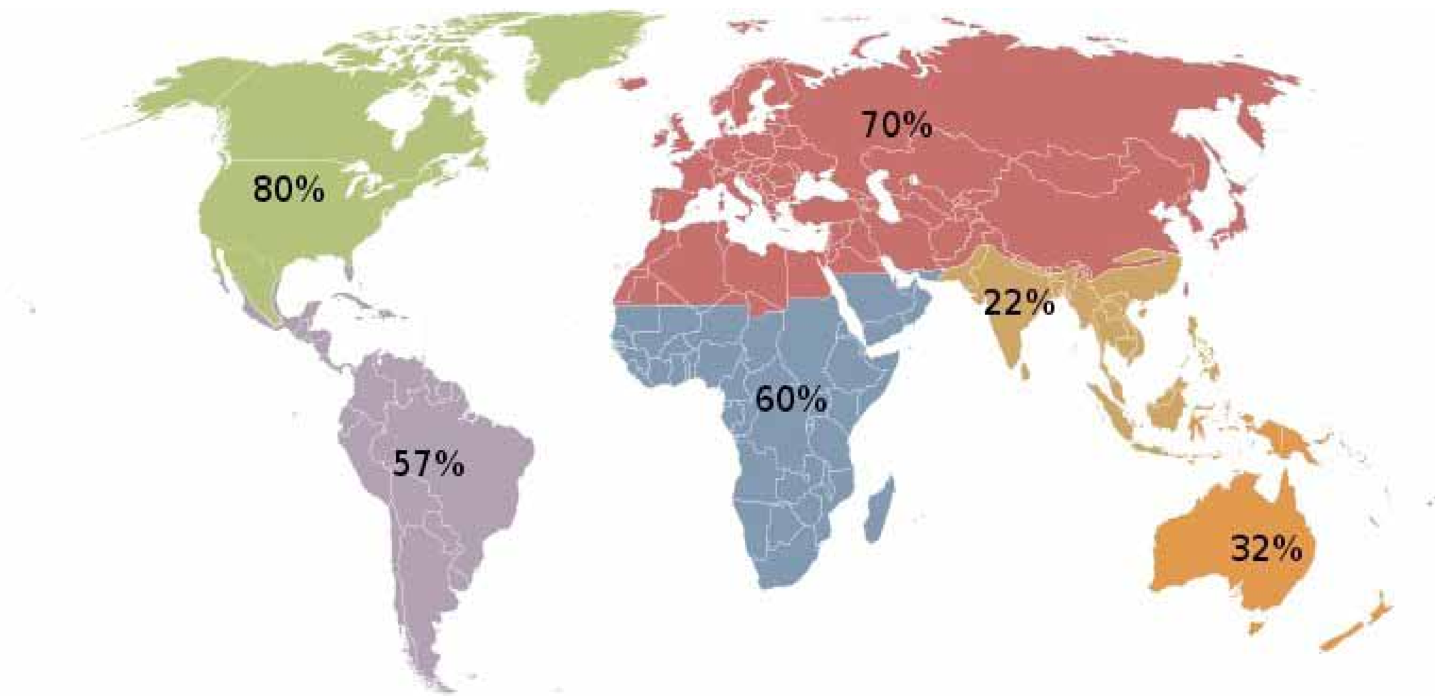
It is hoped that the book will both encourage people to pay more attention to drylands biodiversity and will contribute to discussions about how drylands can best be conserved. We hope to contribute to the discourse on how to strengthen local economies by promoting sustainable use and management of natural resources. To this end, biodiversity conservation should not be seen as an additional or a separate environmental goal, but as part and parcel of sustainable land management and broader development planning.

The Richness of Dryland Biodiversity

Drylands are globally well known for charismatic wildlife species such as the Lion (*Panthera leo*), African elephant (*Loxodonta africana*), Bactrian camel (*Camelus ferus*) and bovines like the wild yak (*Bos mutus*) and the American bison (*Bison bison*). While these species may attract millions of tourists annually for wildlife 'safaris', particularly in East Africa where the term originates, it is commonly overlooked that drylands provide crucial habitats for a vast number of less charismatic species. Drylands support iconic plant groups such as the cacti and succulents, trees such as acacia and baobab and many of the world's grasses. Overall, 10,000 mammals, birds and amphibian species can be found in drylands: 64% of all birds, 55% of mammals and 25% of amphibians. In comparison, the richest terrestrial biome – tropical and sub-tropical moist broadleaf forests – supports around 70% of global terrestrial fauna[31].

Looking at different realms of the world, the drylands provide habitats for 80% of North America's mammal, bird and amphibian species. In Europe, Asia and North Africa the figure is around 70% and in sub-Saharan Africa and Latin America it is around 60%. Of the vast number of species occurring in dryland habitats, 4% of mammals and amphibians, and 3% of birds are endemic to drylands and do not occur outside them.

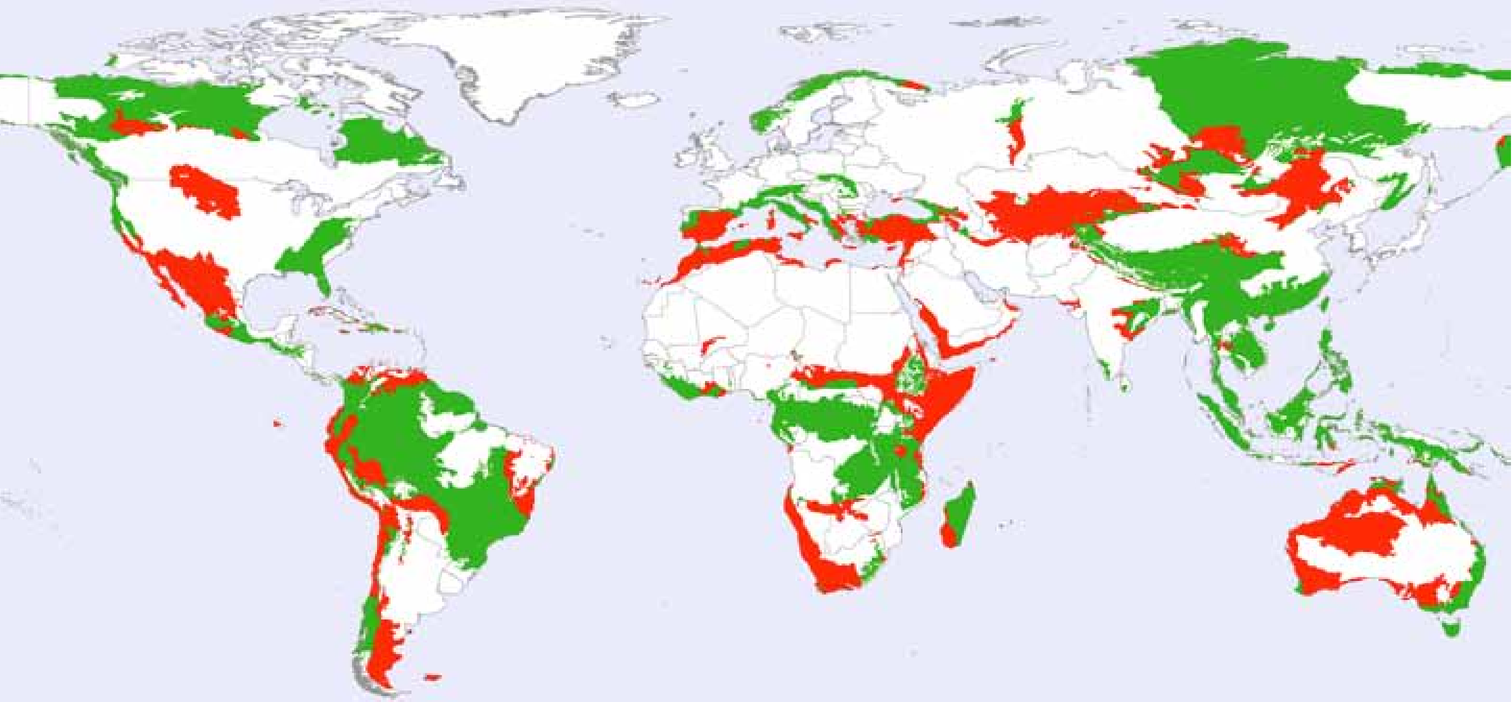
Percentage of mammals, birds and amphibians occurring in drylands for different realms[32]



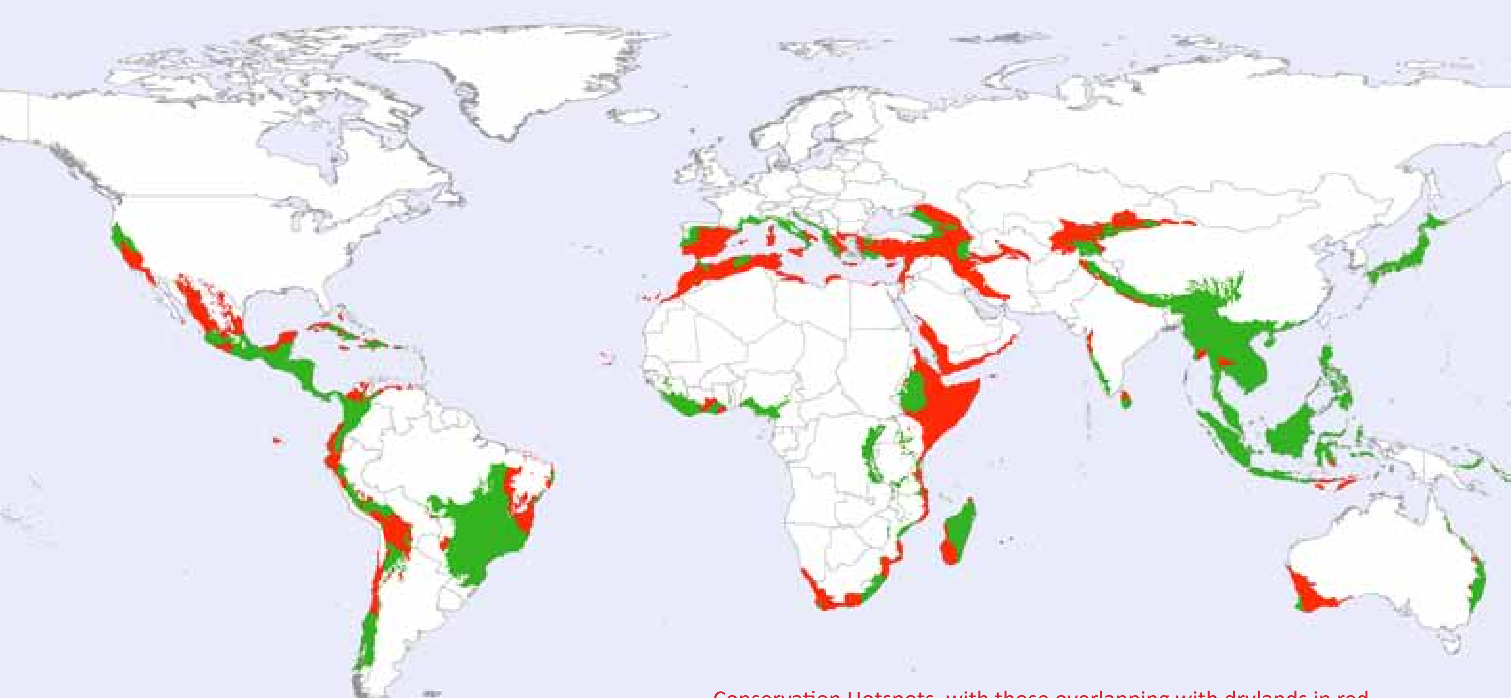
While providing habitat for a vast number of species, some drylands have naturally low species richness per unit area, especially in hyper-arid areas such as the Sahara, Central Australia and Central Asia. Yet other areas have relatively high levels of species richness, such as Africa's Sahel and North America's grassland plain, and some drylands boast exceptionally high number of species per unit area, such as arid and dry sub-humid areas in the Andes. Other habitats such as the Cape Floristic Region, the smallest and richest of the world's six plant kingdoms, have very high species richness in plant groups but relatively low richness in vertebrates[33].

Such differences in species richness are driven by the seasonal pattern of water availability, which is a critical environmental factor affecting all aspects of a species' life history. It shapes how animals and plants adapt to their environment and determines species richness. As aridity increases, primary productivity falls and reduces the availability of resources for wildlife, resulting in declining species richness. This is clearly reflected in the species richness of flowering plant species across a gradient of aridity. The lowest number of flowering plant species is found in hyper-arid drylands and species richness rapidly increases with humidity, peaking in the dry sub-humid subtype. Species richness in the less arid drylands can be higher than in temperate habitats in Western Europe and the number of flowering plant species may be above half that found in the humid tropics.

Biodiversity hotspots and conservation priorities and in the drylands[34].



Global 200 list of ecoregions identified as priorities for conservation, with those overlapping with drylands in red.



Conservation Hotspots, with those overlapping with drylands in red.

In addition to large-scale biogeographical variation in species richness, local changes in topography and water availability create strongly contrasting habitats: one may contain very few species, while another contains an abundance of life. Spectacular examples of adaptation to water availability are mist oases found in a few mountainous regions of the Sahara, East Africa and the Arabian Desert. The most overlooked source of water in dryland is the hot desert air. As hot air is lifted up and cools down, its stored humidity is released through condensation. Similarly, as air heated during the day cools during the night, dew will form and in some places in deserts dewfall may be higher than rainfall. Where mist occurs regularly and with high intensity, mist oases can form.

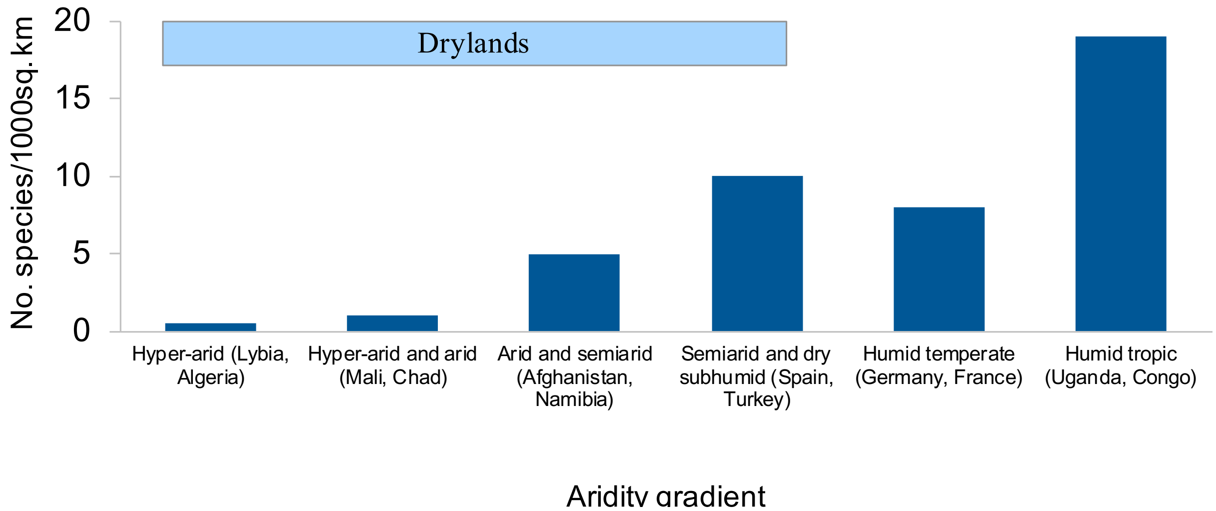
Sacred Crocodile in Mali's Mopti region are highly adapted to local drought conditions - ©IUCN Mali

Reptiles in drylands

One of the more familiar species groups associated with deserts and drylands are the reptiles, including snakes, tortoises and lizards. They are distributed in many of the world's harshest environments, however surprisingly little is known about these species, especially about their conservation status. IUCN has yet to comprehensively review all reptiles against the IUCN Red List Categories and Criteria, but status assessments have been made for a number of the world's dryland regions.

Preliminary results from the Arabian Peninsula suggest that reptiles may be of less conservation concern in this region than comparable species groups, with perhaps fewer than ten of the approximately 160 species found here being threatened with extinction. While some dryland reptiles may therefore be relatively secure, threats do remain. Habitat loss, over-harvesting and climate change are among the leading causes of population decline. Continued monitoring of reptile populations is needed to ensure that any changes in species status are identified at an early stage so that remedial action can be taken.

Species richness in flowering plants in the drylands[35].



Flowing plants per aridity type: each column represents a mean of two countries, with the dryland countries comprising at least 95% dryland.

The 'mist oases' in Sudan and Egypt contain unique ecosystems that are not found anywhere else. These local biodiversity hotspots contain lush vegetation, the trees are covered in lichens and their biological diversity is unparalleled in the arid environment of the continent. The relative abundance of moisture in Jebel Elba, Egypt, supports a diverse flora of some 458 plant species – almost 25% of plant species recorded for the entire country.

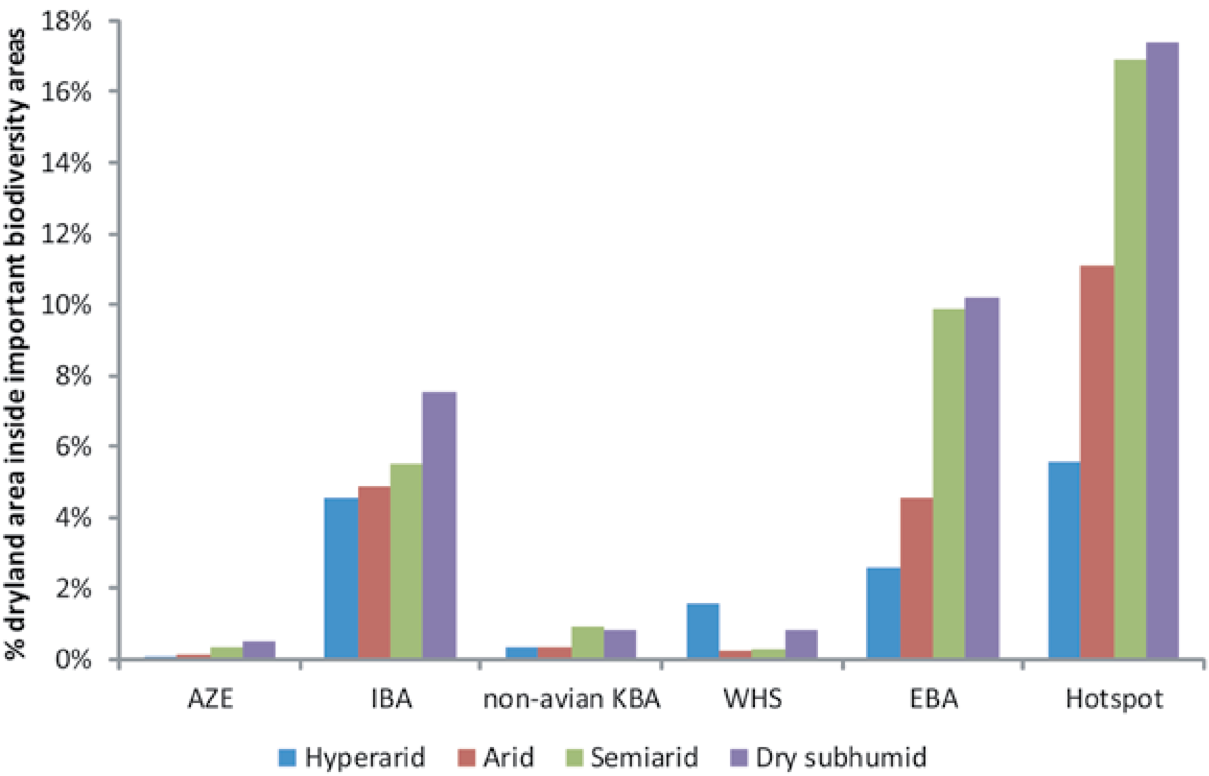
Importance of dryland biodiversity to global conservation

Drylands provide important habitats for many unique species that are of global conservation concern, such as the Saiga antelope (*Saiga tatarica*) found in the Asian steppe, Jerdon's Courser (*Rhinoptilus bitorquatus*) a nocturnal bird endemic to the Eastern Ghats of Andhra Pradesh and southern Madhya Pradesh in India, the Carpentarian Rock-Rat (*Zyzomys palatalis*) that occurs in tiny pockets of northern Australia, and a large number of amphibians primarily from drylands in the South American Andes.

Indeed, drylands are well-represented in many designations of global biodiversity importance. About 30% of the total area of sites of important biodiversity fall within drylands[36]. For example, drylands are home to 35% of the global hotspot area[37] and 28% of the total area of World Heritage Sites (WHS). Biodiversity Hotspots[38] designated by Conservation International contain high numbers of endemic species. Each biodiversity hotspot faces extreme threats and has already lost at least 70% of its original natural vegetation[39].

One third of all Endemic Bird Areas[40] (33%) and Important Bird Areas (31%) are also found in the drylands. A similar proportion of the area designated as non-avian Key Biodiversity Areas (31%) is situated in drylands. Endemic Bird Areas (EBAs) are regions supporting two or more restricted-range bird species (i.e. those with distributions smaller than 50,000 km^2): half of these are already threatened whilst the other half is vulnerable to the loss or degradation of habitat owing to the small size of their ranges[41]. The Alliance for Zero Extinction[42] (AZE) identifies sites supporting the last remaining populations of Endangered or Critically Endangered species, as listed on the IUCN Red List. Drylands contain 28% of all AZE surface cover and thereby directly contribute to the existence of many highly endangered species[43].

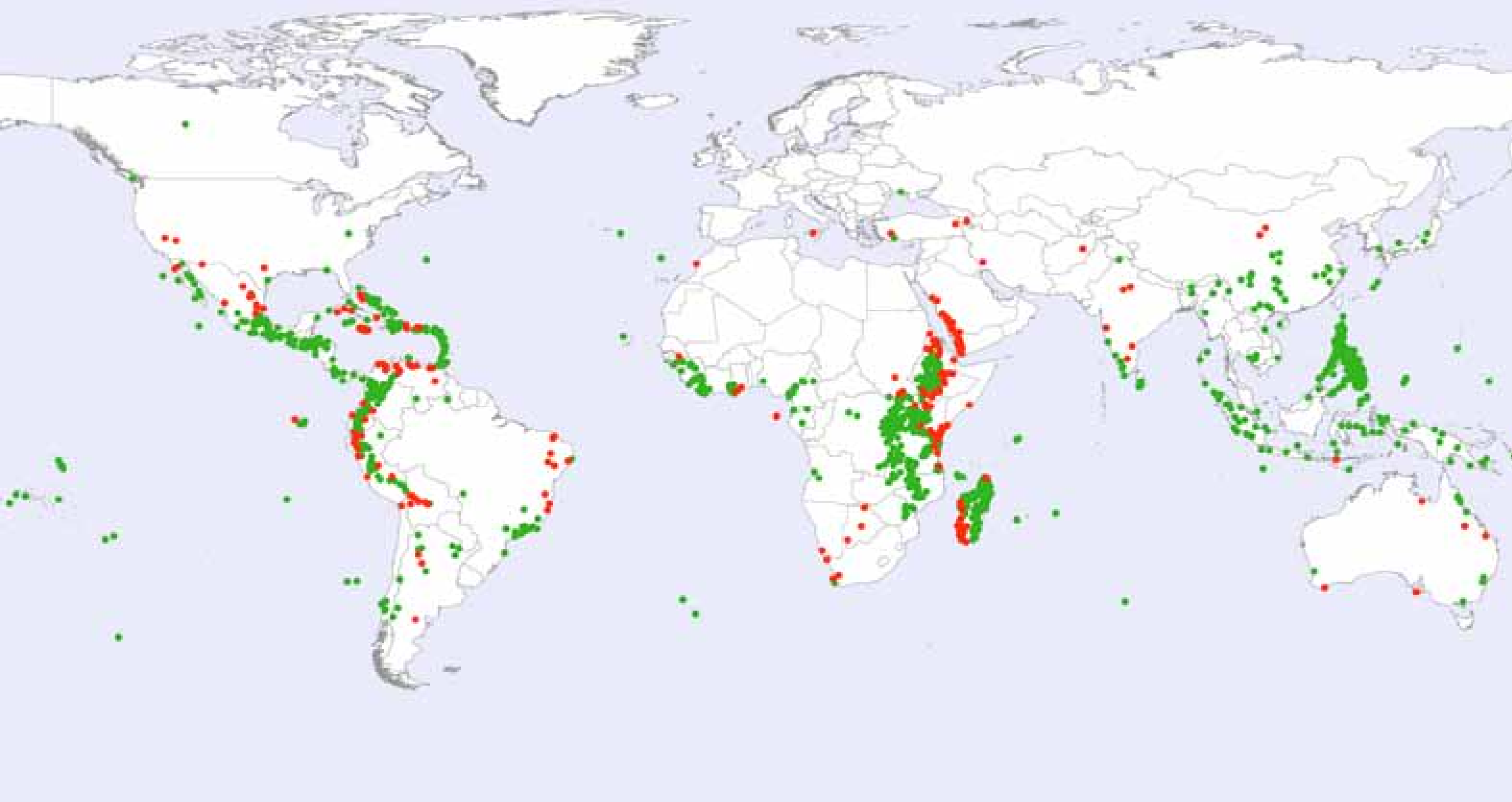
Percentage of area of important biodiversity sites in dryland subtypes[44].



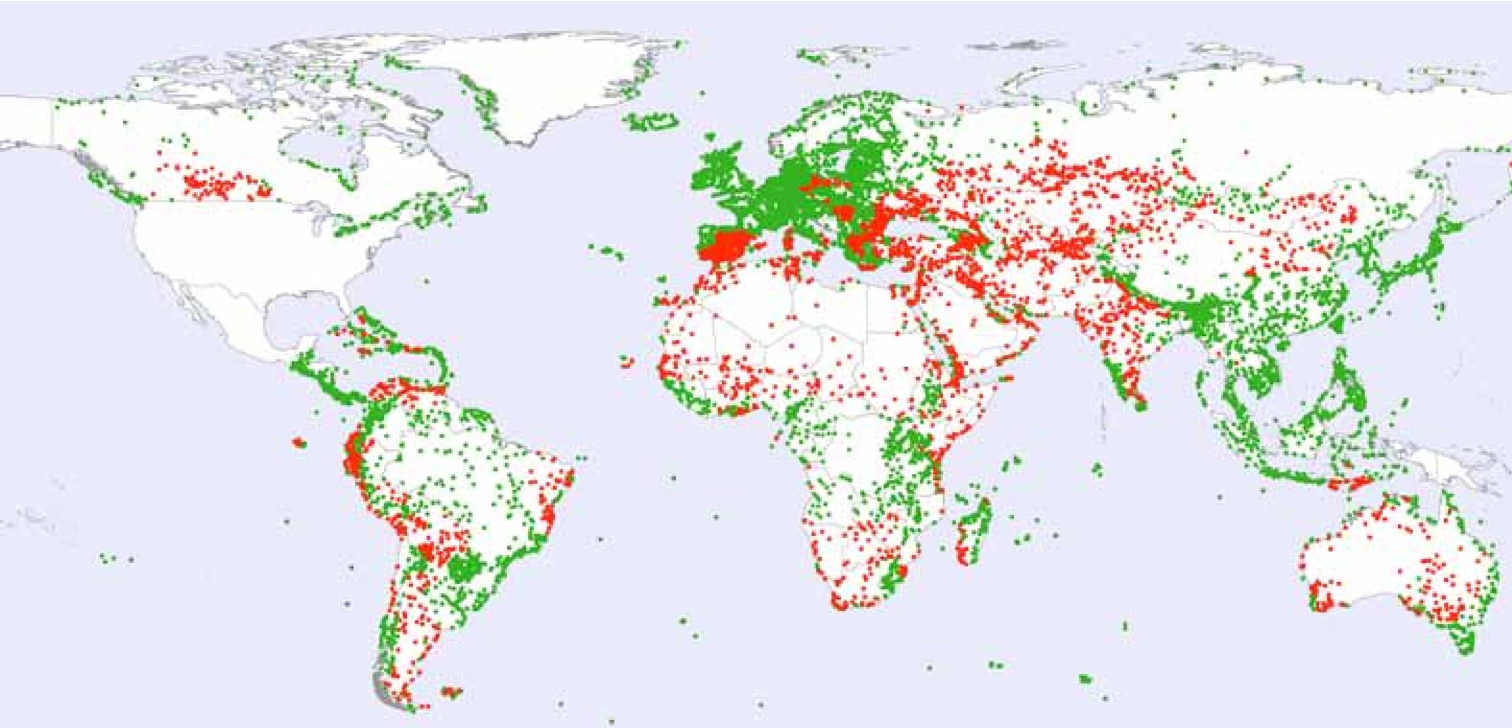
AZE: Alliance for Zero Extinction
KBA: Ley Biodiversity areas
WHS: World Heritage Sites
EBA: Endemic Bird Areas
Hotspot: as per Conservation International
IBA: Important Bird Areas

Interestingly, while the presence of important biodiversity areas in drylands reflects relative aridity, the distribution of dryland species does not always follow well established concepts in ecology. Studies of small mammal populations in South American drylands show that expected relationships between species richness, habitat area and altitude may not always be valid in drylands. In contrast to prediction, small mammal communities were more species-rich in the high altitude desert, or Altiplano, where endemics account for more than 50% of all mammal species, than in the northern lowland deserts of Atacama and Caatinga[45].

Global importance of dryland biodiversity [46].



Key Biodiversity Areas, those overlapping with drylands in red.



Important Bird Areas, with those overlapping with drylands in red..

Keystone species: dryland ecosystem engineers

Burrowing rodents as dryland keystone species

In many drylands however, burrowing rodents are particularly important for their influence on ecosystems. Keystone burrowing rodents include the plateau zokors (*Myospalax fontanierii*) from the Tibetan plateau of China, and the prairie dog (genus *Cynomys*) in North America, whose tunnel systems channel rainwater, influence soil composition and aeration and maintain grazing lands that favour larger herbivores[47].

A keystone animal in South American drylands is the tuco-tuco (*Ctenomys mendocinus*), a small subterranean species that despite its small size (80g), modifies and shapes its native Prosopis woodland habitat. Tuco-tucos create a highly sophisticated system of caves and their burrowing action modifies soil composition and nutrients. They are a solitary species, which nevertheless occur in high densities of 10-12 individuals per hectare and a single animal can build more than 20 caves. Tuco-tucos feed on the stems of Jarilla (*Larrea divaricata*), which create dense mono-specific thickets. By feeding on them, Tuco-tucos modify the vegetation and create space for other species to grow.

Termites as dryland ecosystem engineers

Termites are important components of many dryland ecosystems and constitute one of the most significant animal species in terms of biomass. Although often considered pests, their role in the decomposition of organic matter in the soil and in improving soil structure and chemistry is of major global significance. Termites, along with ants, play a similar role to earthworms in more humid areas.

The precise taxonomy of termites is still debated, but they are estimated to number approximately 2,600 species distributed among 280 genera globally. Termites are social insects that form colonies composed of individuals from more than one generation, with cooperative care of young and reproductive distribution of labour. The colony is centred on one or more reproductive pairs and can number from a few hundred to several million individuals. In drylands, the winged reproductive termites, or alates, typically leave the nest in large swarms after the first rains, providing a crucial food source for migrating bird species.

Termites influence soil characteristics through their nesting, foraging and feeding behaviour. Some colonies build architecturally complex nests, or 'biogenic structures', that incorporate galleries, casts, mounds and fungus chambers. Termite colonies influence the dynamics of soil carbon, both directly by digesting cellulose and indirectly by breaking down litter and creating conditions for improved microbial action. Their ability to digest cellulose has particular environmental significance since cellulose represents half of the biomass synthesised by plants. Termites also accelerate soil rehabilitation by breaking up soil crusts, reducing compaction, increasing porosity, improving water infiltration and enhancing water holding capacity.

As a result of these actions, termites contribute to improving root penetration and vegetative cover. They also play significant positive and negative roles in local and global carbon cycles, through production of greenhouse gasses (e.g. methane) and through carbon sequestration. Overall the role of termites in maintaining ecosystem function, for example in African savannahs and Indian grasslands, exceeds the effect of herbivores.

Termite Mound – ©Simon Greig

The uniqueness of dryland biodiversity

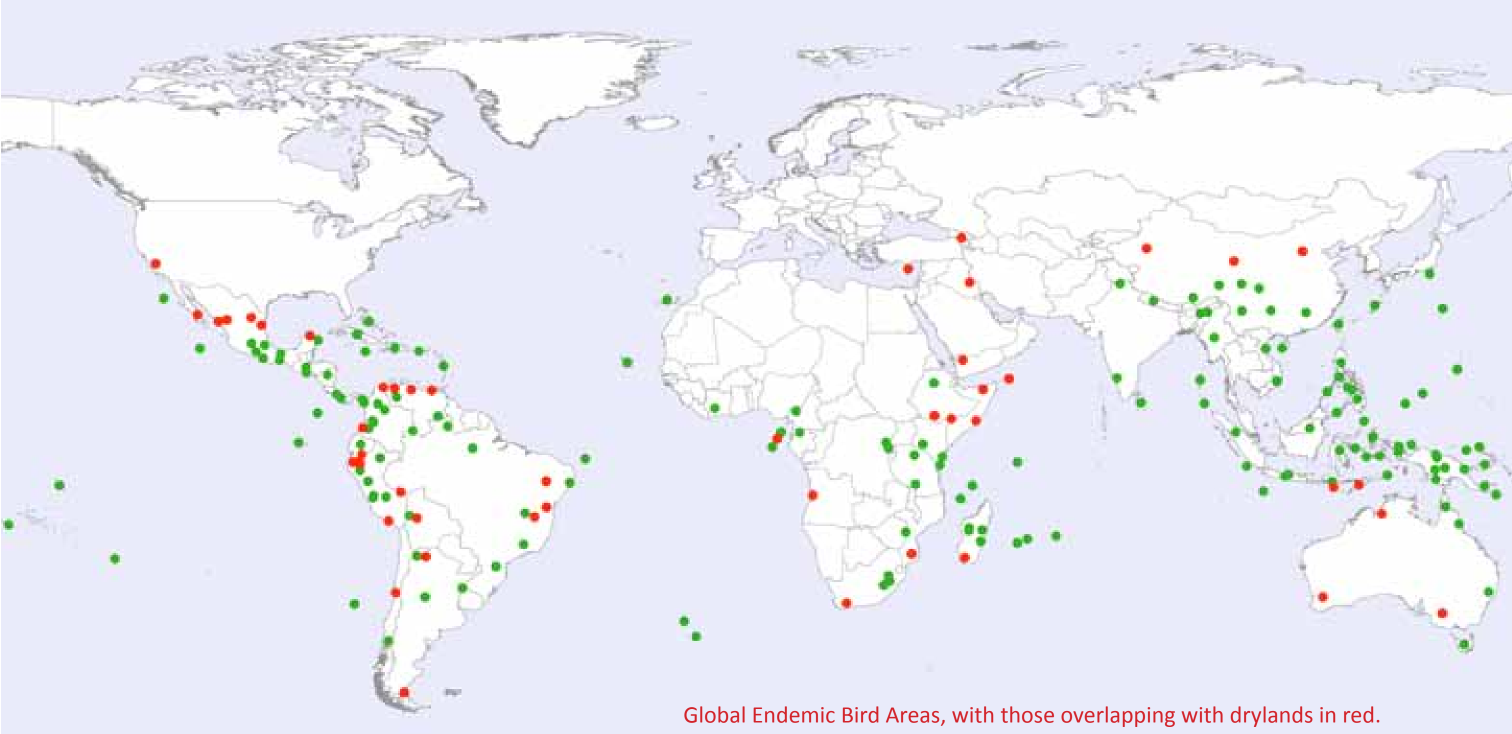
Over millennia the availability of water, or rather the lack of it, has caused dryland organisms to adapt in many ways to survive. Some animals have the opportunity to move in response to water availability and long-range migrations are a common feature of drylands, but dryland fauna and flora display a tremendous variety of adaptations. Four broad categories of adaptation can be identified[48]:

- **Drought escapers:** animals migrating in search of water or pasture, or insects 'escaping' into the egg or pupal stage until wet weather returns
- **Drought evaders:** plants like the salt bush with deep and efficient root systems or animals such as certain reptiles that avoid the heat by burying themselves underground
- **Drought resistors:** cacti that store the water in roots and trunks, or camels that minimise water loss
- **Drought endurers:** shrubs and trees that go dormant, or animals such as frogs that estivate during dry seasons.

Adaptations to dryland conditions also include adaptation to fire and herbivore pressures. Many plant species rely on both these phenomena to create conditions that favour their growth or reproduction. Plants that not only tolerate, but can benefit from the action of herbivores, for example through removal of dead matter around grassy tussocks, transportation of seeds or improved conditions for germination, will out-compete other plants in herbivore-dominated drylands. Similarly, plants that can tolerate fire are more likely to thrive in fire-prone drylands. Fires and herbivore impact, particularly the impact of certain 'ecosystem engineers', change dryland habitats and allow colonisation by other animal species[49].

Dryland habitats also display unique features, particularly related to the availability of water. Wetlands within drylands, for example, provide habitats of particular importance that are integral to wider ecosystem function and to seasonal migrations of dryland and non-dryland species. Oases, pans and ephemeral (or fossil) rivers, such as *wadis*, allow the growth of greater biomass than surrounding areas and are often pivotal to the survival of dryland biodiversity. Not surprisingly these resources are considered as high value pockets and are often coveted for agricultural use or urban development.

Endemic bird areas in drylands[50]



Global Endemic Bird Areas, with those overlapping with drylands in red.

Acacia tortilis - ©Ecoprint

Adaptations in dryland flora

When the area of the present day Sahara started drying up around 5,500 BP, lush vegetation contracted into small pockets where water was still available. Perhaps the most extreme cases of this contraction are still in evidence today in the Western Desert of Egypt, where isolated populations of *Acacia tortilis* and *Acacia ehrenbergiana* are found in the middle of vast deserts, in some cases further than 100 km from the next stand.

These trees manage to survive in one of the world's driest environments by having developed two fundamentally important adaptations: deep roots to access deep ground water and longevity to enable reproduction during the rare events when seedlings can grow. The absolute maximum depth of roots is not known for certain, but great depths have been reported for *Boscia albitrunca* (68 m) and *Acacia erioloba* (60 m) in the central Kalahari, for *Prosopis juliflora* (53 m) in the Sonoran Desert and for *Tamarix* spp. (50 m) in Egypt. Horizontal roots of up to 20 m take up and store soil moisture after rainfall and perhaps even also dewfall[51]. The extensive root system redistributes water upwards, downwards and sideways between soil layers. One of the processes of soil water redistribution is called 'hydraulic lift', where deep soil moisture is lifted to shallow dry layers through root systems, especially during the night, which improves nutrient cycling and water balance. This may help to keep shallow, lateral rootlets alive during dry periods and thereby 'alert' after rainfall to quickly absorb soil moisture.

The second important adaptation is the extreme longevity, as found among *Acacia tortilis* ssp. *raddiana* in the Egyptian Eastern Desert, with individuals perhaps as old as 650 years[52]. Although the soil acts as a seed bank for these trees, beetles attack the seeds of many tree species thus requiring the constant input of new seeds to ensure that when rain finally falls, sprouting viable seeds are present. Most seedlings will not survive the first drought as they have not developed the extensive root network needed to access deep ground water. As a result, the prospects for reproduction are extremely limited and longevity is essential for long-term survival.

Dryland soils dry quickly and young roots need time to reach the permanent soil moisture at deeper levels. For these reasons, survival of saplings in hyper-arid areas probably involves rare occasions of several consecutive rainfalls. Many dryland tree species have therefore developed the ability to switch between regenerating from seeds in resource rich sites where water stress is low, and sprouting in climatically harsh sites, where water stress is high[53]. Saplings such as *Acacia tortilis* demonstrate a great ability to re-sprout (sapling banks) and in cases where green biomass is removed either by browsing animals or drought, this secures the persistence of populations.

The adaptations of dryland tree species are part of defining concepts such as the 'persistence niche' and the 'storage effect', referring to their ability to endure long droughts and to set seed and reproduce when rare, but optimal conditions occur. This means that even a seemingly declining population can be vigorous and increase or maintain its size in a long-term perspective. In other words 'the average population growth rate is more strongly affected by the benefits of favourable periods than by the costs of unfavourable periods'[54]. Evidence of a lack of recruitment of dryland trees does not therefore automatically indicate long-term deforestation. Nevertheless, understanding the life-history of these trees highlights the importance of protecting and conserving mature individuals.

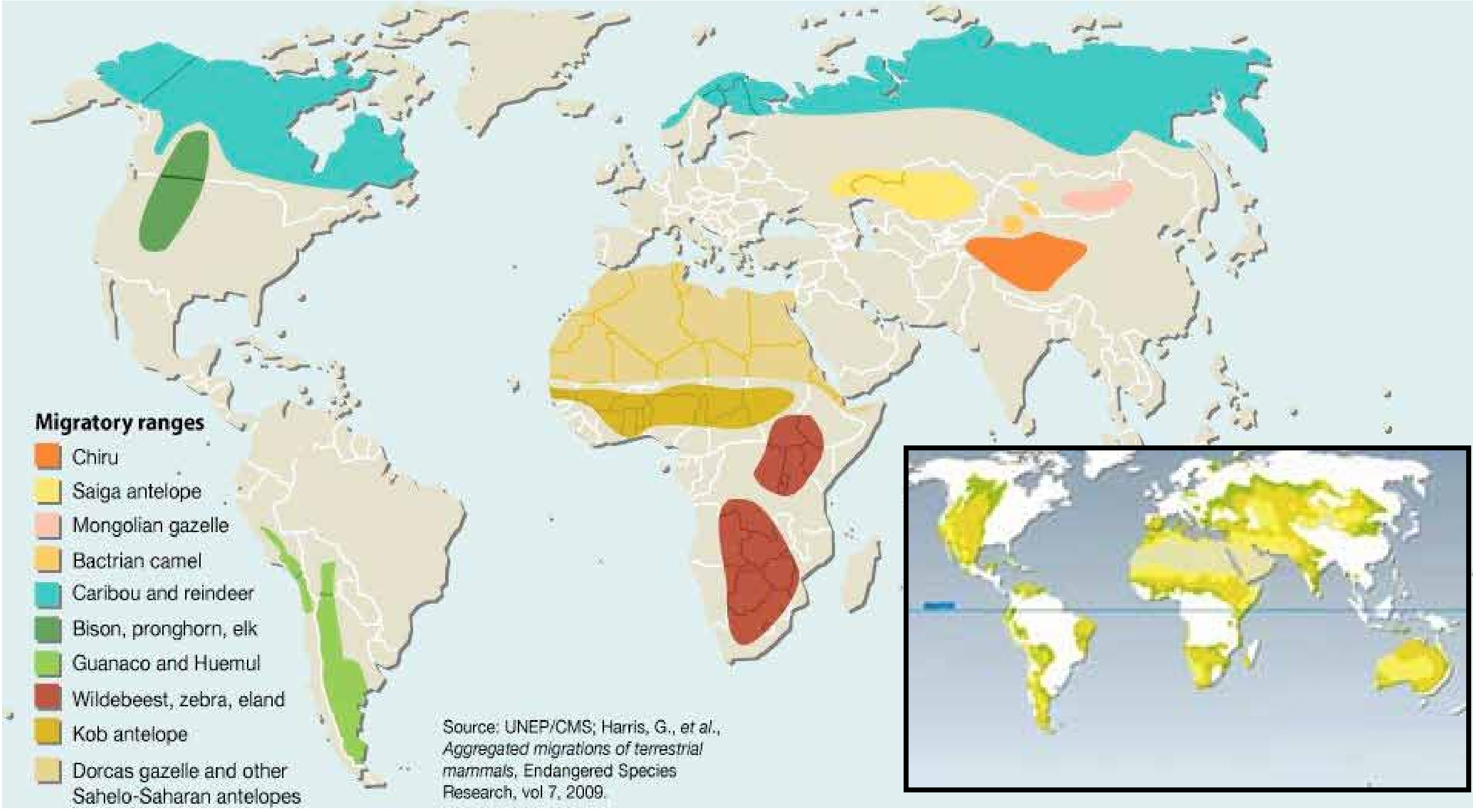
Migratory species: the movers and shakers in dry ecosystems

From wildebeest (*Connochaetes taurinus*) in the Serengeti to Demoiselle Cranes (*Anthropoides virgo*) across Eurasia and Africa – mass migration is a common feature of many drylands around the world[55]. There are many reasons for these seasonal journeys between one place and another, often between a breeding and a non-breeding site and back. Migratory species make the most of briefly-available resources such as the rich seasonal growth found in many deserts, and move on when conditions are less optimal. Mongolian gazelle (*Procapra gutturosa*) are known to follow the rain and their presence correlates well with vegetation growth, which can easily be measured remotely via satellite. Animals tend to avoid harsh climatic conditions such as snow, for example Saiga antelope (*Saiga tatarica*) remain just south of where the snow occurs in winter[56].

Predators and seasonal diseases also influence the pattern of movements, as does the selection of the optimal location to give birth, to overwinter or to moult. White-headed Duck (*Oxyura leucocephala*) and many other birds specifically spend their flightless moulting period in remote areas where there is little predation[57]. The timing and direction of migration often correlates with optimal winds and temperatures to make the arduous journeys as energy-efficient as possible[58]. Animal migration is closely linked to climatic factors and allows migrants to flourish even in harsh environments through their opportunistic travel schedule.

Migratory species are important for arid ecosystems for several reasons. Firstly, mass migration is a vital mechanism for nutrient cycling, reducing fire loads and fertilising the drylands. Ungulate herds tend to follow the vegetation peaks with remarkable accuracy and as they move through an area their droppings play an essential role in fertilising the soil, facilitating seedling survival and growth. Their hooves can also support the aeration of topsoils and thereby increase productivity significantly[59]. The removal of biomass during migration does also have implications for fire frequency and extent. Simulations from the Serengeti, for example, have shown that a collapse in wildebeest would lead to a strong increase in the area burned by bushfire each year[60]. Not only do migrants remove biomass and thereby have an impact on the fire regime, they can also act against natural succession by removing small trees and even large ones in the case of elephants[61].

Migratory ranges for selected ungulates[62]. Map of drylands inset[63].



Migratory birds connect drylands across continents

During their annual cycle, migratory species make use of many different habitats, often covering vast geographical areas in the process. Migratory birds are the record-breakers for long-distance migration in the animal kingdom. Species such as the Barn Swallow (*Hirundo rustica*) are capable of covering over 10,000 km on their annual journeys, crossing and connecting the deserts of Asia and Africa. Birds often provide a vital ecological connection between continents, as in the case of African-Eurasian migrants which breed throughout Europe and spend the winter south of the Sahara where they feed in open, low vegetation habitats, such as savannahs or light woodlands.

Barn Swallow - ©Andrea Valadao

Birds accumulate considerable amounts of fat before embarking on their long and arduous trans-Saharan flights. There is, however, a physical limit to the amount of energy reserves that migratory birds can store prior to departure, which limits the overall distance that a bird can fly without needing to refuel. Desertification causes loss of suitable habitat and feeding sites in the Sahelian zone south of the Sahara, which undermines these migrations. This is aggravated by the effects of climate change and could rapidly lead to major threats to the survival of many species of long-distance migrants moving between Europe and Africa. Birds such as the Barn Swallow (*Hirundo rustica*) or the Pied Flycatcher (*Ficedula hypoleuca*), once common and widespread summer visitors across Europe, are already showing severe local population declines because they cannot overcome the expanding desert barriers. Intact drylands are therefore crucial for successful migrations and the birds' overall fitness.

The fascinating link between migratory passerines and blooming flowers is one of the many examples of the ecological services offered by birds as potential pollinators[64]. This relationship offers an opportunity for monitoring initiatives to halt soil erosion and restore ecosystems, using the presence and stopover behaviour to monitor habitat changes. Such studies can also be useful for promoting awareness and outreach across all countries sharing the same populations of migratory birds.

By moving seeds, spores and small organisms from one area to the next, migrants aid species dispersal and genetic exchange across large areas. This allows other less mobile species to 'move' and thereby assists them in adapting to climatic and other change. However, migrants can also act as vectors of disease, and in the case of birds and bats this may be across numerous continents. Pastoralists such as the Maasai actively minimise the transmission of malignant catarrhal fever from wildebeest to their livestock by avoiding the migrant herds during the wet season[65]. Nevertheless, many of the diseases that can be transmitted through migratory species can have profound economic impacts, making it important to monitor and fully understand the factors that drive individual migrations.

Mass migration plays a vital role for the wider food web within arid ecosystems. Migrations are relatively predictable in both time and space, allowing predators and other species to adapt their own lifecycles to that of a particular migratory species. Sociable Lapwing (*Vanellus gregarius*), for instance, are thought to have adapted to the saiga antelope migration, which provides the lapwing with short grass in which to breed during the spring. The manure of the herds attracts insects, which in turn provide food for the birds.

Eleonora's Falcon - ©Ignacio Yufera

Predators across the world have also adapted to feast on mass migration. Lions in the Serengeti time their reproduction to coincide with the presence of migrant wildebeest. Similarly, the breeding season of Eleanora's Falcon (*Falco eleonorae*) in the Mediterranean matches the migratory waves of songbirds each autumn, upon which they feed. Entire communities and food chains are therefore dependent on migratory species. This was illustrated when a species of parasitic botfly went extinct at the beginning of the 20th Century when Saiga antelopes went through a period of severe overhunting[66].


Oases in Umm Al' maa Lake, Libya - ©Patrick Poendl

Caravans: trade-dependence on dryland biodiversity

Drylands have historically created frontiers between civilisations, and trade across these frontiers has played a major role in the global spread of culture and ideas. This trade was historically based on livestock caravans (usually camels), and biodiversity within the drylands was crucial in determining the path and the availability of these trade routes. Many herding-based cultures have developed around the caravan trade, including the Tuareg, Bedouin, Kurds, Mongolians, Kuchi and Tibetans[67].

The relationship between caravans and herding groups seems to rely on the existence of pastoralist corridors in every pastoralist culture, which in turn are probably based on pre-existing wild herbivore migratory corridors. These corridors increase the long-distance dispersal capacity of plants, which is especially relevant in hyper-arid areas where the climatic variation between years is huge and suitable habitats for most plants are isolated patches (oases) embedded in an unsuitable matrix. The continued use of these routes by livestock caravans ensures the preservation of ecosystem function and therefore of diversity once the wild herbivores have disappeared[68].

Trans-Saharan trade has existed since prehistoric times but trade peaked from the 8th century until the late 16th century. Biodiversity enabled these routes through provision of fodder and water and patches of shade. Rich culture grew up around these trade routes and national monuments such as the Great Mosque of Djenné, Mali, founded in 800 and now a World Heritage Site, were constructed. The silk route that linked China with Europe, West Asia and North Africa during the same era also passed largely through drylands and led to the emergence of numerous cultures and a great diversity of important cultural heritage sites.

Caravans remain in use in a number of dryland regions, most notably in Africa where they are particularly associated with the Tuareg in the Sahara and the Somali and other pastoralists in the Horn of Africa. These caravans traditionally traded salt, which was formerly used as currency, and other dryland products. In the Horn of Africa, caravans also brought high value dryland goods to the coast where they were traded for thousands of years and whose production was compatible with the maintenance of high biodiversity in the landscape[69]. These included gum arabic (from Acacia senegalensis), frankincense (from Boswellia sacra) and myrrh (from Commiphora myrrha and C. guidottii). Frankincense and myrrh remain important goods that are globally traded from the drylands of the Horn of Africa[70]. The biodiversity of the oases where the camels fed across their routes has also benefited from the positive effects of herbivory in a highly productive environment[71].

Frankincense Tree – ©Markos Markovic


Terfezia leptodermatino - ©Micologia.net

High value natural dryland products

Truffle

'Desert truffles' are periodically common in many arid and semi-arid regions in the world, usually following rains. Desert truffles (Terfeziaceae) have been gathered and consumed by humans for centuries as a nutritious and tasty source of food and used for their medicinal values. The Pharaoh Khufu served them at his royal table and the prophet Mohammad was quoted as saying that 'water of truffle cures the eye'. Moreover, truffles serve as a food for many wild animals, which in turn distribute the spores for propagation[72]. One kilogram of truffles sold in the Saudi Arabian market can fetch up to US$60[73].

Honey

One of the most important products that desert ecosystems produce is honey. Honey produced in drylands is considered pure and of high quality with medicinal properties, since bees gather nectar from medicinal plants. For example, wild honey is commonly traded for US$150 per kg and may be as high as US$250 to US$300 per kilogram, but little information exists about pricing since wild honey is not openly traded but sold directly to customers willing to pay a high price for the delicacy. As a result, honey is listed among the main suggested sources of alternative income projects for local people living in drylands[74].

Biological diversity and human adaptation to drylands

The world's drylands are home to 2 billion people, many of whom depend on natural resources, biodiversity and agro-biodiversity for their livelihoods. A substantial portion of these 2 billion are urban dwellers, reliant on ecosystem services for clean water, air and food. Many more are rural residents who depend on biodiversity for food production, fuel provision and other resources that are essential to survival. Where dryland ecosystems support woody vegetation (especially in Africa and parts of South America), the value of trees and tree products is always important to rural livelihoods. Trees not only provide fodder for livestock but they also provide fuel, shade and shelter, building materials, medicine and food. The utilisation and management of trees was documented as long ago as around 3,600 BP in the Egyptian New Kingdom. Uses included direct browsing of trees, harvesting pods for fodder and pollarding of trees to obtain otherwise unreachable products. These same practices can still be observed in drylands today.

The value of drylands is not simply utilitarian. Drylands are also culturally valued both by the people who live there and the world at large. Twenty six per cent of all World Heritage Sites, which aim to protect the world's cultural and natural heritage, are located in drylands. Examples include the Uluru Kata Tjuta National Park in central Australia that features spectacular geological formations and that forms part of the traditional belief system of one of the oldest human societies in the world – the Anangu Aboriginal people. The World Heritage Site in Tassili n'Ajjer, Algeria contains one of the most important groupings of prehistoric cave art in the world. More than 15,000 drawings and engravings record the climatic changes, the animal migrations and the evolution of human life on the edge of the Sahara from 8,000 BP to the first centuries of the present era.

Centres of diversity of crop plants and domesticated animals in dryland mountain regions[77]

North-west America	South America	Mediterranean Region	Sahara and sub-Saharan Africa	West Asia	Central Asia
Crop Plants	***Crop Plants***	***Crop Plants***	***Crop Plants***	***Crop Plants***	***Crop Plants***
Mexico and Central American Vavilov centre[78]	**Central Andes Vavilov centre**	**Mediterranean Vavilov centre**	**Ethiopian Vavilov centre**	**Middle East Vavilov**	**Central Asia Vavilov centre**
Maize, several bean species, grain amaranth, Malabar gourd, winter pumpkin, chayote, several cotton species, henequen (sisal), sweet potato, arrowroot, pepper, cashew, wild black cherry.	Potato species, edible nasturtiums, starchy, maize, beans, pepino, tomato, ground cherry, pumpkin, pepper, cocoa, passion flower, guava, heilborn, quinine, tobacco.	Olives, grapes, wheat, oats, canary-grass, pea, lupine, clover, serradella, flax, rape, turnip, lettuce, asparagus, celery, chicory, parsnip, caraway, anise, thyme, sage, hop.	Wheat, teff, flax, cowpea, millet species, grain sorghum, barley, pigeon pea, sesame, castor bean, garden cress, coffee, okra, myrrh, indigo.	Wheat, two-row barley, rye, oats, lentil, lupine, alfalfa, clove, fenugreek, vetch, apple, pear, pomegranate, cherry, quince, hawthorn.	Wheat, pea, chick pea, lentil, horse bean, mung bean, flax, sesame, hemp, cotton, onion, garlic, spinach, carrot, pistachio, pear, almond, grapes, apples.
	Animals	***Animals***	***Animals***	***Animals***	***Animals***
	Llama and alpaca: Central Andes (ca. 6,000–7,000 BP).	Sheep: centre of domestication in mountains of SE Turkey (ca. 8,000-9,000 BP). Donkey: domestication in North Africa (ca 6,000 BP).	Nubian wild ass: Sudan/Somalia (ca. 6,500 BP).	Goats: centre of domestication in Zagros mountains (10,000 BP). Pigs: (ca. 9,000 BP). Camels: Arabian peninsula (ca. 5,000 BP). Bactrian camel: central Iran (ca. 2,600 BP). Cattle: (ca. 10,000–8,000 BP).	Horses: Kazakhstan (3,700 BP). Yak: Tibetan plateau. Reindeer: Altai Mountains (ca. 2,500 BP).

Crop cultivation

Many crop cultivars and livestock breeds originate from drylands. At least a quarter of the world's 5,600 mammalian livestock breeds were developed in the drylands and 30% of the cultivated plant species originate in drylands. Wild grasses that would become wheat and barley originated in south-west Asia while maize, squashes and beans originated in Mexico and wild potatoes in the drylands of Peru. Wild relatives of crops have value today, such as wild maize (*Zea diploperennis*) from the Sierra de Manantlan protected area in Mexico, which has been crossed with crop cultivars to increase disease resistance in cultivated varieties. Similarly the Karacadağ Mountain protected area in south-east Turkey was created in part for its role in the domestication of the wild einkorn wheat (*Triticum boeoticum*). In many dryland situations these wild relative crops are declining and some are at risk; research shows that levels of protection in centres of crop diversity are considerably lower than the global average[75].

In many landscapes, indigenous communities use their local knowledge to conserve native cultivars, maintain crop varieties and apply particular agricultural practices, such as low tillage and terracing, which enhance agricultural production in periods of low rainfall. Thus the heritage of agro-diversity is dynamic, adaptive and specific to place and time, maintained by selection and controlled crossing in the face of an uncontrolled 'genetic anarchy' in the surrounding wild vegetation. Loss of genetic diversity is not a new phenomenon[76] and neither is adoption or hybridisation in the interests of maintaining consumable biodiversity.

Pastoralism

The most widespread land-use system in the drylands is pastoralism, which has been defined as extensive livestock production on rangelands[79] and which relies on a diversity of grasses and shrubs as key productive inputs. Pastoralism, although not unique to drylands, is the only feasible agricultural strategy in many dry areas, particularly when assessed at a landscape scale. Dryland pastoralism depends on herd mobility to track the extremely high seasonal variability of vegetation and other resources. Pastoral mobility varies greatly in both extent and pattern and includes nomadism and transhumance. Transhumance implies mobility between two or more seasonal grazing areas while nomadism often refers to mobility without a fixed home base, although the term is often interpreted more broadly in different countries. Nomadism becomes more common in the more arid drylands where climate patterns are typically most unpredictable[80].

Biodiversity is central to the economic rationale and success of pastoralism. Despite often being challenged as economically irrational – and being subject to government policies of substitution and eradication – pastoralism has been clearly demonstrated to be more economically productive than other forms of land use in dry rangelands. Its economic success hinges on diversity of livestock, of inputs and of outputs. Rangeland biodiversity is essential for this economic diversity, providing a variety of pastures, shrubs and plants with medicinal or unique nutritive value that support different animals (grazers or browsers) through different seasons[81].

Pastoralism has been described as an adaptation to the uncertainties of dryland environments and traditional pastoral practices are highly in tune with dryland ecology. Herding strategies and pastoral culture more generally have been strongly shaped by the demands of the drylands, creating highly flexible and resilient livelihoods[82]. However, pastoral production has also played a role in shaping many dryland environments and enriching biodiversity through systematic resource use and management techniques. Livestock play a role in the fertility and distribution of plants, transporting seeds over great distances and fertilising the ground where they are deposited. Selective grazing and browsing by livestock and the active management of herders influence the distribution of plants and enable a wide diversity of plants to thrive. As a result, pastoralism has modified grasslands and created environments that are favourable to certain kinds of wildlife species[83].

In many countries today, overgrazing is cited as a significant factor in the loss of biodiversity and breakdown in ecosystem services. There are numerous factors that influence overgrazing, but it is often simplistically attributed to overstocking. Often overgrazing is associated with a combination of restrictions on herd mobility and breakdown in customary governance arrangements, and where these factors remain intact overgrazing tends not to be so evident[84]. Changes to governance and mobility patterns are in turn influenced by many factors, including social or political pressures, rising human populations and fragmentation of land.

Vicuña conservation: local livelihoods and high fashion

Vicuñas (*Vicugna vicugna*) and guanacos (*Lama guanicoe*) are some of the few native large herbivores that inhabit South America and are the most abundant free-ranging ungulates to inhabit the continent's deserts and high plateau scrublands and grasslands[85]. Vicuñas live above 3,700 m in the Puna and Altiplano regions in Argentina, Bolivia, Chile, Ecuador and Peru. The area is characterised by very harsh conditions such as low annual rainfall, high daily temperatures, long dry seasons, irregular precipitation, and low temperatures with frequent frosts, rugged topography and poor soils[86].

Vicuñas have developed extraordinary adaptations to cope with the life in the Altiplano. The vicuña´s natural protection against extreme temperature fluctuations has resulted in the rarest, finest, most valuable and highly priced natural fibre in the world, with insulating properties that have been recognised for millennia by local inhabitants[87]. Behind each expensive vicuña suit sold in London, Dubai or Tokyo there is a wild protected species that recovered from the brink of extinction and an Andean community that has protected its vicuñas using ancestral methods and communal management of the drylands.

Before the European Conquest, vicuña fibre was sacred and only shorn for making special garments used exclusively by the Inca. The rules and regulations prevented over-exploitation by controlling access to and use of the species. With the advent of European domination, this highly prized species became an open-access resource and the vicuña was hunted to the brink of extinction. By 1960, it was estimated that the population had dropped from its pre-colonial population of 2 million to an estimated 10,000 individuals.

International, regional and national conservation efforts were successful in halting further population decline. Strict conservation regulation, through the Vicuña Convention, and the entry into force of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975, helped to rebuild populations to approximately 421,500 individuals by 2010[88]. The global programme of conservation was so successful that it resulted in a progressive shift in international policy from strict preservation (Appendix I of CITES) to sustainable use (Appendix II of CITES), allowing trade in fibre obtained from live-shorn target populations. In 1979, Argentina, Bolivia, Chile, Peru and Ecuador signed the Convention for the Conservation and Management of the Vicuña (The Vicuña Convention).


Sheering of Vicuna - ©Daniel Maydana

Biodiversity as a safety net

Rural communities in drylands often reside in areas with limited access to markets and scarcity of income-generating livelihood options, making them dependent on natural products for income and subsistence needs. Dryland communities make use of a wide range of wild plants and animals to supplement their diet, making it more diverse and nutritional, and thereby contributing to good health. In some cases, and notably for the poorest dryland households, natural products may provide the principal means of subsistence and income. These products generally require little capital investment and are accessible to a wide range of socio-economic groups, including the poor and women, who may face difficulties engaging in alternative livelihood activities[89].

The use of biodiversity for subsistence and as safety nets varies during the course of the year and between years. Certain wild plants and animals have particular importance during the 'hungry season', when grain stores are empty and the new crop is not yet harvested, or when milk yields are at their lowest. Household vulnerability to seasonal production and income shortages increases during droughts and can result in the progressive depletion of food stocks and capital assets. Coping strategies employed by households to survive such periods are strongly dependent on wild plants and animals that are often the only sources of food available[90]. Often 'famine foods' are not part of the normal diet, for example, the root of young doum palm (*Hyphaene thebaica*) plants can be dug up and eaten (either raw or boiled, like a carrot), but this is a food of last resort[91]. As such wild foods can be of critical importance to the survival strategies of rural communities. This also assumes that such foods are available. The increasing commercialisation of 'bushmeat' and similar wild foods is encouraging over-exploitation in many areas and therefore removing this critical safety-net.

Biodiversity and famine foods

An inventory of 'famine foods' used during the Sahel Drought of 1972–1974 was carried out in 125 households in five villages distributed widely in (then) Kano State[92] and yielded 47 species of herbs, grasses, trees and shrubs used as food sources. Other famine foods, known but not recorded in use at that time, extended the list to 68. Although there are clear limits to the role that dryland biodiversity can play in escaping from poverty, it nevertheless clearly plays an important role in livelihood resilience[93]. Although these foods cannot substitute for cereal grains or cassava, many supply vitamins or other substances of dietary significance and are used to supplement the daily diet, generate income or substitute occasionally for meals. However, this fall-back may be threatened by land-use change if the common woodland, grassland or agricultural fallows on which many wild foods are found are reduced[94].

Threats to dryland biodiversity

Despite the importance of dryland biodiversity for conservation and human livelihoods, greater attention has been placed on protecting more humid biomes such as tropical rainforests[95]. Our knowledge about the status and threats to dryland biodiversity, including dryland ecosystem function, is limited and hampers the planning and implementation of sustainable land-use strategies. A few global assessments of drylands have been conducted[96] and other studies have been conducted at regional or national levels. However, some of the global studies rely on expert opinion rather than empirical data, while the empirical studies examine relatively few factors in biodiversity loss.

The IUCN Red List[97] provides data on the threat to species of mammals, birds and amphibians in the drylands. Two dryland species have gone 'Extinct in the Wild' in recent times, namely the dryland endemic Sahara Oryx (*Oryx dammah*) from North Africa and the Milu (*Elaphurus davidianus*) that occurred in drylands and marshland in China. Overall, 71 endemic dryland species are critically endangered, which means that their numbers have decreased, or will decrease, by 80% within three generations, making species extinction a likely event in the near future. A further 200 species that are either exclusively or predominantly found in drylands are endangered and about 500 species occurring in drylands are vulnerable to extinction. The Living Planet Index provides a global assessment of the population status of different dryland species showing that wildlife populations in dryland systems have declined by about 44% since 1970[98].

Endangered or critically endangered species in drylands[99]

Desertification resulting from various factors, including climatic variations and human activities, contributes to decreasing primary production and declining species richness, and it reduces the ability of ecosystems to provide humans with services and goods. Globally, between 10% and 20% of drylands may be degraded, mainly as a result of increased susceptibility to water and wind erosion. Factors that increase the risk of erosion include unsustainable agricultural practices and overgrazing, strip mining, vegetation damage by off-road vehicles and in some areas impacts of war or oil pollution[100].

Alliance for Zero Extinction: last remaining areas for Endangered or Critically Endangered species (those overlapping with drylands in red).

Threat level for dryland endemics across ecozones:number of endemic species (% of endemics)		
	Critically endangered	Endangered
Afrotropic	8 (5%)	14 (9%)
Australasia	6 (8%)	10 (13%)
Indo-Malay	2 (6%)	2 (6%)
Nearctic	10 (3%)	27 (8%)
Neotropic	36 (13%)	42 (15%)
Palaearctic	10 (5%)	11 (6%)

Beyond these preliminary assessments we have limited knowledge about the extent to which dryland ecosystems are in danger and, more crucially, how dryland degradation is influenced by management practices or unsupportive policies. IUCN's Red List of Ecosystems (RLE) initiative will address this knowledge gap and will complement the Red List of Species[101]. The RLE will be linked to the World Database on Protected Areas (WDPA) and Key Biodiversity Areas (KBA) providing an insight into the scale and extent of overlap and will help to improve the process for management responses and action.

The RLE process will bring together world experts and practitioners to further develop, test and communicate a standardised yet flexible system that is globally applicable and internationally recognised and will provide the first comprehensive overview of the status of the world's ecosystems. The process will define a set of globally agreed criteria for assessment of ecosystems and will draw attention to data-poor areas, such as drylands, where data need to either be gathered or disaggregated. Red Listing Habitats is not new and a number of dryland countries have a partial (e.g. South Africa, Australia) or complete listing of habitats (e.g. USA).

The RLE will enable endangered drylands to be highlighted and will recognise and reward those that are being well managed. The RLE will take this process one important step further by linking ecosystem listing to land use and macro-economic planning to provide a basis for developing payments for environmental services. It is also hoped to explore the hypothesis that, for many ecosystems that are endangered or critically endangered, poor governance is a strong contributing factor.

Red Listing of ecosystems

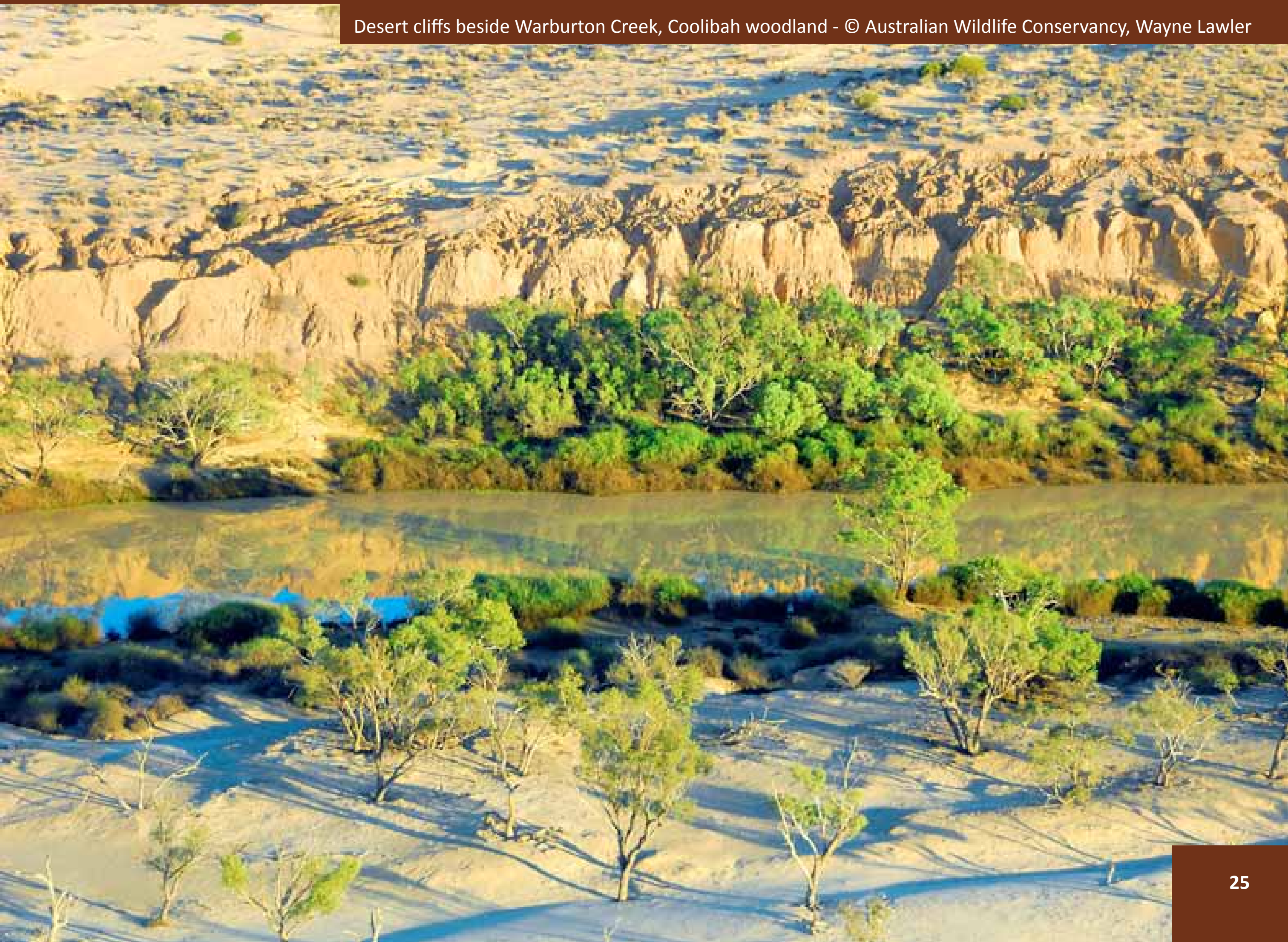
Assessing the status of ecosystems in the USA has shown that 33 ecosystems are endangered, of which 27 are in drylands, and a further 20 are critically endangered, including 11 in drylands. Historic loss of these dryland ecosystems can be very extensive – from 83% to 95% for four dryland ecosystems, and between 50% and 60% for eight further dryland ecosystems. There are various reasons for this loss, including degradation and conversion, which represent both historic and present day loss in an area[102].

A more detailed example comes from the subtropical/semi-arid Coolibah-Black Box Woodlands of south-eastern Australia that are classified as an Endangered Ecological Community[103]. In its mature state, the woodland has an open structure with widely scattered trees, a variable cover of shrubs and grassy ground layer – resembling African savannahs. The annual rates of decline in the distribution of Coolibah-Black Box Woodlands were estimated at 0.79% per year between 1984 and 2004, suggesting that the historic distribution of Coolibah-Black Box Woodland has declined by between 50% 67%.

Four main processes threaten the persistence of this ecosystem[104]:

1. Expansion and intensification of agriculture has replaced large areas of woodland with crops and pastures[105], and has resulted in the spread of invasive plants reducing the diversity and abundance of native biota.
2. Extraction of water from rivers for irrigation has altered flood regimes and their spatial extent[106], reducing opportunities for reproduction and dispersal of characteristic flora and fauna[107].
3. Invasive plants have spread with agricultural intensification and are reducing the diversity and abundance of native biota[108].
4. Overgrazing by feral goats and rabbits and domestic livestock has altered the composition and structure of the woodland vegetation through selective consumption of palatable native ground layer plants and seedlings of trees and shrubs[109].

Desert cliffs beside Warburton Creek, Coolibah woodland - © Australian Wildlife Conservancy, Wayne Lawler



Endangered or critically endangered dryland species that are on the EDGE of existence (Evolutionarily Distinct and Globally Endangered[110])

Hirola (*Beatragus hunteri*): critically endangered, population trend: decreasing

Perhaps the world's rarest and most endangered antelope, the hirola is the sole survivor of a formerly diverse group, and is often referred to as a living fossil. Once common throughout East Africa, the species has suffered a devastating decline in the last 30 years, with numbers plummeting from around 14,000 in the 1970s to an estimated 600 today. The surviving hirola are threatened by drought, poaching and habitat loss. Intensive conservation efforts are needed if this rare and beautiful antelope is to survive.

Endangered Hirola Antelope - ©Gwili Gibbon

Bactrian Camel (*Camelus ferus*): critically endangered, population trend: decreasing

The Bactrian Camel is probably the ancestor of all domestic two-humped camels. It is superbly adapted to life in the harsh Gobi Desert, one of the most hostile and fragile regions on the planet. The species can withstand drought, food shortages and even radiation from nuclear weapons testing. Fewer than 1000 individuals survive today in only four location: in north-west China (Lake Lob, Taklimikan desert and the ranges of Arjin Shan) and one in the Trans-Altai Gobi desert of south-west Mongolia. The largest population lives in the Gashun Gobi (Lop Nur) Desert in Xinjiang Province, China, which for 45 years was used as a test site for nuclear weapons. Classified as Critically Endangered, these animals continue to be threatened by hunting, habitat loss, and competition for resources with introduced livestock.

Bactrian Camel, Kazakhstan - ©Maxim Petrichuk

Numbat (*Myrmecobius fasciatus*): endangered, population trend: decreasing

The numbat is a highly distinctive carnivorous marsupial. It is not closely related to any living marsupial (one of its closest relatives is the now extinct thylacine or Tasmanian tiger), lacks a pouch, and is one of only two marsupials to be active exclusively during the day. It is also the only marsupial to feed strictly on social insects: individuals suck up around 20,000 termites a day with their long, sticky tongues. Once widespread across Australia, the species is now extinct in over 99% of its former range, primarily as a result of introduction of foxes by European settlers, and changes in fire regimes. Extensive conservation efforts are underway to save the two remaining natural populations, while conservation breeding and reintroduction programmes have succeeded in establishing six populations in areas of the Numbat's former range.

Rare Australian Numbat - ©Julian W

Drivers of dryland biodiversity loss

The Millennium Ecosystem Assessment provides details of numerous pressures that impact on dryland biodiversity, including habitat conversion, climate change, over-harvesting, grazing pressures, introduced species and inappropriate soil management (such as excessive use of fertiliser). Many of these pressures are strongly influenced by systemic policy failure, for example in relation to land rights and natural resource governance, and lack of public investment, which push people into adopting unsustainable practices. Urbanisation also contributes strongly to dryland biodiversity loss[111].

Although some of these pressures are common to other terrestrial ecosystems, several of them illustrate the uniqueness of the drylands. For example, fire is an important natural event in dryland ecosystems and changing fire regimes in the drylands –changing frequency or increased intensity of fire – can decrease biodiversity. Changing patterns of water availability also affect dryland biodiversity to a greater extent than other climate zones since water is much more of a limiting factor in the drylands. Other authors have listed different drivers of dryland biodiversity loss, such as fragmentation or pollution[112]. It is challenging to untangle ultimate and proximate causes of change, since drivers of change are often cyclical processes: for example, human poverty sometimes drives over-exploitation and over-exploitation can contribute to poverty.

Root causes of these five drivers of change include population growth, urbanisation and economic policies that encourage natural resource exploitation and mono-cultures at the expense of sustainable development. Unsustainable land use and land-use changes pose particular threats to dryland biodiversity and rural development. Loss of biodiversity caused by changing land management is further exacerbated by climatic factors on both local and global scales.

Land-use change

Land-use change can contribute to biodiversity loss directly, through ploughing rangelands or clearing woodlands, and indirectly through fragmentation of land. Agricultural development has led to widespread deforestation and conversion of rangelands to crop lands, with serious environmental and economic consequences. Irrigated crop cultivation often uses localised water resources that are of high value to a much larger dryland ecosystem. However, the system-wide cost is seldom factored into local-level decision making. In some countries drylands are negatively impacted by upstream use of water resources and there is often an assumption that downstream costs are insignificant and do not need to be taken into consideration. This attitude is made easier in countries where dryland residents are ethnic minorities that are poorly represented in government.

Land-use change itself has a number of underlying drivers and can be caused by government development policies, weak valuation of existing land uses and low regard for the value of dryland ecosystem services. Traditional pastoral production systems can be more economically viable at the ecosystem-scale than crop cultivation, but government policies favour crop production because they are assumed to be more productive and easier to tax[113]. Market forces also directly drive agricultural expansion, although selective government policies also mediate on this driver. For example, burgeoning global demand for milk and meat creates new opportunities for pastoral products that have great export value, yet government policies in many dryland countries prioritise crop cultivation and invest in markets to favour that sub sector.

Conversion of rangelands to crop lands often leads to a significant decrease in plant productivity, an increase in soil salinisation and erosion, and is a major source of greenhouse gas emissions[114]. An outcome of this degradation is a reduction in the provision of water-related services which has a knock-on effect on the wider ecosystem and land uses. Poor understanding of the value of drylands has also allowed some countries to follow environmental policies of grassland afforestation: changing natural rangelands into unnatural woodlots. This overlooks the serious threat to dryland biodiversity and the risk of replacing biodiverse and productive rangelands with monocultures of trees, and in some cases with invasive alien species. If carbon finance continues to favour above-ground carbon storage then 'environmental' incentives may continue to drive this potentially harmful practice.

Changes in land-use and production practices can be sustainable depending on the model that is employed. Conservation agriculture, for example, offers an opportunity for more sustainable cultivation practices, as discussed in the following chapter. However, the value of such land-use practices must be weighed against the values that are being replaced, and this evaluation is seldom performed. Land-use changes – particularly those instigated by government and large-scale investors – frequently pay no attention to environmental costs, and particularly ignore the long-term costs associated with degrading ecosystems. Irrigation projects for example have led to waterlogging and salinisation in many countries. Conversion of rangelands, particularly in some mountainous drylands, has greatly increased the costs of flooding, often many years after land clearance began to take place.

Ecosystem resilience is derived to a large extent from the diversity of functional groups in the ecosystem, the diversity of species within those functional groups and the diversity within species and populations. When ecosystems are modified they may be made ecologically simpler and this reduces their resilience to external pressures. For example, susceptibility to invasive species (or the risk that new species become invasive) is increased by the absence of higher order predators within the ecosystem. This reduction in ecosystem resilience raises the risk of ecosystem failure and pushes up the need for artificial measures to sustain ecosystem services[115].

Unsustainable grazing

For millennia, food production in many drylands has centred on pastoralism: the extensive production of livestock, often deploying herd mobility as a management strategy. The rationale of pastoral mobility and the associated common property tenure arrangements have often been challenged and concerted efforts have been made to replace pastoralism with other forms of livestock production; this tension stretches back for millennia. In more recent times, many efforts have been made to replace mobile herding with sedentary livestock production, to replace common property with private tenure, to substitute indigenous livestock with European breeds, and to switch pastoralism from a multi-species and often dairy or fibre-based economy towards single species meat production[119].

The outcome of these changes has been both economically and environmentally harmful and the policy of livestock intensification and sedenterisation has been a major contributor to land degradation. In fact the suggestion that these policies constitute intensification has been challenged since pastoralism traditionally is highly labour intensive. By shifting from a mobile, labour intensive to a sedentary, capital intensive development model, governments have undermined the application of indigenous knowledge that has traditionally enabled sustainable management of rangelands. Traditional control systems such as *hima* in West Asia have been broken down by the desire of particular actors to assume overall control of areas rather than foster more local management approaches[120].

In some countries, notably in West Asia and North Africa, livestock development policies have additionally contributed to land degradation by supporting capital intensification with policies to subsidise feed and other inputs. Elsewhere traditional strategies of herd maximisation during productive periods have led to uncontrolled herd growth when other factors that limit growth have been removed (for example through provision of additional feed inputs or veterinary care). The result is that livestock numbers have risen dramatically, far exceeding the capacity of the rangelands to support them, particularly when mobile herding strategies have become constrained. In some countries, rangelands have become little more than a holding ground for industrially-fed livestock. The result is that rangeland biodiversity has become heavily degraded, in some cases irreversibly so [121].

Salinisation in Australia

Australia is the most salt-affected continent on earth with around 260 million hectares of salinised area. A major cause of salinisation is ground water-induced salinity as a result of irrigation, which occurs in the low lying areas such as valleys and at the base of slopes where soils are generally heavier. This leads to waterlogging and seepage which allows capillary action to draw salt from relatively saline water tables up to top soils. The total annual cost to the Australian economy caused by all forms of salinisation is estimated to be more than US$1.5 billion. To reduce salinisation, engineering measures are deployed to manage the water tables, for example by withdrawing water from underlying salt-affected aquifers, mixing irrigation water with fresh water and using moderately salt-tolerant crops such as lucerne[116].

However, in the long-term irrigation is likely to induce salinity as a widespread soil degradation problem. Many arid and semi-arid areas around the world face secondary salinisation caused by inappropriate irrigation and drainage practices. Up to 50% of global irrigated areas are similarly affected, representing a serious threat to sustainable food production and deterioration of natural terrestrial resources[117]. To mitigate these risks, the FAO recommends, among other measures, avoiding high risk sites, improving the efficiency of irrigation projects and using alternative technologies[118]. Such practices may be less favourable since they imply significant costs.

Poorly planned water developments in pastoral rangelands have further contributed to degradation. Water points almost invariably attract degradation in their immediate vicinity, but where they are planned to enable seasonal mobility this degradation can be managed, with adequate periods for pasture recovery. However, water shortage is frequently identified as a development challenge in drylands and rather than adapting to the environmental conditions, development actors invest in infrastructure to increase water availability. This often occurs without consideration of the impact on rangelands management or pastoral resilience and contributes to degradation of both[122].

Demographic change

Urbanisation, migration and population growth are in rapid transition in drylands. Many drylands have doubled their resident populations in 30 to 40 years with much of the growth taking place in urban areas (including often quite small settlements). Urbanisation rates in the drylands have exceeded those outside drylands (4% 16% in drylands compared with 3% outside drylands during the last forty years[126]. Phoenix in the United States has grown from about 500,000 people in 1960 to 1.5 million today. Fast growing urban centres like Bejing, Dubai, Karachi, Santiago and Tehran are all in drylands. Dryland food producers may soon be outnumbered by urban consumers, which has important implications for the rural economy and creates many opportunities for economic growth.

The sprawl of settlements and associated industrialisation in the drylands exerts unprecedented pressure on water resources. Water extraction from the Zarqa Aquifer Basin in Jordan, for example, has increased dramatically during the past decades to meet increasing water demands for a rapidly growing urban population and large-scale agricultural production in rural areas. Draining millions of cubic meters per year from the ground water basins has disturbed the fragile moisture balances in the deeper soil layers where roots of trees and shrubs get their water and as a consequence most of the area has dried out. The natural vegetative cover has almost been eliminated and soil quality and land-use patterns have been negatively affected[127].

While urban centres experience increasing commercialisation and economic growth, they continue to depend on rural agriculture as well as natural resources such as fuel wood and construction materials. Unsustainable resource use and unplanned growth cause severe disruption to the traditional pastoral and rainfed cropping systems as well as wildlife populations that depend on mobility to cope with environmental fluctuations typical in drylands.

Climate change

Climate change is reported to be an important driver of ecological change in the world's drylands[128]. There will be significant regional differences in the outcome of climate change, but in general it is projected that climate change will lead to a decrease in water availability and quality of 10% - 30% in the next 40 years, while extreme weather events such as droughts and floods will increase in number and/or intensity. Rising temperatures and changing precipitation patterns are predicted to lead to an expansion of drylands worldwide. Climate change is predicted to reduce agricultural productivity overall in the drylands and this will have severe impacts on food security. Climate change is also projected to increase the rate of urbanisation, with associated links to environmental impact (both negative and positive)[129].

Climate change will affect the range of many species, enabling some and disabling others, with the more adaptable invasive species likely to be the first to benefit in many cases. There are fears that the rate of climate change may be too fast for some species to adapt their range, leading to their extinction. In the drylands, these risks may be greater since many species already exist at the climatic threshold for survival. Furthermore, the ongoing process of land fragmentation is likely to impede the adaptive spread of species into new ranges.

On the other hand, a defining feature of drylands is their extremely high climatic uncertainty, with great variability in precipitation between seasons and between years. Dryland biodiversity is supremely adapted to these uncertainties and is able to survive under very dry and highly variable conditions. Similarly, people who have adapted to survive in the drylands typically follow livelihood strategies that

How many livestock?

Livestock development policies in many rangeland countries have been built around the concept of defining a carrying capacity and calculating a desirable stocking rate. This management approach has not been successful in drylands where environmental conditions are extremely variable. Under such conditions, carrying capacity varies so enormously between years that it becomes impractical as a management tool. The solution of selecting a conservative stocking rate that works even in dry years is ineffective, since rangelands depend on herbivore activity for their health and a conservative stocking rate will not provide the necessary grazing pressure[123].

Under such conditions of variability, mobility and varying herd sizes are more appropriate management tools. These are part of the traditional pastoral management strategy that could be greatly strengthened through appropriate investments and technologies, for example in pasture and rainfall tracking or in improving markets for livestock off-take. Pastoral herding strategies and communal management practices have been shown to be economically and environmentally rational[124]. Although it is evident that the variable carrying capacity of rangelands can be exceeded, such problems tend to arise where local governance breaks down, where mobility is impeded, and where investments promote unplanned livestock population growth[125].

are highly tuned to these environmental conditions. In many places these strategies have been constrained, by unsupportive policies and by loss of access to key resources, and this has undermined resilience to some extent. However, given more enabling policies and investments it is possible that drylands and dryland peoples could be better equipped to adapt to climate change than more humid areas and their peoples[130].

Breakdown in governance

Governance over resources depends to a large extent on the strength of institutions for resource allocation and control. Often dryland communities traditionally had strong systems of governance but their institutions have been weakened by the emerging state, yet the state has not put in place adequate alternatives, creating a power vacuum. Land reform policies, such as nationalisation of land, or favouring of private land title, have further weakened governance. Traditional governance systems have also been undermined by population growth, poverty and the emergence of local 'elites' that challenge customary authorities[131]. It has been reported that where traditional governance structures remain functional, such as in some of the more remote drylands, evidence of widespread drylands degradation is scarce[132].

In drylands, common property arrangements are often essential for sustainable management, and customary tenure arrangements are frequently the principal means through which communities can regulate resource use. Many countries offer legal opportunities for local solutions to strengthen governance, for example through policies of devolution, through land laws that allow local ownership and control or through laws that legitimise customary institutions. However, local government often lacks the capacity or the will to engage with customary leadership and local (traditional) rules and regulations are seldom codified or recognised in law[133].

Governance is not only about the capacity of communities to take matters into their own hands. An important part of strengthening governance is to strengthen the relationship between communities and the state. Drylands suffer from many policy failures and this reflects to a large extent the lack of communication between dryland communities and government decision makers. This is particularly the case in drylands where the indigenous population is ethnically different from those in power. Policies of decentralisation offer opportunities to build such relationships, although they are not an automatic outcome. The opportunities offered by decentralisation can be better grasped if efforts are made to build capacity and awareness among both communities and government decision makers[134].

Invasive alien species

Global trade, transport and tourism are leading to a global homogenisation of biodiversity, as species are moved into new areas that are foreign to them. Many species do not adapt to their new environment and cannot survive there. However, some of these species do survive and even thrive in their new environment, to the extent that they cause an infestation that has a negative impact on the economy and biodiversity of a region. These species are termed invasive and they are a major cause of species extinctions, increasing the rate of extinction by about 1000%[135].

Invasive alien species are animals, plants or other organisms introduced by humans into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species. Alien invasives are a significant threat in many drylands, often assisted in their expansion by the destruction of indigenous habitat as a result of land-use changes. In some cases, exotic plants have been introduced to combat perceived (although not always real) environmental problems such as desertification. Other species have been introduced through agricultural development projects or simply as ornamental plants. Invasive plant species are often unpalatable and sometimes even toxic to herbivores, which undermines local productivity and may contribute to their competitiveness against indigenous vegetation. Invasive plants can reduce access to productive resources, such as pasture and water, for instance, by forming impenetrable thickets or by lowering water tables, and their economic impact is often highly significant[136].

Invasive alien species are one of the greatest threats to biodiversity worldwide, replacing indigenous fauna and flora and in many cases significantly affecting ecosystem function. These species often lead to land degradation, pest infestations and reduction in crop productivity. Semi-arid areas, particularly grasslands, have been hugely affected by invasive species that have accompanied farming, including the widespread introduction of non-native grass species for livestock grazing, such as buffelgrass (*Pennisetum ciliare*). Invasive plants are for instance estimated to affect 10 million hectares (8.28%) of South Africa with significant ecological and economic costs.

Invasive trees, such as mesquite (*Prosopis* spp.),with high evapotranspiration rates are an immense burden to already water-scarce regions and reduce the amount of water available in reservoirs. With an annual government budget exceeding US$100 million annually, the South African Working for Water Programme provides training and employment to clear invasives such as black wattle (*Acacia mearnsi*) in important watersheds like the Baviaanskloof and Drakensberg mountains and the Table Mountain complex, which are major water towers for the metropoles of Johannesburg, Port Elizabeth and Cape Town. These clearance programmes provide important conservation and social benefits by removing invasives in fynbos habitats and providing large-scale employment programmes to poor communities – a win-win for water supplies, poverty alleviation and biodiversity[137]. Other restoration efforts link habitat restoration with employment and livelihood opportunities as well as enhanced ecosystem services.

Conversely, in a number of the driest environments, some species that are today seriously invasive were originally introduced precisely because they could withstand the harsh environments and were considered to be useful. Examples include the feral camels that disrupt the ecology of drylands in Australia and the rabbits that cause losses to the Australian wool industry estimated in 1995 at Aus$115 million[138].

Mesquite invasion: a global dryland challenge?

Prosopis is native to the Americas, yet it has become invasive in several regions of the world including many hot drylands of Asia, Africa and Australia. In its native Latin America the species of the genus Prosopis are commonly called mesquite and several species of this thorny leguminous tree have been introduced to African, Arabian and South Asian drylands in order to prevent perceived land degradation over the past 100 years. However, many of the species, and in particular *Prosopis juliflora*, have become a conservation concern as they have spread rapidly, displacing native vegetation and resulting in economic losses among local people.

Mesquite grows fast under high water stress, a feature that made them attractive for desertification projects in the first place. They out-compete native vegetation, including valuable trees and grasses that constitute the food sources for pastoralists' livestock, and their allelopathic[139] properties ensure that native undergrowth is restricted or completely removed and local biodiversity is significantly degraded. In some regions where mesquite is invasive, some people favour them due to certain products that can be derived, including fuel wood, timber and livestock fodder. However, the economic harm of this plant would appear to greatly outweigh the benefits in many places

Although many countries appear helpless to address the mesquite problem, there is also debate over what measures will be most effective. Some countries advocate for greater utilisation, such as producing flour from ripe pods and wood products from green mesquite – something that is strictly forbidden among most pastoralists when it comes to native tree species. Other measures such as mechanical removal seem to be in vain since *Prosopis* spp. have a tremendous coppicing capacity and develop a significant seed bank in the soil below and around them. Biological control by seed-eating beetles has been tested with promising results, but spread of viable seeds by livestock is difficult to control. Some areas invaded by mesquite now seem to be lost forever and urgent action is needed in many countries to protect areas that remain uninfested.

Prosopis Invasion - ©Jonathan Davies

Taking dryland biodiversity into account

This chapter has attempted to portray the great diversity and value of drylands biodiversity to local users as well as to outsiders. Dryland communities are intimately aware of these values and a significant proportion of them rely on it for their livelihoods. People outside the drylands may be much less aware of the biodiversity, or may be aware of it without associating it directly with the drylands. Many 'iconic' species of wildlife are found in, and sometimes are endemic to, the drylands. When it comes to awareness raising, these so-called charismatic wildlife species could become the dryland ambassadors that arouse in people a realisation that the drylands are valuable and important to them.

Although we maintain that dryland peoples have a deep knowledge of their environment and are best placed to conserve their biodiversity, it is evident that many pressures are weakening their capacity to do so. Demographic changes and governance failures are major obstacles to the transmission and application of indigenous knowledge and management strategies. To conserve drylands biodiversity, support must be given to adapt indigenous and local knowledge systems to changing political, economic and environmental (including climatic) conditions.

A significant change in scientific understanding of the drylands has taken place over the past two decades, but this change is not adequately recognised in many government policies. Failed development paradigms and investments continue to be favoured by many states, and public investment is often driven by the short-term interests of political elites rather than the local needs of dryland populations. Even where government attitudes towards the drylands are more sympathetic, sectoral constraints can put undue pressure on ecosystems that lead to their further fragmentation and mismanagement, for example where water and land resources are planned and developed by separate ministries. Such failings can be addressed to a large extent by empowering dryland communities to be much more influential in decision making processes. This will have multiple benefits, including reducing environmental degradation, promoting sustainable economic development, and strengthening resilience in a rapidly changing world.

Although data on dryland biodiversity is weak, the little we do know is inadequately used in decision making. However, it is evident that we know enough to make a strong case for increasing support to conserve dryland biodiversity. It is also evident that dryland biodiversity is currently conserved through a combination of formal protected areas and informal protection through traditional land use and cultural practices. Under-development in many drylands has contributed to traditional knowledge systems remaining intact, and as we discuss in the following chapter, these knowledge systems will continue to play a pivotal role in conserving dryland biodiversity.

Arabian Oryx - © Pablo Demio

Managing and Conserving Dryland Biodiversity

Human diversity in drylands

The American exchange student asked the ǂKhomani San elder, Jacob Malgas, how he knew where he was in this vast red desert of the southern Kalahari. Did he not feel alone and disoriented by the endless sea of sand and dunes? Uncle Jacob looked surprised. He scanned the open expanse between two distant dunes. He said: 'I was born and grew up here. I know this land like I know my wife's body. We are not alone here; we are surrounded by our ancestors' spirits and the life of the desert.' I was translating that day, and shuddered with the beauty of how Jacob saw this landscape which I could not understand but had come to love and appreciate. What for the student was a great arid vastness, for Jacob was home, was intimate, was full of life, memories, food, water, biodiversity and one day would take him back into its arms, as it had done for millennia with his people[140].

In the 1980s, linguists began to elaborate an important hypothesis about human linguistic diversity. Researchers, including Daniel Nettle, Suzanne Romaine and others noted that there seemed to be a correlation between human linguistic diversity and biological diversity. The first clue was the intense linguistic diversity of places like Papua New Guinea, and the remarkable homogeneity of the linguistic diversity of the vast Arctic territories. In their famous book on vanishing languages, Nettle and Romaine put forward the hypothesis that human culture adapts to a specific biological niche, and over time, language and culture adjust to the specificity of this narrow niche of using biodiversity and ecosystem knowledge[141].

Two San Bushmen, Southern Africa - ©Pichugin Dmitry

The Deccan Wolf, India – ©X/D photography

Conserving the Deccan Wolf in India

The Deccan plateau of South-central India is home to the Indian grey wolf (*Canis lupus pallipes*) and the southernmost range of wolves worldwide. The Deccan wolf is the top carnivore in India's semi-arid open plains, which include agro-pastoral lands, scrub forests and grasslands, and it shares its habitat with the Great Indian Bustard (*Ardeotis nigriceps*), blackbuck(*Antilope cervicapra*), chinkara (*Gazella bennettii*), nilgai (*Boselaphus tragocamelus*) and wild cat (*Felis silvestris*).

The Deccan plateau is also home to traditional shepherding communities – the Dhangars, Kurumas, Gollas and Kurubas – who have herded sheep for thousands of years. The shepherds believe that the gods created them to rear the black Deccani sheep, and they persist in their transhumant lifestyle despite being squeezed out of their land by rapid urban expansion in Hyderabad, Pune and Bangalore. A steady decline of pastoralism has proceeded in parallel with a decline in the wolf population, possibly in part due to the reduction in sheep on which the wolves traditionally prey.

Wildlife reserves in the Deccan are too few and too scattered to effectively protect the wolf population. However there are continuous reports from shepherds of wolves outside the reserves, suggesting that pastoral lands provide important ranges for the wolves and support connectivity between the reserves. At the same time, evidence suggests that in semi-arid and arid areas where pastoralism still takes place, transhumant grazing is preventing overgrazing and maintaining overall conditions in the Deccan.

Nevertheless, changing agricultural patterns, expansion of cropping into rangelands, and rapid industrialisation continue to threaten the mobility that makes pastoralism viable. There appears to be a close relationship between persistence of pastoralism and survival of the wolf. However, for this relationship to continue, pastoralists must continue to incur losses, and one way that government can play a role in supporting this is by improving access to compensation payments for wolf-predation of sheep on the open rangelands. Conservation strategies need to be revised to focus on landscape-scale management, incorporating the role of pastoralist communities and their knowledge systems and attitudes that play a vital role in conserving the entire ecology of an area, including its wildlife[142].

The Great Indian Bustard – ©Arjun Haarith

At the same time, human occupation transforms and may help protect the landscape to ensure mutual sustainability. People protect plants that they find useful, and can even transform landscapes to help maintain biodiversity. The ||Anikhwe San people of the Okavango Delta in Botswana used traditional burning during the cool winter months to help stimulate regrowth of diverse grasses which would nourish antelopes and other wildlife on which they would rely during the long hot summer periods. Repeated burns helped maintain specific plant and animal biodiversity until this was banned. The interface between human culture and the maintenance of biological diversity has been ascribed its own term in English, that of 'bio-cultural diversity' – an important conceptual advance for Western knowledge systems which have tended to undervalue traditional and indigenous knowledge systems.

Drylands are challenging environments where human ingenuity, knowledge systems, and careful use of resources are essential for survival. Whereas human use of ecosystems predisposed to agriculture tended to reduce biodiversity, more arid areas obliged humans to be more respectful of the fragile connections between species and the ecosystem. Very specific human cultures emerged that tended to protect arid and semi-arid biodiversity as part of the human survival strategy. Through cultural inventories and participatory mapping, it is possible to understand how a particular civilisation has developed in an arid or dry sub-humid landscape, and how the types of governance (rights and responsibility) systems have evolved to sustain both the biodiversity and the people living there.

Dryland cultural ecology often involves mobility. As already discussed, livestock mobility allows humans and domestic stock to take advantage of rainfed natural resources without overgrazing or overhunting a single site on the landscape. Mobility is itself quite complex and closely related to the abundance of biodiversity and water resources. Mobility may involve a seasonal migration, often with domestic animals adapted to arid conditions, or it may be driven by rain patterns which are quite erratic. These movements are not arbitrary and are associated with long-term traditional tenure agreements, which are nested into larger human landscape systems of rights and responsibilities.

There are vertical nomadic groups who use altitude to secure resources. They will move up and down a mountain escarpment as the seasons change, but with rights to move laterally if necessary, according to certain social rules. There are people who live in fairly flat territories, but will move animals to higher or lower altitudes in the case of prolonged drought. There are others who have widespread territories with migratory corridors to move in between sedentary communities or navigate landscape features such as mountain valleys. They will typically not use a part of their territory in order to protect it as a refuge during times of climatic stress.

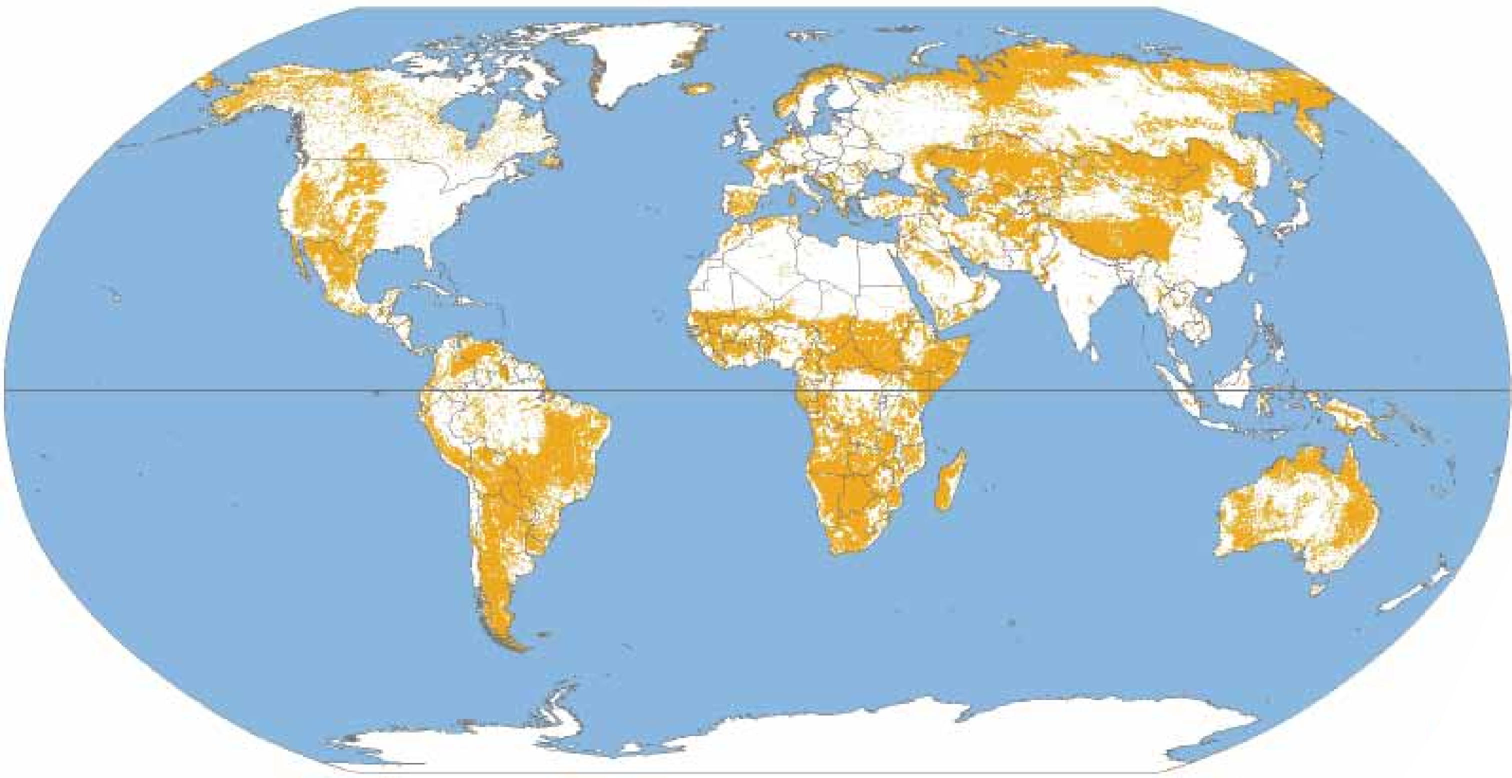
These types of mobile systems reach back far into the history of modern human civilisation. The Kalahari San have probably occupied arid and dry sub-humid regions of South Africa for at least 100,000 years. Other dryland peoples such as the Bedouin or the Mongols have managed their rangelands for less time, with possibly 6,000 to 8,000 years of occupation and specialisation. The ecosystems where these peoples live have changed radically during these time frames, with the natural resource and other governance systems having to adjust over time, and shifts in exploitation of different species required for human survival and ecosystems integrity. Changing political boundaries and governance systems have altered the power dynamics, tenure systems, land use and occupancy patterns, and in some cases have substantially disrupted the ability of dryland peoples to govern their traditional territories or move smoothly across the landscapes.

Mobile pastoral systems are a feature common to all dryland regions from mountain ecosystems in Latin America, Europe and Asia to the savannahs of Africa. Livestock mobility is an ancient form of land use that is well adapted to the challenges of both coping with scarce natural resources and environmental constraints such as drought, and maintaining sustainable and productive livelihoods. Such economies are based on domesticated animals, including cattle, sheep, goats, horses, camels, yaks, llamas, and alpacas. The herds undergo seasonal migrations which guarantee a constant supply of fodder and water. More than 200 million people are estimated to rely on pastoralism, and their livelihoods make a major contribution to the national economy of many countries. In Mongolia, for example, livestock is responsible for one-third of GDP and 50% of the population is dependent on livestock production for their livelihoods[143].

One of the interesting elements of understanding governance and decision making in ecologically sensitive environments is to study the indigenous systems which are based on principles of rights and responsibilities, equity within the community of users, and also the need to respect the capacity of the ecosystem to regenerate and provide ongoing services to future generations. Indigenous systems in the drylands are based on sustainable use, knowledge of biodiversity and of dryland ecology, and then a moral/normative framework that includes both humans and other species. This contrasts with modern state systems wherein there may be a normative framework concerning rights and responsibility of the citizenry, but this may not be associated with environmental duties and intergenerational responsibilities for sustainability.

The state may also be promoting development and relying on income sources which are provided by extractive industries exploiting resources in the dryland areas, such as mining and fossil fuel extraction or large-scale crop cultivation. These land-use interests may generate more state revenues than the partially subsistence economies of

Global distribution of areas where pastoralism is practiced[144]



small scale dryland farmers, nomadic herders or hunter-gatherers, but put increasing pressure on natural resources and limited water supplies. There is almost always an acute tension between what the local and indigenous peoples need from their ecosystem, and what the state may gain from a non-ecological approach to surplus extraction.

In these cases, we are faced with the issue of the quality and type of local governance in rural dryland areas. If the state is accountable to its citizenry, then decisions can be influenced by local knowledge and values. If, however, the state is controlled by other ethnic or class groupings, and the dryland indigenous or local peoples are not represented equitably in the state system, there can be conflicts over the competing views of the land's value, the need to protect ecosystem resilience and our human obligations to each other and to nature.

Human cultures are also not static. As land-use patterns and technologies change, indigenous peoples and local communities may also experience changes in their values, land-use patterns or interests. In a detailed participatory mapping exercise in the dryland Mukogodo Forest of central Kenya, Maasai and Yiaku elders noticed that their traditional systems of altitudinal adaptation had been lost almost without them noticing. In their living memory, they had social rules to keep all domestic animals in the lower valleys during droughts. This would allow acacias to bloom on the upper slopes where bees pollinated them and produced honey, a vitally important food particularly in an extended drought. Only after all lowland resources were exhausted, would herders be allowed to move to higher altitudes with livestock. That entire management system has disappeared in the past two decades due to social, economic and political changes.

Throughout the drylands, settlers have sought to develop livelihood systems to match the often difficult conditions. In the Sierra Nevada of Spain, shepherds use a complicated system of signs by tying varying knots in clumps of grass to pass on information about the location of pasture. Throughout the Mediterranean, elaborate systems of terracing help to conserve soil and moisture. More recent settlers, like the farmers in the dry grasslands of North and South America and Australia, have sought a multitude of techniques to facilitate farming, with varying success. Whenever food production in drylands moves from being mainly a cultural, subsistence approach to one driven primarily by economics or status, the tendency is to see a drift into less sustainable methods.

The future of dryland areas will require a deeper understanding of how cultural, economic and ecological systems can support each other. The age-old knowledge and governance systems need to be taken into account in national resource planning, and ideally, to incorporate the human institutions from these territories into the modern forms of management. The benefit of this is that the human and ecological systems can continue to evolve together, and the chance of managing conflict and 'policing' biodiversity conservation is enhanced by this integrated approach.

Rangeland Rehabilitation in the Baadia, Jordan - ©Jonathan Davies

Hima as a model for natural resource management in West Asia and North Africa

The *hima* is a traditional system of resource tenure that has been practiced for more than 1,400 years in the Arabian Peninsula. Predating Islam, the *hima* is the most widespread and longstanding indigenous conservation institution in the Middle East, and perhaps on earth. The Arabic word *hima* literally means 'a protected place' or 'protected area.' Access to this place was declared forbidden by the individual or group who owned it. Later its meaning evolved to signify a reserved pasture, a piece of land set aside seasonally to allow regeneration.

Hima is an example of a human-centred development model where people are viewed as trustees of this earth responsible for the 'construction of the world' (*emmarat al-kawn*). It is based on sound local governance rooted in a culture of coexistence, integrity, trust, care and respect for both the natural and human environment. The principles of *hima* are in harmony with the key concepts of ecosystem management, which include: 1) building consensus and a sense of ownership with stakeholders; 2) dealing with the natural system as one integral unit that includes socio-economic and ecological governance and 3) ensuring a process of feedback and social learning evident in local knowledge, culture and religion.

In several countries, including Jordan, Lebanon and Egypt, *Hima* is being revived as a sustainable development and conservation model, particularly in rangelands where policies have, in recent years, undermined local environmental governance. In many ways *Hima* is similar to the Community Based Natural Resource Management (CBNRM) initiative in Africa and Community Conservancies such as those developed in Namibia and Kenya. They strengthen local capacities to regulate resource use and agree on sustainable development and environmental goals. *Hima* can be sustained and resourced by community-based financing models such as *waqf* (trust funds), which is an innovative way to secure resources such as land, energy and water for disadvantaged communities by enhancing social responsibility and solidarity[145].

Sustaining ecosystem services and livelihoods in dryland environments

Drylands societies have been shaped by, and in turn have shaped the environments in which they live. Traditionally societies have developed resource use practices that help them cope with unpredictable rainfall patterns and habitats that are often marginal for agriculture. Sustainable land management practices cover a wide mosaic of land uses from traditional rotational grazing and nomadic pastoralism to small-scale community agriculture, habitat restoration and strengthened protection and management of areas where the primary management objective is conservation.

Water scarcity in drylands limits the production of crops, forage and wood, but many agricultural systems have adapted to these conditions with farmers selecting breeds and crop varieties best suited to the harsh conditions of their regions. The farming system developed to cultivate enset (*Ensete ventricosum*) in the highlands of southern Ethiopia, for example, supports an estimated 15 million people and provides several foods as well as medicinal plants, fodder and fuel for household use. Associated animal husbandry – cattle, sheep, goats, horses and donkeys – provides a supplementary source of protein and satisfies the high demand of the enset system for manure[146].

Traditional crops and farming practices may produce lower yields in good years than new and improved crop varieties, but produce a more reliable harvest in times of drought. Many mountain peoples have also developed large-scale hydrological and agricultural water-harvesting infrastructure to overcome water constraints. Water harvesting by early farmers may have been pivotal in the emergence and diversification of food production and the domestication of plants and animals, and for the shaping of eco-cultural landscapes. The Inca civilisation, in the central Andes, for instance, had a social organisation based on water management and work sharing and cooperation. Irrigated terraces play an important role in protecting soil against erosion and in maintaining agricultural fertility, but they are also cultural and landscape elements that provide a strong identity for numerous mountain landscapes in the Mediterranean Basin from North Africa to southern Europe and the Levant[147].

Globally, agricultural intensification is a major threat to biodiversity and has led to conversion of natural habitats worldwide. The temperate grasslands have been particularly affected with some 41% converted for crop farming[148]. In some regions, such as the tall grass prairie in North America, areas of remaining natural habitat are very small and fragmented. This trend is continuing with large-scale commercial agriculture continuing to convert both temperate and tropical grasslands. Conversion of former rangelands for growing wheat in Sudan and Kenya, for instance, is fragmenting rangelands, reducing habitat and restricting migration. Elsewhere, however, local communities often engage in small-scale farming practices which may involve a mosaic of land uses, including retaining forest patches for shade, non-timber forest products and riverine protection. In the Sahel, farmers have learned that mixing trees and crops – agroforestry – brings a range of benefits. The trees' shade and bulk offer crops relief from the overwhelming heat and gusting winds and can increase crop production. Similarly sacred groves like the khaloas in North Africa not only have a spiritual value but also play an important role in ecosystem management, protecting water sources and biodiversity conservation, and acting as recruitment areas for seed dispersal by birds and bats[149].

Conservation agriculture[150]

Over the past 40 years agricultural production in sub-Saharan Africa has grown significantly, but has barely kept pace with population growth. As pressure to produce food has grown and land holdings have shrunk in size, many farmers have stopped the practice of allowing their fields to lie fallow, farming their land continuously year on year. Use of mineral fertiliser has not increased significantly during the same period, and traditional organic methods are not encouraged by government, resulting in crop yields that are far below the global average. Farmers effectively mine the fertility of their soil and watch their yields decline.

Conservation agriculture aims to increase productivity in smallholder farming systems through a combination of soil conservation and restoration practices. These include planting nitrogen fixing trees on farmland to improve soil fertility combined with minimum tillage, crop rotation and early planting. Through such practices, yields among practising farmers in Malawi and Zambia have doubled and could even triple in future. Conservation agriculture builds on indigenous knowledge and traditional practices of low-tillage farming. It is based on three main principles: minimal soil disturbance, maintaining a cover of organic matter and rotating crops, including leguminous plants to enrich the soil. In addition to boosting agricultural productivity and reducing poverty, conservation agriculture is estimated to have the potential to capture 50 billion tons of additional carbon dioxide from the atmosphere over the next 50 years[151].

Terraces of Machu Pichu, Peru - ©Agne Alminaite

Water is a critical limiting factor in dryland habitats, and dryland mountain habitats are often especially important for delivering essential water supplies for downstream communities. In semi-arid and arid regions, mountains may be the only areas with sufficient precipitation to generate runoff and ground water recharge, serving as 'water towers' for millions of people living in surrounding lowland areas. Mountains play a key role in the hydrological cycle of dryland regions, and are the source of many of the world's greatest rivers including the Nile, Colorado, Yangtze and Mekong. Unfortunately over-exploitation of natural resources and land conversion, as well as the spread of invasive alien species and now climate change, are altering hydrological and fire regimes leading to land degradation and desertification and impacting on their ability to deliver key ecosystem services such as water[152].

In addition to acting as water towers, mountains often provide seasonal refuge for migratory species and mobile pastoralists. Mountains often have unstable soil on steep slopes, and face extreme weather conditions, which make them especially vulnerable to degradation from deforestation and vegetation loss. Moderate to extreme wind and water erosion problems now occur in all dryland mountain regions worldwide. There is a vicious cycle of interactions between loss of biodiversity, deforestation and desertification which compromises the resilience of ecosystems and people to climate change. Vegetation loss, soil erosion and degradation lead to further reduction of carbon sinks, with an estimated 300 million tons of carbon lost to the atmosphere from drylands each year[153].

Watershed-based management can be enhanced by the diversification of land-use strategies along agro-ecological zones, for example upland grasslands, upper slope protection forests, and utilisation of foothills for agricultural land. Depending on harvesting pressure, some species and habitats may be subject to total or seasonal protection. In the arid mountains of Jabal Al Akhdar (Oman) for instance, herders conserve resources through the establishment of *hamiyaat*, traditional livestock-free protected areas where fodder is cut by hand. Elsewhere in the Near East the *hima* system establishes rules for the grazing of herds in a territory utilised by one or more pastoralist communities, and specifies areas where grazing is allowed year round, areas where grazing is only allowed under exceptional conditions (i.e. drought periods), areas reserved for beekeeping and those reserved for the protection of forest held as common property.

In some countries central governments are beginning to realise that public administrations are not always the best way to manage natural resources and are again devolving some rights to manage resources to local communities. In Mongolia, for instance, some 90% of forests are officially designated as Protected Zone Forest where only forest regeneration and use of non-timber resources are permitted. Due to limited resources actual protection on the ground is very weak and unsustainable harvesting of firewood and timber and illegal logging have led to the loss and degradation of approximately 60,000 hectares over the last decade. To address this challenge the government is now working with nomadic herders to establish forest user groups (FUGs) from local families and community groups to implement forest protection, ecosystem management and sustainable harvesting within their grazing territories[154].

Local forest stewardship is already having positive results with reduced levels of illegal cutting and forest fires. Although FUGs are expected to gain some livelihood benefits from participatory forest management, most groups have a mix of objectives including environmental protection, water conservation, pasture and wildlife management, reduction in illegal activities, and greater rights to control activities within their rangeland territory. Similarly, agreements between the Iranian government and the Centre for Sustainable Development, a national NGO, have laid the groundwork for the restoration of the ancient *Qashqai* nomadic pastoral system which defined migratory routes over hundreds of kilometres, and shaped a common property regime that supported a thriving economy based on wool, meat and dairy products[155].

Maintaining the functionality and sustainability of dryland systems requires sustainable land management over large territorial units. Through seasonal migrations, people, livestock and wildlife have influenced the structure, composition, distribution and dynamics of natural habitats in large territories, and contributed to the creation of unique landscapes. Since ancient times, herders in dryland regions have developed solid social organisations and mechanisms of mutual aid and collective control, and management of natural resources. These often include communal property and management regimes such as communal grazing and harvesting in grasslands and forests, and communal water-sharing systems for agriculture. These communal arrangements are central to sustaining ecosystem services, to enabling sustainable livelihoods in the drylands and ultimately to conserving biodiversity.

Transhumance in Spain - ©Garzon

Livestock management as a conservation approach

There is a growing argument that sustainable rangelands management is not only good for pastoralism, but is also of benefit to biodiversity: a rare win-win outcome of economic growth and biodiversity conservation[156]. In several developing countries this opportunity is of particular interest considering the size of both the livestock and the tourism sectors. In Kenya for example, tourism (which is dominated by wildlife tourism) accounts for 13% of GDP while the livestock sector contributes between 5% and 10% of GDP[157].

However, experiences appear to differ widely, with some evidence supporting this argument and other evidence suggesting that wildlife numbers are higher where livestock is excluded. A study in Kenya's Laikipia County found that species richness of large mammals was highest on conservancies (which have moderate livestock stocking rates) and sanctuaries (with no livestock) and lowest on fenced and group ranches where livestock densities are highest. This research however contrasts with research in other parts of Kenya that found wildlife populations higher on communal pastoral lands adjacent to protected areas than inside them[158]. The presence of high numbers of wild herbivores on rangeland that is grazed by cattle has been observed in several countries, including the United States and Mongolia[159]. Additionally, the time spent by wildlife on different rangelands is important, since pastoral lands may act as corridors between other areas or may provide seasonal grazing or watering points.

The differences between observations may be explained by the degree of rights that land users have over wildlife, the incentives in place to tolerate or actively protect wildlife on grazing lands and the relationship between communal livestock herders, wildlife authorities and the beneficiaries of wildlife tourism. The lack of user rights and uncertain land tenure may create disincentives to protect wildlife on some rangelands. National conservation strategies might consider a landscape-level approach to land-use planning in order to increase the area under conservation by providing incentives, or removing disincentives, for conservation on community properties. This could be achieved by improving access to ecotourism benefits, forging agreements to maintain wildlife areas and corridors, resolving land ownership conflicts, restoring degraded rangelands, expanding opportunities for grazing leases, and allowing direct benefits to landowners from wildlife harvesting[160].

Wildebeest and Sheep in Naivasha, Kenya - ©Jonathan Davies

Using protected areas to promote sustainable land management

While it is now generally accepted that natural ecosystems offer substantial benefits to human society in dryland areas, this realisation has come at a time when such ecosystems are under unprecedented pressure and there is much less consensus about how ecosystem degradation in drylands can be slowed or halted. Indeed, in some areas rates of degradation are increasing, as in the Northern Great Plains of the United States where grasslands are being ploughed for crop production at a faster pace than seen for decades. Protected areas such as national parks, wilderness areas and protected landscapes provide a model that has in many parts of the world already proved to be successful in maintaining or restoring healthy dryland ecosystems. Although primarily seen by outsiders as tools for nature conservation, many protected areas have a far wider social and economic role.

The concept of setting aside areas of land for the common good has been understood and applied in drylands for more than a millennium and modern protected areas draw on this experience. In the Arabian Peninsula for instance, the concept of *hima* (discussed earlier) was championed and promoted by the Prophet Mohammed, but originated even earlier[161]. Although modern protected areas have been set up primarily to protect biodiversity, wildlife and scenic landscapes, their wider benefits are being recognised in terms of ecosystem services, sustainable land management and socio-cultural values which range from tourism to the protection of sacred natural sites.

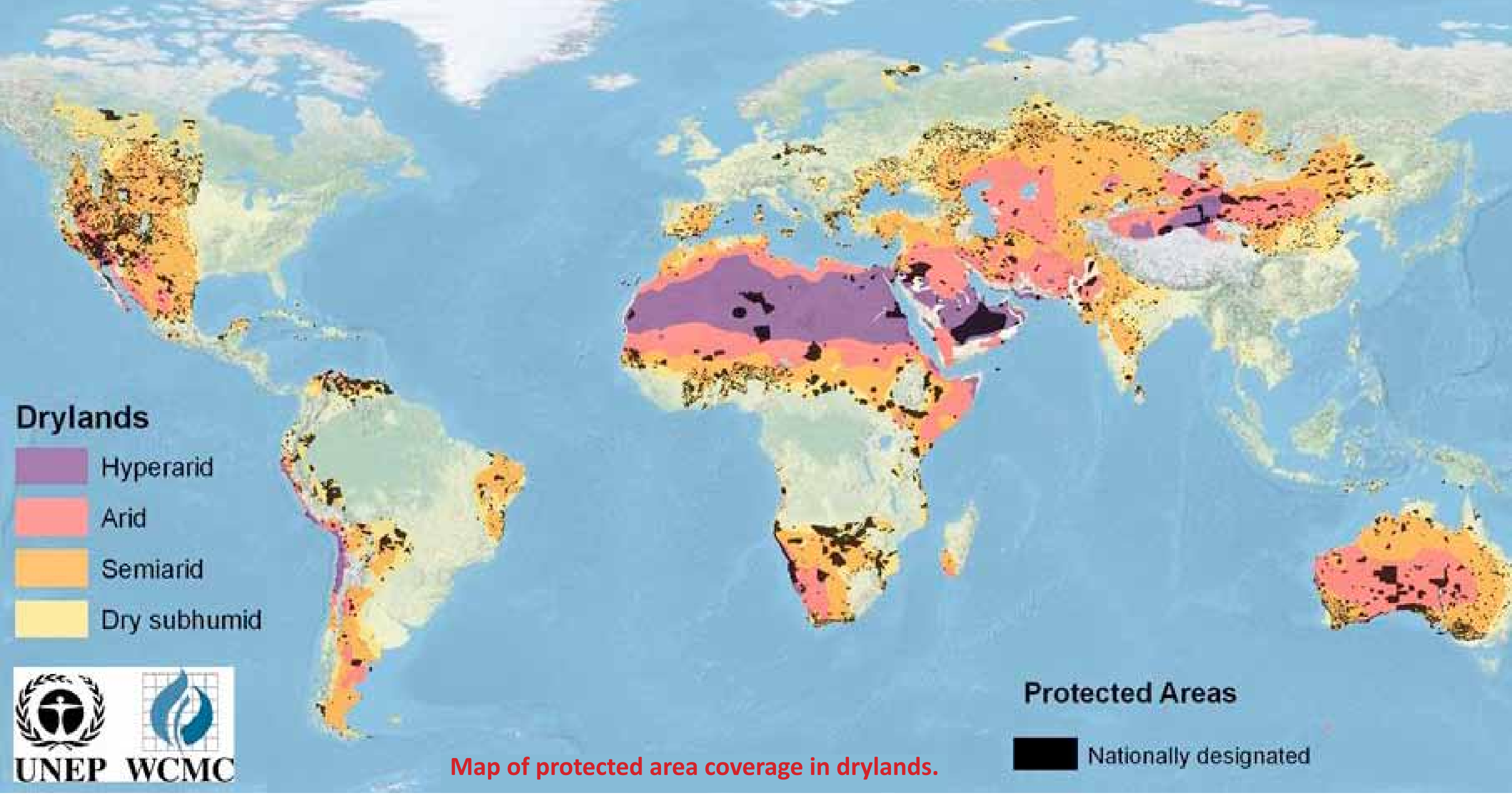
Restoring degraded thickets in the Eastern Cape, South Africa[162]

The Working for Woodlands Programme in the Eastern Cape is creating a new rural economy, based on restoration of degraded thicket vegetation. Land degradation from overstocking has reduced more than one million hectares of natural thicket vegetation to an open desert-like state, with little or no value for agriculture or grazing livestock. These degraded lands are now being reclaimed through planting of Spekboom *(Portulaca afra*), a typical native thicket plant, which grows quickly from cuttings into tall dense vegetation without irrigation.

Large-scale restoration efforts will provide multiple environmental benefits, including improved carrying capacity of managed livestock and wildlife; conservation of topsoils and less sediment deposition in rivers and dams; greater water infiltration into soils and aquifers thereby replenishing ground water; sequestration of carbon and enhanced biodiversity. Socio-economic benefits include improved water supplies, creation of jobs for previously disadvantaged groups as well as improved opportunities for more sustainable livestock farming and ecotourism. Restoration of Spekboom thickets is being undertaken both on private and community lands as well as in three major protected areas – Baviaanskloof Nature Reserve, Addo National Park and the Fish River Reserve which all have large areas of degraded thicket.

Many of the areas being rehabilitated are also part of important watersheds for major metropoles and more than 647 hectares have already been restored within the reserves, funded by the water authority and voluntary carbon credits. Since Spekboom has high carbon sequestration potential it is expected that future restoration efforts can be at least partially funded through carbon credits and more direct payments for ecosystem services such as water.

Spekboom - ©Four Oaks



Map of protected area coverage in drylands.

IUCN defines a protected area as 'a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values'[163] , with nature conservation the priority objective. Within this broad framework, protected areas can be managed in a wide variety of ways and under a range of governance types anything from a strict 'no-go' area entirely set aside from human intervention, to a protected landscape consisting of long-managed areas and settled human communities; or from a reserve owned and run by a government, to a self-declared protected area run by an indigenous community within their traditional territory. The range of management and governance approaches is reflected in a typology agreed by IUCN and illustrated below, which also shows clearly that any management category can be applied in any governance type.

Many of the world's protected areas encompass significant dryland areas, noted for their floral and faunal biodiversity, their cultural importance and their scenic wonder. Drylands cover almost half of the world's terrestrial surface and contain a lot of diversity. This diversity in habitats and species includes the world's driest places, the world's broadest expanses and the world's most spectacular wildlife migrations. Although far from complete, the network of protected areas in drylands is beginning to capture this diversity, while supporting sustainable land management on an ecosystem scale through the delivery of a number of ecological goods and services, restoration programmes and a home space for traditional mobile indigenous peoples.

Some 9% of the world's desert and xeric grassland biomes are designated as protected areas[164], but the extent of these varies according to biome or ecoregion. Temperate grasslands, for example, are among the least protected biomes in the world, with only about 5% protected, often in small reserves in highly fragmented environments such as in the North American prairies and the steppes of Eastern Europe[165]. Elsewhere, however, temperate grasslands make up some of the largest protected areas in the world. For example, the Quingtang Nature Reserve on China's Tibetan Plateau encompasses 280,000 km^2 of high elevation grasslands while other important areas include Grasslands National Park in Canada, the Eastern Mongolia Steppe Strictly Protected Area in Mongolia and Saryarka in the steppes of northern Kazakhstan.

Target 11 of the Aichi Biodiversity Targets under Strategic Goal C[166] ('To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity') includes securing 17% of terrestrial areas 'conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures'. Many dryland ecosystems are protected through indigenous management practices and knowledge systems for the production of food and other goods, with intentional or unintentional conservation benefits. These Indigenous and Community Conserved Areas (ICCAs) are tacitly recognised in the Aichi target outlined above, but may sometimes fall outside the IUCN categorisation of protected areas if conservation is not the explicit goal. Although 9% of drylands are currently protected – over 50% of the Aichi target 11 – this excludes many areas that are de facto protected through community management practices. In reality drylands offer one of the greatest opportunities for surpassing the Aichi targets, simply through recognising ICCAs and the opportunities for achieving dual conservation and rural development goals.

The Somkhanda Game Reserve: land restitution with conservation benefits

In the northern parts of KwaZulu Natal Province, close to the Mozambican border, the Gumbi Community have opted to conclude a Nature Reserve agreement on conservation-worthy land they own. The Somkhanda Game Reserve is part of a land restitution project in which the community has successfully reclaimed 21,500 ha of land – land from which they had been forcibly removed at the end of the 19th century. The tribal authorities formed a legal entity, the Emvokweni Community Trust, which negotiated with the provincial conservation authority to establish the Somkhanda Game Reserve under a biodiversity stewardship agreement. The reserve included a tourist lodge and a residential estate, benefits of which would be transferred to the community. The bulk of the land was set aside for the reserve, but a small portion was retained for settlement and for cattle grazing.

The community will benefit through support from the provincial conservation agency and an NGO for developing a management plan, mapping of invasive alien plants, developing an invasive alien species strategy and donating game to stock the reserve. The community is being empowered to manage the game reserve through a range of training programmes, including accredited law enforcement training and use of a GPS-based patrolling system. They will also benefit through a strategic business partnership with a private property development company to develop a residential estate linked to the game reserve. Monetary benefits accruing to the community as a result of this development will provide the necessary resources for management of the game reserve, the development of tourism opportunities and the provision of housing and accommodation for the community[167].

Some of the world's largest reserves are located in the true deserts of the arid and hyper-arid moisture regimes, in both hot and cold latitudes – for example in the Sahara region and the Arabian Peninsula – in part because low human population and poor economic potential mean there are few competing land uses. The second-largest protected area in the world is the Ar Rub'al Khali Wildlife Management Area in Saudi Arabia, a vast expanse of 640,000 km^2 of hot sand desert. Other hot desert protected areas include the Kalahari Gemsbok National Park in South Africa and the Ouadi Rimé-Ouadi Achim Faunal Reserve in Chad. Most cold deserts lie in Asia and North America and include such protected areas as the Great Gobi Strictly Protected Area in Mongolia and the national parks of the Colorado Plateau in the United States. In the hyper-arid deserts – the driest deserts in the world – Namibia has protected the Namib-Naukluft National Park and Chile the Pan de Azúcar National Park in the Atacama Desert.

Many natural and semi-natural grasslands have high levels of floristic diversity, in some areas approaching the diversity of tropical forests. Tropical grasslands are relatively well represented in global protected area networks, epitomised by the savannahs of eastern Africa and the Mara-Serengeti-Ngorongoro ecosystem (a World Heritage Site). Natural grasslands and savannahs often support high biomass of animal communities and some of the greatest wildlife spectacles in the world including the wildebeest and zebra migrations through the Serengeti-Masai Mara national parks (Kenya and Tanzania) and the mass migrations of white-eared kob (*Kobus cob leucotis*) and other ungulates between the Sudd swamps in South Sudan and Gambella National Park in Ethiopia. India, too, is well known for its grassland protected areas, many designed to protect the Asian tiger, as in Ranthambore and Kanha national parks.

Semi-arid regimes are represented in Mediterranean-type ecoregions which, in addition to being found around the Mediterranean Sea, are also found in the Cape Floristic Region in South Africa and parts of California, Chile and southern Australia. These areas are popular for human settlement, and protected areas are relatively small and few, collectively covering only 4% of this ecosystem. The Mediterranean-type vegetation of the Cape Floristic Region is the most floristically diverse area in the world, although animal species richness is generally lower. Important conservation areas that protect the unique *fynbos* vegetation include Table Mountain National Park and the Cape Peninsula National Park as well as mega-reserves such as the Cederberg, which extends from the mountains to the sea and includes a connected network of national parks, reserves, private properties and community-managed lands under conservation stewardship arrangements.

In recent years a notable feature of many dryland protected areas has been increasing collaboration with local producer or community organisations to address both land degradation and biodiversity issues. Such involvement gives communities additional livelihood opportunities and a key stake in sustainable resource management and biodiversity conservation. In Bolivia, indigenous communities in the Kaa-Iya National Park and surrounding territories co-manage a large area of semi-arid lands zoned according to conservation and community needs, from strict protection to limited extraction and intensive use. Many dryland protected areas are zoned for multiple uses and have established programmes that work with local communities within and beyond their boundaries to improve human welfare. These programmes aim to reconcile biodiversity conservation and human needs through improved rangeland management and alternative livelihoods and tourism benefits. In India, eco-development opportunities associated with the Ranthambore Tiger Reserve in drought-stricken Rajasthan have combined

IUCN protected area matrix: showing both management category and governance type

Governance types / Protected area categories	A. Governance by government			B. Shared governance			C. Private governance			D. Governance by indigenous peoples and local communities	
	Federal or national ministry or agency in charge	Sub-national ministry or agency in charge	Government-delegated management (e.g., to an NGO)	Transboundary management	Collaborative management (various forms of pluralist influence)	Joint management (pluralist management board)	Declared and run by individual land-owner	...by non-profit organizations (e.g., NGOs, universities, co-operatives)	...by for-profit organizations (e.g., individual or corporate landowners)	Indigenous peoples' conserved areas and territories – established and run by indigenous peoples	Community conserved areas – declared and run by local communities
I a. Strict Nature Reserve											
Ib. Wilderness Area											
II. National Park											
III. Natural Monument											
IV. Habitat/ Species Management											
V. Protected Landscape/ Seascape											
VI. Managed Resource Protected Area											

Nachusa Grassland, Illinois, USA: private reserve bought by The Nature Conservancy, bordering state-owned Category V protected area, in an area of dry grassland.

Paruku Indigenous Protected Area, Australia: indigenous territory, equivalent to IUCN Categories II and VI, a large area of rangeland and desert.

Wadi Rum protected area and natural World Heritage site, Jordan: IUCN Category V, managed by the government, includes settled and nomadic communities in a desert habitat.

Serengeti National Park, Tanzania: IUCN Category II, managed by the government, managed by the Tanzanian National Parks Authority for the government, major tourist destination in tropical savannah.

Examples of dryland protected areas in different categories and governance types

Gilgit-Baltistan: sustainable wildlife management in high altitude drylands in Pakistan

Gilgit – Balistan, Pakistan - ©IUCN

Gilgit-Baltistan possesses one of the most rugged landscapes on earth, at the convergence of three of the world's greatest mountain ranges — Hindu Kush, Himalayas and Karakoram. With 101 peaks above 7,000 metres, including Nanga Parbat and K-2, more than half the region is located above 4,500 metres. Gilgit Baltistan is rich in biodiversity with 230 species of birds and a considerable number of globally threatened mammals, such as the snow leopard (*Panthera uncial*) and the Ladakh urial (*Ovis orientalis vignei*). It is believed to support some of the richest plant communities in Pakistan, including medicinal plants.

To conserve this rich biological heritage, an extensive network of protected areas has been established in Gilgit-Baltistan, including four national parks, three wildlife sanctuaries and nine game reserves, covering a total area of 2.07 million hectares, or approximately 28% of the region. Additionally, eight community-controlled hunting areas of over 518,200 hectares have been created as conservancies to promote the concept of sustainable use. The communities have developed Valley Conservation Plans and District Conservation Committees, which support wildlife management and a livelihoods programme based on trophy hunting. There has been a special emphasis on species conservation of the snow leopard which was historically killed to prevent depredation of livestock. The Hushe Community was awarded the Disney Wildlife Conservation Fund's 2004 Conservation Hero Award for Asia and a Commendation for Conservation Action Certificate by the Snow Leopard Conservancy for releasing a trapped snow leopard that had killed more than thirty sheep and goats.

Snow Leopard, Pakistan - ©Elle 1

conservation and famine relief funds to restore ancient step wells within and around the park, to provide new water supplies for communities, livestock and wildlife.

As pressures such as agricultural development lead to further fragmentation and degradation in dryland ecosystems, protected areas are becoming isolated 'islands' of natural habitat, with increasing threats to biodiversity and ecosystem services. As a result, increasing attention is being paid to maintaining connectivity often through mosaics of land uses around, and between, protected areas. Programmes such as CAMPFIRE in Zimbabwe (Community Areas Management Programme for Indigenous Resources) and models of community wildlife management piloted in West Africa are now being extended and replicated to effectively extend the wildlife estate into community rangelands and the production landscape. Elsewhere, private sector initiatives, community conservancies and stewardship arrangements are helping to expand conservation objectives to private and community lands. Payments for ecosystem services may help to create new incentives for such initiatives, especially payments for carbon, water and biodiversity benefits. Thus a scheme to pay Maasai communities is helping to keep open an essential wildlife corridor across their rangelands enabling migrating wildebeest to reach the Nairobi National Park, Kenya.

Although drylands appear to be well covered by protected areas, this masks some areas of poor representation as well as a significant missed opportunity. The level of protection of drylands may reflect an overall recognition of their biodiversity value, but may also reflect the comparative ease with which dryland areas can be alienated from indigenous communities. It also reflects the large scale of some desert protected areas, whereas some of the less arid drylands, including areas of important biodiversity, are less well represented. However, a significant proportion of dryland biodiversity protection takes place outside formal protected areas, where such conservation outcomes are under threat, for example from pressures to convert land to other uses. This represents a missed opportunity in terms of both conservation and sustainable development. As the following section discusses, the drylands may be unusual in offering significant scope for greatly surpassing current conservation targets through genuine complementarity between conservation and development goals.

Indigenous and Community Conserved Areas

In recent years, there has been much debate on whether global efforts to achieve conservation and biodiversity goals have been at the cost and exclusion of indigenous peoples and local communities. In many dryland ecosystems indigenous peoples and local communities are already custodians and managers of territories, which are historically shaped by their cultures and governance systems, and in turn have shaped these civilisations. Such areas are often referred to as Indigenous and Community Conserved Areas (ICCAs) and their contribution to conservation of biodiversity and ecosystem services is recognised in the Aichi targets of the Convention on Biological Diversity (CBD) adopted in Nagoya in 2010. An ICCA may be formally recognised by a State Party as a formal Protected Area, such as the Australian framework for Indigenous Protected Areas, or be part of national policy frameworks such as in Namibia.

National recognition of ICCAs can take place in various ways. Since independence in 1990, Namibia has elaborated a policy and benefit-sharing model to support communities to govern and conserve their traditional territories in cooperation with the Ministry of the Environment and Tourism (MET). The legal framework was adopted by the independent Namibian state in 1996. This national network of community conserved areas are known as conservancies, and are important mechanisms for conserving biodiversity, introducing new income streams to communities, as well as maintaining customary sustainable use capacity and institutions, partially acknowledged by the state . Examples include indigenous peoples' territories in remote dryland areas, such as the Ju|'hoansi territory of Nyae Nyae Conservancy, the !Kung territory of N‡a Jaqna Conservancy, and several Himba Conservancies in the arid Kunene Region (known as the Kaokoveld).

The conservancy system is proving to be a successful model for conserving mammalian diversity and promoting sustainable use and conservation of valuable wild plants, including devil's claw (*Harpagophytum procumbens*), and *Commiphora wildii* resin as well as traditional knowledge systems related to plant and animal biodiversity, such as tracking, traditional medicine, and management of wild food resources. Besides Namibia, other countries such as the Philippines, Mexico and Kenya are working on efforts to increase state-supported processes for recognising ICCAs and their contributions to biodiversity protection.

In countries where ICCAs are not recognised under national legislation, the activities of indigenous peoples and local communities are contributing to biodiversity conservation, connectivity strategies, wildlife corridors and buffer zones to formal protected areas. In the Eastern Himalayas, local communities are engaged in conservation management to enhance connectivity networks. Nepal has elaborated a framework to establish joint management between indigenous peoples and national protected areas, benefit-sharing contractual agreements, a forest law to promote community ownership and management of 'buffer' areas. The overall goal is a social compact to assist in reconnecting biological corridors and help to conserve biodiversity which underpins human resource use and culture.

Neighbouring Bhutan already has a well-established system of corridors linking key protected areas. The International Centre for Integrated Mountain Development (ICIMOD) is working within the countries of the Himalayan region to promote transboundary conservation and connectivity, which includes protected areas and the broader production landscape including lands managed by communities. The Kailash Sacred Landscape Conservation Initiative, for instance, covers a vast territory of the Hindu-Kush-Himalayas, including portions of the Tibetan Autonomous Region of China, India and Nepal.

The IUCN working group TILCEPA (Theme on Indigenous Peoples, Local Communities, Equity and Protected Areas [168])has emphasised how ICCAs create opportunities for improved biological and ecological connectivity in landscapes and seascapes. While protected areas are the cornerstones for any national conservation strategy, they need to be integrated into the broader landscape through land management planning at different scales to maintain connectivity, biological diversity and genetic flow. ICCAs provide a fresh opportunity to harmonise the goals of sustainability, cultural diversity and biological diversity.

In the last few years, a robust network of local custodians, advocates and researchers have come together to form the ICCA Consortium, which is an active member of the IUCN and engages in policy work with the CBD. The ICCA Consortium emphasises that ICCAs all have their own localised institutional framework, intimately related with sustained natural resource management over extended time frames. The opportunity is to create synergies, collaboration and respect between the national protected areas system managers and the custodians associated with ICCAs. Other international processes are underway, supported by institutions such as UNDP and UNEP-WCMC, to help document ICCAs as a means to raise awareness of their significance in relation to protected areas. The global ICCA Registry offers an opportunity for communities to register their validated ICCAs, a process which has helped lead to their increased acceptance by national governments.

Wider values of protected areas

Many protected areas support ecosystem services or cultural values that would otherwise have been at risk of degradation or loss. Some examples illustrate the range of benefits involved:

Controlling desertification: In Dana Wildlife Reserve, Jordan (31,000 ha and an MAB Biosphere Reserve), degradation has been partially reversed by agreeing with local farmers and herders to reduce stocking densities of goats by 50% and providing alternative livelihood options through ecotourism and craft development [169]. Conversely, private and communal conservancies in Zimbabwe and elsewhere have greatly improved biodiversity by increasing stocking rates for cattle in planned-grazing strategies that mimic the natural herding instincts of wild ungulates[170].

Protecting crop wild relatives for crop breeding: In Kyrgyzstan, the Sary-Chelek (23,868 ha) and Besh Aral State Nature Reserve (63,200 ha) were established in part to protect semi-arid walnut and juniper forests and high mountain pastures which are home to snow leopard (*Panthera uncial*) and argali sheep (*Ovis ammon*). The region is a recognised centre of agricultural biodiversity, including medicinal plants, herbs, grasses (lucerne grass originated from here), grapes, tulips and walnut and apple trees. Many domesticated apple varieties originated in these mountains and the remaining wild relatives in the Tien Shan may offer potential for developing scab resistant species[171]. Similarly, the Kazdagi National Park (21,300 ha) in Turkey is rich in fruit progenitor, nut, ornamental and forest species[172].

Promoting sustainable grazing regimes: Research in the Chimborazo Faunal Production Reserve, Ecuador, has shown the ecological benefits of encouraging the husbandry of native camelids instead of cattle and horses. Benefits include a higher stocking rate with llamas and improved pasture condition. Similarly in Hövsgöl National Park in northern Mongolia, uncontrolled grazing by sheep, goats and cattle on the mountain slopes around the lake and the gathering of fuelwood have caused the forest edge to retreat, accelerating the rate of permafrost melt caused by climate change. To mitigate these effects, herders have changed to rotational grazing and improved range management, helping to protect Mongolia's water resources, biodiversity, and natural ecosystems[173].

Izoceno, Bolivia – ©Jorge Orias Herrera

Community conservation in Bolivia: the Izoceño

In South America, Bolivia is a continental leader in the recognition of indigenous territories, with 60% of its population being indigenous in origin. More than 15% of Bolivia's land area has been incorporated as Native Community Lands, legally held by indigenous groups through collective titles. Several national parks and other forms of protected areas have been created in Bolivia in conjunction with, and co-managed by, indigenous people.

Lying in the rain shadow of the Andes, Kaa-Iya del Gran Chaco (KIGC) National Park and Integrated Management Natural Area was created in 1995 to protect a representative portion of the extensive Chaco grasslands and dry deciduous woodlands in the dry south-east corner of Bolivia. At 35,000 km^2 in size, the park is the largest in Bolivia and one of the largest in South America. It is considered to contain the largest tropical wooded area in the world.

KIGC was established through the direct action of the Capitania de Alto y Bajo Izozog (CABI), an organisation representing the interests of the Izoceño people. CABI negotiated an impact and management agreement with the owners of an oil pipeline that was built through the area, to support ongoing management and administration, which is carried out jointly between the Bolivian Government and CABI. Under this agreement and joint administration, the Izoceño have continued their traditional hunting practices, nomadic gathering and use of the forest for raw materials and medicinal use on a sustainable basis. Through adopting community-based wildlife management, this collaborative arrangement in the KIGC has both improved the ecological condition of the Chaco ecosystem and provided benefits to the Izoceño.

Increasing carbon storage to mitigate climate change: Grasslands constitute about 34% of the global stock of terrestrial carbon. In Xinjiang, China, flocks of livestock (camel, sheep, goats) are moved up to summer in mountain pastures in the protected areas of the Tien Shan, Altai Shan, and Qilian Shan. Changes in grazing regimes to delay and shorten the grazing season are designed to increase species diversity, improve grazing conditions and productivity for wild ungulates as well as livestock, reduce soil loss and increase the amount of carbon entering the soil as plant residues. Since China's grasslands cover vast areas, these changes could have widespread effects on regional climate and global carbon cycles.

Reintroduction of extirpated species: The American bison (*Bison bison*) once had the largest distribution of any indigenous mammal in North America. It all but disappeared from the continent following excessive hunting in the late 19th century. With the subsequent onset of what is now one of the most intensive cattle ranching areas in the world, the competition for grazing space relegated the few surviving plains bison to the protective embrace of Yellowstone National Park. Over time, other populations have been established in several national parks and other protected areas in Canada, the United States and Mexico. Populations have now recovered to the point where efforts are underway to establish new herds of bison, as well as other endangered species such as the black-footed ferret, in an attempt to re-establish a semblance of the wild prairie landscape in naturally functioning grassland ecosystems.

Livestock in the Gobi Desert - ©Marc Van Vuran

Maintaining sacred natural sites: In Southern Madagascar the Mahafaly and Tandroy communities along with local authorities and the national government have committed to conserve the sacred forests of Sakoantovo (6,163 ha) and Vohimasio (30,170 ha), part of the dry spiny forests, one of the biologically richest drylands on earth. Responsibility for management has been transferred to the local population[174]. In Mali, The Cliffs of Bandiagara (400,000 ha) is one of the main centres for the Dogon culture where species such as the Pale fox (*Vulpes pallida*) are regarded as sacred and revered in ritual rain dances[175].

Protecting threatened human cultures in drylands: Many of the world's protected areas inhabited by temporary or settled human communities and in some cases provide shelter for fragile communities that would otherwise be swamped by development. Over the last few years in Australia, over 20 million ha of self-declared Indigenous Protected Areas have been established, mainly in desert and semi-desert areas, to protect both traditional aboriginal culture and associated biodiversity. Similarly, indigenous Quechua communities in the Pisac-Cusco area of Peru have established the Potato Park as a community-based, agrobiodiversity-focused conservation area to protect their cultural heritage in an area of the high Andes where potatoes have been cultivated by Andean farmers for over 7 000 years.

Learning about dryland restoration: In areas where desertification or other forms of environmental degradation are already advanced, protected areas can provide a controlled environment to carry out experiments on rehabilitation. Drylands in Kuwait suffered enormously during the first Gulf War, when a thick layer of oil covered hundreds of square kilometres of the country, and also from overgrazing and the impact of off-road vehicles. In Sulaybia Experimental Station (4,000 ha) research is being undertaken on ways to restore dryland vegetation on degraded land, building up seed banks and experimenting with different restoration techniques.

Providing a source of income: Lupande Game Management Area, adjacent to the South Luangwa National Park (Forest Reserve 5,613 ha and Game Management Area, 484,000 ha,) in Zambia provided annual revenues of US$230,000 for the 50,000 residents through two hunting concessions. The revenue is distributed both in cash to the local community and to village projects such as schools. Ultimately a total of 80% of revenue from hunting goes to the community[176].

North American Bison - ©Jeff Banke

Spiny Desert Flora, Madagascar - ©The Africa Image Library

These examples clearly show some of the values of creating protected areas, but as the examples illustrate, they do not only apply to protected area Categories 1 and 2 (strict nature reserves or wilderness areas). Many of the benefits of protected areas are only possible if communities and their land management practices are part of the protection strategy. In many countries the idea of protecting land for (rather than against) local communities is a novel concept that is yet to gain traction. However, as the many examples of ICCAs clearly demonstrate, not only do dryland communities conserve biodiversity, but by recognising this, governments can contribute to strengthening sustainable land management strategies, and can thereby strengthen resilience and development in the drylands.

Enabling people-oriented solutions for conserving dryland biodiversity

Drylands not only harbour extensive biodiversity that is both locally and globally important, but they are home to many indigenous cultures that have historically played a major role in shaping and conserving that biodiversity. While protected areas offer important opportunities for conserving drylands biodiversity, there are further opportunities for conservation through ICCAs that currently fall outside IUCN's protected area categories. At the same time, there are categories of protected area that may be under-utilised in the drylands, which could give much greater recognition to community conservation and thereby provide incentives to help sustain them.

Preserving and enhancing ecological and cultural diversity in dryland ecosystems is often the best strategy to build resilience and to reduce human-induced pressures on the environment. There are underlying barriers and disincentives to this strategy however, both to implementing new measures and to sustaining traditional practices. Governance failures and insecurity of land tenure are of particular importance and there is often a need for much greater devolution of responsibility to a local level, where decision making can build on traditional knowledge and communal institutions for management of natural resources. The process of devolution frequently needs to be accompanied by a change in attitude of governments towards supporting local livelihood strategies, since devolution may be constrained if some government departments are still pushing a strong agenda of land-use change.

Government can play a strong role in supporting better application of indigenous knowledge and better functioning of customary institutions. The state can establish mechanisms for improved spatial planning for appropriate land use and development, for example to improve the integration of planning between sectors such as agriculture, water and the environment. This could create integrated public planning processes that more accurately reflect the holistic nature of natural resource planning as practiced by dryland communities.

There is particular need to recognise where synergy or complementarity can be achieved between development and environmental outcomes. Resilient livelihoods and resilient ecosystems depend on the conservation of biodiversity, although the precise relationship remains open to debate. Nevertheless there are a growing number of examples of dryland communities pursuing their own development goals through environment-related activities, which provide inspiration and experience to draw upon. Drylands offer a particularly wide range of opportunities for large-scale conservation <u>through</u> sustainable land management by local communities and there is still much to learn about the different conservation outcomes and potential trade-off between them. Through a pastiche of different protected area types and ICCAs it is possible to maintain highly productive, resilient and inter-connected landscapes in which ecosystem function and species diversity are conserved for both local and global benefit.

The Dogon Valley, Mali - ©Jonathan Davies

Prospering in Uncertainty: Conserving Dryland Biodiversity and Sustaining Life

Dryland biodiversity for life

One word that could sum up biodiversity in the drylands is adaptation. Since water is a key ingredient for life on earth, its scarcity drives extraordinary biological, and often cultural, diversification in the drylands. The combined challenges of aridity, seasonality and climatic uncertainty have contributed to a diversity of adaptations and evolutions in dryland species and ecosystems. As a result the drylands are home to a wealth of unique biodiversity in addition to some of our most treasured global natural heritage.

Although dryland biodiversity can be disaggregated into agricultural biodiversity (in a broad sense) with visible production functions, and natural dryland biodiversity with usually less visible functions, both are intricately related and are referred to simply as dryland biodiversity. As an example, natural dryland biodiversity provides a variety of services, including a genetic reservoir for the renewal of domesticated species, an aspect which may be critical in the event of a pandemic in cultivated strains.

Biodiversity loss in the drylands is closely linked to land-use change, which is driven to a large extent by a disregard for existing sustainable land-use practices and poor valuation of their environmental benefits. Data on dryland biodiversity and environmental degradation is generally inadequate and there is insufficient knowledge of biodiversity, disaggregated by dryland subtypes, and the implications for sustainable management and conservation. It is not accurate to say that drylands are neglected in terms of conservation. An estimated 9% of drylands are formally protected, and much larger areas are protected through local land use and cultural practices that are not officially recognised. Nevertheless, there remain important dryland sub-types that are under-represented in terms of protection. More broadly, the drylands are neglected in terms of understanding their specificities and the implications for sustainable land management and human well-being.

Dryland poverty is often linked to failure to satisfy basic human rights as well as failure to secure rights to manage and control natural resources. In some cases rights have been weakened as a result of policies favouring either private or state tenure over communal or customary tenure. These policies have undermined traditional management practices and communal tenure systems that are often vital for effective dryland management. In other cases, legislation offers an opportunity to strengthen local tenure arrangements, but these laws are frequently not applied because of a lack of investment or capacity (both within government and among dryland citizens). Most recently these weaknesses in resource rights have allowed large-scale land acquisitions by foreign investors to take place, for example in sub-Saharan Africa, which have driven further impoverishment and biodiversity loss[177].

While land acquisitions have indeed led to impoverishment of some sort (e.g. loss of livelihoods, loss of land, weakened local level institutions etc.) we should also acknowledge the fact that in some cases land acquisitions have delivered benefits (e.g. new investments leading to an improvement in infrastructure, new employment opportunities, new marketing opportunities). The key here is to clarify winners and losers from these investments, but also to clarify the risks and opportunities for dryland biodiversity.

Land and ecosystem degradation in the drylands exacerbates poverty and biodiversity loss in a vicious circle. Land degradation reduces productivity, increases vulnerability in rural communities and undermines water and nutrient cycling and other ecosystem functions that sustain species diversity. Poverty contributes to land degradation by increasing unsustainable natural resource extraction and reducing people’s capacity to implement sustainable land management practices. The outcome is disempowerment and a rise in social conflicts and human displacement. Land degradation and respective habitat destruction contributes directly to biodiversity loss as well as the loss of specific ecosystem functions related to soil formation, soil protection, soil quality, vegetation cover and composition and related water and nutrient cycling.

From an economic and ecological point of view it is more cost-efficient to safeguard biodiversity in the first place than invest later in restoration measures. This requires attention to both conserving biodiversity and reducing poverty and vulnerability in the drylands[178]. This already monumental challenge related to dryland livelihoods is amplified by the uncertainties of climate change, which has direct impacts on livelihoods, food and water insecurity, land degradation and biodiversity, as well as the interplay between them. It is only through understanding the drivers and intimate relationships between these phenomena that we can identify solutions for escaping the vicious cycle and embrace opportunities for progress.

A future vision for the drylands

As this book has illustrated, the drylands are different in a number of important ways from humid lands. In many cases, development pathways for the drylands are driven by a distorted idea of how drylands should or could exist. Notions of greenness and 'greening the desert' often betray a deep misunderstanding of dryland environments and seasonality, and there are many examples of efforts to 'green' drylands that have been environmentally damaging[179]. Misrepresentation of drought and water scarcity in the drylands diverts attention away from sustainable and adaptive management of limited resources towards trying to create resources where they don't exist. This can lead, for example, to diversion of water into small pockets and excising them from the wider ecosystem, which puts the wider system at increased risk of degradation. The result of these misrepresentations is that rather than adapting development strategies to fit the drylands, considerable effort is expended on trying to adapt drylands to fit development strategies.

In order to address these shortcomings, a more nuanced vision is needed for the drylands. Such a vision must reflect the social and ecological realities of the drylands and provide a framework against which policies and investments can be judged. The following section offers four 'future scenarios' that should be components of a global vision for drylands based on the intersection between sustainable land management and biodiversity conservation:

1. Adapting green economic growth to the drylands
2. Sustainable biodiversity management and landscape connectivity
3. Land health as the basis for secure food and water provision
4. Resilience and risk management in uncertain environments.

Green economic growth in drylands

Green Economic Growth in the drylands will protect natural assets and maintain the provision of resources and environmental services on which growth and well-being depend. Green growth will be tailored to the environmental conditions of drylands, ensuring that dryland ecology is respected while unique opportunities for growth in the drylands are sustainably pursued. In this vision of Green Economic Growth in drylands, dryland biodiversity will become integral to economic growth rather than simply protected from it.

The related challenges of biodiversity conservation and resilient development will be addressed through an integrated development pathway that protects ecosystem services to ensure long-term sustainability. Green economic growth refers to economic growth and development that protects natural assets and maintains the provision of resources and environmental services on which growth and well-being depend. Green growth in drylands will be enabled through more systematic and comprehensive valuation of natural capital as a factor of production. It will be built on improved understanding of dryland ecosystem services and institutionalisation of their measurement. Green growth will require improved monitoring of the status of natural assets and the use of these data, for example to plan industry, urbanisation and other developments[180].

Green growth in the drylands will be based on longer-term decision making over public policy in order to reduce the path-dependency that can be created through short-term solutions. New tools and a change in attitudes and practice will enable planners to routinely gather and use projections on long-term environmental impacts and risks[181]. Planning decisions will be based on clear recognition of the real costs of development and the benefits of actions to offset those costs. In addition to greater foresight, economic planning will be based on improved awareness of the scale and complexity of socio-ecological systems, through the use of ecosystem approaches and stronger participation of multiple stakeholders, including rural and urban populations.

In order to ensure biodiversity protection, environmental concerns will be mainstreamed across all sectors. The role of environmental ministries in mainstreaming is crucial to green growth and their capacity will be strengthened to play a more meaningful role. Roles will include establishing environmental standards and ensuring capacity at different levels of authority and in different institutions to adhere to those standards. The uniqueness of dryland ecosystems will be factored into the development of environmental standards to ensure suitable development approaches, for example in the agricultural or water sectors.

Desert Village in Chad - ©Eco Images

Addressing desertification through sustainable management of biodiversity: the Great Green Wall

The Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI) is an effort by 11 Sahelian countries that has been established to address concerns of desertification and poverty in the drylands of the Sahel. The initiative provides an opportunity for dialogue on dryland management across a vast landscape that could demonstrate the way forward for implementing sustainable land management practices in other countries.

The Great Green Wall is ambitiously envisioned by many actors as a vast landscape of healthy, natural Sahelian rangelands – a diverse ecoregion of semi-arid grasslands, savannahs, dryland forests and thorn shrublands – providing sustainable livelihoods for millions of dryland inhabitants. The GGW will also promote biodiversity conservation through a great diversity of protected and sustainably managed areas, including private farms and forests, communal rangelands, reserves and community forests, community wildlife areas and national parks. The initiative provides an opportunity to safeguard biodiversity of great local and global importance, with emphasis on protecting local biodiversity rather than promoting non-native species that risk becoming invasive or impose a burden on ecosystem services.

The initiative offers both the political will for greater investment in drylands and the opportunity to distil the lessons of the past to ensure long-term sustainability of natural resource management in the Sahel. A number of initiatives that have been proposed to develop the GGW will focus on strengthening environmental governance in order to establish rules and regulation for natural resource management. Such rules have existed in the past in most Sahelian drylands, but over the past century have become weakened, or their enforcement has become obstructed. A variety of technological solutions to environmental degradation have been proposed, and indeed many are widely known to dryland resource users, but these are of limited value if the users cannot protect their resources from over-exploitation by others.

The GGW offers an opportunity to mobilise local and indigenous knowledge in tandem with science to strengthen land management strategies. Dryland communities are well aware of the vagaries of their environment and over centuries have developed ways of managing resources that have stood the test of time. Crop farmers have developed cultivars that are tolerant to water shortages and high temperatures, and protect trees in their farmland that promote soil fertility and provide shade. Livestock keepers have developed migration strategies and maintain variable herd sizes to track patchy and unpredictable resources. All resource users have developed elaborate social structures and economic practices to spread risk and promote resilience. These strategies will be supported in order to develop and evolve and they should play a central role in poverty reduction and environmental management.

Ankole-Watusi Cattle in Sudan - ©John Wollworth

Healthy dryland ecosystems and agricultural biodiversity are central for food security and poverty reduction, and poverty alleviation will remain an imperative in many dryland regions. Green growth will also address inequities in the drylands and will focus on eradication of extreme poverty found in some countries. In richer communities the role of biodiversity will be better appreciated and biodiversity protection will become central to land-use planning. Agricultural development strategies in all wealth groups will be established to meet food production needs without jeopardising the resource base in the long-term.

Innovation is essential for green economic growth and depends strongly on indigenous knowledge as well as the adaptation of science to the conditions of the drylands. Innovation will be enabled in the drylands through investment in education and local expertise and improved access to services including banking and finance. Dryland peoples will become less dependent on external expertise and will play a stronger role in emerging fields such as renewable energy or payments for ecosystem services. Innovations in the use of natural resources, from soil conservation practices and other land improvements to the use of alternative construction materials, will increasingly come from within the drylands.

Land tenure and governance will be strengthened in the drylands, providing a stronger foundation for environmental custodianship and for investment in sustainable natural resource use. Stronger institutions will enable wider adoption of payments for dryland ecosystem services, including carbon sequestration, water supply and water regulation amongst others. Other innovative approaches to rewarding ecosystem services will play a stronger role in dryland development, including better targeted investments in the sustainable use of biodiversity.

Conservation and sustainable management of dryland biodiversity

Considering the extent of drylands, their importance to food production, and the importance of agricultural (including pastoral) development for economic growth, conservation strategies will be broadened to capitalise on the environmental benefits of different farming systems. These systems will continue to rely heavily on indigenous knowledge and institutions and will be enabled by strengthening governance and empowering dryland peoples. This vision of dryland biodiversity management and landscape connectivity is one of integrated agricultural and environmental development, in which farming systems become tools for conservation and conservation becomes a tool for sustainable agricultural development.

As with green economic growth, conservation and sustainable use of dryland biodiversity depends on significantly improved recognition and valuation of dryland biodiversity. An integrated conservation and development strategy will depend on recognition of both natural and agricultural biodiversity, and will sometimes require compromises to ensure that both are protected. Recognition of this diversity will be integral to developing more sophisticated conservation and sustainable development strategies that recognise the conservation value of multiple land-use systems. Dryland conservation strategies will increasingly look at using protected area status as a mechanism for protecting both biodiversity and environmentally-friendly farming systems. It will also look beyond protected areas to strengthen conservation in sustainably managed agricultural landscapes, for example through greater legitimisation of Indigenous and Community Conserved Areas.

The role of traditional land-use systems, such as agroforestry and pastoralism, in providing food and income as well as protecting biodiversity will be strengthened and will become integral to national conservation strategies. Similarly, innovative agricultural systems that protect and support ecosystem services, such as new forms of conservation agriculture, will be protected for their environmental benefits. The importance of indigenous knowledge and institutions for environmental custodianship will receive greater legitimacy and support from government and will become the anchor of integrated agricultural development and conservation approaches.

Environment authorities will develop more elaborate conservation strategies, encompassing formal protected areas and community conserved areas that will have different environmental objectives. Appropriate governance and management options will be developed depending on whether the goal is protection of specific species, protection of specific ecosystem services, the promotion of overall biomass or the maintenance of corridors and landscape connectivity. Conservation strategies in the drylands will therefore encompass multiple sectors – including agriculture and water – and will revolve around a pastiche of conservation zones managed variously by government, communities and private individuals or companies.

Landscape approaches will be at the heart of dryland conservation, recognising that ‘the cultural and natural values of landscapes are inextricably linked, and that communities living in or near these landscapes are central to sustaining them’[182]. Dryland conservation will therefore hinge on the concept of stewardship, in which communities and individuals take collective responsibility for their environment. Much of the conservation of dryland biodiversity will take place in areas that are sustainably farmed, with environmental concerns at the forefront based on regulations agreed between farmers and conservation managers to ensure both agricultural and environmental goals.

Dryland biodiversity management will be enabled by significant investments in monitoring and communication. Time-based indicators for monitoring biodiversity will be developed or strengthened by specialised agencies acting as observatories and will be appropriately tailored to the scale and climatic conditions of the drylands. The Red List of Ecosystems will strengthen the use of ecosystem-based metrics as a tool in environmental planning. Monitoring systems will include climate, ecology, socio-economic trends and other indicators required for the development of models that will inform stakeholders about potential vulnerabilities, risks and hazards. The management of dryland biodiversity will be improved with better communication networks between multiple stakeholders including farmers, investors and different government agencies. Communication of threats to biodiversity and opportunities to respond will become essential tools in strengthening the roles of environmental stewards.

Land conservation and restoration as the basis for food and water security

The fundamental importance of land for food and water security will form the basis of integrated dryland ecosystem management. Land-use systems that protect and restore land will be promoted and land-related ecosystem services will be compensated. Global attitudes towards soil and land will change from treating soil as an unlimited resource towards seeing soil protection as a vital management strategy. Countries will adopt targets for conserving soil and achieving a long-term balance between land degradation and land rehabilitation.

The sustainable future of drylands is contingent on a major shift towards recognition and conservation of land as one of the fundamental determinants of ecosystem health and biodiversity. The process of soil formation and its relationship with biodiversity and other ecosystem functions will be better understood and this will influence land management strategies. New international targets will be agreed for conserving soil and achieving a long-term balance between land degradation and land rehabilitation, or ‘land degradation neutrality’, as proposed

©Clara Murueta-Goyena


Indian Spiny Tailed Lizard– ©Niraj Mistry

Saving the sanda: long-term conservation of the Indian spiny tailed lizard

The Indian spiny-tailed lizard or Sanda (*Uromastyx hardwickii*) is listed as vulnerable in the IUCN Red List. The Sanda is endemic to the arid region of the Thar Desert and the semi-arid parts of Rajasthan and Gujarat in the north-western part of the Indian subcontinent. These lizards live in clusters and each lizard excavates its own burrow that leads into a long tunnel and ends in a small chamber. Apart from serving as a refuge from predators, the burrow also provides shelter during nights and the long winter hibernation when the lizard plugs the mouth of the burrow with soil. Little is known about the life history of this species and much that is written is anecdotal. The adult lizards are considered herbivorous and feed on grass, flowers and fruits, whereas the juveniles have been observed to eat locusts in captivity.

The Sanda is of importance to local rural livelihoods: its meat is palatable while the oil (*Isanda ka tel*) is considered medicinal and is used as both an aphrodisiac and an antidote to joint pains. The lizards are usually captured by smashing or excavating the burrow and are immobilised by dislocating the spine and kept alive until required. Large numbers are believed to be traded for meat and oil, with many of them sold in the urban markets. The Sanda has been exploited for centuries, especially by the Bhil, Naik, Jogi and Baori who were quite literally the ‘lizard oil merchants’ but have more recently shifted to farm employment.

Currently, the most serious threat to this species appears to be habitat loss brought about by developmental activities such as canal irrigation, afforestation and urbanisation. From interviews conducted with hunting communities it appears that the volume of trade and exploitation of the Sanda has declined and no longer constitutes a major threat, primarily due to the enforcement of protection laws by the Rajasthan Forest Department. Conservation plans for the species have been developed, involving regular patrolling by the Rajasthan Forest Department and imposition of fines for poaching, formulation of a management plan for Thalar habitats (gravel plains vegetated by herbs and short grasses) and implementation of recommendations of the XI Planning Commission’s Task Force on grasslands and deserts.

by the UNCCD during Rio+20. This will generate the necessary commitment and support for sustainable dryland development, including the requisite financing from both public and private sectors.

Attitudes towards land and soil will change substantially, and measures of land degradation will be incorporated into routine land-use decision making. Technology and methodologies for monitoring land degradation will become increasingly accessible to dryland countries, and services will be established to make data better available to land managers. The status of land degradation, or its corollary land health, will be embedded as an indicator of sustainable development in rural areas.

Innovative farming practices that can reinforce the ecosystem services upon which they depend, such as conservation agriculture, will receive greater recognition from national governments. At the same time, the existing value of traditional practices such as pastoralism and agroforestry will be better recognised and supported by public policy. Better understanding of how these land-use systems contribute to soil formation will lead to policies and investments that promote such environmental services. Simultaneously, investments in these land-use systems will ensure that they continue to adapt and develop, and incorporate new relevant science and technology that contributes to sustainability.

Innovations in preventing land degradation and rehabilitating degraded drylands will boost agricultural productivity and reduce desertification in the drylands and low-cost approaches to soil rehabilitation and protection will be integrated into management strategies. Knowledge of the value and vulnerability of land in dryland agricultural systems will be strengthened and will contribute to mainstreaming land protection as an underlying agricultural development philosophy. Development planners and land managers will increasingly focus on soil-protection as an essential component of effective land management.

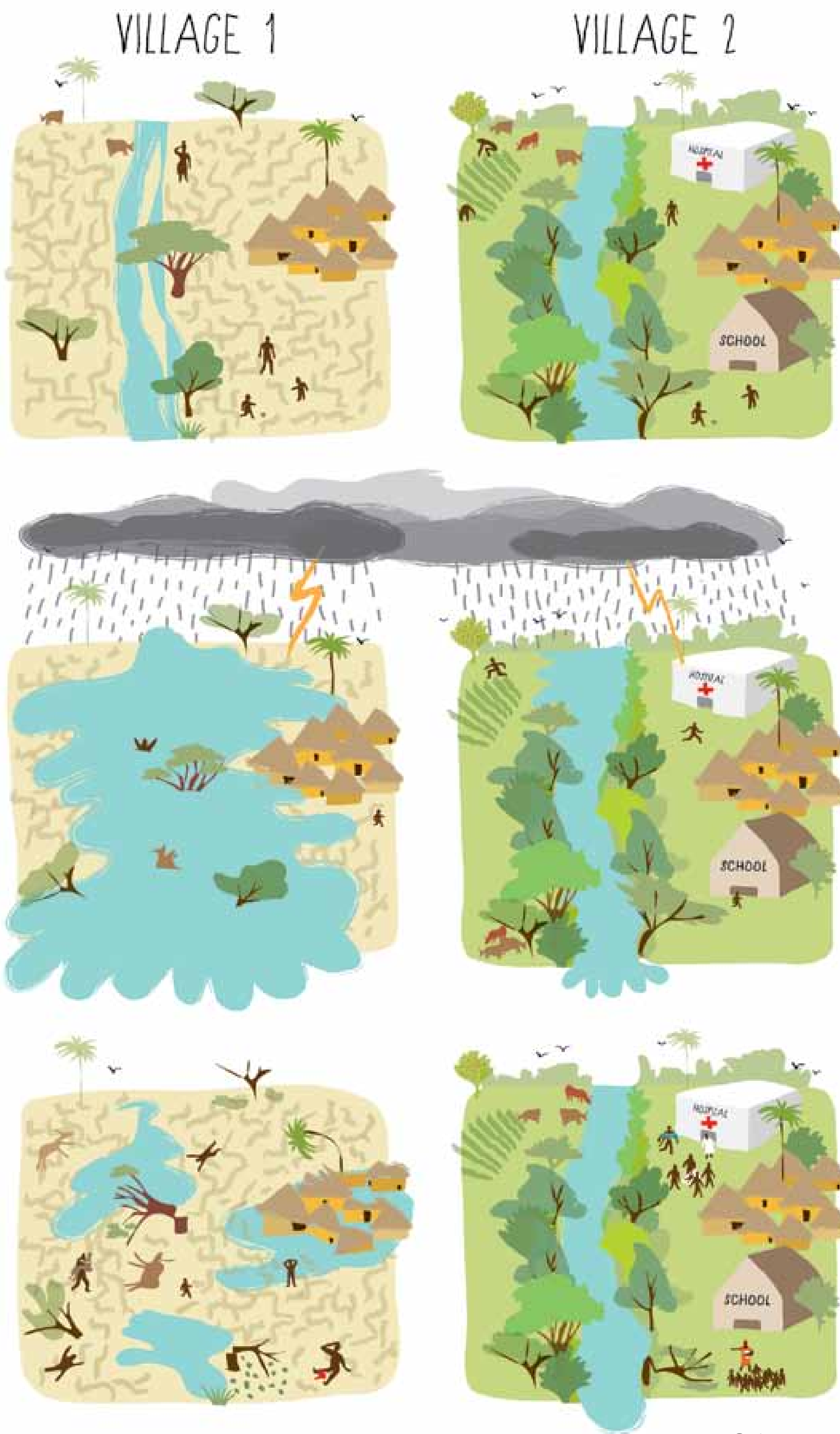
In developing regions, efforts to strengthen food and water security will be based on long-term ecosystem-based planning as well as strong participation with communities, ensuring that short-term and emergency interventions are not detrimental to long-term sustainability goals. More accountable and better integrated planning will become the building blocks for effective drought risk management and ecosystem-based adaptation. Specifically, planning in the water, agriculture and wildlife sectors will be closely integrated to ensure coherent ecosystem-based planning. Integrated planning processes will be built on greater respect for the rights and responsibilities of rural dryland communities, which will strengthen their resilience to shocks and trends (including climate change) and will enable them to become more food secure.

The vision for drylands is one in which food and water security is assured through integrated planning that takes ecosystem functioning into consideration. The biodiversity that underpins food and water security is protected through appropriate land use, and conservation strategies contribute to food and water security. This will be achieved through a global drive to raise public consciousness that our insatiable appetite for consumptive growth comes at a cost to the thin layer of soil that sustains life on land.

Balochistan: from policy to field

Balochistan is the largest but least populated and industrialised province of Pakistan with the lowest Human Development Indicators. The dryland province has a rugged and varied topography with denuded watersheds creating an extremely fragile environment where droughts are common and flash floods occur occasionally. Land degradation and poverty are rampant in an area where livelihoods depend mainly on crop and livestock agriculture.

Against this backdrop, the Government of Balochistan, with technical assistance from IUCN, developed and approved the Balochistan Conservation Strategy in 2000 as its long-term sustainable development framework. The Strategy addresses the vital issue of water availability and use through an Integrated Water Resource Management (IWRM) approach, which has supported the rehabilitation of traditional water management systems (*Karezes*), the introduction of sustainable agricultural practices and diversification of livelihoods. In coastal areas, mangroves and salt-tolerant plantations have been promoted as natural barriers to natural disasters and desertification. Working closely with communities, a large tract of Persian Juniper (*Juniperus excelsa polycarpos*) has been protected and efforts are underway to get the area declared as a Man and Biosphere Reserve. The local stakeholders have been equipped with requisite capacities to plan, implement and monitor these community-driven sustainable development initiatives. Studies on the impact of climate change in the drylands of the province have provided guidelines to tackle droughts and floods through traditional coping mechanisms.



Ecosystem management and conservation of biodiversity is key to strengthening resilience

Resilience and risk management

Conservation of dryland biodiversity through sustainable land management is at the heart of resilient dryland development. Resilient dryland development will encompass the dynamic relationship between ecological and social systems. Institutions will be strengthened as the basis for resilience, recognising that divergent resilience goals require more equitable negotiations between individuals, communities and states. Improved dryland ecosystem planning will mitigate potential drought emergencies and improved emergency response will ensure that short-term interventions are less harmful to long-term development goals.

Implicit in the previous visions is the overarching vision of resilient dryland ecosystems in which dryland development continues to adapt effectively. This is particularly relevant in dryland ecosystems since they are characterised by high levels of variability and subject to continuous processes of ecological transition. Resilience and adaptive capacity will be at the heart of sustainable dryland development and conservation of dryland ecosystems. Investments and policies will be better informed by an improved understanding of the many factors that determine resilience. Resilient development will recognise the multiple changes that influence the drylands, including emergence of markets, political changes, conflict, population change and climate change. Investments will be guided by recognition that resilience does not mean resistance to such changes, but the capacity to transform and adapt proactively[183].

Understanding of resilience and adaptation will be achieved by strengthening scientific research, improving communication of this research, and greatly increasing the use of indigenous or local knowledge in public discourse. This will help to identify investments that build adaptive capacities, in recognition that there are many forces of change in the drylands including some which cannot yet be foreseen. Empowering dryland people and institutions to make effective choices will become central to adaptation strategies, reflecting the complexity of socio-ecological systems and the uncertainty associated with adaptation choices. Communities and states will be more capable of managing the risks and taking advantage of opportunities that are presented by changing circumstances.

Biodiversity and ecosystem services underpin dryland resilience and therefore biodiversity protection will become integral to sustainable development. Dryland development will be based on an understanding of the dynamic relationship between ecological and social systems. In particular, the importance of connectivity and ecosystem integrity to ecosystem adaptation will inform development planning. Investments and policies will raise capacities to monitor and analyse imminent threats or opportunities and will enable institutions and individuals to make informed choices over how they respond. Strong emphasis will be placed on creating flexible and adaptive institutions that can manage the unpredictable and dynamic interaction between social and ecological systems.

Dryland development and conservation strategies will be strongly informed by improved monitoring of economic, climatic and environmental trends and risks. The ability to react to changes will be strengthened through greater capacity to interpret trends and shocks at the level of individuals, communities and institutions. Development will also address the underlying contributors to poverty and vulnerability in drylands, including marginalisation of dryland communities, demographic changes, weakening local governance, low public investment and the continued use of failed development approaches. Development strategies will preserve and enhance ecological and cultural diversity in dryland ecosystems to build resilience and reduce human-induced pressures that increase vulnerability to climate change.

Improved understanding of dryland ecology and the implications of climate change will lead to improved management of land and water and reduced risk of drought. Emphasis will be placed on ecosystem management to protect and enhance water cycling and to promote investments that are tailored to the constraints around water supply. Short-term measures to address the impacts of drought emergencies will become sensitive to long-term development plans, with, for example, emergency water interventions informed by ecosystem-scale long-term water development strategies. The importance of dryland biodiversity and the size of dryland populations demand that future global strategies for poverty reduction and environmental sustainability will be more strongly oriented towards drylands.


Horses in Mongolia - ©Pichugin Dmitry

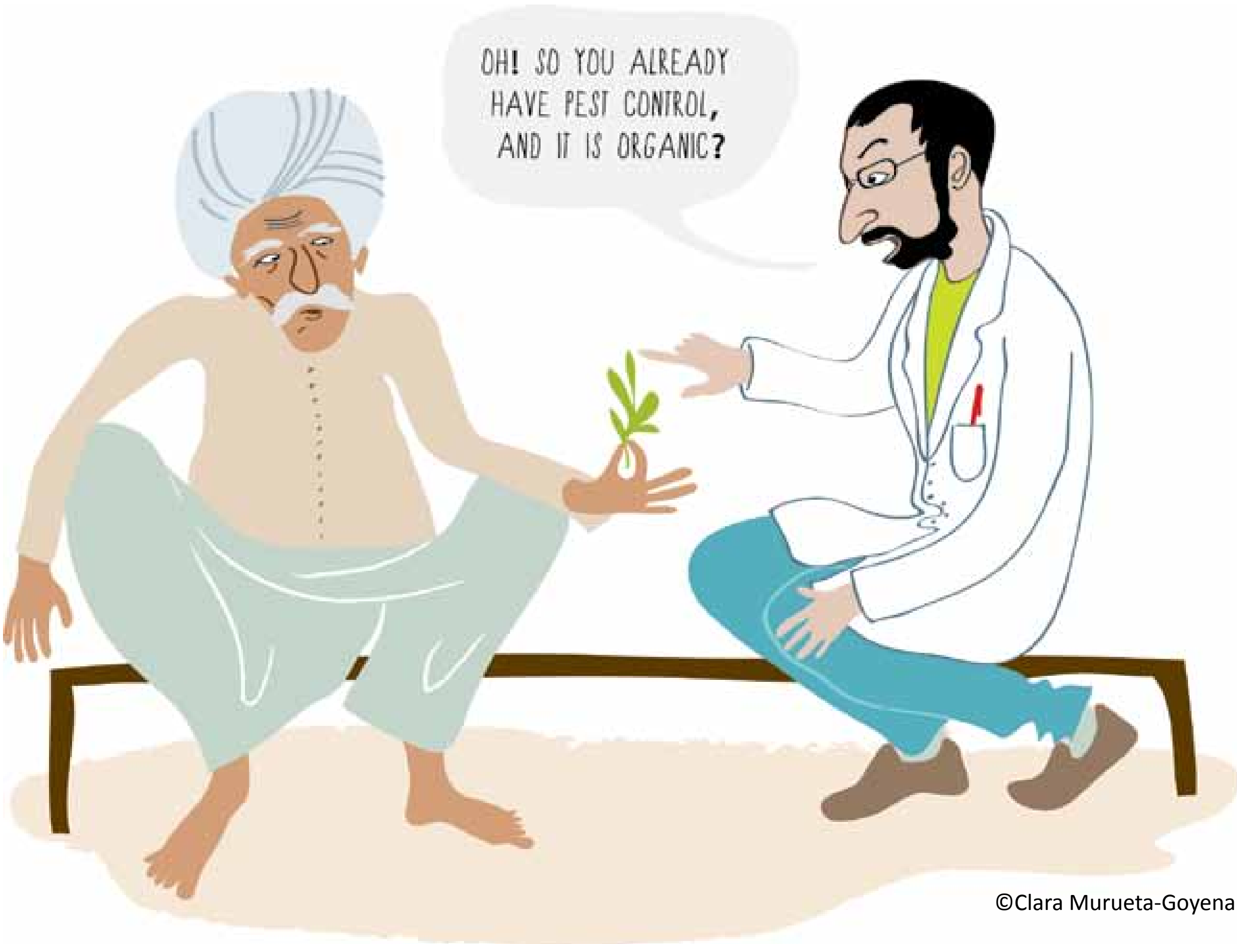
Investing in resilience in the Mongolian Gobi

Mongolia is among the world's fastest growing economies. It is a dryland country that includes the Great Gobi Desert – a World Heritage Site – and its grasslands are one of the few un-fragmented examples of one of the world's most threatened terrestrial ecosystems. Over the past 60 years, Mongolia has experienced an increase in annual mean temperatures of 1.8°C along with changes in the duration of heat and cold waves and changes in the pattern and predictability of rainfall. Ground water tables are falling in the driest areas and desertification has increased as a result of water shortages and reduced precipitation. Extreme weather events such as drought and blizzards (dzud) have also increased in frequency and intensity. These climatic changes impact heavily on the country's dominant rangeland economy and biodiversity.

Mongolia has a long history of sustainable pastoralism and its rangelands form a complex system of related political, economic, social, ecological and cultural subsystems, connected through community and family relations. The vibrancy of these related systems determines the overall resilience of the rangeland system, which means that strengthening resilience in the rangelands requires attention to a seemingly disparate range of sectors. Investing in Community Based Natural Resource Management offers a powerful opportunity to achieve this, through the empowerment of communities to make and enforce decisions over their resources, livelihoods and ecosystems.

Research has shown that the most resilient investment scenarios are those that simultaneously improve human welfare and cultural/ecological use of the landscape. Livestock intensification along the lines of so-called 'western ranching models' does not offer the best scenario. The ideal outcome is achieved through investment in traditional systems and modern technology. In particular, investments are recommended in communication and information technologies and in developing renewable energy. A green economy approach will strengthen both social resilience (including equity, institutions, leadership and trust) and ecological resilience (ecosystems and biodiversity)[184].

Mongolian Women - ©Chikto



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Strategies for dryland biodiversity conservation

The future scenarios that are outlined above require sustained investment in a broad suite of actions. Many dryland areas have been deprived of investment for decades and often the most basic steps still need to be taken, for example to strengthen primary education or penetration of markets. Fundamental questions remain unanswered and there is a gulf between the slowly emerging science on drylands and its application on the ground.

This section suggests strategic priorities for investment that will begin to deliver the scenarios outlined above. As was evident in the previous section, a number of major issues emerge as vital for progress towards these future scenarios and these constitute high value activities. Four major categories can be identified, although it is clear that these categories are mutually supportive and overlapping:

1. Innovation, knowledge and science
2. Incentives and investment
3. Governance and empowerment
4. Mainstreaming dryland biodiversity.

Innovation, knowledge and science

Science, knowledge and innovation are identified throughout this publication as important gaps that undermine conservation and sustainable management of dryland biodiversity. Drylands suffer in particular from a combination of limited understanding of dryland ecology and poor investment in applying science to the drylands. Although a modest body of dryland research is available it is often poorly employed in dryland development and conservation. Local and indigenous knowledge of dryland managers is often rich but is widely ignored in development planning and is even sometimes perceived as irrelevant or unreliable.

Both science and local or indigenous knowledge, when enabled through sound local governance, are essential for the effective conservation and sustainable use of land, as well as for innovation and adaptation. Field-level initiatives in many countries demonstrate how science and local/indigenous knowledge can be effectively combined to improve land management practices, but these approaches are sometimes rejected as unscientific and there would be value in improving the validation of local/indigenous knowledge and practices. Some stakeholders doubt the primacy of science and therefore do not consider scientific validation of local/indigenous knowledge as legitimate. To ensure support from a greater number of stakeholders, suitable processes of mutual validation are required through collaborative research involving communities, government and scientists.

The science of dryland ecology remains under-researched, but even the research that is available often does not find its way into policy making and investments in the drylands. Decision making in many countries continues to be influenced by non-dryland ecology and is poorly informed about issues such as climatic uncertainty, ecological flux and the relationship of drylands with herbivores and fire. A particular concern is poor understanding of the relationship between land management, water cycling and drought and there is an urgent need for better informed and more integrated planning of land and water resources.

Drylands provide many opportunities for investment in green economic growth, for example in renewable energy, better adapted crop varieties or improving soil rehabilitation technologies. However, solutions currently depend too heavily on capital and expertise from beyond the drylands. Local innovations should be more strongly encouraged, through better adapted education and training (academic as well as non-academic), information, finance, and other services that enhance local capacities. Innovations in the use of natural resources, from soil conservation practices and other land improvements to the use of alternative construction materials, need to be similarly encouraged from within the drylands. Support should also be oriented to boost entrepreneurship around new biodiversity-based business opportunities. This will necessitate the development of incentives based on secure and transparent policy, legal and financial frameworks.

Several global initiatives are underway to improve understanding and valuation of dryland ecosystem services, as discussed previously in this book. Different ecosystem services may be of greater or lesser importance in drylands and the most relevant datasets should be made available for decision making in the drylands. Studies into the economics of land degradation and drought will highlight the importance of sustainable land management

Standardising monitoring

Dryland ecosystems are highly vulnerable to climate change and land-use effects and therefore urgently require the implementation of standardised monitoring and assessment tools, which would allow timely prevention and adaptation actions at the various decision-making levels. However, changes in biodiversity and of species composition cannot be detected by remote sensing technology. It is therefore important to combine field analyses with data provided by remote sensing tools. The assessment of dryland biodiversity in different regions and under different land-use systems requires permanent terrestrial observation systems to be set up. These should operate on the basis of scientifically sound instruments and dedicated individuals, communities or other institutions that can ensure long-term regular monitoring.

Monitoring and assessment should be conducted through a standardised approach to allow for comparative evaluations and analyses at different scales, over regions and between continents. For example, the IUCN Red List of Ecosystems discussed earlier, will establish repeatable and cost-effective assessment criteria that will enable global, systematic and regular monitoring and assessment. With similar goals in mind, the international BIOTA AFRICA biodiversity monitoring initiative implemented a series of standardised biodiversity observation sites or ‘Biodiversity Observatories’ from southern to northern Africa[186]. These observatories provide insight to the effects of different types of land-use systems on the natural environment at various scales.

To ensure the long-term survival of these observatories, BIOTA AFRICA developed a non-academic training programme to include local land users in monitoring activities and provided opportunities for long-term and fulltime employment in research projects. These ‘para-ecologists’ have improved the dispersal of research-based knowledge on environmental sustainability at the community level and demonstrate the importance of local participation for both sustainability and enhanced outreach[187]. Although monitoring sites are spatially dispersed, they should be interlinked by the implementation of scientifically sound sets of biophysical, socio-economic and institutional indicators, which help to detect medium- and long-term changes rather than short-term rainfall induced fluctuations, for example in biodiversity or land-use intensity. These indicators should incorporate those identified by the CBD and the UNCCD in order to promote synergies.

and draw attention to the urgent need for investment in agriculture and soil productivity. Stronger science and knowledge are needed to make the case for green economic growth in drylands and there is a strong case for conducting a 'State of the World's Dryland Biodiversity' assessment.

There is a comparatively small body of work on dryland soils and their formation and there remains widespread disagreement among scientists and practitioners about what is successful in practice. A significant push is needed to reach consensus on how to protect and regenerate soil through land management and to develop extension services that can provide relevant technical advice to land users. The process of developing these services must also pay serious attention to the knowledge of dryland land managers to ensure that land management tools are coherent with local land management goals and livelihood objectives.

Greater understanding of what constitutes land health in the drylands and how it can be monitored is necessary to support improved decision making over sustainable land management practices. Existing methodologies for monitoring land degradation and soil condition need to be more widely applied and the data made available to land managers for use in routine planning. Data need to be made accessible at the local level at a scale that is useful to land managers, but also aggregated up to national level to enable effective monitoring. This will require standardisation to internationally accepted methodologies to allow comparability and use between countries and regions.

The lack of effective monitoring can limit government understanding of dryland biodiversity and the threats it is facing. To improve monitoring, relevant methodologies need to be developed and resources must be allocated to establish and maintain monitoring systems. Progress has been made on the former in recent years, for example through improvements in land degradation assessment and investments in monitoring endangered species[185]. Less progress has been achieved in institutionalising monitoring in the drylands of developing countries, where resources are scarce and competing demands are high. Improved research is needed to evaluate the effectiveness of different protected area types and conservation approaches, to assess values of dryland ecosystem services, and to track diverse threats such as changes in climate and population. Particular emphasis should be placed on monitoring dryland biodiversity and ecosystems and ensuring that they are represented in the global red listing process.

As noted above, data alone do not have the required impact to influence decision making processes. Significant measures need to be taken to inform decision makers of the uniqueness of drylands and the implications of neglecting them in decision making. The findings of research and monitoring should be made more accessible to a wider variety of decision makers, but equal attention must be paid to demonstrating how this information can be effectively applied. A significant improvement is also required in ensuring evidence-based policy making and greater emphasis is needed on translating knowledge into a policy-relevant format. Networks and knowledge platforms can play an important role in improving access to and exchange of information, and can facilitate stronger linkages between research and development institutions and between practitioners and policy makers. At the same time, greater emphasis should be placed on generating public awareness of the value of land and soil in drylands and the effective measures for its sustainable management.

Incentives and investment

Long-term underinvestment in drylands is manifested in the comparatively low performance against human development indicators in many countries. This underinvestment is reflected in low levels of education, weak infrastructure and poor penetration of other government services such as security. Low investment can undermine sustainable land management and conservation efforts in the drylands. Reversing land degradation and protecting biodiversity therefore requires significant multi-sectoral investments to establish conditions for sustainable growth, including investing in building human capital and reforming governance arrangements.

If awareness of national and local authorities and land users on the long-term costs of unsustainable land management practices is increased, they may be more inclined to adopt or continue with practices that are less harmful to the environment. However, this depends on overturning policies that favour less sustainable land uses and ensuring appropriate incentives for the more environmentally-friendly land-use options. In some cases incentives are required to compensate land users for possible short-term losses in production. Sustainable land management measures provide ecological and social co-benefits such as improved water quality, increased agricultural productivity, rehabilitation of degraded soils and ecosystems and improved biodiversity. Where land-use strategies present a win-win opportunity (environmental sustainability and economic growth) incentives may still be needed to redress the legacy of former harmful policies and investments or to rebuild appropriate governance, institutions and management arrangements.

Women Selling Papayas in Market in Nuba, Sudan - ©Africa 924

Sustainable land-use strategies, such as soil conservation practices or improved systems of transhumance, can also be incentivised by factoring costs of land degradation into decision making and establishing regulations to mitigate the long-term effects of unsustainable development. Market-based incentives have been successfully used in some countries to reward protection of biodiversity and ecosystems, for example strengthening market access for non-timber forest or rangeland products, or promoting eco-labels and other trademarks[188]. Investments to capitalise on biodiversity (e.g. ecotourism) have also proved to contribute to conservation goals, directly and indirectly, especially in the drylands of Africa. Investments can also be made in developing crops and livestock breeds that are adapted to the drylands and suited to low-environmental impact agriculture.

Payments for ecosystem services and other incentives for environmental custodianship have an important role to play in support of sustainable development and conservation in the drylands. However, many of these opportunities are constrained by insecure property rights and the lack of institutional arrangements to lower the transaction costs. Carbon sequestration is a prime example of this with huge potential to both capture and to hold carbon in dryland soils being squandered through weaknesses in property rights and effective institutional arrangements[189].

Emerging opportunities for green economic development and the global appetite for such growth present specific opportunities for the drylands. High levels of insolation and wind create unique potential for renewable energy development, which is already being explored in both developed countries (e.g. Spain, USA) and developing countries (e.g. Kenya), and provides opportunity for energy export, such as in North African states that aim to produce renewable energy for European markets. Particular caution needs to be exercised however in relation to hydroelectric power generation, considering the sensitivity of many drylands to water supply. Improved environmental impact assessments are required to factor in the downstream ecosystem and economic costs in drylands when upstream water use is modified, and particularly to addresses implications for seasonal resource access and drought management strategies.

Local risk management practices in dryland areas make an important contribution to adaptation in drylands and in mitigating the effects of desertification and drought. Traditional and contemporary management practices, such as conservation agriculture and agroforestry, help to prevent desertification, mitigate climate change and adapt its adverse impacts. There are significant opportunities for mitigation and adaptation that also deliver important environmental and socio-economic benefits. Adaptation strategies need to focus on more than climate change and recognise that adaptation to one threat has implications for how another threat is perceived. Greater attention is also needed to understand resilience as an emergent property of social-ecosystems, and to reduce policies and investments that lead to mal-adaptation and the resilience of undesirable states in the drylands, such as poverty traps or bush-dominated rangelands.

Diversity is central to adaptive capacities and resilience, including diversity of income sources, diversity of livelihood strategies, and diversity of social institutions and social capital. The importance of biodiversity for dryland safety nets should be factored into plans and this value of biodiversity needs to be taken into consideration at the ecosystem scale when land-use changes are made. Appropriate investment models for the drylands are often those that invest in multi-functionality across ecosystems rather than narrow sectoral investments in a few isolated pockets of high value resources.

Governance and empowerment

Good governance is essential to achieve the inter-related goals of security, poverty reduction and sustainable environmental management. The term governance refers to the powers and responsibilities to make and to implement decisions, and it therefore concerns the relationship between citizens and state. Significantly, environmental governance refers to who makes and enforces decisions over the management and use of resources and how these decisions are reached.

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Sustainable management and conservation of dryland biodiversity depend on governance at all scales. Land managers need to be enabled to exercise controls over their resources, while state institutions need stronger capacity to regulate resource use on a larger scale. Good governance requires these controls at different levels to be made more participative, transparent, equitable and accountable. Good governance also depends on the principle of subsidiarity, or delegating decision making and implementation to the lowest decision-making level possible.

In many countries, and particularly in the developing world, land managers in the drylands need greater support to enforce rules of sustainable land management. In some cases this means the right to manage the resources that they use, or the right to implement rules over resource use. In other cases they may nominally have the right of management or the right of exclusion, but require the skills and amenities to exercise these rights more effectively. It is clear that uncertainty over where responsibility for natural resource management lies is one of the principal factors in dryland degradation and biodiversity loss, and reversing this situation is essential to achieve sustainable land management and conservation[190].

New opportunities have emerged in recent years for improved dryland governance through national policies of decentralisation and related opportunities for improved participation. In reality these opportunities are frequently missed by communities who lack awareness, capacity and sometimes confidence in the process. However, the policies create valuable space for Civil Society to strengthen local governance, as a growing number of examples attest. In particular, there are opportunities, and a growing body of experience, in strengthening local institutions to play a stronger role in governing natural resources.

Customary institutions can be supported to strengthen governance at a local level in many communities, but policies of decentralisation do not achieve this on their own. Government also has an important role to play in legitimising or reinstating customary arrangements, for example through establishing land trusts, local conventions, conservation covenants or similar tools, and in many countries this requires a shift in attitudes that have historically been hostile towards communities from the drylands. Customary institutions have evolved through trial and error over time, are highly attuned to local livelihoods and resource challenges and have a high degree of local acceptability. Legitimising these institutions must go hand-in-hand with reversing historic discrimination of dryland communities and enabling them to take their place in national political processes.

Empowerment of one group in relation to the state should not be at the expense of another group, whether within the same community or in a different community. Good governance has to be built on the principle of equity and this includes gender equity within society as well as equity between societies. Ensuring good governance therefore requires a commitment to identifying all stakeholders, enabling continuous dialogue and negotiation among them, and ensuring that decisions are made with prior informed consent. At the same time, many dryland populations are undergoing dramatic demographic changes which have particular implications for gender equity (positive and negative) that need to be better understood and responded to.

Good governance also entails more effective negotiation of resource use within ecosystems such as river basins as well as sometimes across boundaries. This requires institutions that operate effectively at the relevant scales and across the relevant sectors, and can often be best achieved through a combination of state-supported institutions and local community institutions. In many cases, improved governance is needed across international borders, demanding greater regional and international cooperation and shared understanding of the ecosystem services and their values. This will benefit from stronger commitments to shared goals on biodiversity conservation and sustainable land management. The axiom that 'drylands make good frontiers' is reflected in the realities in many countries, and this demands greater attention to international dialogue about the constraints to sustainable dryland management that international boundaries present.

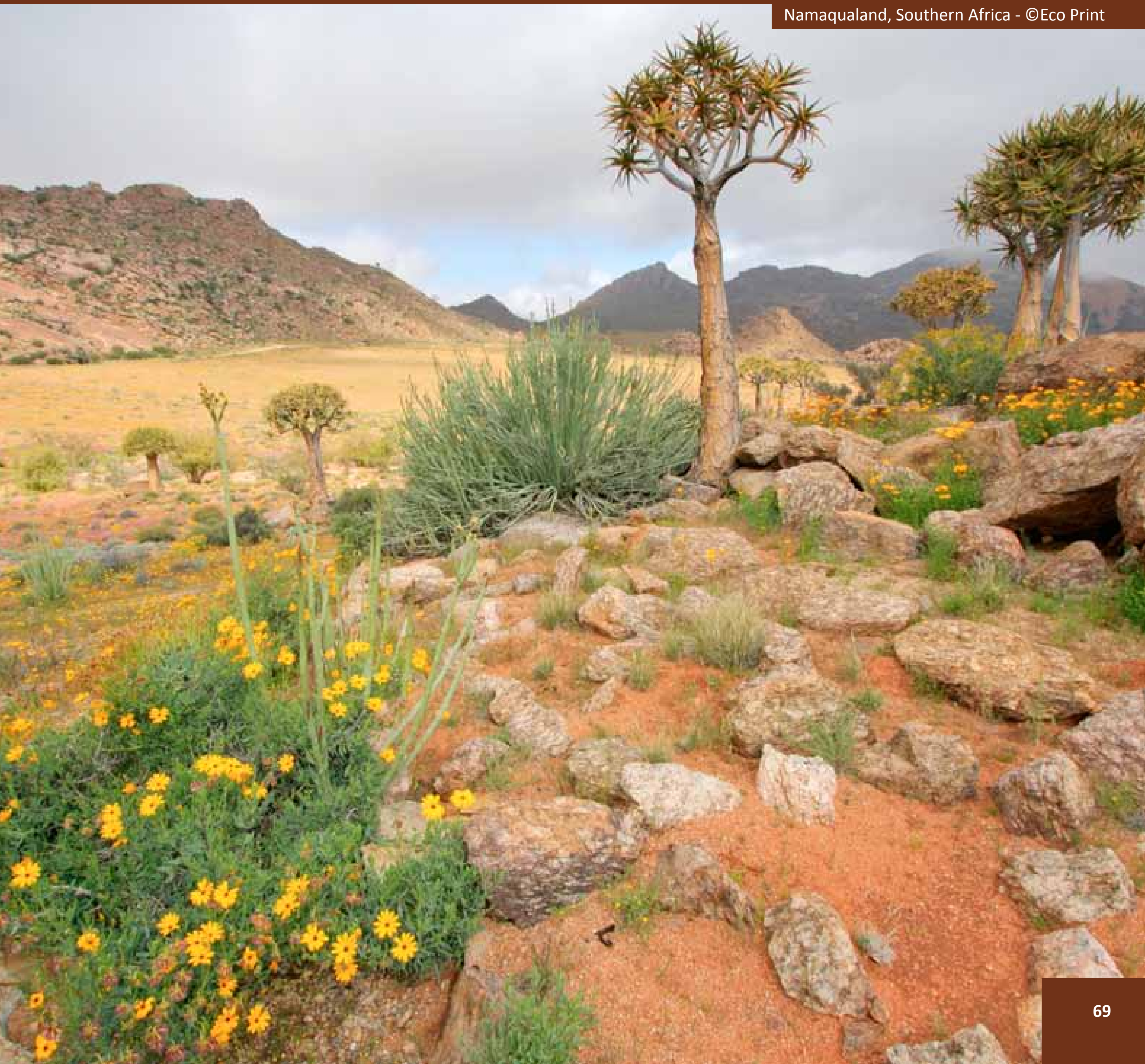
Fragmentation is a major driver of biodiversity loss and is accelerating in drylands, and a concerted effort is needed to maintain ecosystem connectivity[191]. The scale of drylands and the risk of investment in localised pockets that are seen as resource-rich (e.g. riparian areas or oases) pose particular threats to connectivity. Greater support for land-use practices that respect biodiversity and maintain biological corridors can overcome connectivity threats. Mobile pastoralism is an obvious example, but similar connectivity can be enhanced through agroforestry and other forms of agriculture that maintain natural biomass and protect underlying ecosystem services. Indigenous Community Conserved Areas have a particularly important role to play in dryland biodiversity conservation, since they recognise and build on traditional practices and capitalise on proven local governance arrangements that enable the use of indigenous knowledge.

Securing support for biodiversity: the launch of the Namaqua Biodiversity Sector Plan

The Namaqua District Municipality in the Northern Cape Province is the biggest district in South Africa and includes components of the Succulent Karoo, Nama Karoo and Fynbos biomes. It is an area of exceptional biodiversity, including Namaqualand (famed internationally for its impressive displays of spring flowers) and the Richtersveld (a region bordering the Namib Desert that is increasingly affected by mining activities). Due to its aridity, the area is sparsely populated, mostly rural and presents few economic opportunities to its mostly poor population.

The Namaqua Biodiversity Sector Plan was developed to inform land-use planning, environmental assessments, decision making, and natural resource management in order to promote ecologically sustainable development. The plan was used to raise awareness of the unique biodiversity of the region, the value this presents to people and the management mechanisms that can ensure its conservation and sustainable use. As a result of the intensive stakeholder engagement process, the plan was quickly taken up in the Integrated Development Plan and Spatial Development Framework of the Namaqua District, an important step in mainstreaming biodiversity into spatial development planning, thereby promoting conservation of dryland biodiversity, protection of ecosystem services and sustainable development.

Namaqualand, Southern Africa - ©Eco Print



The Dogon Valley, Mali - ©Jonathan Davies

Strengthening natural resource governance in Mali[192]

The semi-arid to arid Mopti Region of Mali lies predominantly on the south bank of the Northern Curve of the Niger River. In the districts of Douentza and Bandiagara the population is ethnically mixed and includes pastoralists and crop farmers, although fishing, bee keeping and forest exploitation also provide important natural resource based livelihoods. These resources have been collectively managed, based on historical negotiations between different ethnic groups who use resources in different seasons. However, nationalisation of natural resources, along with distrust between communities and government, has led to a widespread breakdown in the governance of natural resources, which has manifested in deforestation, degradation of water sources, pasture mismanagement, and increasing tension between communities.

Since 1991 Mali has pursued a policy of decentralisation that has enabled greater recognition of local resource management arrangements, transfer of power to local decision making structures, and greater participation of local groups and associations in decision making. In response to this opportunity, and in order to restore local management capacities over natural resources, the Near East Foundation supported the creation of 13 village associations and their aggregation into a larger association called Waldé Kelka Collective. The collective has been instrumental in changing the relationship between community and government, in strengthening inter-community relations and promoting participatory decision making.

A local convention has been agreed between collective members and the local government, which strengthens the rule of law and the transparency over local decision making and clarifies roles and responsibilities. This convention has contributed to reducing conflict over natural resources and provides a clear legal basis for governance-related decisions. With greater freedom to make and enforce decisions over resource use, local communities are experimenting with new approaches to protect and restore natural resources. Confidence in the overall governance arrangements has grown, along with confidence to engage with government services over natural resource management issues.

Landscape restoration and protection has grown exponentially in recent years, after 15 years of establishing rules and regulations. Isolated forest restoration pilot sites have been spontaneously replicated throughout the collective, through application of a range of different technologies (both natural and assisted regeneration). Water catchments and barrages have been restored, leading to expansion of small-scale market gardening and fishing, improved seasonal water access for pastoralists and investment in ecotourism to view the famous sacred crocodiles. Based on the successful regeneration of forest patches, communities are beginning to protect pasture zones and experiment with pasture management approaches and improved grazing systems. Investments in marketing of biodiversity-based products (e.g. non-timber forest products) are incentivising collective management of newly restored forest and wetland patches.

Given the sensitive nature of discussions around governance, Civil Society Organisations (CSOs) often play a pivotal role in mediating between communities and government. Governments can strengthen this role of CSOs by increasing the space for Civil Society in national and local dialogue and recognising the importance of their role in linking policy and practice. Governments can also promote multi-stakeholder platforms for decision making, particularly at the local level, and can sanction the role of CSOs in leading local initiatives for community-based dryland biodiversity management. Government should recognise the institutional flexibility of CSOs to operate across multiple natural resource sectors and beyond to achieve more holistic and integrated planning.

Poverty reduction strategies in drylands should factor in the importance of biodiversity for rural livelihoods by strengthening rather than undermining governance. Benefit sharing should also be promoted to avoid risks of appropriation of resources and elite capture as a result of development investment in a context of weak property rights and poor representation. Investments in conservation, particularly on communal resources, should adhere to the principle of prior informed consent, and rigorous processes of consultation and participation need to become the norm in dryland conservation.

Empowerment is at the heart of development and is a key factor in ensuring sustainable land management and biodiversity conservation. More empowered resource users will have greater capacity to make and enforce decisions over resource management, and are in a better position to factor-in long-term consequences of short-term actions that could undermine sustainability. Empowerment therefore needs to be seen as a principle of both conservation and development and can help to ensure compatibility between conservation and development goals. With a shift in emphasis, conservation can become a powerful contributor to poverty reduction. Although the dryland conservation sector finds itself critically short of resources, it often attempts to operate in isolation from the 2 billion dryland inhabitants. Dryland communities are by far the biggest global resource available for the fight against desertification and biodiversity loss and it is only through their empowerment that this resource can be mobilised.

Mainstreaming dryland biodiversity

Conservation of biodiversity and sustainable land management in the drylands is hampered by weak integration between sectors, which contributes to fragmentation of ecosystems, uncoordinated development of different resources and weak environmental-accountability. To protect ecosystems as the foundation of life and prosperity requires a concerted effort to manage them holistically. While this is true for all ecosystems, in drylands there are particular challenges of scale, communal governance arrangements and capacity gaps that must to be overcome. This can be achieved practically by mainstreaming environmental issues and a strong understanding of dryland ecology at all levels, from the farmer to the state and across borders, including in international treaties and through Intergovernmental Bodies.

Day to day land-use planning by farmers, pastoralists and other managers seldom respects the artificial division of resources between sectors. When decisions are made they are usually based – whether explicitly or intuitively – on the manager's understanding of water, land and other natural resources as well as the interactions between all of these. Land managers therefore deal with the complexity of their socio-ecosystem, based on their experiences of drought, resource degradation, disease, conflict and other concerns, as well as their diverse and varying goals of health, wealth and happiness. It is unusual to find government services that are equally holistic in their approach and that can respond to the multi-sectoral nature of dryland natural resource management. Complex systems such as those found in the drylands derive resilience from their complexity and diversity, and adjusting elements within these systems without awareness of the system-wide implications, as sectoral approaches do, often undermines the system[193].

Strategies are therefore needed to ensure more integrated and holistic planning of multiple resources, and to mainstream dryland biodiversity in rural development. This may be most feasible at the level of the land users, since they naturally operate in this way, and government institutions need to be tailored towards supporting and augmenting the skills of land managers. A priority is to greatly increase the use of tools that integrate the planning of land, water and biodiversity and to accelerate the adoption of effective participatory approaches by government services.

Mainstreaming dryland biodiversity in key sector strategies such as agriculture, or in poverty reduction strategies, can contribute to conservation and more sustainable use of biodiversity[194]. The ecosystem approach provides a framework for linking development and conservation and accommodating multiple agendas in a single landscape. It enables ecosystem services to be factored into planning in order to enhance the resilience and productivity of agro-ecosystems. National Biodiversity Strategy and Action Plans (NBSAPs) can play an important role in linking biodiversity and development priorities, including on dryland biodiversity issues[195].

Regional networking to strengthen transboundary dryland management

The drylands of the Gran Chaco encompasses northern Argentina, western Paraguay, eastern Bolivia and the Mato Grosso plateau of Brazil. This sparsely populated, hot and semi-arid lowland in the Río de la Plata basin is intimately connected to the famous Pantanal region, one of the world's largest wetlands. The Chaco has a great diversity of fauna and flora with sparsely vegetated dry zones, boreal zones and humid zones with savannah-type vegetation. The Gran Chaco has some of the highest temperatures on the Latin American continent and supports xerophytic deciduous forests as well as riverine forests, wetlands and cactus stands. It also has high faunal diversity including at least ten species of armadillos and the Chacoan peccary (*Catagonus wagneri*) which was thought to be extinct by scientists until 1975.

Large areas of the Chaco have fertile soil that is suitable for agriculture, despite the constraints of water availability, and clearance for crop cultivation creates significant risk of soil erosion. Livestock production is widespread and has traditionally made use of seasonal pastures, limited by the six months dry season. However, modern livestock development has led to clearance of large swathes of land to establish artificial pastures. Deforestation has also become widespread in areas.

Sustainable development challenges have motivated agencies in the Chaco region, from the countries of Argentina, Paraguay and Bolivia, to form the Redes Chaco, or Chaco Network. The network was established in 1992 to develop joint initiatives for sustainable agroforestry and to harness the support of thousands of small farmers and indigenous communities that inhabit the vast land. The network includes NGOs, universities and government agencies committed to facilitating regional dialogue and reaching consensus on the management of this transboundary resource. Dialogue has included regional discussions about water management, forest management and climate change adaptation strategies

To reverse declines in dryland biodiversity and to ensure sustainable land management require greater attention to the condition of land and soils. A concept of land health should be factored into agricultural sector policies and investments to ensure sustainability. Incentives and policies or regulations are required to promote integrated farming systems in which biodiversity conservation is an explicit agricultural output, whether to produce marketable goods or to receive payments for ecosystem services. The value of dryland ecosystem services needs to be understood in all sectors and appropriate measures should be implemented to mitigate the costs of reducing those services. This includes costs that are imposed outside of the drylands, which demands integration of resource planning from the local to the national and sometimes the international level.

Sustainable management of drylands also requires comprehensive and effective protected area systems. These need to draw upon a full range of management approaches, from strict protection to more open systems in cultural landscapes, and to consider all governance options, including state and private reserves, indigenous and community conserved areas, and various options for shared governance. Building social support for protected areas is essential. And while protected areas generally repay their investment in terms of biodiversity conservation, ecosystem services, social benefits and straight economic returns from tourism, many of these values are shared among many stakeholders as essentially 'free goods' so that they still require committed investment from governments and the international community.

Governments should increasingly look to champion the role of land managers as environmental stewards in 'Green Community Landscapes'. This stewardship would be constructed around customary practices and rules based on the community's cultural lifestyle, in which biodiversity use is regulated or prohibited, whether fully or seasonally, and in which resource pressure is carefully managed. Government can play a strong role in supporting these customs by both legitimising them and assisting communities to plan and regulate more effectively, for example through improved access to environmental monitoring or better oriented supportive investments. Indigenous and Community Conserved Areas and other community-based approaches to sustainable resource management deserve greater recognition for their land management and conservation benefits and should be made more central to national conservation strategies.

The role of environmental authorities should be adjusted in some countries to ensure that the authorities have the mandate and capacity to play a mainstreaming role. This includes acceptance in other sectors of the regulatory role of the environment authority as well as acceptance within the environmental authority that environmental actions are the mandate of other sectors.

Environmental authorities can play a much stronger role in adapting indicators for effective environmental monitoring in the drylands. This includes indicators of land degradation or land health, indicators of species diversity and range, and indicators of ecosystem health. Such indicators need to be employed more routinely in planning from the local to the national level, and also scaled up for global monitoring, for example through improved red-listing.

Institutions for mainstreaming dryland biodiversity may also be needed at the international level. Dryland biodiversity does not stop at the borders between countries. Activities or events in one country often have implications for biodiversity and landscapes across the border. However, most dryland countries are members of regional organisations that can facilitate movements between member states, which can include livestock movements through transhumance agreements. Similarly regional economic organisations like the Common Market for Eastern and Southern Africa (COMESA) or the Mercado Común del Sur of Latin America (MERCOSUR) can play a role in establishing standards and norms relating to the management of biodiversity, particularly in relation to regional agricultural production and trade.

At the global level, countries can make greater use of the environmental conventions that they have ratified, both to influence the policies and investments of neighbouring countries, as well as to strengthen calls for domestic action. Many countries would benefit from greater internal coordination of environmental dialogue, bringing the views of communities, civil society and scientists into national debates, both to promote national concerns globally and to strengthen their capacity to domesticate international agreements.

A call to action for dryland biodiversity

The global extent of drylands and the unique features and values of dryland biodiversity mean that no global solution for environmental sustainability – or indeed for poverty reduction – can be successful if dryland biodiversity is neglected. The long-term future of drylands must be one in which the land is managed sustainably to protect the biodiversity and ecosystem services upon which life and prosperity depend, both in the drylands and beyond. This is a vision of biodiversity conservation and sustainable management of land, including all agricultural landscapes, and it depends heavily on the resilience of the development process and of the ecosystems that sustain development.

Biodiversity conservation and sustainable land management must be made central to dryland development. When managed and used sustainably, dryland resources can facilitate rural poverty reduction and food security. The visions and strategic priorities outlined here provide a road map for the urgently needed action to protect dryland biodiversity and to switch to more sustainable dryland development pathways. Development needs to be better informed by the risk of losing dryland endemic species and ecosystem services and reducing the viability of wildlife populations.

Achieving a sustainable future for drylands requires an intentional change that recognises the protection and sustainable management of land as one of the major determinants of ecosystem health and biodiversity. The process of soil formation and its relationship with biodiversity and other ecosystem functions has to be better understood to influence land management strategies. International negotiations should include new targets for land and soil by achieving long-term balances between land degradation and rehabilitation, or 'land degradation neutrality", as proposed by the UNCCD Convention at Rio +20. This should be accompanied by a greater commitment towards drylands and their biodiversity, to increase public and private investment and improve local governance.

The conservation and development challenges facing drylands are enormous. Poverty in some regions is deeply entrenched, investment is low and drylands are not viewed as a national development priority. This book demonstrates how short sighted this view is and the significant costs that countries will incur if they maintain such a limited perspective. Dryland biodiversity underpins the livelihoods of large populations in many countries and allowing it to be degraded will condemn many people to greater poverty while undermining the only livelihood systems that can deliver sustainable land management at scale. Even in industrialised countries there is weak recognition that drylands are a source of high-value ecosystem services. Greater investment in these services should be made integral to newly evolving Green Growth Strategies.

The challenges of the drylands need to be tackled holistically and coherently from the local to the global scale. As the Millennium Ecosystem Assessment and the Millennium Development Goals have underlined, a disaggregated approach to conservation and development in drylands serves the interests of neither. This book highlights promising strategic multi-scale, integrated and holistic development actions for both development and biodiversity conservation in drylands. Long-term sustainability in the drylands can only be achieved through developing an equally long-term vision, ensuring that diverse dryland stakeholders own that vision, and investing in concerted action to manage the complexity and uniqueness of the drylands.

African lion (*Panthera leo*) - ©Jonathan Davies

Endnotes

1. Cardinale et al., 2012
2. Safriel et al., 2005
3. Smith et al, 2010
4. Safriel et al., 2005
5. Bonkoungou, 2003
6. SBSTTA, 1999
7. Redford et al., 1990
8. Packard and Mutel, 1997
9. UNEP-WCMC, 2011
10. Medina and Huber, 1992
11. The IUCN Red List of Threatened Species™ is the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species.
12. McNeely et al., 2001
13. The UNCCD Convention defines land degradation in Article 1 as: 'reduction or loss in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain fed crop land, or large, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns'.
14. Henwood, 2010
15. Dudley, 2008
16. IUCN, 2009
17. Roe et al., 2012
18. Middleton et al., 2011 ; Safriel et al., 2005
19. Safriel et al., 2005
20. Mortimore et al., 2009
21. Toulmin and Quan, 2000
22. Middleton et al., 2011
23. Desertification is defined by the UNCCD as land degradation in the drylands, caused by a variety of factors, including climate change and human activities.
24. Holtz, 2007
25. Reid et al., 2008
26. TEEB, 2010
27. Ntiamoa-Baidu, 1997
28. Mortimore, 2003
29. Schumann et al, 2002; Nosberger et al, 2000, Fan et al., 2008 ; Amundson, 2001 ; Grace et al, 2006 ; Conant et al, 2001
30. See for example Mortimore et al., 2009
31. Safriel et al., 2005
32. Source: UNEP-WCMC, based on IUCN Red List data and Hoffmann et al. 2010. Realms based on Olson et al. (2001) simplified biogeographical realms
33. Kreft and Jetz, 2007
34. Source: UNEP-WCMC, based on Conservation International dataset (2004) with additional hotspot identified in Williams et al. (2011)
35. Adapted from Safriel et al., 2005
36. UNEP-WCMC's 'A to Z Guide to areas of biodiversity importance' provides clarification on these varied terms: www.biodiversitya-z.org
37. Biodiversity hotspots from Conservation International dataset (2004) with additional hotspots identified in Williams, et al. (2011); World Heritage Sites based on the February 2012 version of the World Database on Protected Areas
38. To qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its original habitat
39. Mittermeier et al., 1998
40. Key Biodiversity Areas, Important Biodiversity Areas and Endemic Bird Areas obtained from Birdlife International (version Feb 2012)
41. Stattersfield et al., 1998
42. Alliance for Zero Extinction obtained from Alliance for Zero Extinction (2010) and Rickets et al. (2005) (obtained in Feb 2012)
43. Ricketts et al., 2005
44. See preceding text for details and sources
45. Ojeda et al., 2001
46. Source: UNEP-WCMC, based on Birdlife International (version Feb 2012) for Key Biodiversity areas and Butchart et al., 2012 for Important Bird Areas (IBA)
47. Zhang et al., 2003; Redak et al., 1998
48. SBSTTA, 1999
49. Ludwig et al., 1997 ; Slotow and Prins, 2003
50. Source UNEP-WCMC, based on Stattersfield et al., 1998
51. Kassas and El-Abyad, 1962; Canadell et al., 1996
52. Andersen and Krzywinski, 2007
53. Bond and Midgley, 2001; Garcia and Zamora, 2003
54. Warner and Chesson, 1985: 769
55. Harris et al., 2009; Milner-Gulland et al., 2011; Newton, 2008
56. Bekenov et al., 1998; Singh et al., 2010
57. Salomonsen, 1968

58. Åkesson and Hedenström, 2000
59. Holdo et al., 2011
60. Sinclair et al., 2007
61. Lawes and Chapman, 2006
62. Harris et al., 2009
63. MEA, 2005
64. Cecere et al., 2011
65. Barnard et al., 1994
66. Lushchekina et al., 1999
67. Nori, 2010
68. Manzano et al., 2005; Manzano and Malo, 2006; Manzano and Casas, 2010; Azcárate et al., pending
69. Notebaert et al. 2012
70. Groom, 1981
71. Huston, 1994
72. Trappe and Claridge, 2010
73. Mandeel and Al-Laith, 2007
74. El Tahir and Gebauer, 2004
75. Stolton et al., 2008
76. Brookfield, 2001
77. Source: FAO, 2011
78. A region of the world considered to be an original centre for the domestication of plants
79. Blench, 2001
80. Davies et al., 2010
81. Scoones, 1995
82. Davies and Nori, 2008; McGahey et al., 2008
83. Mearns, 1996; Warren, 1995
84. Niamir Fuller, 1999
85. Franklin, 1983
86. Wheeler and Laker, 2009
87. Wheeler and Laker, 2009
88. Lichtenstein, 2010
89. Falconer, 1994; Paloti and Hiremath, 2005
90. Webb et al., 1992
91. Harris and Mohammed, 2003
92. Mortimore, 1989
93. Sallu et al. 2010
94. Roe, 2010
95. Global Environment facility, 2010
96. Oldeman 1992; Middleton and Thomas, 1997; Lepers 2003, Bai et al., 2008
97. www.iucnredlist.org
98. WWF, 2003
99. Source: Alliance for Zero Extinction (2010) and Rickets et al. (2005) (obtained in Feb 2012)
100. Middleton and Thomas, 1997; Van Lynden and Oldeman, 1997; Lal, 2001
101. Rodriguez et al., 2011; IUCN, 2011
102. HRWG, 2011
103. TSSC, 2011; NSW Scientific Committee, 2004
104. NSW Scientific Committee, 2004
105. Keith et al., 2009
106. Thoms & Sheldon, 2000; Thoms, 2003
107. Kingsford and Thomas, 1995; Kingsford and Johnson, 1998; Sims, 2004; Kingsford and Auld, 2005
108. Taylor and Ganf, 2005; Price et al., 2010; 2011a,b
109. Robertson and Rowling, 2000; Reid et al., 2011
110. http://www.edgeofexistence.org/about/default.php and Isaac et al., 2007
111. MEA, 2005
112. Bonkoungou, 2001
113. Davies and Hatfield, 2008
114. Worldwatch Institute, 2009
115. Walker and Salt, 2006
116. Ondrasek et al., 2011
117. Ondrasek et al., 2011
118. FAO, 1997
119. Scoones, 1995
120. Davies et al., 2010
121. Davies and Hatfield, 2008
122. Davies et al., 2010
123. Savory, 1999
124. Behnke et al., 1993; Scoones, 1995
125. Niamir Fuller, 1999
126. UN-Habitat, 2011
127. BRP-NCRD, 2011
128. IPCC, 2007

129. IPCC, 2007; Stern, 2007
130. Davies and Nori, 2008
131. Mwangi, 2009; Hesse and Trench, 2000; Toulmin and Quan, 2000
132. Niamir Fuller, 1999
133. Cuskelly, 2010; Alden Wily, 2008 and 2011
134. Work, 2002
135. Invasive Species Specialist Group, 2012
136. Veitch and Clout, 2002 (eds.); IUCN, 2000
137. Pierce et al., 2002
138. Williams et al., 1995
139. Allelopathy is a biological phenomenon by which an organism produces one or more biochemicals that influence the growth, survival, and reproduction of other organisms.
140. Nigel Crawhall: personal testimony
141. Nettle and Romaine, 2000
142. Ghotge, 2010
143. IUCN, 2010
144. The World Initiative for Sustainable Pastoralism (the International Union for Conservation of Nature, the United Nations Development Programme and the Global Environment Facility)
145. Al-Jayyousi, 2010
146. FAO, 2011
147. FAO, 2011
148. White et al., 2000
149. Dudley et al., 2005
150. http://www.worldagroforestry.org/downloads/publications/PDFS/b09008.pdf
151. World Agroforestry Centre, 2009; Twomlow and Hove, 2006
152. Barnett et al., 2005
153. FAO, 2011
154. World Bank, 2006
155. Borrini-Feyerabend et al., 2007
156. Mearnes, 1996; Savory, 1999; McGahey et al., 2008
157. Davies and Hatfield, 2008
158. Kinnaird and O'Brien, 2012; ILRI, 2006
159. Mearns, 1996
160. Kinnaird and O'Brien, 2012
161. Kilani et al., 2007
162. Source: Mills et al., 2010
163. Dudley, 2008
164. UNEP-WCMC, 2011
165. Henwood, 2010
166. http://www.cbd.int/sp/targets/#GoalC
167. Cadman et al., 2010
168. http://www.iucn.org/about/union/commissions/ceesp/what_we_do/wg/tilcepa.cfm
169. Schneider and Burnett, 2000
170. Savory, 1999
171. MacKinnon et al., 2005
172. Tan, 1998
173. World Bank, 2010
174. WWF, 2003
175. Cissé, 2004
176. Child and Dalal-Clayton, 2004
177. Cotula et al., 2009; German et al., 2011
178. Chazdon, 2008; TEEB, 2009; Nellemann and Corcoran, 2010
179. Keck, 2012
180. UNEP, 2011; OECD, 2011
181. UNEP, 2011; OECD, 2011
182. Brown et al., 2005
183. Gunderson and Holling, 2002
184. Togtokh, 2011
185. United Nations, 2011
186. Jürgens et al., 2012
187. Schmiedel et al., 2010
188. UNEP, 2011
189. UNCCD et al., 2009
190. United Nations, 2011
191. Galvin et al., 2008
192. IIED, 1998; IUCN, 2010
193. Walker and Salt, 2006
194. SCBD, 2010
195. Bass et al., 2010; Smith et al., 2010

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