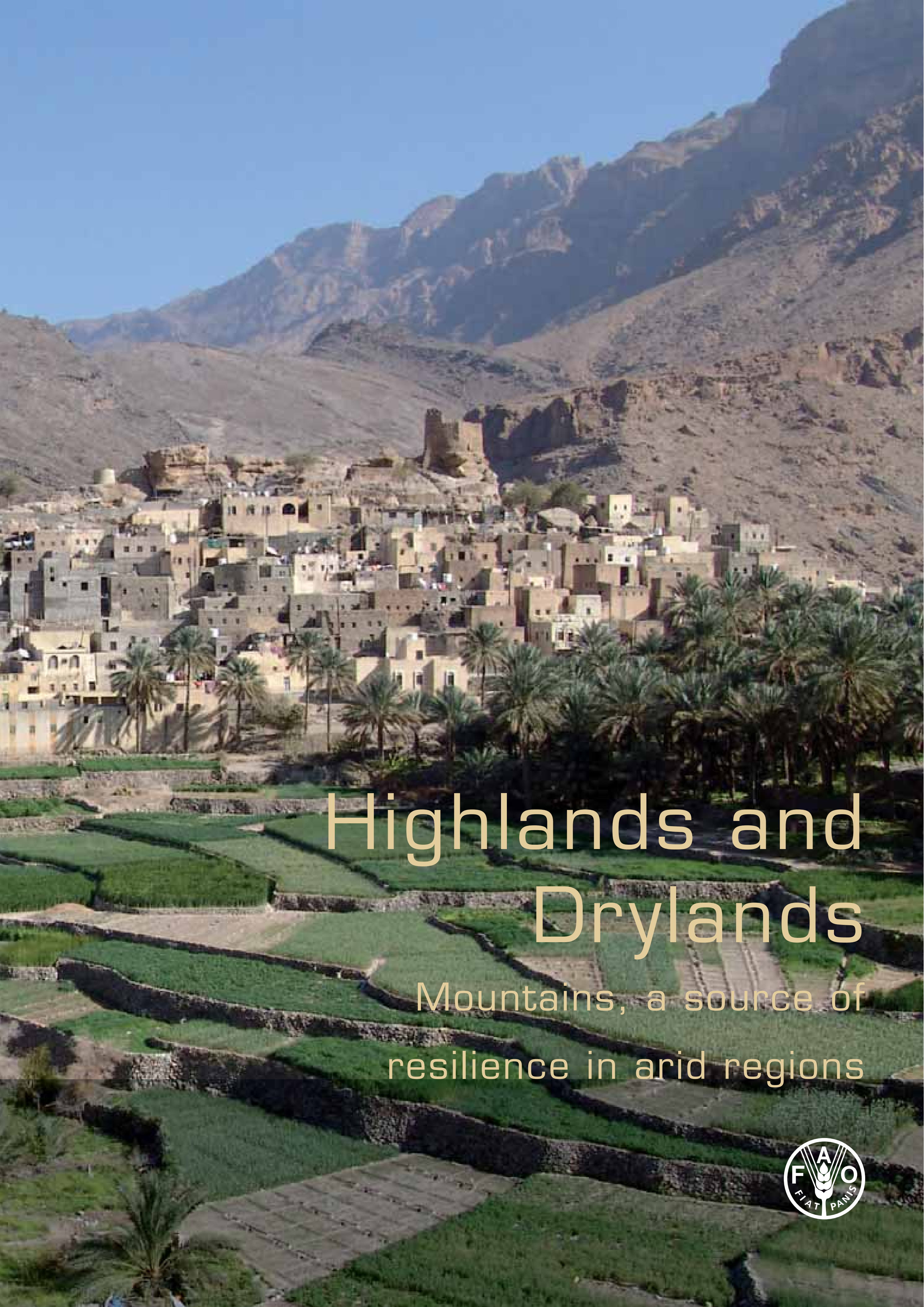

Highlands and Drylands

Mountains, a source of resilience in arid regions

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Mountains, a source of resilience in arid regions

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Cover photo: Mountain area, Oman (Daniel Maselli)

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Abbreviations and Acronyms

AARINENA	Association of Agriculture Research Institutions in the Near East and North Africa
ACS	Al Shouf Cedar Society
AGOCA	Alliance of Central Asian Mountain Communities
AI	Aridity Index
AKRSP	Aga Khan Rural Support Programme
BC	Before Christ
BP	Before Present
BR	Biosphere Reserve
C	Carbon
CA	Conservation Agriculture
CAMP	Central Asia Mountain Partnership
CAP	European Union Common Agriculture Policy
CAPE	Cape Action Plan for the Environment
CBD	Convention on Biological Diversity
CCA	Community Conserved Areas
CDE	Centre for Development and Environment
CDM	Clean Development Mechanism
CESAR	Centre for Environmental Studies and Research
COP	Conference of Parties
CSCW	Centre for the Study of Civil War
DRR	Disaster Risk Reduction
DSHL	Dry and Sub-Humid Lands
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIAHS	Globally Important Agriculture Heritage Systems
GLOCHAMORE	Global Change and Mountain Regions
GLORIA	Global Observatory Research Institute in Alpine Environments
Gt	Gigatonne
HA	Hectare
HFA	Hyogo Framework for Action
HKH	Hindukush-Himalaya
ICARDA	International Centre for Agriculture Research in the Dry Areas
ICIMOD	International Centre for Integrated Mountain Development
ICO	Eastern Training Institute
INTERREG	Inter-Regional Cooperation between EU Countries
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
IUCN	International Union for Conservation of Nature
JWP	Joint Work Programme
LMT	Lebanon Mountain Trail
MEA	Multilateral Environmental Agreement
MBR	Mountain Biosphere Reserve
MDGs	Millennium Development Goals
NAP	National Action Programme to Combat Desertification
NBI	Nile Basin Initiative
NEPAD	New Partnership for Africa's Development

NGO	Non-Government Organisation
NP	National Park
NRM	Natural Resource Management
NW	North-West
NWFP	Non-Wood Forest Products
ORNL	Oak Ridge National Laboratory
PA	Protected Area
PES	Payments for Environmental Services
PGR	Plant Genetic Resources
PoW	Programme of Work
PRSP	Poverty Reduction Strategy Paper
R	Rand
REDD	Reduction of Emissions from Deforestation and Forest Degradation
SBR	Shouf Cedars Biosphere Reserve
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
SDC	Swiss Agency for Development and Cooperation
SFM	Sustainable Forest Management
SLM	Sustainable Land Management
SMHRIC	Southern Mongolia Human Rights Information Centre
SWC	Soil and Water Conservation
TCP	Technical Cooperation Programme
TNC	The Nature Conservancy
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP/GRID	UNEP/Global Resource Information Database
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNODC	United Nations Office on Drugs and Crime
USA	United States of America
USGS	United States Geological Survey
WCMC	World Conservation Monitoring Centre
WFD	Water Framework Directive
WOCAT	World Overview of Conservation Approaches and Technologies
WWF	World Wide Fund for Nature
YR	Year

Acknowledgements

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Foreword

Since the Rio Earth Summit in 1992, mountain ecosystems and those who live in mountains have received greater visibility and attention than ever before. The striking beauty, ruggedness and isolation, as well as the enormous cultural diversity found in mountains, continue to fascinate many visitors. But these remote mountain regions have also become increasingly recognized as home to many of the world's poorest and hungriest people, where living conditions and livelihood opportunities are among the harshest and most difficult in the world. While the understanding and appreciation of the global significance of mountains is increasing - e.g. as the source of most of the world's fresh water and home to an invaluable wealth of biodiversity ranging from important food crops such as potatoes to medicinal plants of tremendous value – their political and economic support remains insufficient.

This general situation is even worse with regard to the world's dryland mountains. We actually still know very little about these important ecosystems, which represent more than one third of all mountains. Their role in fresh water supply, for example, is often much more significant than in wetter areas of the world, with up to 90 percent of fresh water being provided from the respective mountain systems. Poverty and food insecurity appear to be even more exacerbated in mountainous dryland areas while more than one quarter of the world's biodiversity hotspots are found in dryland mountain areas. Yet, these fragile ecosystems are under increasing threat from a variety of causes such as climate change, tourism, mining, and even conflicts. The populations and natural resources of dryland mountains are unique, both biologically and in their cultural diversity. In order to help reach the MDGs by 2015, investment in dryland mountain ecosystems are required today.

This publication aims at raising the awareness of the global role of dryland mountains by including these key ecosystems in important global processes such as in particular the UN High Level Panel on Sustainability (GSP), the Rio2012 Conference on Sustainable Development, and the forthcoming next biennium of the Commission for Sustainable Development (CSD) in 2013/2014. It also helps address the particularities of dryland mountains within the global process of the United Nations Convention to Combat Desertification (UNCCD). We are convinced that it is very important to flag the crucial role of dryland mountains in the global discourse on how to redefine and implement a truly sustainable development. We thus hope that through this publication, a concerted, long term effort can be generated in order to ensure that the political will is strengthened, new financial resources are mobilized and sustainable development policies and programmes at all levels fully recognize the importance of dryland mountains and their respective communities. Ultimately these efforts are meant to improve people's livelihoods and maintain the vital function of these key ecosystems.

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1 Introduction

Gansu Province, China (HP. Liniger)

Highlands of Eritrea (M. Gurtner)

Why this publication?

Dryland mountains are among the least-known environments in the world, and certainly one of the most overlooked by decision- and policy-makers.

Dryland mountains have an outstanding strategic value. They act as water towers for surrounding dry lowland areas, as shown by the examples of the Rocky Mountains of North America, the Central Andes, the mountains of the Mediterranean Basin, the Sahara and Sub-Saharan Africa, West Asia, and Central Asia

Drylands are home to more than 2 billion people – about 35% of the human population on Earth – and have some of the highest levels of poverty (47%). Although dryland mountains are often sparsely populated – with 296 million inhabitants globally – millions of people living in lowland areas depend on the water and other environmental services generated within these mountains. Global changes in these mountains will not only affect mountain dwellers, but also the livelihoods and welfare of a considerable portion of humanity.

Table 1: Population in all mountain areas and in dryland mountain areas

Population (millions)			
Continent / region	In dryland mountains	In all mountain areas	In dryland mountain as % of all mountain areas
Asia	197	338	58.3
Europe	1	4	25.0
North America	33	108	30.4
Africa	50	331	15.2
South America	15	64	22.6
Australia	–	–	
Oceania	–	–	
Total	296	847	35.0

Sources: USGS; UNEP/GRID, compilation S. Eckert / T. Kohler, CDE University of Bern

Over the past millennia, the ecological and social systems in dryland mountain regions have developed very successful strategies to withstand a number of environmental stresses including water scarcity – the main limiting factor to life. The adaptive knowledge and skill of dryland mountain people are increasingly recognised as key tools for coping with current and forecasted changes in climate – namely the exacerbation of extreme weather events. Dryland mountains may well become global change laboratories for monitoring the combined effects of climate and socio-economic changes, assessing the effectiveness of adaptation options, and proposing responses at local, regional and global scale.

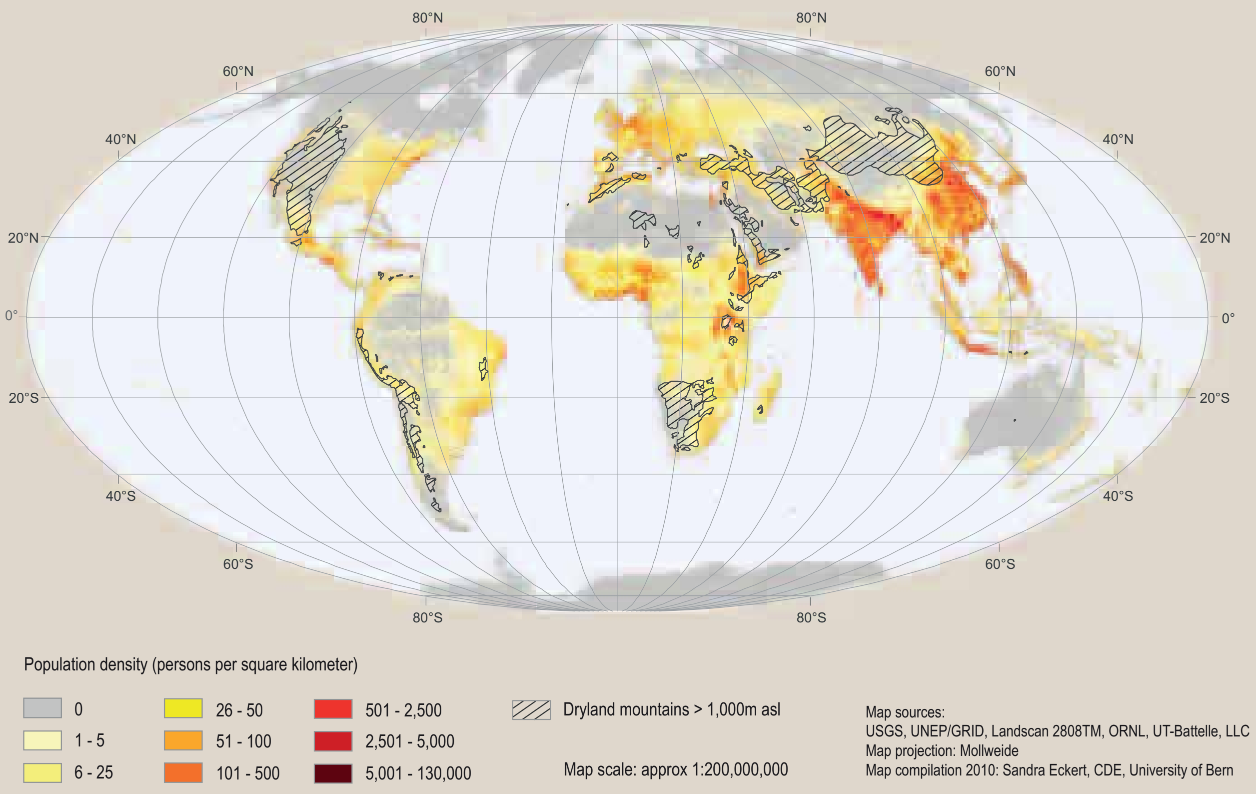
The majority of dryland mountain regions are outstanding in terms of biodiversity, but this extraordinary wealth is critically endangered by threats such as the over-exploitation of natural resources, land conversion into unsustainable land uses, altered hydrologic and fire regimes, pollution, unsustainable population densities, armed conflicts, and the invasion of exotic species leading to desertification processes. This explains why dryland mountains are considered a priority area of work for the implementation of the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD).

In the light of knowledge gaps and the lack of awareness of and attention given to dryland mountains, and as part of its activities to support sustainable mountain development, sustainable forestry and combat desertification in drylands, The Food and Agriculture Organization of the United Nations (FAO) together with key partners such as the Mountain Partnership Secretariat, the UNCCD Secretariat, the Centre for Development and Environment of the University of Bern and the Swiss Agency for Development and Cooperation, identified an urgent need to prepare this publication in order to:

- Provide an overall vision of the ecological, social and cultural features of dryland mountain socio-ecosystems, highlighting those processes and elements which have determined their resilience to past and present disturbances, describing current and future impacts, and offering a perspective on conservation and sustainable development based on successful examples from all regions of the world.
- Raise the awareness of development experts, donors and policy and decision makers about the relevance, extent, main challenges, solutions and good practices developed to address desertification and development issues in dryland mountain ecosystems worldwide.

The ultimate objective is to demonstrate the importance of investing human and financial resources in dryland mountains in the framework of the global effort to limit the impact of global change on the livelihoods of human societies and on the natural and cultural wealth of our planet.

Figure 1: Population distribution and dryland mountains



1.1 Contents of this publication

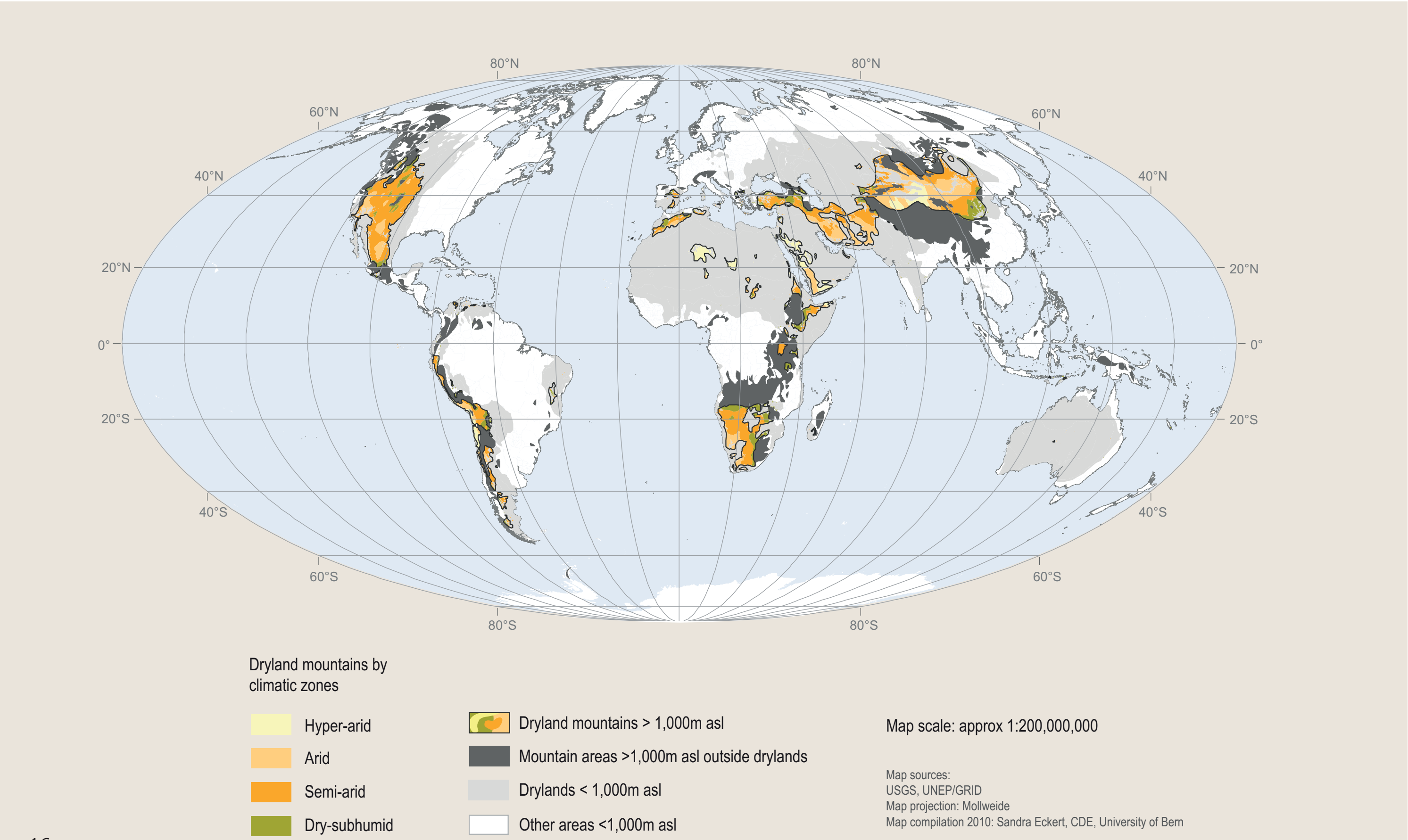
The present publication is structured into four main sections:

- The *environment, socio-economy, and culture of dryland mountains*. This section describes the physical, environmental, and ecological features, as well as the aspects related to the economy, resource management, culture, and conservation of these regions.
- The *decline of dryland mountains – impacts and threats.* This section features a detailed analysis of the most serious human-induced disturbances that cause the degradation of these ecosystems, including climate change.
- *Good practices for building the resilience of socio-ecosystems in dryland mountains.* This section gathers examples of case studies, available knowledge and experience, recommendations, policies and governance models that can inspire decision-makers and other concerned stakeholders towards improved and effective management of dryland mountains.
- In its final section, the publication concludes with the main *key messages and a set of recommendations* calling upon policy-makers, donors and other relevant actors to take urgent action.

1.2 Mountains in arid regions: defining the scope

The text of the UNCCD describes drylands as all the *arid*, *semi-arid and dry sub-humid areas*, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration, known as aridity index (AI) falls within a range from 0.05 to 0.65; this encompasses 34.9% of the Earth's land surface.

Figure 2: Drylands and mountains in a global perspective



Rainfed terraces, Atlas Mountains, Morocco (HP. Liniger)

The CBD definition of 'drylands' used within its Programme of Work on Dry and Sub-humid Lands (UNEP/CBD/SBSTTA/5/9) differs from the UNCCD definition in two ways (1):

- It also includes hyper-arid zones (UNEP/CBD/SBSTTA/5/9) (AI < 0.05), which represent approximately 6.6% of the Earth's land surface. All areas with AI less than 0.65 are therefore included; this encompasses 41.5 % of the Earth's land surface.
- Major vegetation types are used to define dryland areas in addition to those defined based on the climatic criterion (AI) (UNEP/CBD/SBSTTA/5/9). Hence, the CBD PoW not only applies to the biological diversity of drylands senso stricto, but also includes Mediterranean, grassland and savannah ecosystems (Decision V/23). These ecosystem types are present in some areas with AI ≥ 0.65, including humid and cold areas.

This publication uses the CBD definition, and thus includes all hyper-arid, arid, semi-arid and dry-subhumid mountain areas with AI ≤ 0.65. Under this definition, dryland mountains cover 12,723,995 km² worldwide (8.5% of the Earth's land surface), with the largest extension in Asia (almost 6 million km², covering 18.2% of the continent), North America (3 million km², covering 16.9%) and Africa (2.75 million km², covering 11.6%) (Figure 2 and Table 1).

Table 2: Dryland mountain area in Africa, Eurasia and America (> 1,000 m)

Dryland mountain area by dryland category	Africa		North America		Asia		South America		Europe	
	km²	%	km²	%	km²	%	km²	%	km²	%
Arid	377,731	13.7	429,176	14.2	2,302,858	39.2	191,823	19.6	0	0
Hyper-Arid	297,008	10.8	0	0	674,951	11.5	140,779	14.4	0	0
Semi-Arid	1,400,586	50.9	2,244,581	74.4	2,259,757	38.4	437,153	44.7	47,057	51.2
Dry-Sub-humid	678,056	24.6	344,846	11.4	642,978	10.9	207,699	21.2	44,824	48.8
Total mountain dryland area	2,753,381		3,018,603		5,880,545		977,454		91,881	
Area of continent	23,643,664		17,858,217,7		32,328,749		15,475,962		9,387,662	
Dryland mountain area in % of area of continent		11.6		16.9		18.2		6.3		0.9
In % of total mountain area		27.2		35.8		38.0		15.0		5.1

Source: USGS; UNEP/GRID, compilation S.Eckert, T.Kohler, CDE University of Bern

2

The Environment, Socio-Economy, and Culture of Dryland Mountains

Cardones National Park, Argentina (P. Regato)

Hillside terracing, Eritrea (M. Gurtner)

A challenging environment

Through the millennia, dryland mountains have been shaped by the severe environmental constraints of these regions, namely the combination of water scarcity, extreme and changing climatic conditions (i.e. frequent and intense droughts and heat weaves), landform heterogeneity with predominant shallow, poor, and steep soils, and seasonal changes in the spatial distribution of resources.

Large territorial units were required to maintain the functionality and sustainability of such vulnerable systems – both in ecological and socio-economic terms. An example of this is the upland-lowland seasonal movements of people, livestock, and wildlife to overcome the scarcity of seasonal resources and fulfil their needs in time and space. Through these movements, people, livestock and wildlife have influenced the structure, composition, distribution and dynamics of natural habitats in large territories, and contributed to the creation of very unique landscapes.

In order to truly understand the dynamics of dryland mountain ecosystems, it is important to realise that human influence has shaped them perhaps more profoundly than anything else on earth. The interactions and adjustments between these ecosystems and culturally rich societies have produced highly resilient interdependent social and ecological systems[1], thereby reducing the likelihood of abrupt regional changes. Thus, in order to avoid trespassing on the ecological thresholds that lead to abrupt undesirable landscape changes, it is also necessary to avoid crossing socio-cultural thresholds.

2.1 The climate and physical environment of dryland mountains

According to the Millennium Ecosystem Assessment (2), drylands are defined as those regions where evapotranspiration exceeds precipitation – no matter the amount of precipitation – and water scarcity limits the production of crops, forage, wood, and other ecosystem services. The climate conditions in dryland mountains usually differ from the dry climate zones in which they arise: the extreme conditions are exacerbated by the combined effect of aridity and extreme cold, and the sharp altitudinal gradients of temperature and atmospheric pressure that lead to the appearance of different climate zones and vegetation belts at reduced distances.


Carrying firewood, Eritrea (M. Gurtner)

Dryland mountains are found in most of the world's biomes and climate zones:

- Tropical and sub-tropical mountain grasslands, shrublands and forests, with semi-arid to sub-humid, warm year-around climate, and seasonal rainfall occurring once during the year, sometimes in a time lapse of just a few weeks;
- Tropical and sub-tropical mountain deserts and xeric shrublands with hyper-arid to arid hot climates. The cold ocean currents flowing from the poles to the Equator affect the western coastal margins of the continents, causing low sea-surface evaporation and low precipitation, often in the form of fog;
- Mountains with a Mediterranean climate characterised by warm and drought-prone summers, and cold to very cold, rainy winters, found at 30º-40º latitude on the western coast of all continents and hemispheres;
- Temperate mountain deserts and steppes with arid to semi-arid, continental, extreme winter-cold climate. The continental effect towards the centre of the large landmasses favours aridity and more variable and extreme temperatures.

For the sake of simplicity, we have grouped the world's dryland mountains considered in this publication into 6 blocks:

- North-west America, including the dry mountains of central and northern Mexico, the rocky mountains and coastal ranges in the west of the USA, and the hyper-arid mountainous deserts between Mexico and the USA;
- Central Andes, including the cold and dry Andes of Bolivia, Peru, Chile and Argentina, and the western slopes of the Chilean Andes with a more Mediterranean-type climate;
- The Mediterranean Basin, including an important number of isolated continental and island mountain ranges in southern Europe, North Africa and the Middle East;


Threshing grain, Bolivia (S. Rist)

- The hyper-arid Sahara mountains, and the Sub-Saharan African mountains between the Ethiopian highlands and South Africa;
- The dry mountains of West Asia, including those of the southern Arabian peninsula, and the large mountain ranges between eastern Anatolia and the Himalaya[2];
- The very cold and dry mountains and high plateaus of Central Asia.

We shall not take into consideration those dryland mountains that may exceptionally occur in humid regions. Likewise, dryland regions with low elevations, such as the case of south-western Australia, are not included here.

2.2 Hydrology: a key feature of dryland mountains

Water is obviously the most serious limiting factor to life in drylands. It is no surprise that early human development in these regions was based on the innovative management of mountain water resources to overcome water scarcity (Box 1).

In semi-arid and arid regions, mountains are the only areas with sufficient precipitation to generate runoff and groundwater recharge. In fact, dryland mountains are often considered the "water towers" or "water castles" that store water and regulate runoff, extending their influence over large and often distant territories (12). Mountains play a key role in the hydrologic cycle of dryland regions, and are the source of many of the world's greatest rivers – from the Nile to the Colorado, to the Yantze, the Mekong, and many other rivers in Southeast Asia. It thus can be argued that these mountains play a key water-supplying role for a large portion of the world's population (Figure 3).

Water in dryland mountains occurs in different forms: glaciers and snow packs, freshwater and salty lakes, ephemeral and permanent rivers, and underground water.

Box 1 | Hydraulic societies in dryland mountain regions

The presence of sophisticated, high technological, large-scale hydrologic and agriculture water harvesting infrastructures since ancient times in all dryland mountain regions illustrates the ability of mountain peasants to overcome environmental constraints and make wise use of the resource most vital for life – water.

The first evidence of groundwater harvesting as an adaptation to climate change in north-western USA is the prehistoric wells excavated by the Clovis people around 11,500 BC, in response to a period of drought that occurred during the Pleistocene-Holocene transition (13). In south America, the Inca civilisation developed a "hydraulic state" or "watershed management-based state" with highly sophisticated terraces and water provisioning systems (14).

The ancient method of groundwater management known as *qanat* dates back some 5,000 years, and it is still in use nowadays (15). The *qanat* system, which is in place in North Africa and West and Central Asia, takes advantage of natural gravity to bring water from "mother wells" – usually excavated at the foothills of dryland mountains – to the lowland arid lands, through a network of underground tunnels connected to well-like vertical shafts (15). Over centuries, this system enabled the establishment of thousands of villages and towns around green oases.

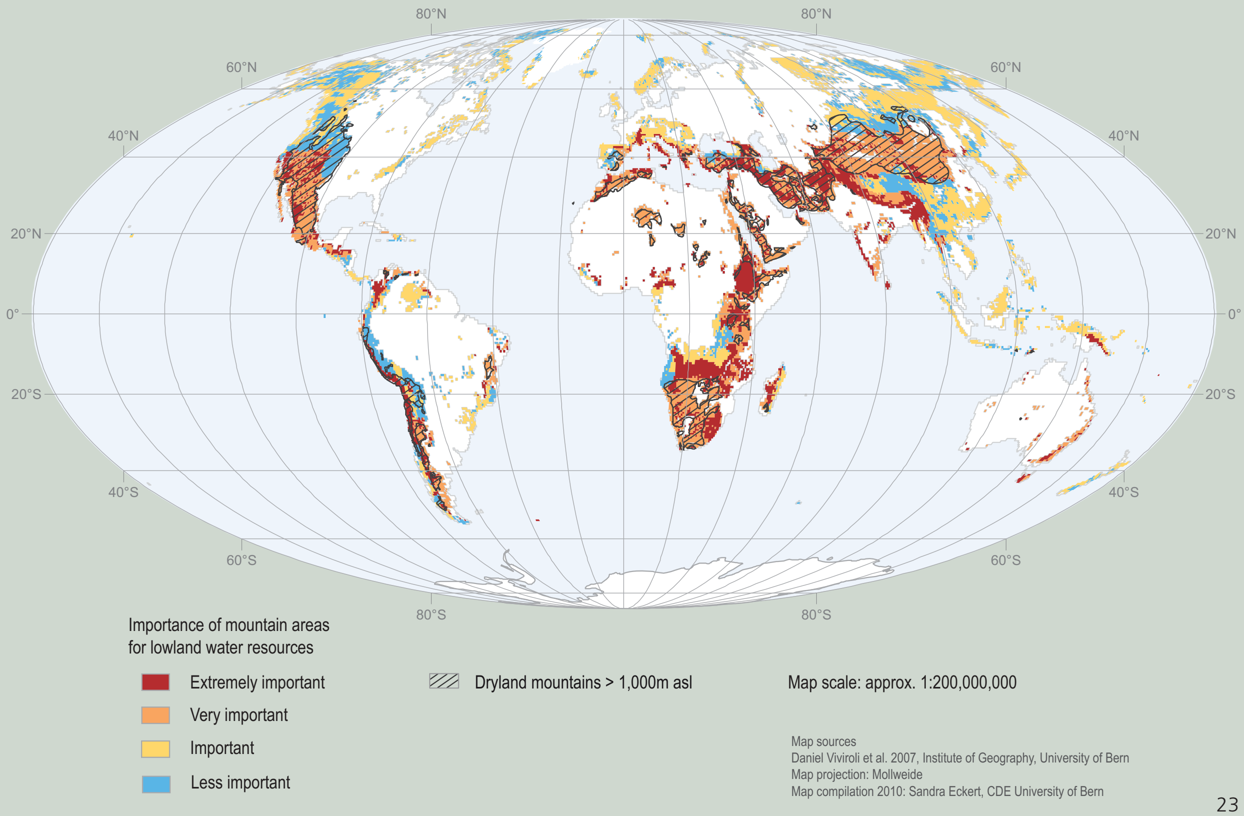
Source: Pedro Regato

Glaciers and snow packs

Glaciers act as natural stores of water in the form of ice and snow, which regulate and retard a gradual discharge, and control the runoff of rivers, especially in the dry season. Some relevant features about glaciers in dryland mountain regions are:

- More than 99% of all tropical glaciers are located in the Andes (16). Countries such as Bolivia and Peru rely to a great extent on freshwater from glaciated basins during the dry season (17). The amount of water stored in the central Andes between Santiago (Chile) and Mendoza (Argentina) guarantees the water supply to the agglomerations of Santiago (5.3 million inhabitants), and Mendoza (1.1 million inhabitants), and to the surrounding, irrigated farmland (18).

Figure 3: Mountains are the water towers of dryland areas



Gorge and glaciers, Tajikistan (S. Eugster)

- With a total surface of 580 km^2, the Rocky Mountain glaciers in the western USA store water and provide much of the stream and river flow in the dry summer months (19). With the exception of the wettest states of Washington and Oregon, dryland mountain glaciers occur in 7 states with a total area of about 162 km^2.
- Large parts of Central Asian mountain summits are glaciated and ensure a year-round water supply to millions of people. For instance, glaciers in the north-western mountains of China supply 15-20% of the water to over 20 million people in the Xinjiang and Qinghai provinces alone (20).

Ephemeral and endorheic[3] rivers

Ephemeral rivers and endorheic basins occur in all dryland regions. In these ecosystems, a layer of unsaturated soil acts as a natural filter for pollutants and decreases the risk of direct pollution from their immediate surroundings (21). Groundwater recharge is one of most important functions of floods in ephemeral rivers. People living in drylands depend greatly on groundwater and ensure their yearlong supply by pumping water from the riverbed. These systems are hydrologically fragile and subject to increasing human and development pressure (21).

Groundwater

Water runoff from snowmelt and rain falling in dryland mountains is stored in the surrounding lowlands in the form of groundwater. The water running in rivers from mountainous areas to the interior basins of NW China, for instance, accounts for 70–80% of the total groundwater recharge (22).

Groundwater in drylands is mainly used for irrigation, exceeding a rate of 80% in countries like Saudi Arabia, Tunisia, South Africa and Spain (22). Groundwater is also an important source of human water supply in drylands, and it is likely to become even more important under current climate change predictions. In California, the largest user of groundwater in the USA, about 43% of all citizens obtain drinking water from groundwater (23).

As demand increases, the potential for conflict over the use of mountain water grows. Careful management of mountain water resources must therefore become a global priority in a world fast moving towards a major water crisis.

2.3 The biodiversity of dryland mountains

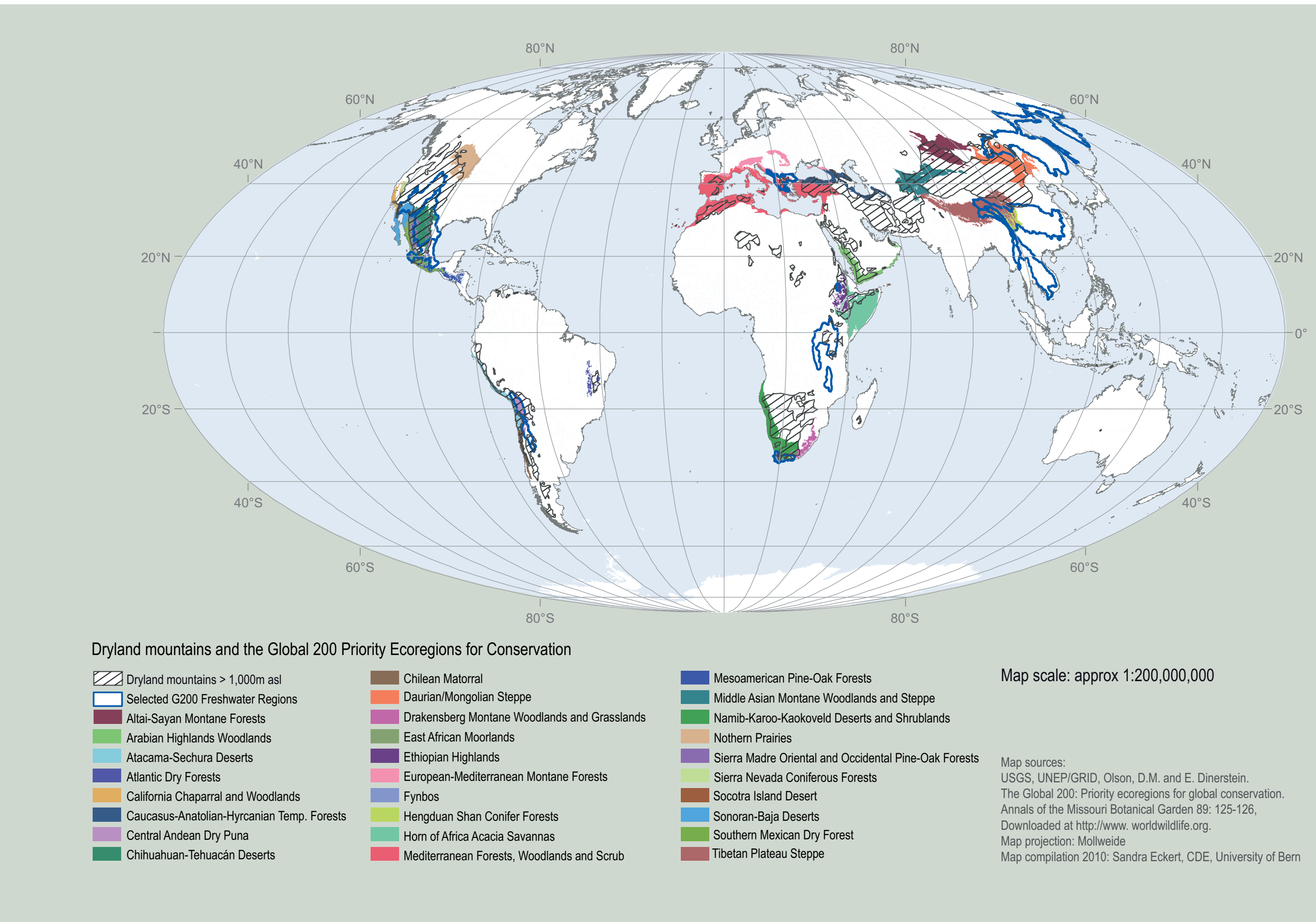
Species and ecosystems in dryland mountains are the outstanding result of unique evolutionary phenomena, as they have developed very effective strategies to cope with environmental constraints such as water scarcity, extreme hot and cold temperatures, and un-predictable long drought periods with sporadic rainfall. These species and ecosystems are highly resilient in the face of extreme weather events and disturbances and are of great significance in the context of climate change.

Dryland mountain regions are represented in 9 out of the 34 biodiversity hotspots (4). They include two of the most globally important regions for plant endemics: the Tropical Andes and the Mediterranean Basin. Mediterranean dryland mountains, for instance, have very high rates of endemism of above 20%.

The World Wide Fund for Nature (WWF) analysis of global patterns of biodiversity (5) yielded 238 priority ecoregions – the so-called *Global 200* – where effective conservation could help preserve the most outstanding and representative habitats of the planet. According to this analysis, most dryland mountain regions are associated with 40 terrestrial and freshwater *Global 200* ecoregions on all continents (Figure 4).

The following "dryland mountain" ecoregions host outstanding freshwater biodiversity and generate environmental services – especially freshwater – which are vital for vast lowland regions (5):

Figure 4: Dryland mountains and the Global 200 Priority Ecoregions



- The high mountain lakes of the Central Andes, the Sierra Madre in Mexico and the Ethiopian highlands host many endemic fish, amphibians and invertebrates, and are critical areas for migratory and resident bird species, such as the three threatened Andean flamingo species. They are all considered highly fragile due to climate change and human pressure (tapping of aquifers for agriculture, mining, pollution).
- The rivers and streams of the South African Cape, the Eastern Mediterranean Basin, and the Colorado watershed in North-west America have many endemic fish species. They are all substantially altered by regulation systems (dams) for hydropower, irrigation and drinking water supply.
- The catchment areas of some of Asia's largest rivers (i.e. Yangtze, Mekong) and Lake Baikal are all found in the Central Asia dryland mountains.
- The xeric basins in the highland steppes of Central Anatolia with their many endemic fish species, and the Chihuahuan desert in north-west America, one of the most globally outstanding aquatic desert systems, are threatened by excessive pumping for irrigation and by pollution.

Table 3: Biodiversity hotspots in dryland mountain regions

Biodiversity hotspot	Endemic plant species	Endemic bird species	Endemic mammal species	Endemic amphibian species
Tropical Andes	15,000	110	14	363
Mediterranean Basin	11,700	9	11	14
Cape Floristic Province	6,210	0	1	7
Madrean Pine-Oak Woodlands	3,975	7	2	36
Horn of Africa (including also parts of Saudi Arabia, Yemen and Oman)	2,750	9	8	1
Irano-Anatolian	2,500	0	3	2
Succulent Karoo	2,439	0	1	1
Chilean Winter Rainfall - Valdivia	1,957	6	5	15
Mountains of Central Asia	1,500	0	3	1

Source: Myers et al, 2000 (4)

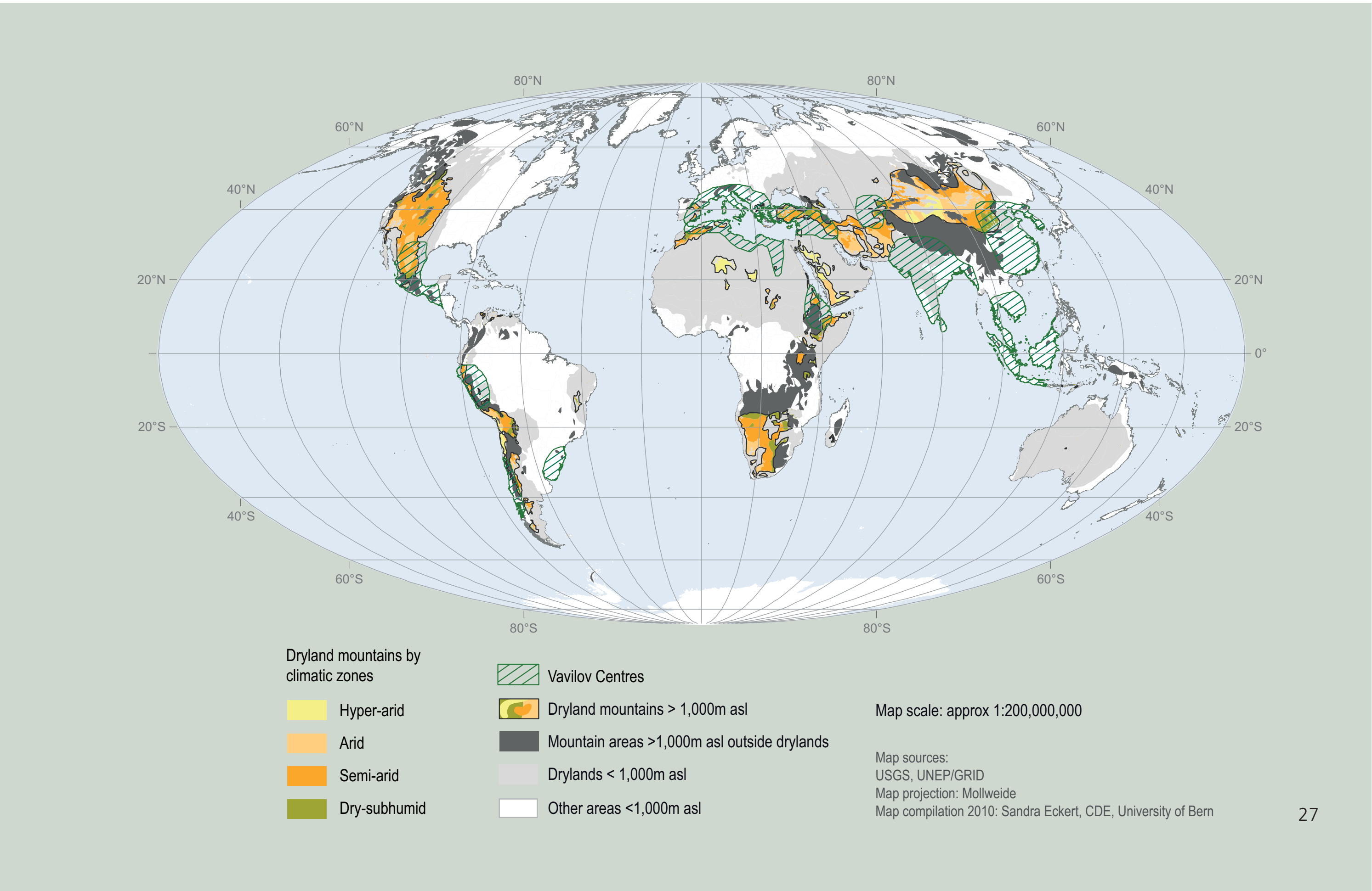
Agro-biodiversity in dryland mountains

Most dryland mountain regions are the centres of origin of the wild relatives of domesticated plants and animals that have tremendous economic significance for the global economy. The domestication of these plants and animals started several millennia ago, and is the product of the efforts of farmers and herders who bred and selected the innumerable varieties adapted to different altitudinal zones and climatic areas. These farmers and herders are the most extraordinary innovators and conservers of agriculture biodiversity (6), as they managed to develop unique and highly technological agriculture and pastoral management systems – many of them still in use – adapted to very adverse and changing environments.

Six out of the eight Vavilov centres[4] of agro-biodiversity for domestication of plants and a number of centres for wild relatives of domesticated animals are found in dryland mountain regions (Figure 5 and Table 4).

An outstanding example of agro-biodiversity is found in the Central Andes, where 18 different agro-ecological zones occur along the sharp altitudinal gradient of this high mountain range, the home of a wide array of wild crop relatives and crop systems based on a high diversity of cultivated varieties (6). The local indigenous people still farm traditional crop varieties and animal breeds, and maintain a high level of genetic diversity. The region of Cusco in Peru, for instance, has more wild potato species than anywhere else in the world, as well as more than 400 of the currently used 1,300 potato varieties; in some cases, farmers grow up to 100 different potato varieties on the same plot (6). This region is also a very important genetic reservoir for other Andean crops, such as *ollucu*, *oca*, *tarwi*, *kiwicha* and *quinua*, and many horticultural and medicinal plants. The domesticated vicuña, alpaca and llama, which are an important component of these agro-pastoral systems, have considerable social, economic and cultural significance as well.

Figure 5: Vavilov Centres in dryland mountains



Another example of high agrobiodiversity is the *enset* (*Ensete ventricosum*) farming system in the highlands of southern Ethiopia, which supports an estimated 15 million people and provides several food and non-food (medicine, aesthetic, religious, fodder, housing) uses. The *enset* is the most complex agriculture system in Ethiopia: it consists of a very high diversity of *enset* varieties (up to 24 varieties, with an average of 8 varieties per farm plot in the region of Sidama) in intimate association with other crops such as cereals, root crops, fruits and vegetables (8). Animal husbandry – cattle, sheep, goats, horses and donkeys – satisfies the high demand of the *enset* system for manure, and is a supplementary source of proteins.

Table 4: Centres of diversity for wild relatives of crop plants and domesticated animals in dryland mountain regions

North-west America	Mediterranean Region	West Asia
Crop Plants: Mexico and Central American Vavilov centre. Ex: maize, several bean species, grain amaranth; Malabar gourd, winter pumpkin, chayote; several cotton species, henequen (sisal); sweet potato, arrowroot, pepper, cashew, wild black cherry.	Crop Plants: Mediterranean Vavilov centre (84 listed plants). Ex: olive, grape, wheat, oats, canary-grass, pea, lupine, clover, serradella, flax, rape, turnip, lettuce, asparagus, celery, chicory, parsnip, caraway, anise, thyme, sage, hop. Animals: Sheep: centre of domestication in the mountains of southeast Turkey (ca. 8,000-9,000 BP). Donkey: one centre of domestication in North Africa (ca. 6,000 BP). Pig: 3 centres of domestication (ca. 6,000 BP) Cattle: ca. 10,000-8,000 BP.	Crop Plants: Middle East Vavilov centre (83 listed plants). Ex: wheat, two-row barley, rye, oats, lentil, lupine, alfalfa, cove, fenugreek, vetch, apple, pear, pomegranate, cherry, quince, hawthorn. Animals: Goat: centre of domestication in the Zagros mountains (ca. 10,000 BP). Pig: Near East centre (ca. 9,000 BP). Camel: Arabian peninsula (ca. 5,000 BP). Bactrian camel: earliest evidence in central Iran (ca. 2,600 BP). Cattle: ca. 10,000-8,000 BP.
South America	**Sahara & Sub-Saharan Africa**	**Central Asia**
Crop Plants: Central Andes Vavilov centre. Ex: several potato species; edible nasturtium; starchy, maize, beans, pepino, tomato, ground cherry, pumpkin, pepper; cocoa, passion flower, guava, heilborn, quinine, tobacco. Animals: Llama and alpaca: Central Andes (ca. 6,000-7,000 BP).	Crop Plants: Ethiopian Vavilov centre (38 listed plants). Ex: wheat, teff, flax, cowpea, millet species, grain sorghum, barley, pigeon pea, sesame, castor bean, garden cress, coffee, okra, myrrh, indigo. Animals: Nubian wild ass: Sudan/Somalia (ca. 6,500 BP).	Crop Plants: Central Asia Vavilov centre (43 listed plants). Ex: wheat, pea, chick pea, lentil, horse bean, mung bean, flax, sesame, hemp, cotton, onion, garlic, spinach, carrot, pistachio, pear, almond, grape, apple. Animals: Horse: Kazakhstan (ca. 3,700-3,100 BP). Yak: Tibetan plateau. Reindeer: Altai Mountains (ca. 2,500 BP).

Source: http://en.wikipedia.org/wiki/Center_of_origin; www.ilri.org

2.4. Managing scarcity: the collaborative management of natural resources

Demand and scarcity are incentives to regulate the use of natural resources, and they are behind many decisions on management and use regulations (24). Since ancient times, the herders and farmers in all dryland mountain regions have developed solid social organisational mechanisms of mutual aid and collective control and management of natural resources, so as to better face severe environmental constraints (6). Communal property regimes under the jurisdiction of a community of users of natural resources, such as communal grazing and harvesting in grasslands and forests, and communal water-sharing systems for agriculture, are the predominant form of land tenure in such traditional societies.

A basic feature of both communal property regimes and the collaborative management of natural resources in dryland mountains is the impressive capacity to overcome the constraints and hazards posed by the environment, secure the health of animals and crops, and adapt in response to the demographic, economic, social and cultural changes affecting the local communities (25). However, these systems can only work if well-defined membership and strong social control (i.e. rules of inclusion and exclusion; rules to regulate internal competition) are ensured over rangeland, forest and water resource use. In fact, most mobile pastoral and mountain farming societies rely on complex pasture and water tenure regulations, which usually include water, rangeland and forest conservation measures (24).

2.4.1 Culture and sustainable resource management

Besides the basic components of communal property regimes, the endurance of traditional collaborative management systems in dryland mountains is closely related to the existence of very solid cultural, social and ecological interactions that help consolidate them (6). Both knowledge and institutions require mechanisms for cultural internalization, so that learning can be encoded and remembered by the social group (26). For instance, taboos, rituals, ceremonies and other traditions are social mechanisms for resource conservation that help people remember rules and maintain the resilience of these socio-ecosystems.

A good example is the cosmic vision of water developed by the Andean people, which shapes the cultural values, ethics, and the basic norms and rules that govern nature and human society (27). According to these cultures, humans are part of an interacting set of living things, and the complex management systems involving social, cultural and ecological factors are approached through a strongly holistic vision of life (Box 2).

The sustainability of many socio-ecosystems in dryland mountain regions is based on the capacity developed by local societies to generate knowledge, practice, and belief about the relationship between living beings and their environment. In this sense, traditional knowledge systems are adaptive management processes handed down from one generation to the next, through cultural transmission (26). Berkes et al (2000) have undertaken bibliographic research to analyze the role of traditional knowledge and practices in responding to and managing ecosystem processes and functions, with special attention to ecological resilience (26). The following practices described by the authors are common and well developed in dryland mountain regions:

- Uncertainty and unpredictability are features common to all these ecosystems, including managed ones, and social learning appears to be the way in which societies respond to uncertainty. This often involves social learning at the level of the society or institutions. Adaptive management is designed to improve on trial-and-error learning.
- Monitoring the status of resources and changes in the ecosystems is essential. For example, transhumant and nomadic herders in dryland mountains from the Mediterranean basin, West and Central Asia, monitor grazing pressure and the state of the pastures to make decisions about rotating or relocating herds (28).
- Certain species and habitats are subject to total or seasonal protection. For example, sacred groves like the *khaloas* in North Africa not only have a faith value but also play an important role in ecosystem management and biodiversity conservation (29). These places act as recruitment areas for seed dispersal by birds and bats, which are important for the renewal of surrounding ecosystems (30). They also represent the sole example of undisturbed habitat, and the reference ecosystem in ecological restoration work.
- Temporal restrictions of plant and animal harvesting are in place.
- Multiple species management rules allow the maintenance of multiple tree species and age classes to help diversify uses.

- The management of landscape takes into account the seasonal and spatial variation of plant productivity and diversity: an efficient use of upland-lowland gradients is guaranteed through resource rotation (i.e. livestock rotational management system to enable the recovery of heavily grazed rangelands) and the diversification of uses along altitudinal agro-ecological zones. Watershed-based management is ensured by the distribution of land uses with different functions (upland grasslands, upper slope protection forests, foothills agriculture land).

Box 2 | The Huanchaco religious festival in Cajamarca, Peru: an example of cultural resilience that strengthens Andean agrarian socio-ecosystems

The Huanchaco religious festival is one of the most important traditional celebrations based on water. Since the beginning of recorded history, this event has contributed to coherent, community-based management of the irrigation system, and has helped perpetuate the system over time. The festival provides a link between the material (maintenance/cleaning of the channels), faith-related (spiritual cleaning and request for a good harvest), and social factors (social organisation for the festival and the management of the irrigation system) needed to guarantee the success of the system.

All water users are registered and organised in water users' committees, following an altitudinal gradient. The maintenance and reparation needs for the water conduction infrastructure are agreed among all committee members, who define the tasks of each user, to be finalised before the festival. Three days before the start of the celebration, the members of the lowest group check that everything is ok, and communicate the results to the committee members uphill – and so on until the last committee at the top of the watershed. If a committee has failed to complete the maintenance/reparation works, it is given 8 more days to do so, until the second major and last event of the Huanchaco celebration. Water users who do not complete their part of the work cannot attend the social event.

The Huanchaco festival strengthens the cultural resilience of the community and contributes to the maintenance of the socio-ecosystem through a solid social collaboration agreement where:

- Boundaries between users are clearly defined;
- Congruent rules between resource appropriation and local conditions are established;
- Decisions and agreements are reached collectively;
- Community supervision is ensured;
- Conflict resolution mechanisms and gradual sanctioning mechanisms are in place.

Source: Pedro Regato, extracted from Castañeda et al (27)

2.4.2 Forests, woodlands and scrublands

Dry forests, woodlands and scrubland are an important component of most dryland mountains, hosting high numbers of endemic plants and species diversity. Even the hyper-arid mountains of the Sahara are the home of Acacia woodlands and some very threatened endemic and relic tree species, such as *Olea laperrini* and *Cupressus dupreziana*.

Mixed conifer and hardwood forests are typical of the dryland mountains in north-west America, North Africa, the Ethiopian highlands and Eurasia. The lower elevations are home to hardwood species, such as the evergreen oaks of Mexico, the south-west USA and the Mediterranean Basin, and the *Acacia* and *Commiphora* spp. in the Arabian Peninsula. A number of wild relatives of the olive tree are present in the dry forests of the Mediterranean, the Ethiopian highlands, and the

Arabian Peninsula. A very high diversity of conifer genera and species predominate at higher elevations in the Mediterranean and north-western American mountains. Scrublands characterise the Mediterranean climate-type dry mountains of South Africa, Chile and north-western America. These areas have outstanding species diversity and plant endemics (80% in the Fynbos (31), and 95% in the Chilean *matorral* (32)).

The gifts of the forest

Dryland mountain forest landscapes provide a wide range of non-wood forest products – including food, medicine, cosmetic, ornamental, forage, raw materials, building, and energy – and contribute to the livelihood diversification and food security of rural and urban communities. At present, gums, resins, honey, cork, medicinal plants and mushrooms are probably the most marketed dryland mountain forest products (9).

Plants rich in essential oils, gums and mucilage are much more abundant in drylands than in humid zones (9). Medicinal and aromatic plants are important components of these forest landscapes worldwide and have always played a significant role in the economy of rural households, both for self-consumption and for trade. In the Mediterranean basin, the harvesting of medicinal plants supplies domestic and foreign markets and provides an important source of cash income in countries like Turkey, Lebanon and Spain. Approximately 90% of the European species are collected from the wild, with the Mediterranean and Eastern European mountain regions being the main suppliers (33). Turkey exports approximately 28,000 tonnes of medicinal and aromatic plants per year, mainly from mountain forests, with an annual income of nearly 50 million dollars (34).

In West Asia, many mountain species that are domesticated and widely cultivated, such as the pistachio (*Pistacia vera*), are still extensively collected from the wild (9). The coastal foggy mountain forests of Oman and Yemen host plant species with remarkable medicinal or other economic properties, such as the oleo-gum-resins from the genera *Boswellia* and *Commiphora*. The famous frankincense tree (*Boswellia sacra*) played a key role in the economy of these countries until recent times (9). The island mountain of Socotra, likewise, is a former major source of gums and resins, largely from *Commiphora* and *Boswellia* species but also from Dracaena – the famous source of "dragon blood" with medicinal and commercial value.

In the mountain forests of Nepal, Olsen (1998) estimated that 470,000 households are engaged in the commercial collection of medicinal plants (35). The mountainous region of southern Africa is also a major source of raw material for herbal trade, with approximately 900 species recorded with specific medicinal uses (9).
Non-forest vegetation types, such as the succulent scrublands, also provide important ecological services. The *Opuntia* cacti scrublands of the Central Andes, for instance, perform a major role in the protection of slopes against erosion, the improvement of soil properties, and the harvesting of products, including the cochineal insects – a highly valued source of dyes (36). The collection of these insects has been an important economic activity since pre-Columbian times, and currently represents between 85% and 90% of the global market, coming mainly from the poorest Andean areas of Ayacucho in Peru. The Sierra Madre Oriental and Sierra Madre Occidental in northern Mexico are the centres of origin and diversification of Agave species, many of which are used for food, the production of spirits (i.e. tequila), medicines, and fibres (37) (38).


Exploiting forest, Mongolia (HP. Liniger)

Regulating services

Undisturbed forests are generally assumed to be the most efficient land cover type in mountain watersheds from the hydrological point of view, as they guarantee the best water flow regulation, better water quality, and minimise the occurrence and damage of fast-flood risk. This is especially true in dryland mountain regions with torrential watersheds and a high risk of erosion and flash flood (39). Although deforested catchments might increase stream flow and aquifer recharge (40), the temporal or permanent elimination of forest cover often leads to an important reduction in water quality and to an increase of pollutants such as nitrates, and to flash-floods and soil erosion.

Finally, dryland mountain forests play an important role in climate regulation. A good example of this is found in the forested mountains bordering the arid coasts of the Arabian Peninsula and the Central Andes, which show an outstanding capacity to intercept fog water and perhaps trigger rainfall and produce a humid microclimate (41).

Supporting services: soil protection, carbon storage, nutrient cycling, biodiversity

Most terrestrial biodiversity is found in forests. The tropical Andes and the Mediterranean forests, woodlands and scrub are the two most important biodiversity hotspots in terms of plant endemics worldwide. The mountains around the Mediterranean Basin, for instance, are home to 36 endemic conifer species and subspecies, 15 of which are included in the 1997 IUCN Red List of Threatened Plants (42). The dry forests of the Mexican mountains of Jalisco, Sierra Madre Oriental and Sierra Madre Occidental are among the richest worldwide, and a well-known centre of diversity for oak species; Sierra Madre Occidental alone has 200 oak and 23 pine species.

Dryland mountain tree species have demonstrated a remarkable ability to persist in the face of abrupt and intense climate changes in the past (43). This is why many

Rural scene, Central Asia (H. Meessen)

researchers consider them as important genetic reservoirs, which might potentially play a critical role in climate change adaptation (44).

Dryland mountain forests also play an important role in soil protection, as healthy soils have the capacity to better retain rainfall water. Globally speaking, dryland soil organic carbon reserves make up 27% of the organic carbon reserves in the world as well as nearly all the inorganic carbon (2). According to Lal (2001) it is estimated that dryland ecosystems have the potential to sequester up to 0.4-0.6 gigatons of carbon per year, an amount comparable to about 8% of global emissions from all sources combined (45).

Cultural services: spiritual, recreational, tourism, aesthetic

Sacred groves are forest stands that owe their conservation to prohibitions on tree-felling, burning, poaching, cultivation of crops and even entry, because of their spiritual significance (9). These "sacred forests" are a frequent feature in most dryland mountain regions. Besides their faith-related value, they also play an important role in ecosystem management and biodiversity conservation (29), acting as recruitment areas for seed dispersal by birds and bats that is important for the renewal of surrounding ecosystems (30). In some regions, they also represent the sole example of undisturbed habitat and are key reference ecosystems for ecological restoration work.

2.4.3 Rangelands and animal resources

Mobile pastoral systems are a feature common to all dryland mountain regions. These systems represent 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 *dzud*[5], and maintaining sustainable and productive livelihoods (46). Their economy is based on domesticated animals, including cattle, sheep, goat, horses, camels, yaks, lamas, and alpacas. The herds undergo seasonal

Rangeland and yurt, Kyrgyzstan (D. Maselli)

displacements which guarantee a constant supply of fodder and water. According to United Nations Development Programme (UNDP), between 100 and 200 million people may rely on strict nomadic and transhumant pastoralism livelihoods – a number which might rise substantially if agro-pastoralism is included.

Pastoral livelihoods make a major contribution to the national economy of many countries, although their importance is often not well documented. In Mongolia, livestock is responsible for 1/3 of GDP – the 2nd largest source of export earnings after minerals – and 50% of the population is dependent on livestock production for their livelihood; in Ethiopia, livestock – most of which is managed in a nomadic style – represents 1/3 of the GDP and 8% of export earnings (46).

Rangelands are an important land cover type in most dryland countries, as they extend over 30 to 50% of their territories (47) across different altitudinal zones, from the upland mountain slopes and steppe plateaus to the lowland foothills. The extraordinary diversity of dryland mountain pastures allows for seasonal grazing options and herd diversification, and provides the fundamental resource for pastoral livelihoods. Furthermore, natural pastures are a source of plants used for edible, medicinal, ornamental, and handicraft purposes. In the Mediterranean region, for instance, the rates of plant endemics for pasturelands are 30-40% on the summits of the Sierra Nevada (Southern Spain), 20-30 % on the island of Crete, and 10–20% in the Taurus Mountains of Turkey and the central Anatolian steppes (48). The winter rangeland grounds at the foothills of the central Iberian ranges have an extraordinary plant diversity of 60-100 species per 0.1 ha (49).

The herders of dryland mountains have developed a deep knowledge of the complex ecological dynamics of their surroundings, and since ancient times they have established effective and solid communal management systems that are well-adapted to natural disturbances and unpredictable environmental changes. Most of these systems are based on the set-up of specific groups of users, who take care of the enforcement of agreed rules. These systems are prone to flexibility, with access often granted through alliances and socio-political negotiations that better serve the interests of all partners. Herders are increasingly recognised as the custodians of the 'commons' (50), thanks to their significant contribution in maintaining environmental services and an impressive diversity of animals and plants in all dryland mountains. In the arid mountains of Jabal Al Akhdar (Oman), for instance, herders have set up their own traditional method of resource conservation through the establishment of *hamiyaat*, traditional livestock-free protected areas where fodder is cut by hand (51).

Another traditional grazing scheme combining conservation and sustainable development objectives is the *hima* system of the Near East mountains countries (25). *Hima* consists of a set of rules for the grazing of herds in a territory utilised by one or more pastoralist communities (i.e. tribes or villages). The *hima* rules bind all the members of the community and specify 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 reserved for the protection of forest held as common property. Anyone committing offenses against the *hima* rules must pay a fine and submit to social sanctions.

2.4.4 Agriculture

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 in dryland mountain regions (52). Due to the specific ecological conditions of the steep mountain slopes, many societies focused on erosion control and built impressive terraces, which allowed agriculture on the steep slopes of the Andes, and in Ethiopia, Oman, Yemen, southern Spain and Morocco. In several regions of the world, sophisticated communal water harvesting technologies were developed as well as complex sets of rules for access to land and resources, especially water. Individual, state and communal properties were differentiated, and many collaborative management systems were institutionalised (25). These management rules facilitated the settlement of people and enhanced the resilience of human societies. The Inca agro-centrism in the Central Andes is probably the best example of a dryland mountain state that considered agriculture as the central core of life, with a social organisation based on water management and the establishment of specific work sharing and cooperation rules at a large scale (27).

FAO defines globally important agricultural heritage systems (GIAHS) as remarkable land use systems and landscapes that are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development[6]. An important number of outstanding agriculture systems are still in place throughout the world's dryland mountains, and part of them are already classified as GIAHS. In the *waru waru* cultivation system in the Central Andes around Lake Titicaca (Peru), for instance, farmers dig trenches filled with water (called "*sukakollos*") around their fields, that serve as a protection against frost for several varieties of potato and other native crops, such as quinoa, when temperatures drop at night. Other examples include the farming, sheep herding and ranching communities of the Little Colorado watershed (USA), and the *qanats* irrigation systems and oasis cultivation in North Africa and Iran.

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 (53). In Yemen, a tradition of high-mountain agriculture spanning over two thousand years has produced a spectacular terraced landscape on the steep mountain slopes, where several crop plants, such as wheat, barley and sorghum, are still cultivated and represent an important genetic resource (54).

The Central Andes are the primary centre of origin of potatoes, and their extraordinary diversity in terms of elevation gradients and climate conditions translates into an important number of different ecological and agronomic zones with significant agro-biodiversity. In order to take advantage of this remarkable geography, Andean peasants own land in different ecological altitudinal zones, where they move periodically so they can farm a wider range of crops (6). Terraces allow cultivation on steep slopes and at different altitudes: maize is grown in the lower areas between 2500-3500 m, while potatoes are planted at medium altitudes between 3500-3900 m, and the most resistant crops and rangeland are at higher altitudes, above 4,000 m.

2.4.5 Nature conservation in dryland mountains

The global network of protected areas has grown substantially during the last decades, and now occupies 11.5% of the Earth's land surface. This growth, however, has not been strategically aimed at maximising the coverage of global biodiversity (55). According to UNEP-WCMC, about 32% of protected areas are established in mountain regions (56).

Some kind of nature protection in dryland mountain regions has taken place since very ancient times, thanks to sustainable nature resource management and the spiritual value of systems such as the already mentioned *hima* and *hamiyaat* pastoral management areas and the sacred natural sites (Box 3). Sacred areas are probably the oldest forms of nature protection on Earth, and they have long played a key role in balancing the conservation and use of natural resources in vulnerable habitats (57). Links between faith, sustainable development, and nature conservation exist throughout the world's dryland mountain regions, and play a critical role in strengthening the communal property regimes and management systems of natural resources.

Following is a summary of protected areas legally established by national law, based on data from the different biodiversity hotspots in dryland mountain ecoregions[7]:

North-west America

- A significant percentage of about 37% of the California Floristic Province is under official protection, although less than one third is related to the stricter protection categories (IUCN categories I to IV). The southern Sierra Nevada range includes two of the oldest national parks established in USA, Yosemite and Sequoia.
- The opposite situation is found in the northern Mexico and south-western USA dryland mountains (Madrean pine-oak hotspot) where only 6% of the territory is under some form of protection, and just 2% is related to the stricter IUCN protection categories. Some examples are the Monarch Butterfly Biosphere Reserve in Michoacán, the Monterrey National Park in Sierra Madre Orienta, and the Cumbres de Majalca NP in Sierra Mare Occidental.

Box 3 | Faith and nature conservation in dryland mountains

Many faiths regard all nature or particular elements of nature as being imbued with sacred value. Some individual species, groups of plants and animals or physical elements of the landscape are seen as sacred, possessing or reflecting some unique aspects of the divine. Species can attain their sacred value as a result of the central role that they play in people's lives, because they are seen as an inspiring model for humans (i.e. for Hindus the cow represents patience, generosity, strong maternal instinct, etc) or due to their specific characteristics or size (i.e. huge trees, rare forms of trees and rocks, etc.):

- Sacred sites protected by religious groups and local communities usually encompass any natural or physical element of landscape, and can be small to large-scale. Following are some examples from dryland mountain regions:
- Sacred forests surrounding monasteries of the Orthodox Christian church in north and central Ethiopia represent true islands of original vegetation. The Orthodox church has a long tradition of conservation both for spiritual and material purposes (i.e. fuelwood provision and shade during festivals).
- Lake Funduzi in South Africa is one of the most sacred sites of the Venda culture, thanks to the legendary large white Domba python god that is believed to live below the surface of the water and that ensures good rainy seasons. Visiting the lake requires permission from the Chief and the Priests of the Lake.
- The mountains of Northern Morocco harbour numerous khaloas, which in most cases form scattered forest islands with the last remnants of the original forest cover still in quite pristine condition. They are shrines containing the remains of honoured local figures, and devotees visiting these areas have traditionally respected their natural vegetation, in accordance with pre-Islamic and pre-Christian traditions (29).
- Mount Ararat in Eastern Turkey is related to the Christian myth of Noah's Ark, the only means of survival during the great flood that God inflicted on the Earth to punish the sins of humankind.
- In Mongolia, Buddhists worship the tamarisk tree (Haloxylon ammodendron), with a taboo on chopping these trees down and sometimes even on approaching them.
- In the mountains of California, the Yosemite Valley has been a sacred landscape for the First Nations groups of this region. The high elevations of the Wupatki are considered sacred by the Hopis, who used to climb its peaks in search of golden eagle nests, as eagle chicks were used as part of a ritual to attract rain to the area.

Source: Pedro Regato, extracted from Dudley et al (2005) (57)

Central Andes

- Despite the high level of threat in the Tropical Andes, a network of protected areas today conserves some of the most important remaining intact ecosystems in this hotspot. Protected areas cover some 16% of the original vegetation cover, although only 8% is related to the stricter IUCN protection categories.
- In the Mediterranean climate-type region of the Chilean Andes, about 12.8% of the territory is under official protection, most of it under the stricter IUCN categories.

Mediterranean Basin

- At least 4.8% of the surface area of hotspots is covered by national and/or international protected areas (not considering Natura 2000). There are, however, great differences between countries, from the Euro-Mediterranean (ranging between 6.6% in Italy to 3.3% in Greece), to the Levant (ranging from 4.4%

in Turkey to 0.6% in Syria) and North Africa (ranging from 0.9% in Morocco to 0.4% in Algeria). In the EU countries, the large Natura 2000 network provides coverage of 26% in Spain, 20.1% in Greece, 16.8% in Italy and 11% in Cyprus.

Sub-Saharan Africa

- About 14% of the Cape floristic province in South Africa is legally protected, most of it under the stricter IUCN categories. This percentage covers half of the mountain areas of the country. Eight protected areas together comprise the Cape Floristic Region World Heritage Site, including important mountain areas such as Table Mountain, the Boland Mountain Complex, and the Cederberg Wilderness Area.
- Only 2.5% of the Succulent Karoo is protected (1.8% under the stricter IUCN categories). The largest reserve is the Richtersveld NP in the mountains between South Africa and Namibia.
- In the Ethiopian highlands nature protection is still inadequate, and only two of the planned 14 national parks and sanctuaries have been legally constituted (Bale NP and Simen NP).

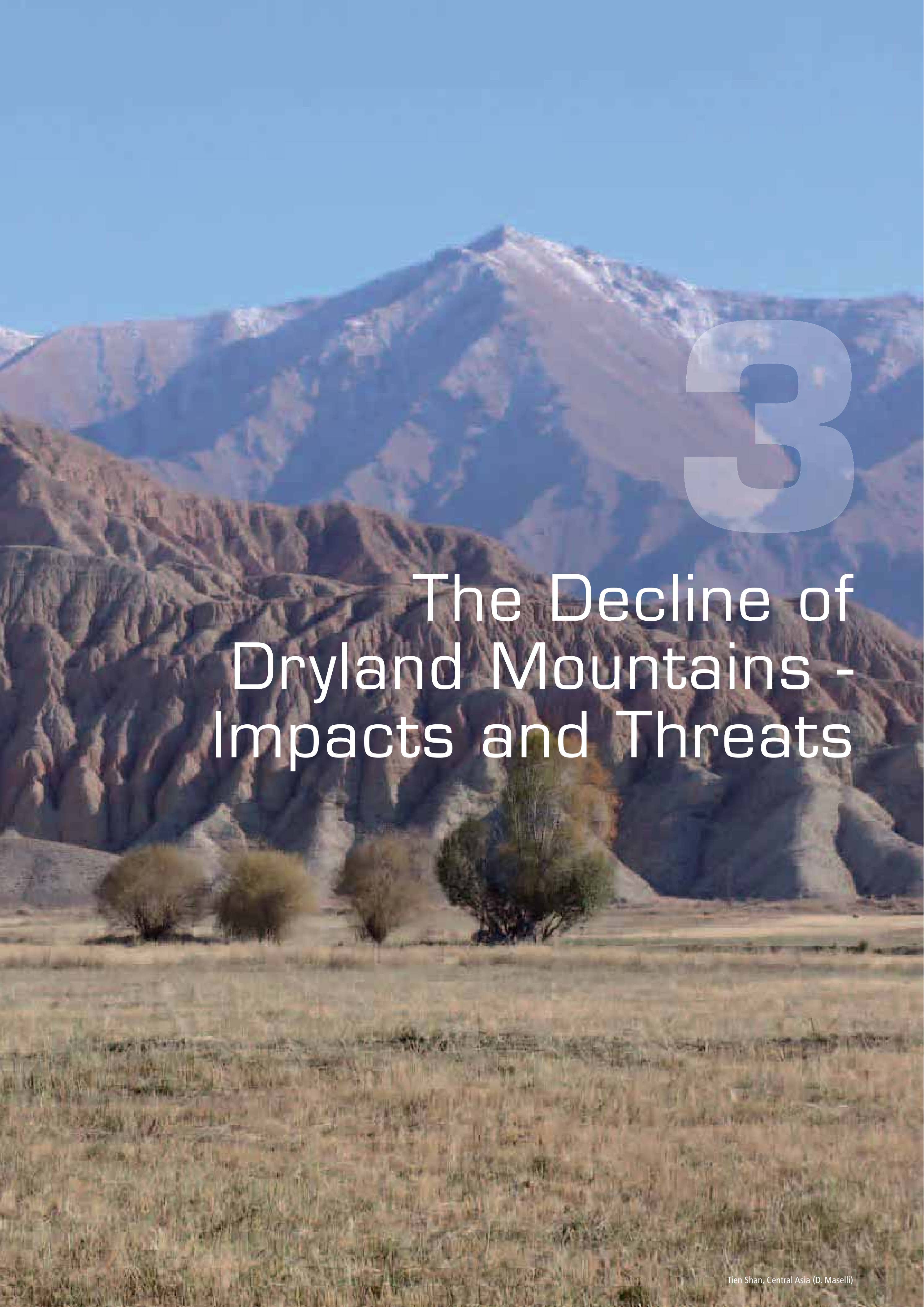
West Asia

- About 14% of the Irano-Turanian hotspot is protected, although only half of it is under the stricter IUCN categories. Among the most important protected areas are the Alborz-e-Markazi Reserve in the central Elburz Mountains and the Urumiyeh Lake NP in Iran, and several national parks in Armenia.
- There is little current information on the status of protected areas in Yemen and the fog-affected woodland on the country's south coast. In Oman, the Jebel Samhan National Nature Reserve was declared in order to protect the Arabian leopard, a critically endangered subspecies.

Central Asia

- About 7% of this mountainous hotspot is under some form of official protection, most of it under the stricter IUCN categories. Nevertheless, many reserves are small and isolated, and some are not yet fully functioning. Large protected areas include: Issyk-Kul Biosphere Reserve in Kyrgyzstan; Mount Tomur Reserve and Boghdad Mountain Biosphere Reserve, both in the Chinese sector of the Tien Shan; Kugitang Strict Nature Reserve in Turkmenistan; and Pamir NP in Tajikistan.

3 The Decline of Dryland Mountains - Impacts and Threats



Tien Shan, Central Asia (D. Maselli)

Threats to sustainability

Over the past decades, global socio-political and environmental changes have taken their toll on the health of many fragile dryland mountain ecosystems, especially in those areas where traditional agricultural practices ensured the balance between the conservation of the ecosystem and its ecological functions, and the needs of human societies.

Afforestation of badlands, Eritrea (M. Gurtner)

Political changes have led to the annulment or weakening of communal property rights and management systems in many regions, while top-down imposed development and conservation schemes have too often brought the loss of tenure rights and restrictions in the use of common property resources in forest and pasture lands by local communities.

The collapse of many traditional societies, and the imbalances caused by demographic, socio-economic and political changes are the root causes of the intense degradation trends that are currently threatening the survival of most dryland mountain socio-ecosystems. The additional impact caused by climate change is exacerbating such negative trends, by reducing the ability of nature and people to cope with future changes, and by increasing the risk of irreversible desertification processes with ramifications downstream and beyond.

3.1 Desertification in dryland mountains

Desertification is defined by the UNCCD as *land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities.* The main outcome of land degradation is a substantial reduction or loss in the biological or economic productivity of drylands, due to the destruction of the soil structure, including loss of organic matter, soil chemical changes (salination, acidification and alkalinisation), and soil erosion (2).

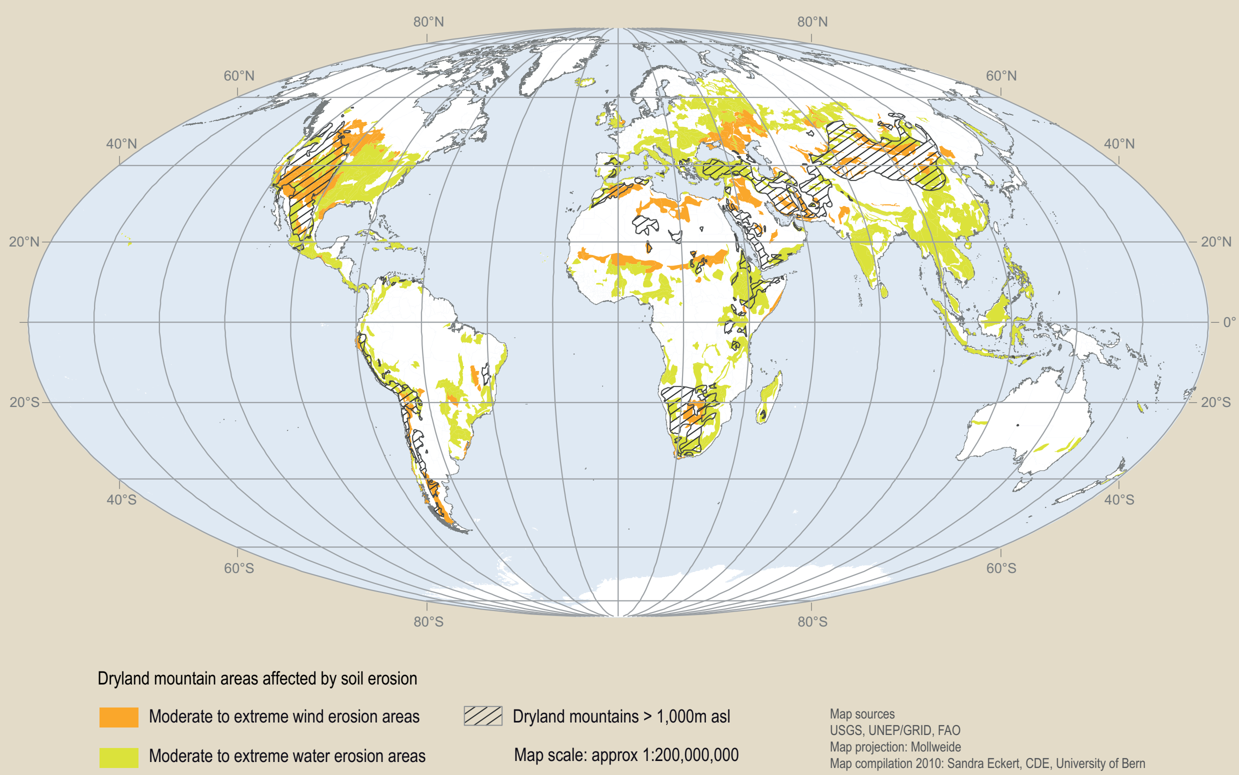
The assessment of desertification processes has been beset (until recently) with problems of data quality and comprehensiveness, with data about the degradation of drylands ranging from 10 to 70% of their global surface (47). A recent study commissioned by the Millennium Ecosystem Assessment indicated with *medium certainty* that about 10–20% of drylands are already degraded; about 1–6% of the dryland population lives in desertified areas, while a much larger number is under threat from further desertification (2).

Dryland mountains are especially vulnerable to desertification processes due to deforestation and vegetation degradation loss combined with the predominance of instable soils on steep slopes and extreme weather conditions. Moderate to extreme wind and water erosion problems occur in all dryland mountain regions worldwide (Figure 6). In the Central Andes and the Mediterranean coastal mountains of Chile, about 60% of soils show visible signs of serious to moderate surface erosion (154). Other large areas severely affected by soil erosion are the mountains of North Africa and West Asia. For instance, up to 5,000 t km^2 of soil is lost in the Rif Mountains in Morocco every year (155). Major soil erosion problems are associated with 48% of Turkish territory having slopes steeper than 20%, where soil fertility is reduced to about 50% and the soil cannot be used economically (153).

In past and current desertification processes, there has always been a correlation between long-term changes in climate and changes in human activities. Thus desertification is caused by a combination of climate and anthropogenic factors. Among the main specific causes of degradation in dryland mountains are the overexploitation of natural resources, improper land management practices, rapid land use changes and land conversion into unsustainable uses, altered hydrologic and fire regimes, pollution (mining, industry, agriculture and urban sources), unsustainable population densities, armed conflicts and exotic species invasions. All these factors are analysed in the following sections.

The Framework Convention to Combat Desertification warns about the tremendous increase of land degradation when desertification processes interact with climate change impacts. In fact, there is a vicious cycle of interactions and positive feedbacks between loss of biodiversity, deforestation, desertification and climate change. Vegetation loss and degradation, and soil erosion in dryland mountains leading to desertification, cause further reduction of carbon sinks (300 million tons of carbon are estimated to be lost to the atmosphere from drylands each year) (2), and compromise the resilience of ecosystems and people to climate change

Figure 6: Soil erosion in dryland mountains




Mountain landscape, Cape Verde (G. Schwilch)

impacts; this in turn exacerbates desertification. Climate change increases water stress and extreme weather events, thus putting more dryland mountains at risk of desertification.

Scenarios of future development show that, if unchecked, the interlinks between desertification, biodiversity loss and climate change and the persistent and substantial reduction in the provision of ecosystem services in drylands will threaten future improvements in human well-being and possibly reverse gains in some regions (2).

The Millennium Development Goals in dryland mountains

With the adoption of the Millennium Development Goals in 2002, the international community has an unprecedented opportunity to alleviate extreme poverty in its many forms, and to improve the livelihoods of millions of people in the world's drylands (160). Nevertheless, implementation of the Millennium Development Goals (MDGs) in dryland mountains faces special challenges due to their extreme environment, harsh living conditions (nomadic life-style and very marked gender inequalities), economic constraints (poor soils, difficult access, scarce infrastructure and limited markets), governance problems and low priority in national policies (dryland mountains are often neglected in development plans, policies and processes).

Unsustainable human and livestock densities due to several factors (i.e. sedentarisation of nomadic people, internal migration) often exceed productivity and degrade natural resources in dryland mountains, a major obstacle to ensuring environmental sustainability (MDG 7) and eradicating poverty (MDG 1). Indeed, the highest incidences of poverty are found in dryland regions, with indications of a positive correlation between poverty and levels of dryness (160). The nomadic life style, isolation, and the inordinate amount of time spent by women and children in fetching water and firewood are distinct disadvantages in trying to attain universal primary education (MDG 2), gender equality (MDG 3) and health care (MDG 4 and 5) in these regions.

Competition for limited resources, namely water, and cross-border political and social conflicts affect many dryland mountain regions worldwide. Well-known examples of this are the political conflicts in the mountains between Iraq, Iran, and Turkey; the Arab-Israeli conflicts in the mountains of the Near East; the socio-political conflicts in the ex-Soviet Republics in Central Asia; and the war in Afghanistan. This gives rise to chronic problems of insecurity and disrupts development opportunities to attain the MDGs.

3.2 Unsustainable use of natural resources

Dryland mountains are seriously impacted by the unsustainable use of their natural resources, and the negative effect on the natural rangelands, scrublands and forestland. Overgrazing and the collection of forage wood due to both bad management practices and excessive livestock numbers are a major cause of land degradation in most areas. Moreover, factors such as grazing competition, feral dogs, and pathogens from livestock pose significant problems to wildlife in regions such the Ethiopian highlands, the southern Arabian mountains, the northern Tibetan plateau, and the Sierra Nevada in California.

After the collapse of communal ownership of forests and their expropriation by the central governments in most regions, public administrations have often neglected forest management and have provided insufficient access to forest lands and unclear land-use rights to dwellers. This has resulted in conflicts between the forest dwellers and the administrative authorities. Practices such as uncontrolled and excessive grazing, irrational firewood collection (which often entails mutilating trees and scrubs and thus favours the spread of pests), and uncontrolled logging, all cause important erosion problems and prevent forest regeneration in large areas. Habitat loss is a major threat in the Horn of Africa and West Asia, where original mountain conifer forests are nowadays reduced to scattered isolated trees, such as the juniper forests on the southern slopes of the Elburz Mountains of Iran and on the Arabian Peninsula and in the Ethiopian highlands. The intense use of fire as a management practice in agriculture and livestock grazing, and the increase of neglected fires and arson due to land use changes and conflicts, often cause uncontrolled fires that burn significant forestland every year. In some cases, as in the western USA, savage fires are the result of very strict and successful fire suppression policies that have changed natural forest dynamics and caused the accumulation of dry, highly ignitable biomass.

The over-collection of plants and wildlife, and the intense pressure of hunting and poaching have a major impact on the biodiversity of all regions. On the other hand, the introduction of alien species for afforestation, as in the South African mountains, is the cause of serious problems, with multiple negative effects on the ecological processes and native species populations, the hydrology (reduction of river water and groundwater) and the incidence of fires (significant increase of fire risk).

Rangelands

Overgrazing and wood collection for forage are the most common threats in all dryland mountain ecoregions and have greatly reduced the overall productivity and species diversity of pastures, leading to significant soil erosion and land degradation rates. As previously mentioned, the excessive exploitation of pastures and forest forage is usually due to drastic changes in the property regimes, and the undermining of the traditional practice of mobile pastoralism.


Llamas in Central Andes, Bolivia (P. Regato)

The state-owned regime for forest and pasturelands and the settlement policies imposed by many national governments in North Africa and West Asia after the colonial period, for instance, have severely disrupted mobile transhumant and nomadic livelihoods. These changes have brought extensive conflicts between pastoral groups and the public administration (25). The expropriation of common lands and their distribution among private individuals has brought about the conversion of important grazing grounds to agriculture - especially in lowlands. Herders have been forced to shift to a more sedentary way of life, and the subsequent lack of control and management rules for resources previously managed at the communal level has led to the over-exploitation of pastoral and forest resources all year round.

Livestock density exceeds carrying capacity in central Mongolia, and recent observations in Inner Mongolia point out that these regions are all experiencing a similar trend towards ecosystem degradation and desertification (58). In Mongolia, land use changes from the socialist period, but especially since the country's transition to a market economy in 1990, have become a critical factor in the vulnerability of pastoral social-ecological systems. The number of herders has more than doubled since the early 1990s, as a result of the economic migration spurred by livestock privatisation, and goat numbers have more than tripled (from 5.1 million in 1990 to 18.3 million in 2007) because of the increased value of cashmere (58). More than half of the herders are considered poor, with less than 100 animals per household.

Forests

Dryland mountain forests will be highly sensitive to the expected increase in temperatures and the increased frequency and intensity of extreme weather events – the combined effect of drought periods and heat weaves – which will multiply the risk of major disturbances such as fires, dieback processes, pests and the spreading of invasive alien species (44).


Herding animals, Central Asia (D. Maselli)

Forest dieback

Forest dieback impacts are considered especially important in the dryland mountain ecoregions of north-west America and the Mediterranean Basin. The forest habitats which are mostly affected by dieback events are common in these areas (60), and include cedar forests in Algeria and Morocco; oak and pine forests in Spain and Turkey; fir forests in Greece; juniper forests in Saudi Arabia; Aloe tree woodlands in South Africa; mountain pine forests in China; and juniper, pine, fir, Douglas fir, spruce, oak, ash, and poplar forests in the USA.

The predicted temperature increase of 2°C to 5 °C by 2055 in almost all dryland mountains is very likely to exacerbate forest mortality risk across a broad range of forest types. Some researchers predict rapid and massive vegetation changes, such as the substitution of forests and woodlands by scrublands in many areas of the Mediterranean Basin.

One consequence of forest dieback events is the rapid release of carbon to the atmosphere. Some researchers consider that the water deficit due to climate change could turn Mediterranean forests from a net carbon sink into a net source in the course of this century (62).

Forest fires

Interacting heat weaves and drought are drivers of severe and intense forest fires in all dryland mountain regions. In addition to this, land use and management changes have created fire-prone landscapes with a high risk of savage fires that are difficult to control (44):

- Homogenisation of mosaic-like landscapes due to land use changes and rural abandonment leading to the colonisation of terraced slopes and grasslands by dense young forests and shrubs with high accumulation of dry biomass. This kind of landscape change has happened in many areas in the Mediterranean basin.

Giraffes in Laikipia, Kenya (HP. Liniger)

- Introduction of fire-prone alien trees, shrubs and herbal plants, which become invasive species rapidly expand into huge areas, replacing the natural vegetation. This case is unique to the dryland mountains of South Africa and to some regions of north-west America.
- Degradation of mature forests, with increased rates of disease and the accumulation of dry biomass. These kinds of landscapes are common throughout most dryland mountain regions.
- Suppression of natural fire regimes and changes in the dominance of forest habitat types. These kinds of landscapes are common in the north-west USA.

All in all, forest loss has dramatically increased over the last decades, leading to very negative environmental and socio-economic impacts. In the USA alone, forest fires release about 290 million metric tons of carbon dioxide each year – the equivalent of 4-6 % of the nation's carbon dioxide emissions from fossil fuel burning (63).

Plant and wildlife over-collection, hunting and poaching

The collection of wildlife and exotic plants has severely impacted the natural populations of many species in most dryland mountains. As an example, the collection of wild bulbs in the mountains of Turkey is far from a sustainable level (64). Many of the ca. 16 endemic species of tulip found in the mountain steppes of Central Asia are in decline due to over-collection for horticulture[8]. Plant collection and illegal trade in succulent plants is seriously impacting the flora of the Namibian mountains (65). The illegal collection of cacti and other succulents is also a major threat in the desert mountains of northern Mexico and western USA (66) (67).

Hunting, poaching and habitat degradation have significantly reduced the populations of the larger mammals in many areas. In the mountains of Sonora, uncontrolled hunting is threatening endangered species such as the mule deer, pronghorn antelope, and mountain sheep (67). Poaching is also a threat to the wildlife of Namibia, and especially to the unfenced black rhino population (68). In the mountains of Yemen, hunting with firearms and large numbers of domesticated and feral dogs has increased pressure on wildlife: more and more leopards are being captured for sale to zoos, and for use in traditional medicine (69). In the Pamir, Tian Shan and Tibetan plateau of Central Asia, mountain people hunt ungulates for meat, while carnivores such as the snow leopard are killed because they pose a threat to livestock (70) (71) (72).

3.3 Agriculture

One of the major global threats to dryland mountains regions is outmigration to lowland urban agglomerations, and the abandonment of traditional agriculture systems in favour of methods and crops that are unsustainable on fragile mountain terrain. On the other hand, the conversion of unsuitable mountain areas into agricultural lands, and the expansion of irrigation in dry lowlands is causing serious soil erosion and hydrological problems and depletes the already scarce groundwater resources.

Freshwater lakes and wetlands have been severely affected by irrigation. The construction of irrigation channels in the East Afghan Mountains causes low water levels during the dry months, and a negative impact on breeding birds and the beverage needs of livestock and herders (73). The rivers and lakes of these regions are polluted from domestic sewage and agricultural effluents, while the massive use of chemical pesticides has contributed to a decrease in the number of mammals such as jackals. In the dry lowlands of north-west USA, the urban and suburban sprawl of cities such as Phoenix and Tucson is pushing agricultural operations further into the desert and along riparian areas, with the subsequent overuse of water resources through water diversion and dam building, and tremendous impacts on wildlife habitat (67).

The Ethiopian highlands have been nearly completely converted into agriculture land, where agricultural production is extremely intense; 70% of the people live in mountainous areas, with very high densities of 100 to 400 people per km^2, and most of them are engaged in subsistence farming, causing important soil losses on steep slopes that can reach 300 tonnes/ha/yr (74). In Southern Africa, large tracts of the higher and wetter areas in the Namaqualand-Namib have been converted for agriculture, while the Drakensberg mountain grasslands are one of the most endangered habitats in the region (75), primarily as a result of extensive fragmentation due to agriculture. Some of the latest trends in South African agriculture, such as the cultivation of indigenous species for cut flowers and the cultivation and collection of plants such as *rooibos* and honeybush tea for beverages and for their medicinal properties, also pose a new threat (31).

Drug crops
Drug crops represent an important threat in some dryland mountain regions. In the Sierra Madre Occidental (Mexico), forestland is cleared for the cultivation of opium and marijuana (76), causing significant erosion, and siltation and drying up of the riverbeds. The cultivation of opium poppy in the mountains between Afghanistan and Pakistan is often associated with insecurity. Although UN figures showed substantial declines in drug production in Afghanistan, which produces 93% of the world's opium, this crop is still a major threat, with more than 100,000 hectares in the region of Helmand and about 2,000 hectares in neighbouring Pakistan[9].

Forest dieback in the Middle Atlas, Morocco (P. Regato)

In the Rif Mountains of northern Morocco, *kif* (marijuana) plantations cause serious problems of deforestation and soil erosion, leading to the eradication of 8,000 ha of cork oak forest cover in the Ketama region in only 6 years, between 1984-90 (77). United Nations Office on Drugs and Crime (UNODC) (2007) estimates that marijuana crops extended over approx. 72,500 ha in 2005, with a reduction of 40% since 2004 due to a combination of factors, including unfavourable climate conditions, governmental eradication policies, and pressure on local farmers (78).

3.4 Alien species

The invasion of alien species is considered to have major, serious impacts in a few dryland mountain ecoregions. The relative isolation and extreme climate conditions of these ecosystems are the root cause of relatively low levels of species invasion in comparison with other biomes (79). Nevertheless, recent findings demonstrate that many alien plants have colonised high-elevation habitats, and some have become true invaders. Because of climate change, plant invasions are likely to increasingly affect biodiversity and cause the disruption of important environmental services, with serious consequences to adjacent lowland areas. This is already the case in South Africa, where the decrease in downstream water availability is clearly linked to this problem. Several estimates of the spatial extent of alien plant invasions in this region suggests that about 10 million hectares have been invaded by approximately 180, mainly woody invader species from the genus *Pinus*, *Hakea* and *Acacia* (80). The uncontrolled situation of many fire-prone invasive plants in the Fynbos and Renosterveld mountains is impacting water yields, increasing fire risk and damage, and replacing natural vegetation. Invasive acacias are considerably impacting the riparian ecosystems in the Highveld plateau (81).

Mining in Cerro Rico de Potosi, Bolivia (P. Regato)

3.5 Mining

The mining industry is a major threat in all dryland mountains, possibly with the highest impact in the Central Andes, North-western America and Central Asia. The mining industry is still growing fast in these regions, due to the existence of huge ore reserves, and it is causing serious problems of water pollution and degradation of glaciers.

The Andes have a long history of mining, often dating back from pre-Spanish colonial times. Nowadays, major mining projects exploit mainly copper and gold reserves in the semiarid Andes of Peru, Chile, Argentina and Bolivia (85). The enormous expansion schemes in the decade of the 1980s have turned Chile into the world's largest copper-producing country, and one of the largest gold producers (18). Half of the world's reserves of lithium lie within the dry Andean high plateau of Bolivia at the Salar de Uyuni. The world's demand for lithium will drastically increase in the coming years, as this mineral is a key component for the batteries of electric cars[10].

Due to increasing demand, uranium projects have been sprouting in many fragile drylands, raising concerns about water quality and public health. Uranium mining represents an important threat in parts of the western USA, Kazakhstan, Uzbekistan, South Africa and Namibia. Despite the efforts made to clean up uranium sites, significant problems still exist today in the Navajo Nation and in the states of Utah, Colorado, New Mexico, and Arizona. The impacts of uranium mining in the USA have raised concerns among many scientists, NGOs and government officials. A Grand Canyon Watersheds Protection Act has been proposed to ban uranium exploitation and protect public lands around that park[11].

Aconcagua, Argentina (HP. Liniger)

Serious and often very violent social conflicts have occurred between local communities and extractive mining industries in several areas around the world. Mining operations often pose important threats to local communities, mainly due to the impact on the quantity and quality of water, and to limitations on the de jure and de facto rights that communities have historically enjoyed (85). These threats have catalysed organised responses in the Central Andes, where local communities have been fighting to protect their territory and their rights to manage their own natural resources.

3.6 Tourism development

Unsustainable tourism development represents an important threat to most dryland mountain ecoregions.

In spite of their economic significance, ski resorts and access roads are an important cause of forest and grassland degradation, soil erosion and pollution, and they have significant impacts on the local water cycle of large regions in north-west America and the Mediterranean Basin. On the other hand, skiing may become a completely economically unviable activity in many places, because of global warming. UNEP estimates that the ski season will shrink considerably in the western USA, while resorts will need up to 187% more artificial snowmaking (87). The effects of climate change on the hydrological cycle due to the melting of glaciers and the higher frequency of torrential rainfalls have already increased the natural hazards, posing increasing threats to trekking and mountaineering.

If not properly planned, ecotourism can have serious impacts on the many vulnerable and rare plant and animal species of the dryland mountain summits. This is already the case in places like the Drakensberg in South Africa (88), or the Central Tibetan Plateau lakes, where the seasonal tourism peak coincides with the breeding season of several threatened birds (71). Unsustainable hunting tourism is also a major threat in Central Asia (i.e. the Alai West Tian Shan steppes in Uzbekistan, Kazakhstan and Tajikistan) (89).

The risk of accidental fires with dramatic environmental and socio-economic consequences is magnified by the fact that the seasonal increase of tourists often coincides with the warmest and driest periods, and by the fragmentation of forestland caused by the sprawl of holiday resorts and secondary houses. This is the case in the mountains of California and the Mediterranean Basin.

3.7 Migration

Seasonal migration from dryland mountains has always been a normal feature of their economies (i.e. the need to seek resources in lowlands when they are scarce in uplands, the export of labour being a fundamental means of improving livelihoods and auto-regulation of mountain population densities) (161). But in recent decades the phenomenon has grown, with more people migrating permanently, and more escaping civil conflict and serious extreme weather events. For instance, the disastrously long and cold winter, known as *dzud*, killed eight million animals in the past winter (2009/2010) in Mongolia – 18% percent of the nation's livestock – where a third of the population depends on herding for a living.[12] According to the Southern Mongolian Human Rights Information Centre (SMHRIC), at least 650,000 ethnic Mongolian herders had been displaced to urban slums as of 2006, and the UN expects 20,000 more people to relocate in urban areas this year. As many herders are unwilling to abandon their lifestyle, nomads have begun to talk of starting herders' cooperatives, reducing herd numbers to focus on healthier animals that produce more meat and cashmere wool, or settling down and growing vegetables.

Factors associated with migration from drylands to urban areas are debatable, but there is no doubt that harsh growing conditions in dryland mountains are a contributing factor. When harsh conditions lead to severe deprivation, people tend to move (161). As more working age men spend more time away from their homes seeking work, it can be expected that there will be a weakening of the capacities of remaining communities to be productive and an increase in the numbers of female-headed households.

Another kind of migration is the permanent settling of nomadic populations in mountain areas, such as in North Africa, due to the growing impediments encountered when moving their livestock to lowland grazing grounds converted into agriculture land. This has increased pressure on natural resources, and soils unsuitable for cultivation have been ploughed, causing serious land degradation problems.

3.8 Armed conflicts

Many armed conflicts have devastating consequences on the environment, people's security and livelihoods in dryland mountain regions. The Israeli-Arab conflict is seriously impacting the environment and local communities on the Palestinian Plateau and Mount Lebanon, and armed conflicts also occur in the dryland mountains of Afghanistan, Chad, and Algeria.

Access to natural resources, especially water, is a major root cause of many armed conflicts, and this is most likely to increase, as water scarcity will become more acute because of climate change. Mountain regions suffer disproportionately from the impact of conflicts because they are often the poorest and least developed places, and the homeland of indigenous cultures[13].

Yapshorf, Bartang Valley, Tajikistan (J.F. Schneider)

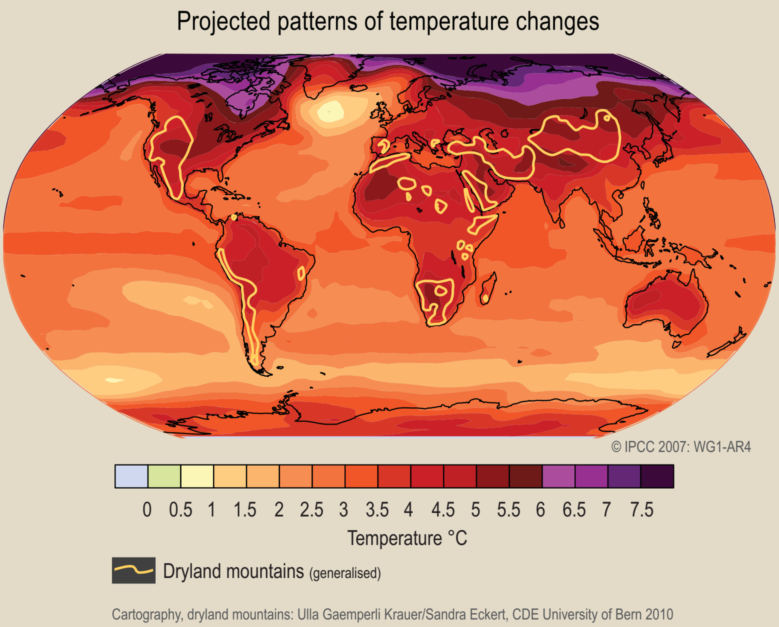
3.9 Climate change

Dryland regions have always been characterised by very changeable and somehow unpredictable climate conditions over time. Detailed and well-dated worldwide palaeo-climate records have documented large-scale changes in climate conditions, with events of extreme aridity, drought, and floods during the Holocene (52). These changes have influenced the co-evolution of human societies, the development of sophisticated adaptive innovations, and the domestication of plants and animals.

In the Mediterranean mountains, there is plenty of evidence that the disappearance of species or ecosystems in prehistoric times was caused by the synergetic combination of climate changes (i.e. increase in temperatures), and intense or rapid anthropogenic changes in land cover and management practices (i.e. extensive and severe fire activity for land clearance) (93) (94) (95). Several studies demonstrate that the ability of species and ecosystems to survive under adverse and unpredictable conditions can be inextricably linked to the evolution of human societies.

Current rates of climate change are more rapid, and could exceed the inherent adaptive capacity of natural systems. Anthropogenic greenhouse emissions, which have risen dramatically since the beginning of the industrial revolution in the second half of the 19th Century, are expected to lead to average global warming of 1.1 to 6.4 °C, over the period 1990-2100, according to various climate change scenarios (96). The average temperature increase in mountain systems globally in the 21st Century (up to 2055) is predicted to be between two and three times greater than the average change recorded in the 20th Century (97). According to Nogués-Bravo et al, the following dryland mountains are believed to experience the highest warming (up to 2055), right behind the northernmost Arctic mountains (97):

- Significant parts of Central Asia, some parts of West Asia and the northern portion of the Rocky Mountains will warm the most, up to 4-5 °C in the worst scenario, and up to 3-4 °C in the most optimistic one. In fact, the increase in



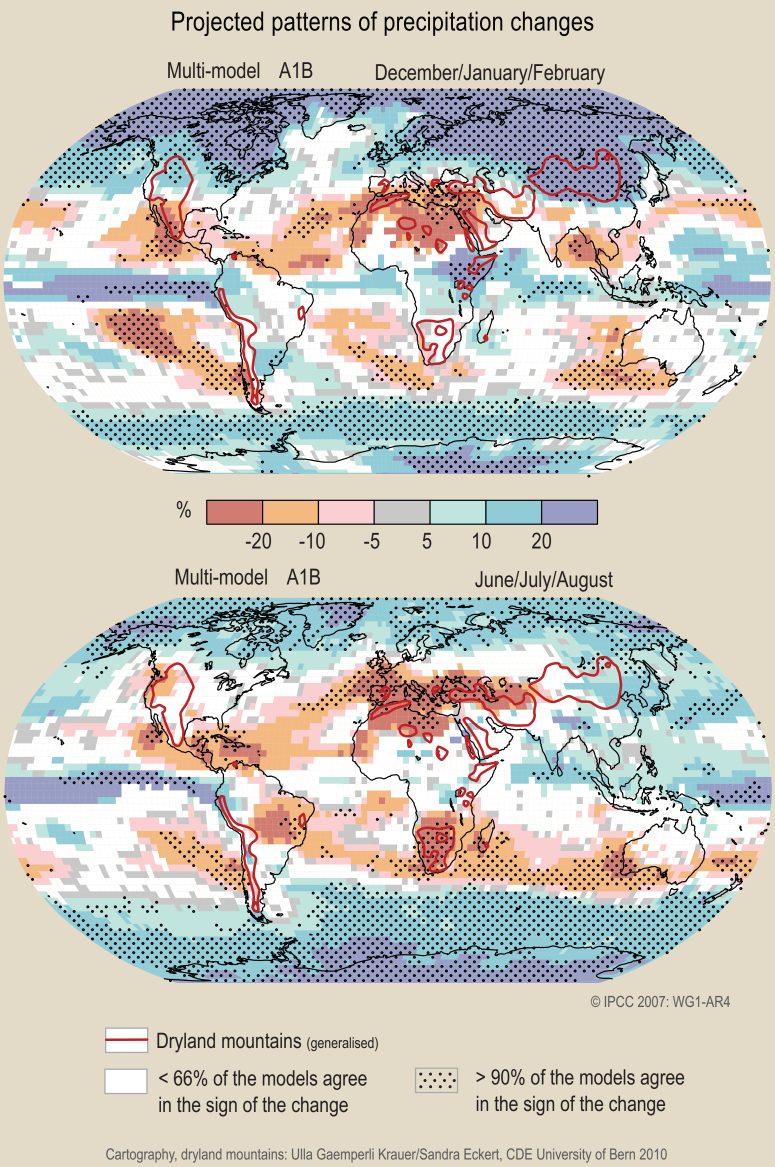


Figure 7: Climate change scenarios for dryland mountains in a global perspective

Jirgetal, Central Asia (M. Maselli)

temperature on the Tibetan Plateau during the period 1955-96 was higher than in other regions located at the same latitude, suggesting that this region is exceptionally sensitive to global climate change (98).

- For the Central Andes, the Mediterranean Basin, the Sahara mountains, the majority of West Asia, the coastal ranges of western USA, and the rest of Central Asia the forecasted temperature increase is 3-4 °C (2-3 °C in the most optimistic scenario);
- Warming expectations seem to be lower for the Ethiopian highlands and South African mountains, with "only" 2-3 °C (0,75-2 °C in the most optimistic scenario).

Although the projection in precipitation changes is less reliable, the inherent water constraints of dry climates and the location of all dryland mountains near desert zones may result in dramatic changes. The IPCC 2007 report indicates a confident precipitation decrease in the Mediterranean Basin and Saharan mountains (99). The general pattern of precipitation decrease in the sub-tropical zone will affect the Central Andes and the South African Mountains, as well as West Asia. Precipitation changes in north-west America are more uncertain. The only pattern of precipitation increase is projected for the East African Mountains and probably Central Asia.

It seems clear that the most significant effects of climate change are related to the increase in frequency, magnitude and severity of extreme weather events (i.e. heat weaves, droughts, strong winds and hurricanes and torrential rainfall) and the resulting large-scale disturbances (i.e. wild forest fires, massive forest dieback and pests, rangeland degradation, lower yields, floods, pollution) that are expected to leave a much greater impact on human society (44). This will exacerbate food insecurity, migration, and socio-political conflicts in dryland mountain regions.

Returning from celebration, Andes (SL. Mathez-Stiefel)

Expected serious impacts of climate change in dryland mountain regions include:

- The local or regional loss of significant numbers of species and habitat types. In the mountains of the Mediterranean Basin it is predicted that approximately 60% of the total flora will be extinct by 2080 (100). In South Africa, large-scale extinctions are predicted over the next 50 years (i.e. 11% of the plant species of the Proteaceae family), with the Succulent Karoo and the Fynbos being the most seriously affected ecoregions (101). In the Central Andes, as many as 12% of the wild relatives of crop plants are likely to become extinct, while the area where wild potato species grow naturally could be reduced by as much as 70% (7).
- Forest loss caused by large-scale fires may significantly increase in the Mediterranean Basin (102), with a predicted 1 to 7 additional weeks of fire risk by 2080, depending on the regions.
- The predicted temperature increase beyond 3 °C in most dryland mountain regions (worst case scenario) is likely to have very adverse impacts on agriculture, water resources, ecosystem production and human health (105). The combination of higher temperatures and water stress will lead to a 30% decrease in crop yields in Central Asia by 2050 (46). In West Asia, climate change scenarios predict a decrease of over 170,000 km^2 in viable rain-fed agricultural land by the end of the 21st Century. The useful grazing period of most rangelands will also shrink because of the longer dry season, while shifting growing seasons due to altered precipitation patterns will force changes in cropping strategy or even crop types (106).

Evidence of climate change impacts has already been reported in dryland mountain ecoregions. Since the beginning of the 20th Century, the combined effect of direct anthropogenic impacts and changes in temperature and precipitation has caused a significant and accelerated retreat of the glaciers in the Central Andes (25% reduction in the last 3 decades), north-west America (ca. 75% of the glaciers in Glacier National Park have disappeared since 1910), and Central Asia (between

16% in the Pamir and 29% in the northern Tien Shan, between the 1950s and the 1990s) (20). This phenomenon has already caused significant alterations in hydrologic regimes, with more frequent and intense floods affecting the security of millions of people in lowland areas. Furthermore, ice landslides have destroyed urban settlements and killed the dwellers of mountain foothills: landslides from the Huascaran Glacier in Peru killed 4,000 people in 1962, while the Yungay and Ronrahirca glaciers caused 18,000 casualties in 1970 (107).

Although the primary productivity of dryland mountain grasslands may increase as a result of the predicted higher average temperatures, some observations suggest that these habitats may suffer because of the degradation caused by warmer and drier conditions (108). The Tibetan plateau already accounts for over 40% of degraded grasslands, and the rate of expansion is 3-4% per year – due to the combined effect of climate change and overgrazing. Overgrazing in the vast Tibetan plateau grasslands of China, for instance, has caused the loss of 3.56 gigatons of soil organic carbon over the last 20 years (151).

Deforestation, land degradation and forest fires in dryland mountains are important global sources of greenhouse gases. Land degradation increases emissions through the direct loss of stored carbon in soils and biomass, and the reduction of a site's potential to store carbon. The climate change-induced increase in the frequency and severity of wild forest fires in the last three decades has consumed over 5000 million tonnes of biomass, with a significant contribution to the emissions of CO_2 to the atmosphere, with about 3,431 million tonnes every year globally.[14] In the Mediterranean Basin, north-west America and Central Asia, uncontrolled large-scale forest fires have devastated millions of hectares of forest land, causing economic losses of billions of dollars, the destruction of houses and infrastructure, and the death of many people, livestock and wildlife (109). These fires have also caused air pollution and important health problems in major urban centres, some located at a considerable distance from the burned areas.

In light of the above, there is an obvious urgent need to strengthen and restore the resilience of mountain socio-ecosystems and their capacity to cope with severe hazards and environmental constraints, as the best option to adapt to future climate forecasts. In fact, it can be argued that the first urgent step in climate change adaptation and mitigation is to stop and reverse the existing "maladaptive processes and practices" that contribute to deforestation and land degradation. Climate change adaptation and mitigation require:

- Greater certainty about temperature and precipitation changes based on regional climate models with higher spatial and temporal resolution in their predictions;
- More precise scenarios about how climate change will affect species, ecological processes and ecosystem services;
- Plans for "resilient landscapes", through stakeholders' consensus and participation and major efforts to reverse the human drivers of climate change, and through integration of land use, water management, disaster management, energy consumption, and human health policies.
- Innovative approaches in adaptive conservation and land use management practices to maintain and restore resilient landscapes and socio-ecosystems;
- Enabling conditions (legislation, financing, competent institutions, stakeholder participation, capacity building and awareness raising) to gain support and enable land managers and users to swiftly adapt to resilient uses and management practices. These conditions will also allow rural economies to become highly self-sufficient and less dependent on subsidies.

3.10 Altered hydrological regimes and water consumption

One of the greatest challenges faced by dryland mountains is the need to rethink the management of freshwater resources, because the combined effect of land degradation and habitat loss on one hand, and climate change on the other hand, will severely alter their hydrologic regimes. Even in the best climate change scenario with no precipitation decrease, higher temperatures and more frequent and intense extreme weather events will substantially enhance the water deficit – higher evapotranspiration, lower capacity of eroded soils to retain water, and reduced runoff during the dry season – with important consequences for the whole hydrologic cycle (44).

Factors such as the trend of sedentarisation among transhumant and nomadic herders, the conversion of forests and pastureland to agriculture, the extraction of minerals, tourism development and urbanisation growth, have all put more pressure on water resources in dryland mountain regions and ephemeral river basins (21). The consequences of glacier retreat and the reduction of the seasonal snow pack will be especially felt in those regions where the water supply is heavily dependent on melting snow and ice. This is the case in the Central Andes, Central Asia[15], the western USA, and some regions of West Asia and the Mediterranean Basin. Experts predict a shift in the peak river runoff to winter and early spring, away from the seasons when water demand is highest, and a less gradual discharge, with high quantities of water released in shorter periods of time (110). These changes will entail a higher risk of devastating floods, in both terms of intensity and size of the area affected, over the next 50 to 100 years. According to some projections for Central Asia, an increase of 2°C – which is actually less than what expected in the most optimistic scenarios – will entail the complete melting of 35% of the present glaciers, and a peak in runoff water between 2030 and 2050, with an increase of 150 to 170% of the flow (98).

Moreover, once all the glacier fossil water has melted, its contribution to the water supply will cease almost abruptly and water deficit conditions will predominate for most part of the year. Under such circumstances, more conflicts in international river basins are to be expected, as is already happening in the Middle East and the Nile Basin (111).

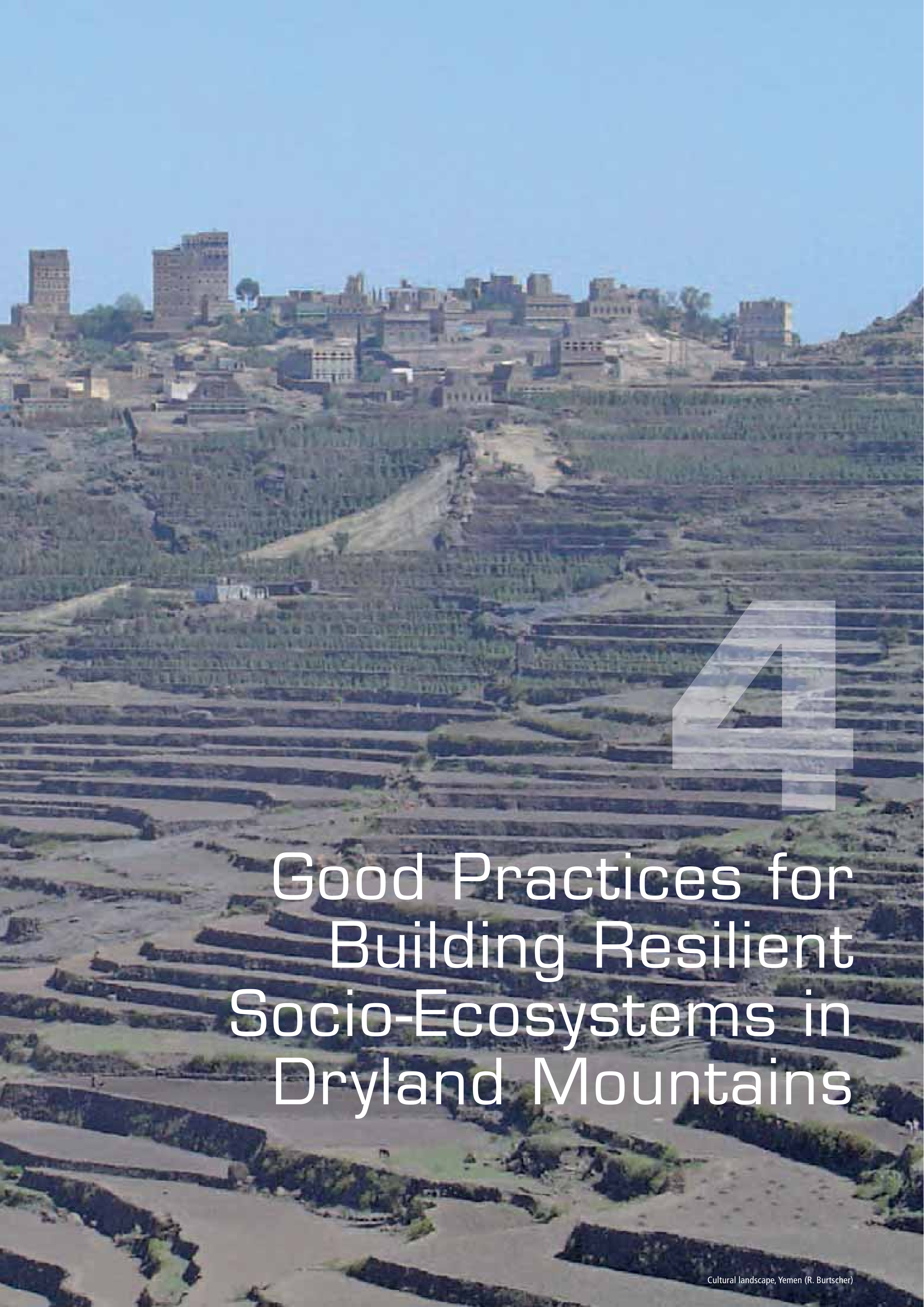
Another important impact of climate change in the hydrologic regimes in dryland mountain regions is the significant reduction of groundwater resources. The following regions are among the most vulnerable according to some scenarios (113):

- 70% reduction in North Africa and South Africa, with a decrease of total water resources for the period 2090-2099;
- 30% to 70% reduction in the Central Andes, Mexico, and parts of the Western USA, Central and West Asia.

Hydropower generation and dams

Energy production, irrigation, water supply and flood control have justified the construction of many dams worldwide, with a peak during the 1970s of the 20th Century (114). A significant number of dams were constructed in the north-west USA, the Mediterranean Basin (Spain and Turkey, North African countries), and Central Asia (India, China). More dams are planned, especially in those river basins whose catchment areas are located in the dryland mountains of Central Asia.

The existing and planned hydropower generation systems of many river basins will be under threat in the likely case of increased landslides and flash floods, and if water flows decrease during the dry season.



4

Good Practices for Building Resilient Socio-Ecosystems in Dryland Mountains

Cultural landscape, Yemen (R. Burtscher)

Learning from what works

The recognition that the climate is already changing because of human-induced global warming makes it urgent to shift our focus from mitigating the effects of increasing greenhouse gas emissions to adapting to the expected adverse impacts (96).

Learning from what works (P. Roden)

This adaptation implies the adjustment of ecological, social, and economic systems to stop and reverse negative processes and practices, and to increase the ecological and social resilience of the system.

In general terms, greater diversity implies a wider range of opportunities and options to cope with any environmental, social and economic change:

- A broader genetic pool in species populations will allow them to react to a wider range of environmental conditions and changes;
- The utilisation and conservation of genetic diversity has played a key role in past adaptation to environmental change and has supported sustainable traditional management systems;
- Species-rich habitats and culture-rich societies can perform more different functions and have a higher number of adaptation options;
- Complex and structured ecosystems and social systems have more solid mechanisms to respond to changes;
- Mosaic landscapes offer a wider range of habitat requirements to species populations, and they provide more goods and services, land use options and economic opportunities to rural societies.

Preserving and enhancing ecological and cultural diversity in dryland mountains is thus the best strategy to build resilience and secure the viability and sustainability of their socio-ecosystems. When it comes to vulnerable socio-ecosystems, adaptation requires the adoption of flexible policies, governance and management systems which can enhance the adaptability of species and habitats, and reduce trends in human-induced pressures that increase vulnerability to climate change.

Highlands of Shangrila, China (HP. Liniger)

4.1 Monitoring change

Knowledge of the Earth's changes caused by climate, land use, biological invasion, global economic forces, or other drivers, and the underlying processes that induce them, have an enormous impact on how societies respond to these changes and, ultimately, on the cost of responding to these changes (29).

Mountains represent unique areas for the detection of climatic change and the assessment of climate-related impacts. Rapid changes in meteorological, hydrological and ecological conditions over relatively short distances along the steep altitudinal gradients makes it easier to observe and analyse shifts in the boundaries of ecosystems and species distribution ranges (116) (117). Moreover, high mountains are ideal places to study the environmental impacts of climate change alone, as their upper portions are not heavily affected by direct human activities.

A number of international organisations and research initiatives are contributing to the generation of new knowledge about the effects of global change in dryland mountain socio-ecosystems. The Global Observation Research Initiative in Alpine Environments (GLORIA)[16] is a network of long-term observation sites in alpine environments from 77 mountain regions distributed over five continents, including a number of dryland mountains, i.e. Sierra Nevada, Glacier NP, Great Basin NP, Rocky mountains NP, Pioneer and Pintlar Range, San Juan Mountains, and White Inyo Mountains in the western US; Sierra Nevada and Sistema Central in Spain; Lefka Ori in Crete; and Cumbres Calchaquíes in northern Argentina. The vegetation and temperature data collected by GLORIA is used to assess environmental trends and predict biodiversity losses and other threats derived from climate change pressures.

The Global Change and Mountain Regions (GLOCHAMORE) project supported by the European Union (117) aims to gain a better understanding of the causes and consequences of global change in selected UNESCO Mountain Biosphere Reserves


Grazing yaks, China (HP. Liniger)

(MBR) around the world (including sites in north-western USA, Central Andes, the Mediterranean Basin, South Africa and Central Asia) and support MBR managers and other stakeholders in the development of adaptive policies. The project has an important networking component, as it promotes cooperation through exchanges and comparative analyses of environmental change processes in biosphere reserves worldwide.

The international conference "Mountains of the World – Ecology, Conservation and Sustainable Development" organised by the Centre for Environmental Studies and Research (CESAR) at Sultan Qaboos University (Sultanate of Oman, 2008) was an important milestone in the history of mountain research, with a specific focus on dryland mountains. The idea for this conference originated from the need to disseminate the success of the recently concluded "Jabal Al Akhdar Initiative" on the ecology, conservation and sustainable development of this arid mountain range (119). This initiative pioneered in the Arabian Region, where mountain ecosystems have received very little attention, and has become a reference for multidisciplinary research in similar environments. The conference provided a forum for mountain researchers from developing countries, and it made an appeal to international agencies about the urgent need to prioritise mountain conservation and sustainable development in economically disadvantaged countries. The conference proceedings include many papers on different issues relevant to dryland mountains, as well as the results of the strategic research project conducted in the Jabal Al Akhdar Initiative from 2004-2007 (119).

4.2 The restoration of the commons: an example of good governance

The different management systems and flexible institutional agreements adopted by farmers and herders in all dryland mountain regions through the centuries have often proved an effective response to extreme environmental conditions, unpredictable disturbances and limited resources. The restoration of these adaptive institutional arrangements and co-management patterns provide interesting alternatives that are worth further exploration (123).

Restoring communal approaches requires the devolution of power (authority and responsibility) from centralised states to local authorities and community groups (24), the identification of new forms of governance, dialogue and participation in decision-making, and adequate policy incentives and innovative technologies to facilitate the integration of traditional systems into the current socio-economic and political contexts.

After a long period during which centralised states have prevented local communities from making adequate use of the traditional communal rights, important lobbying efforts by local communities and NGOs have achieved increased governmental recognition of the value of the commons, and the restoration of the common use of resources in some dryland mountain regions. Recent 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 which supported a thriving economy based on wool, meat and dairy products (25).

4.3 Adaptive management practices

There is an urgent need to identify, test and validate adaptation measures in the conservation and management of the natural resources of dryland mountains before current threats lead to irreversible losses. A precautionary approach is required, so as to avoid the undesirable consequences of adaptation options with high uncertainties and a weak scientific basis (44). In most cases, a successful adaptation strategy will try to promote and restore agro-ecological diversity at all levels (landscape, species, genetic), diversify land uses and complementary income-generating activities, and support the cultural richness of traditional management systems. Adaptation measures will necessarily involve the development of innovative solutions, including new technologies, changes in management systems and institutions, and workable economic incentives, to fit the conditions of modern life and face the greater environmental constraints caused by climate change.

4.3.1 Adaptive forest management

Forests in dryland mountains will need to cope with decreasing water availability due to climate change. Adaptation management options for these forests should involve consideration of ways to achieve a better water balance and a higher resilience to large-scale disturbances like savage fire. Assessing the potential for, and consequences of, extensive climate-induced disturbances is critical in the management of dry mountain forests, because trees grow relatively slowly but they can die quickly (60). Adaptive management decisions should be taken on the basis of regional forest monitoring that can generate reliable data about the status and trends of forest stress and mortality, as well as a good understanding of the ecosystem's response after dieback events.

Several research initiatives have already provided good results, and propose a number of adaptive forest management and restoration measures:

I) Modification of thinning practices, so as to reduce tree density and avoid the high densities of re-sprouting coppice forests and scrub that cause growth stagnation. This measure helps reduce water competition and improves water balance. Moreover, the reduction of tree density and dry biomass reduces the risk of fire, while better-structured and more mature forest stands favour the storage of higher quantities of carbon. These criteria have been applied successfully in different projects in Spain (62) (124) and the western USA (60).

II) Fuel management measures aimed at reducing fire risk and preventing the devastating effects of savage fires:

- The prescribed burning of biomass in high-risk areas is largely practiced in the western USA (125), while prescribed burning has been used extensively in the Fynbos Mountains of South Africa (126), and is becoming a common forest management tool in the mountains of the Mediterranean Basin (122).
- A number of private and community-based initiatives supported by local and regional administrations and NGOs try to combine the collection of dry biomass with the establishment of locally-based, small bio-energy production factories that can cover management costs and create a new source of revenues for local communities.
- National and regional governments and protected areas authorities like those in Andalusia and Valencia (Spain) are currently promoting traditional livestock production in firebreak zones, as a way to absorb firebreak maintenance costs and develop high-quality mountain products for local development. Agro-environmental payments that recognise the essential role played by mountain farmers in providing environmental services are part of the EU Rural Development Programme.

Planning fire-smart dryland mountain landscapes

Fire can be both damaging and beneficial, and its use in ecosystem management can range from traditional burning practices to highly specialised techniques. The reduction of the damage caused by fire and the promotion of the benefits it can bring can be achieved through Integrated Fire Management, a concept that employs social, economic, cultural and ecological evaluations with the objective of minimising the damage and maximising the benefits of fire (122).

The occurrence of large-scale, devastating fires with huge ecological, social and economic costs has pushed the authorities of several countries such as South Africa, Lebanon, Portugal, Mexico, and Mongolia to revise their legislative frameworks in order to improve fire management and fire disaster management. Under the current climate change scenario, the assessment of past successes and failures indicates that a comprehensive, integrated fire management strategy should build fire-smart landscapes through participatory planning processes, which can identify the most resilient land uses and landscape patterns that help reduce the risk of fire. More and more societies in fire-prone regions will need to learn how to live with fire. In most cases, this means regaining and enhancing traditional land uses and mosaic-like landscape patterns that appear to be more resilient against these environmental disturbances.

The South African Working for Water initiative is a good example of how participation in watershed management contributes to smart-fire landscapes, while creating opportunities for poverty reduction in mountain areas (Box 4).

Box 4 | Working for Water: Job creation, watershed management and the control of invasive plant species in the Western Cape Province of South Africa

Water is a limiting resource for development in South Africa, and invasive alien plants have a negative impact on the supply of water from the ecologically fragile fynbos (17) catchment areas, in the Western Cape Province. Conservative estimates indicate that invasive alien plants in these catchments are currently using 143 million m^3 of water per year, which is equivalent to 4.1% of the registered water use.

In 1993, a group of scientists and conservation managers called the Fynbos Forum decided to approach political decision-makers about alien clearing. A landmark presentation in 1995 described the devastating impact of invasive alien plants and suggested a revolutionary way of addressing the problem through creating work opportunities, an approach which had been piloted through a project on Table Mountain led by an NGO, the Botanical Society of South Africa. This led to the appointment of a leading scientist to work with the then Minister of Water Affairs and Forestry to initiate a Water Conservation Campaign, based on the idea of controlling invasive alien plants while creating work for the previously unemployed. The objective was to improve water supplies through better catchment and water-demand management, in preference to the construction of new dams – a revolutionary approach for the department at the time.

In 1995 the Working for Water programme was started, and Rand 25 million (US$3.3 million) was secured for the labour-intensive clearing of invasive alien plants throughout the country. Working for Water uses labour-intensive mechanical and chemical methods to remove alien plants from mountain catchments and river corridors. The programme creates temporary jobs and provides training for unemployed people, while also restoring the productivity of the land and the natural functioning of these ecosystems – the way water moves, the way fires burn, and the way plants and animals live.

Since then, the Working for Water concept has been extended, and similar programmes have been initiated: Working for Wetlands, Working on Fire and Working for Land. All focus on providing work and training for the unemployed, while meeting environmental goals. Their consistent focus on work creation and delivery has secured them long-term political support.

In the Western Cape, the target for the programme's cycle (2000-2010) is to clear 636,000 ha of invasive alien plants in the Berg, Breede, Fish-Tsitsikamma, Gouritz and Olifants-Doorn catchments. If invasive vegetation is not cleared, the water wasted by invasive alien plants could increase to 457 million m^3 per annum, or 13 % of the registered water use.

Over its 14 years of operation, the Working for Water programme has spent Rand 4 billion (US$ 527 million) in clearing nearly 2 million ha of invasive alien plants across South Africa, out of an estimated total of 16 million ha infested. In so doing they have created 27.5 million person-days of employment. The remarkable achievement of this programme has been recognised by numerous awards.

Source: Caroline Petersen[18]

Forest restoration in dryland mountains

Forest restoration should be oriented towards efficient water use, and the reduction of runoff under heavy storms (39). In the Central Andes and the Mediterranean Basin, the use of runoff and fog water produced upslope has been an efficient, traditional agriculture practice, which may play an important role in the restoration of degraded areas (Box 5). Deep water infiltration and groundwater recharge, especially for heavy rains, can be improved through several techniques of watershed management. This is the case for some pilot restoration initiatives in the degraded mountains of Valencia (Spain), where researchers have tried to secure the long-term survival of seedlings (127) through the use of lateral channels that divert surface runoff water towards the hole where the seedlings are planted. The survival rate of *Quercus ilex* planted with this technique increased by 25% as compared with control holes. At the same time, the application of 3-5 litres of water collected from fog to *Quercus ilex* seedlings once or twice during the first summer after planting raised survival rates to close to 100%.

Box 5 | Forest restoration in the arid coastal mountains of Peru: an eco-cultural practice combining land restoration and water security

Fog oases occur in the sea-facing slopes of the hyper-arid monsoonal mountains of the southern Arabian Peninsula and the coastal mountains of Peru and northern Chile, where trees intercept fog droplets and help produce a humid microclimate that prevents dehydration during the dry season. These mountain oases host important plant diversity: in the case of the so-called “lomas” of Chile and Peru the number of plat species is ca. 1400, with many endemic taxa, often exceeding 40% of the local flora. The trees and columnar cacti of these forests are useful sources of non-timber forest products.

Historical, palaeoecological, and archaeological evidence suggests that the Incas and other native Amerindian peoples in dry parts of South America used to plant trees as a land-management practice. These afforestation measures were probably intended to optimise water use and improve crop, animal, and forest production under a climatic regime characterised by scarce and seasonal rainfall. Various multi-purpose native legume trees were apparently used for this purpose, including Acacia Geoffroea, and Prosopis, among others (Aronson 1990; Towle 2007).

More recently, the critical levels of poverty caused by severe deforestation and water shortages (Ferreyra 1986; Masuda 1985) have triggered a new awareness in the Atiquipa community about the link between forest conservation and human subsistence, and the initiation of forest restoration initiatives (Torres & Velásquez 2007) where Tara trees (Caesalpinia spinosa) were chosen to provide both ecological services and goods of commercial value such as tannins and gums (de la Cruz 2004; Villanueva 2007).

Source: Pedro Regato, extracted from Balaguer et al (41)

Adaptive forest management should enhance the diversification of tree and shrub species at the landscape and forest stand level. Conservation, management and restoration measures that promote economically valuable tree and shrub species with different life strategies (i.e. re-sprouting species and fruit trees/shrubs which attract seed-dispersal fauna) help diversify the forest responses to climate stressors and disturbances (44). This is especially true for the trees and shrubs of riparian forests, because of their role as corridors in the migration of species, and as barriers that prevent the spread of fire over the landscape. The establishment of incentives and market opportunities for non-timber forest products not only facilitates the readiness of forest owners to shift from mono-specific plantations to more diverse forest stands, but also generates opportunities to diversify and increase local income. Several projects addressing post-fire forest restoration in the Mediterranean Basin, from Portugal to Lebanon, are adopting this adaptation strategy. The use of shrubs as nurse plants for reforestation has proved a viable technique for increasing the success of reforestation in Mediterranean mountain forest ecosystems such as those in the Sierra Nevada (southern Spain), mainly due to the reduction of solar radiation, the improvement of soil water retention, and the protection from herbivore damage (128). In addition, this technique offers the advantage of following natural succession, and thus minimises the impact of afforestation on the natural vegetation. The use of nurse plants in reforestation has also been tested in the olive-juniper forests of the Ethiopian mountains, where planting under shrubs during above-average rainy summers favours forest regeneration, keeps levels of indigenous biodiversity high, limits livestock damage to olive saplings, and reduces the risk of soil erosion. (129). In Mexico, results show that the use of nurse plants increases the survival rate of oak seedlings only when water is supplied. This suggests that restoration of oak forests in these degraded areas requires both nurse plants and watering. (130).

Adaptive management in mountain forest conservation

Forest species and populations with higher phenotypic plasticity and genotypic diversity can better tolerate changes in the environment. The forests of the Mediterranean Basin are often characterised by very high species and genetic diversity, including highly resilient, old taxa that have experienced many abrupt and intense climate changes in the past (43). The inventory and conservation of genetic reserves in dry mountain forests will help ensure higher forest adaptive capacity. Moreover, the enhancement of gene flow (hybridation) will facilitate the selection of drought-tolerant provenances and genotypes to plan and adapt forestry in dryland mountain regions (131).

Strict conservation measures in the absence of a natural perturbation regime may result in increased vulnerability of mountain forests to climate change (Box 6); adapting conservation needs to climate change may require a shift to proactive management.

Box 6 | Adaptive management in mountain forest conservation: the case of the Abies pinsapo relic forests in Southern Spain

Most forests in the Mediterranean basin are nowadays concentrated in climate change-vulnerable, mountainous areas, which act as genetic reserves and host more or less isolated populations of ca. 35 endemic and relict conifer tree species and subspecies (Boisvenue & Running, 2006).

In southern Europe, major land-use changes have occurred during recent decades, as a result of the abandonment of traditional uses along with the adoption of protection measures. Conservation policies have often been rather strict, because of the high conservation value, the limited distribution area, and the low overall economic impact of their traditional uses in these endemic forests (Ojeda, et al., 1996). At first, protection measures were frequently directed towards encouraging natural regeneration and/or reforestation. The absence of management and protection against any natural or human-induced perturbation regime, has led to the densification of the forest, and has diminished the ability of trees to cope with climatic stress, especially drought (Valladares, 2008). After the intense drought of the 1990s, symptoms of acute decline and dieback episodes were observed in the Spanish populations of Abies pinsapo, a relict fir endemic to the mountains of both sides of the Strait of Gibraltar, while no such symptoms had appeared in the Moroccan populations. This contrasting behaviour and the fact that traditional land uses still occur in the Rif mountains, suggests the hypothesis that the greater vulnerability of the Spanish populations might be related to the predisposing effect of excessive stand densification obtained through the severe protection measures. On the contrary, the maintenance of low-intensity traditional uses (grazing and scattered logging) in the Moroccan forests may have promoted greater structural diversity, which might explain their higher resilience to recent climate change.

As this example shows, adaptation to climate change requires a shift to proactive management, directed towards the enhancement of canopy structural diversity at both stand and landscape levels (Millar, et al., 2007). Pilot experiments to test adaptation options suggest that structural diversity enhancement at the stand level, and the implementation of a minor perturbation regime, through low-intensity thinning practices, help reduce the severity and degree of incidence of possible mortality and increase resilience of the Spanish Abies pinsapo populations to climate change at the landscape level.

Source: Pedro Regato, extracted from Carreira et al (124)


Rock water harvesting, Mukogodo, Kenya (HP. Liniger)

4.3.2 Adaptive management of water scarcity

Water has always been a scarce resource in drylands, giving rise through history to equity considerations in its allocation. Traditional communal systems for managing water scarcity are often considered to be successful examples of resilient socio-ecosystems.

The management of water scarcity is facing major challenges due to the uncertainties caused by climate and global change, and by fast-changing socio-economic boundary conditions. Adaptive management aims to optimise the use of all sources of surface and underground water while maintaining biodiversity and ecological functions and services, through technical solutions, decision-making tools, and good governance, including adequate participation mechanisms and respect for cultural diversity and heritage.

Integrated watershed management in dryland mountain basins

The efficient management of water scarcity is a big challenge in dryland mountains, and it requires intelligent solutions for the sustainable use of all available water resources in an integrated fashion. Watershed management can be defined as any human action aimed at ensuring sustainable use of watershed resources. It is an ideal framework for supporting food and natural resources production, while protecting soil and water, as it uses river basins as functional landscape units that obey natural and not political boundaries. It addresses the unbalanced flows between catchment mountain areas and lowlands, and provides an important policy tool to balance human development needs and natural resource use between lowland and upland areas.

Collaborative approaches and partnerships for water management are important tools in integrated watershed management in dryland mountains (25) (Box 7).

The Water Framework Directive (WFD) of the European Union is another concrete example of effective participation in integrated watershed management that may

Box 7 | Participatory integrated watershed management in upland areas of Tajikistan

Tajikistan is a mountainous country, with almost half of its territory at more than 3000 m above sea level. The farming system in the uplands consists of rainfed agriculture, and pastures. Forests and bushes are limited to the highest parts of the mountain catchments. Over the last decade, most of the uplands have suffered from overgrazing, deforestation and inappropriate agricultural practices. Recent statistics show that about 98% of these lands are affected by severe erosion. Watershed degradation in the uplands also leads to severe hydrological imbalance in nearby downstream areas.

In recent years the Government of Tajikistan and its international partners have initiated several initiatives related to the sustainable management of upland resources and requested FAO's assistance in addressing these problems, through its Technical Cooperation Programme (TCP). The project ran from 2003 to 2005 and provided assistance in establishing the prerequisites for rehabilitating the country's upland resources. Its specific objectives included:

- Participatory integrated watershed management activities for the rehabilitation of upland natural resources for small-scale demonstration, training and eventual replication;
- Identification and implementation of income-generating activities within the framework of integrated watershed management;
- The development of project profiles for the multiplication of integrated watershed management interventions.

Upon completion of the project, the following results were particularly worthy of note:

- The Bodomo sub-watershed in Faizabad District, which was selected for the project's field component, has evolved into a real demonstration and training site for modern approaches to participatory integrated watershed management. A comprehensive management plan has been developed, with pilot interventions such as afforestation, agroforestry and gully rehabilitation, pasture management, drip irrigation technologies, and water harvesting ponds. A modern greenhouse has been constructed for a tree nursery.
- In the Bodomo catchment, controlled grazing has been introduced, the vegetation has recovered and degradation has been significantly reduced.
- An irrigation calendar allocates water to each household on a specific date and in a specific quantity. Following the installation of pipes, households now get drinking water directly from the spring.
- A revolving fund has been introduced and small enterprise projects are being implemented successfully.
- Staff and technicians at different levels are now aware of the watershed degradation problems and have acquired skills in integrated watershed management. Participants in training sessions and study tours to India and Nepal have already started to apply their newly acquired knowledge in the pilot project site.
- The project has promoted closer collaboration among government agencies at the central, district and community levels.
- The TCP has made it clear that Tajikistan is a mountain country of great diversity, with many opportunities and much potential specifically related to and located in mountains. FAO has included watershed management as a main direction in its five-year strategic plan for Tajikistan. Within the framework of the project, a comprehensive medium- to long-term investment programme was developed and endorsed by the government.

Because of the success of the TCP, the World Bank has outsourced the implementation of one regional component of its Community Agriculture and Watershed Management project to FAO.

Source: Thomas Hofer (i) & Paolo Ceci (ii)[19] be well worth adapting in third countries with dryland mountains. The "river parliament" that was created among different interested parties concerned with the river Drôme in southern France, for instance, is a fruitful experience with local democracy which has led to the formulation of a shared management plan that is now the basis for a number of contracts mobilising conspicuous resources.

The integrated use of ephemeral surface water, perennial river water, groundwater and unconventional water sources in dryland mountains is an effective way to increase the yield and efficiency of a water supply system and reduce water losses. Seely et al (21) offer a good example of conjunctive use of different water sources in Namibia (Box 8).

Box 8 | The Eastern National Water Carrier in Namibia

This integrated water management system interlinks dams from a number of ephemeral rivers, the Windhoek aquifer and the groundwater sources of the karstic aquifer at Groot fontains and Tsumeb. The system helps reduce evaporation and increase water storage, allowing efficient use of water. Some of the elements of the system are: the transfer of water from dams under less favourable evaporation conditions to dams with more favourable conditions; the sustainable safe yield of water from aquifers, with an additional abstraction on a short-term basis of not more than 3 years as a backup if the dams should fail to provide adequate supply; the banking of surface water from dams in the aquifers to provide additional security supply. This type of integrated conjunctive use of different kinds of water resources increases yield and water use efficiency, and helps save water and delays the need to incorporate additional hydrologic infrastructure at early stages, also reducing the unit cost of water. It should be combined with consumption reduction systems and new technologies to reduce the volume of water required to produce specific products or comforts without affecting its quality (i.e. drip irrigation, installation of low-flush toilets, etc).

Source: Pedro Regato, extracted from Seely et al (21)

Fog harvesting: a promising option for adaptive water management

The potential amount of water available in fog is enormous. There is documented evidence that fog water contributes to the hydrological budget of an area, being an important source of water for the recharge of groundwater (132). For the authors citing this evidence, there is no doubt that in arid and semi-arid regions where rain might be absent for many months to several years, fog must be seriously considered as a source of water in the hydrological context. In fact, people in the Middle East, parts of Africa and South America have harvested water from fog since ancient times.

Fog collection technology appears to be an extremely promising and low-cost water harvesting system for drinking water, crop irrigation, livestock beverage and forest restoration in dryland mountains (133). It does not require energy input to operate and utilises clean and abundant water, often more abundant than rain. The system is easy to construct and expandable, it reduces the burden of carrying water from a distance and generates time savings that the community can invest in income-generating activities and education of children.

Many experimental projects have been implemented in countries such as Chile, Peru, Oman, South Africa, Namibia, Eritrea, Spain and Eastern Nepal. International organisations (i.e. www.fogquest.org) and networks of experts have been created for the exchange of know-how and the organisation of scientific conferences.

The successful adoption and local appropriation of new technologies for natural resource management depends on complex interconnections among many factors


Searching for water, Nuba Mountains, Sudan (J. Krauer)

– physical, cultural, social, political, etc – and the transfer of technologies and uses that are new to local contexts (133). This is a lesson learned in the Chungungo fog collection project in Chile, where the water is used for reforestation, drinking, irrigation and livestock beverage; the following elements of success stand out:

- The development of administrative capabilities, solidarity and rational cooperation through an adequate governance modality (water committee) supported by the water users was an important requirement for encouraging participation and making the system affordable.
- A differential gender-related behaviour analysis (local women were more inclined to this project) appeared to be a fundamental consideration.
- It is necessary to incorporate the community in the project before its onset and to empower its members in management and adaptation to the new technologies.
- There is an essential need for continuous monitoring of the social and politico-administrative forces behind the project, in order to adapt it to changing circumstances beyond the mere formal transfer of responsibilities.

Water management and mineral extraction conflicts

The most important challenge facing water resources and indigenous territory in dryland mountain regions such as the Central Andes is the regulation and planning of extractive industry and the integration of water management into the regulations and governance mechanisms of extractive industries (85). As many indigenous and campesino leaders have been suggesting, the current systems that repeatedly prioritise extraction imply that "ministers and presidents believe that gas and copper are more important than water". In Chile, for instance, vast rock glacier areas like those in the Upper Blanco catchment have disappeared almost completely despite explicit environmental legislation requesting governmental approval for any use of both glaciers and rock glaciers (18).

The federation of grassroots users and stakeholders is an essential step in the response to this challenge, and the protection of the natural resource base of rural


Adaptive agriculture, Ethiopia (P. Regato)

and indigenous communities. However, this step is far from being sufficient for changing both the rules of the game and the rights of access of indigenous people and citizens to water resources (85). In Peru, the *Defensoría del Pueblo* (an institution in charge of ensuring that government action and policy do not infringe on citizenship rights) has played a critical role in conflict resolution among indigenous and rural people, water, and the extractive industry; it clearly illustrates the vital role that competent, autonomous and legitimate public institutions have to play in guaranteeing and protecting community rights.

The effective protection of critical water resources such as glaciers requires not only good legislation but also institutional mechanisms to enforce its implementation and to prevent administrative decisions from prioritising economic development at the expense of environmental protection and local community needs (18). Such positive trends can currently be observed in recent political and legislative developments in Chile (18), while in Argentina, on the contrary, a bill for the protection of the country's glaciers was recently vetoed[20].

4.3.3 Adaptive management in agriculture

Agro-biodiversity in dryland mountains is the product of thousands of years of effort by local farmers, who patiently selected those breeds and varieties best adapted to the harsh conditions of their regions. By contrast, the introduction of inappropriate technologies and non-adapted highly productive breeds in recent decades has often failed to produce the expected improvements (9). It is therefore urgent to focus again on the rich gene pool offered by native crops and domesticated animal breeds – the best allies of local breeders in new challenges posed by the need to adapt to climate change.

Under current global change scenarios, ensuring food security in dryland mountain regions will require that governments and aid agencies give high priority to policies and investments that:


Adaptive new technologies (P. Roden)

- Help farmers adapt their agricultural systems to changing climate conditions in an environmentally sound way: empowering grassroots land users through access to knowledge and materials (combining traditional and new technologies), reforms and decentralised governance systems, and adequate economic incentives for the adoption of new technologies and livelihood diversification.
- Strengthen national capacities to manage environmental risks (namely droughts, floods, and wild fires) and production shortfalls.
- Conserve drylands' agro-biodiversity and support research on native species and genetic resources to obtain better-adapted varieties and make more efficient use of natural resources.
- Provide new market opportunities and effective safety nets for the poor against droughts and price spikes.

Interventions should be well targeted to prevent large farmers and herders from benefiting at the expense of the rural poor.

Sustainable Land Management

Sustainable Land Management (SLM) is a supporting tool adopted by most instruments and mechanisms relevant to dryland management (i.e. the GEF, UNCCD, the New Partnership for Africa's Development – NEPAD). It is a holistic, integrative and overarching approach for achieving sustainable development based largely on land productivity, recognising the role of biodiversity and its conservation in the provision of livelihoods and social participation in shaping land-use policies (164).

Promoting conservation and sustainable use of the wide range of animal and plant genetic resources found in dryland mountains is a good strategy for meeting the broader challenges of food and nutritional security, desertification and climate change. The mixture of a diverse set of different species and varieties of crops, which is practiced in places like the Central Andes and the Ethiopian highlands (Box 9), helps reduce losses and offers farmers the possibility to select cultivars and

Box 9 | Sustainable land management in the Ethiopian highlands

The Ethiopian highlands cover an area of 550,000 km^2 – about 50% of the country. These regions are home to over 90% of Ethiopia's population, 60% of the livestock and 90% of the agriculturally suitable area. In the past, over 90% of the highlands were covered with forests, but today these habitats account for less than 4% of the surface area, while scattered trees can be found on an additional 16% of the land. Land use and cover changes have been particularly rapid in the 20th Century, due to accelerated population growth and land tenure policy changes since 1975. At the same time, climate change began showing its effects and the rich, often endemic wildlife was confined to those few areas that were preserved naturally due to the rugged topography or natural aridity.

Soil erosion has been severe throughout the Ethiopian highlands, but mainly on cultivated lands. Nowadays, the severity and extent of soil degradation are seriously threatening food security in this whole, vast region. In an attempt to secure food production and enhance the ownership of land users, a number of soil and water conservation (SWC) measures have been successfully implemented in some parts of the highlands, making use of innovative approaches. In the past 35 years, an estimated 18-20% of the agricultural lands have been treated. This trend is highly encouraging but needs further emphasis in the coming decades, as research shows that such measures are needed in at least 50% of the area.

As researchers have demonstrated, overall production at the farm and catchment levels has increased significantly in the past 20 years. Food security, however, is not guaranteed by these measures alone, since inter-annual variation remains high because of climate variability and other disruptive factors.

If all the agricultural land in need of SWC is treated within the coming decade, food security will be achieved and the natural resources will offer a viable base to the population. The global carbon markets are a possible incentive for enhanced farmland SWC, since degraded soils have a considerable potential to store carbon, thereby improving soil organic matter and agricultural production. Although this does not fully compensate for investment in SWC, it may help to recover some of the costs incurred by the farmers.

Source: Hans Hurni[21], Berhanu Debele[22] and Gete Zeleke[23]

better respond to predicted changes such as the acceleration of maturity due to higher temperatures, water and heat stresses during the growing season, or the increase of biomass under elevated CO_2.

A regional Plant Genetic Resources (PGR) Network has recently been established under the auspices of the Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), as a platform for regional collaboration in setting agriculture priorities to cope with global change (165). ICARDA's genebank holds more than 131,000 accessions of cereals, food and feed legumes, and forages including cultivated varieties, landraces and wild relative species, representing more than 50% of the conserved genetic resources originating from the drylands of Central and West Asia and North Africa (115). At ICARDA, several promising lines with good tolerance to drought have been derived from inter-specific crosses of barley and wheat. Wild relatives of different crops have sustained recurrent drought and heat cycles that allowed natural selection to develop resistance to these stresses; these plants therefore may harbour valuable genes for these stresses.

The modification of soil management practices (e.g. low tillage and the maintenance of permanent soil to reduce erosion rates and downstream flooding and increase water absorption and retention) is a very important factor in adaptation to water stress caused by unbalanced precipitation and increasing temperatures.

It also helps to mitigate climate change effects through soil carbon storage. The work of ICARDA in West and Central Asia shows the advantages of minimum- and zero-tillage over deep-tillage systems, especially if combined with cereal-legume crop rotations, and the beneficial effect on crop yields, soil quality, water use efficiency and net revenue (115).

Conservation agriculture

Conservation agriculture (CA) is an example of a mitigation-adaptation strategy to cope with climate change. It is defined by FAO as "agriculture that maintains and improves crop yields and resilience against drought while maintaining the biological functioning of the soil" (FAO, 2002). Others have defined it more broadly, as the integration of natural resources management with sustainable and economic agricultural production (Dumanski et al., 2006). Notwithstanding these different perspectives, CA has much to offer in adaptation to climate change, as it involves minimal soil disturbance, the maintenance of the land cover through plants or mulches, a soil structure that allows adequate exchanges of gases, nutrients and water, the conservation of organic matter in the soil, and more diverse crop rotations. Additional benefits include savings in labour, time, fuel and machinery, timely sowing, higher yield potential, and less erosion.

Source: Extracted from Thomas et al, 2007 (115)

A number of low-cost, simple irrigation methods are available, which require much less water and labour. Such systems have traditionally been widespread, but they have been poorly studied and documented by modern agronomists (135). Methods such as deep pipes, buried clay pots, porous capsules, wicks, porous hose, and sub-irrigation with perforated pie, could all help increase yields in agriculture, agro-forestry and land restoration. A study by ICARDA on on-farm water use efficiency shows that farmers actually over-irrigate their crops by 20-60%, while the results of field research work on Syrian farmers demonstrate that they could produce 33% more grain from 50% full supplemental irrigation practice compared with full irrigation (115)

The EU-funded project INTERREG/Mediterritage, carried out in various countries of Southern Europe, North Africa and the Middle East, has supported the recovery of the abandoned traditional mixed cultivation and breeding systems of irrigated terraces in the mountains of southern Andalusia (Spain), Mugla (Turkey) and the High Atlas (Morocco). The project aimed to revive this once sustainable model of traditional mountain agriculture, addressing key aspects that may guarantee its sustainability under current global change trends. The project has provided training and resources to small family business groups, while developing awareness raising, marketing, and policy work to promote the multiple functions that mountain terraces can play in different sectors of rural and environmental development (53). Among the positive outcomes of this experience is the restoration of terraces supporting viable farming systems based on high-quality produce, and the establishment of complementary touristic activities based on the landscape value of the terraces. The growing of medicinal and aromatic plants provides a good complementary source of revenue, driven by increasing market demand in recent years (9).

The project demonstrated that the restoration of terraces requires striking a balance between modernity and tradition: the traditional irrigation system must be integrated with modern sprinkler or drip irrigation systems, while elements to facilitate access and work should be added to the terraces, i.e. a monorail system or a transport system by cable; connections between terraces for access ramps for tractors, etc (53).


Grazing sheep, Mongolia (HP. Liniger)

WOCAT (World Overview of Conservation Approaches and Technologies), a global network of soil and water conservation specialists, with a secretariat hosted by CDE, documents proven practices in SLM worldwide, including many mountain regions in dry areas. Working closely with FAO, UNCCD, GEF, and the World Bank, WOCAT's database includes 310 technologies from more than 50 countries. The database is linked to Google Earth, and available on the Internet (www.WOCAT.net).

4.3.4 Adaptive management in rangelands

Attempts to substitute mobile pastoralism with new animal husbandry techniques and replace local breeds with highly productive stock have often failed and caused land degradation (46). In fact, scientific gains demonstrate that mobile pastoralism is more productive than sedentary husbandry under similar environmental conditions, and recognise the valuable role of pastoralists in the efficient protection and use of limited resources. A new generation of pastoral projects combines respect for mobile strategies and indigenous knowledge with a focus on institutional development and systematic participation by pastoralists in the identification of the most effective solutions for the new challenges posed by the current environmental and socio-economic context (Box 10).

In mountain regions such as the Mediterranean Basin, South Africa, the Central Andes and Central Asia, mobile pastoralism is increasingly seen as a viable and modern model of livelihood, and people are going back to ways of life which would have seemed quaint to the previous generation (46). More flexible policies and development agencies are supporting mountain herders in their effort to finds ways to improve their livelihoods, through the combination of traditional and modern techniques, the improvement of communication, better infrastructure to access distant pastures and market places, the diversification of agro-pastoral and non-timber forest products, and the search for new market opportunities that are often linked to fair trade and organic certification, territorial marketing and ecotourism. In the Reserva Nacional de Salinas y Aguada Blanca in Peru, for instance, a controlled market chain was set up for valuable vicuña fibre (47). This implied the establishment of a communal, sustainable management scheme for wild vicuña populations based on rodeos, and the quality control system implemented by the International Vicuña Consortium created by Italian buyers.

Box 10 | The role of women in community-led conservation in Mongolia

Women pastoralists in Mongolia's Gobi desert have faced a harsh, arid mountain environment for thousands of years. The need to protect the vital grasslands from overgrazing gave rise to a traditional, semi-nomadic way of life, moving domestic herds to new pastures over long distances from season to season.

After the transition to a market economy in 1990, livestock was privatised, and with unemployment on a massive scale, the number of herding households doubled. Government institutions were ineffective in coordinating the seasonal movement that had taken place during socialism. Wells fell into disrepair, with the result that useable pasture decreased. Families with their herds gathered around the few remaining water sources, contributing to further degradation of the grasslands and increasing desertification. In addition, several years of *dzud* – summer droughts followed by severe winters – resulted in the death of millions of animals, plunging many herding families into severe poverty.

In 1993, the Mongolian government created the Gobi Gurvan Saikhan National Park in an effort to protect the precious and unique Gobi ecosystem. The families who lived and herded within the territory feared that the Park would jeopardise their land and their way of life, and they were determined to resist. This determination turned into active involvement in protecting their environment, with the help of the Initiative for People Centred Conservation, implementing a project for German Technical Assistance on sustainable natural resource management and improving livelihoods. The project drew on the capacity of the women to take the lead in finding and implementing the most effective solutions to the new challenges facing their families. They formed groups of neighbouring families into *nukhurluls* – meaning "friendship" and "community organisation" – and began cooperating to find sustainable ways of managing the pastures and lifting their families out of poverty.

The members of the *nukhurluls* fenced off areas as emergency pastures and organised summer hay-making to provide fodder during winter. Where the riverbank had collapsed and water was soaking into the sand, they invited local people and the local government to join them in a cooperative effort to rebuild the banks of the river. The group designed a gravity-flow water system in order to better manage the pasture below the mountains, which has no water source. The water was piped eight kilometres across the land to the pasture and also utilised for vegetable gardening and livestock.

One factor contributing to desertification was the fact that local people were gathering saxaul and native bushes and trees for fuel. The *nukhurluls* began to develop local technologies to meet their survival needs without harming their environment. These included producing and selling briquettes of wet animal dung, clay and coal dust which burn hotter and longer than dung itself. Another *nukhurlul* began building and selling fuel-efficient dung stoves, which use a fraction of the fuel of other stoves.

In addition, the women came up with ideas on how to raise their standard of living. They began to experiment with ways to give a new look to traditional products, and went on to develop small businesses and a model for ecotourism. They involved local families in hosting the tourists, and opened shops and markets selling a variety of attractive traditional products. In the process of taking positive steps to preserve their traditional way of life, the women of the Gobi have changed their lives completely. Before, no women used to attend the village meetings. Now they are taking the lead in tackling their own problems, while actively contributing to the achievement of the Millennium Development Goals of alleviating extreme poverty and protecting the environment. They are also helping to raise awareness throughout the world of the importance of mobile pastoralism in conservation.

Source: Douglas Pattie, UNCCD Secretariat[24]

Policies to support climate change adaptation in mountain pastoral socio-ecosystems will need to be linked closely to the development of agri-environmental schemes, an issue that is becoming an increasing component in the EU Common Agriculture Policy (CAP) (138). In fact, The European Agriculture Fund for Rural Development provided payments for improving or maintaining suitable grazing practices and preventing the abandonment of highly diverse pastures, funding for diversifying mountain farmers' income, and agri-environmental measures recognising the essential role that mountain farmers play in providing environmental services. Moreover, a number of regional governments, such as those in Andalusia (139) and in the region of Valencia (140) in Spain, are promoting livestock production in high fire risk areas (a type of natural firebreak) to reduce the risk of fire spreading into mountain areas.

4.4 Building social and cultural resilience

Social resilience to climate change can be defined as the ability of a community to cope with the stress and disturbances caused by climate change (141). Building social resilience involves socio-economic and ecological adjustment that is often similar to what is required to promote sustainable development strategies. In fact, one could argue that the first urgent step in adaptation is to stop or reverse the existing "maladaptive processes and practices" that contribute to forest degradation and loss (44).

The enhancement of adaptive capacity involves a whole set of requirements, among which we may highlight:

- Improved resource access rights and mechanisms;
- Support for social, gender, and intergenerational equity in the distribution of resources and benefits;
- Improved education and information, with respect for local knowledge, cultures and traditions;
- The achievement of adequate living standards (infrastructure, job opportunities, access to new technologies, heath, education, leisure opportunities);
- Income diversification in mountains through the promotion of a wider range of products (i.e. agro-pastoral and non-timber forest products, rural tourism), that can provide complementary benefits and working opportunities all year round;
- The strengthening and innovation of traditional multipurpose agro-forestry systems and the promotion of the multi-functional role of dryland mountains; and
- The maintenance of viable mountain communities and better competitiveness of rural areas.

Special attention should be paid to women, who often suffer the highest illiteracy levels, and bear the burden of the hardest work—gathering fuelwood at great distances, taking care of livestock, etc. The promotion of education at all levels, from the basic to the know-how and managerial skills needed for natural resource management and local business development, and the introduction of new technologies that can help reduce the burden of work, will all help empower women and reduce poverty (Box 11).

Box 11 | Agroforestry and women's participation in Pakistan's mountain deserts

In the mountain deserts of northern Pakistan, approximately 90% of the population is dependent on subsistence agro-pastoralism. Winters are prolonged and severe, and temperatures range from +45°C in summer to –25°C in winter. In these harsh conditions, over-exploitation of natural resources, particularly forests, had begun to take a serious toll. Natural forests, which make up only 1% of the total surface area, are vital for the conservation of soil and water. However, the consumption of fuelwood for heating and cooking is common in the absence of alternative types of fuel. This has led to a severe depletion of forest cover, which in turn created a serious problem of desertification, soil erosion, floods and sedimentation in the rivers and dams. Unsound agricultural practices such as monoculture, partly due to the growing popularity of the potato crop, also contributed to land degradation.

Since the women in Pakistan's Northern Areas undertake the major tasks of agroforestry and livestock, they are the ones who suffer most. In the mid 1980s, the Aga Khan Rural Support Programme (AKRSP) helped the women of Northern Pakistan to rectify the situation. More than 1700 women's organisations have now emerged as strong institutional structures supporting the operation of credit and savings programmes and ensuring proper management of natural resources. They have been instrumental in helping to empower women in decision-making at household and community level regarding farm production, income generation and other socio-economic issues. In the early 1990s, the AKRSP also started the programme "Women, a Catalyst in Environmental Change" aimed at promoting forest plantations on the boundaries of fields, communal land, private land and any other area where original vegetative cover had disappeared. More than one million forest plants and 1000 kg of alfalfa seed to intercrop with the forest plantation were given to the women's organisations in six districts of Northern Pakistan, in order to overcome the fuelwood and fodder shortages in the area.

Subsequently, women started planting trees on their family lands, along riverbeds and on small areas of wasteland with available water. In addition, efforts are now being made to practice crop rotation. The use of farmyard manure as a fertiliser is also helping protect the soil. Recognising the interdependence of agriculture, livestock and forestry on which the population depended, an integrated natural resource management programme merging the three was launched in 1997.

The rural women took an active part in community organisations all over northern Pakistan, forming committees to manage free grazing and forest control.

The members of the women's organisation in the village of Morkhoon, which lies in the Hunza valley at an altitude of 2,780 m, embarked on a project to develop a stony sloping area that had previously been used for grazing. They constructed water channels resulting in 1.8 hectares of barren land being rehabilitated into fertile land, which was used for intercropping and sowing alfalfa seed. The alfalfa is sold in the local market, bringing an annual income of several hundred dollars. In addition, 10,000 local poplar and willow trees were planted in the area. Now the women are able to sell wood to earn income while simultaneously covering their household needs for timber and fuelwood.

Women have also shown a strong inclination towards micro-enterprise activities, and are now becoming increasingly active in generating diversified forms of additional income. They have established private nurseries in the back yards of their homes, producing fruit tree seedlings including apple, cherry and other indigenous and exotic species for sale. Other activities such as bee farming are also proving to be popular with the women. This is having a tremendous social impact, giving the women some financial independence and a stronger position within the household, while reducing pressure on the natural resources.

Source: Douglas Pattie (UNCCD Secretariat)[24]

4.4.1 Eco-cultural protection

Protected areas with strict protection rules that fail to take local people into account may negatively affect their livelihoods and organisational systems. This is particularly true for nomadic and transhumant pastoral societies whose spatial and organisational structure and needs may not fit well with the legislation of many protected areas.

New ideas that can better help maintain the cultural, social and ecological resilience of protected areas should be encouraged and promoted in all dryland mountain regions. Protected areas are increasingly managed by partnerships between governmental and non-governmental actors. The 2003 World Park Congress in Durban endorsed recommendations that identify and acknowledge several governance types for protected areas, including co-management and community management (142). Community Conserved Areas (CCAs) are natural and/or modified ecosystems containing significant biodiversity values, ecological services and cultural values, which are voluntarily conserved by indigenous, mobile and local communities through customary laws or other effective means.

Protecting natural sites with a sacred significance is also a way to protect cultures and traditions, and the role that ethnic/social groups play in protecting the nature of mountain regions. In 2004, the Quechua communities of Q'eros and Ausangate launched the Vilcanota Spiritual Park in Cusco, the first Natural Sacred Site[25] in Peru, which hosts the second most important glacier in the country. The Spiritual Park recognises and promotes Quechua values and principles in the conservation and sustainable use of biodiversity (6). Just like the Potato Park (Box 12), this is a Community Conserved Area, where locals are responsible for planning and managing the landscape, and where traditional agriculture is combined with ecotourism.

The *himas*, an Islamic form of communal protection for rangelands, forests, watersheds and wildlife combined with the sustainable management of mobile pastoralism, are particularly important in the Middle East. Although the *hima* system has been abandoned in many countries, some remnants can still be found in parts of Saudi Arabia, where traditional *himas* are the areas that have best withstood human pressure over time (57).

4.5 Securing environmental services through payment mechanisms: a new economic opportunity

The intimate relation between sustainable land use practices and the long-term availability of environmental services is poorly understood or simply ignored by most policymakers, beneficiaries and society in general. The abandonment of traditional agro-forestry uses and pastoral transhumance and the consequent out-migration that occurred in all the mountain regions in the Mediterranean Basin during the second half of the 20th Century was often seen as an opportunity to regain wilderness and biodiversity. In fact, the populations of many flagship large mammals (ungulates, carnivores) significantly grew and expanded their distributional range over large territories of countries like Italy, France, or Spain. However, the rapid accumulation of dry biomass in abandoned agriculture and pasture land, the loss of traditional rural knowledge, and the spread of leisure activities and urbanisation in rural areas have all significantly increased the risk of severe environmental impacts such as savage fires, which can eventually lead to biodiversity loss and the disruption of ecological processes.

Box 12 | The Potato Park: a holistic, community-based initiative to support the indigenous heritage of the High Andes of Peru

The farming system of the High Andes is dominated by potato, and the wealth of the area is based on the astounding 1,200 different varieties of potato that are named, known and managed by the local people. Trade in potatoes allows the highlanders to exchange the carbohydrates and meat that they produce for vegetable protein from the grains and Andean pseudo-grains produced at middle altitudes, as well as for vitamins and essential fatty acids from the fruits and vegetables grown in subtropical gardens down towards the Amazon. Vertical trade of this kind has been an integral part of the economy of the region since pre-Inca times.

The *Parque de la Papa* (Potato Park) is a unique initiative in indigenous-run conservation, which aims to preserve the huge variety of domesticated potatoes that are one of the most significant elements of the Andes' biodiversity. The park is the brainchild of an indigenous-run organisation called *Asociación Andes* and it is being implemented by a consortium of six Quechua villages in the mountains south of Pisac near Cuzco, in Peru. Under this initiative, the 8,000 villagers of the six communities have agreed to bring together the 8,661 hectares in their six communal land titles and manage them jointly for their collective benefit, with the objective of conserving their landscape, livelihoods and ways of life and revitalizing their customary laws and institutions.

The authority for the Park is shared among the villages, and concerted efforts are made to integrate traditional religious beliefs and understanding into park management. In the Park, new technologies are being applied alongside the old. Greenhouses have been established in the villages to provide vegetables for school meals, and members of the women's cooperative are being trained to make and digitally edit videos, using the local language, Quechua, in order to record and share knowledge of potato varieties and how to manage them. Although the Association opposes the patenting of indigenous knowledge, traditional medicines are being produced by the cooperative for local sale and benefit sharing.

The communities are also re-establishing forests on critical lands. Nurseries for growing thousands of seedlings of native species have been set up. The aim is to regenerate the native forests, most of which were cut down in the 18th Century to provide timber for Spanish silver mines. By regenerating native forests, the villagers hope to promote wild bird and animal species and make the area still more attractive to tourists, who already come regularly to their villages.

The Park is also developing an autonomous programme for controlling tourism and ensuring that local people benefit equitably. Tourism packages are already on offer, including several trekking opportunities with services offered by the indigenous communities, which allow visitors to have a close look at this fascinating reality.

The Potato Park has been developed in the framework of the International Movement for Food Sovereignty. A simple definition of food sovereignty – a concept introduced at the 1996 World Food Summit by the international farmers' confederation *Vía Campesina* – is the ability of countries and communities to control their own food supplies: to have a say in what is produced and under what conditions, and to have a say in what is imported and exported. At the local level, food sovereignty entails the rights of rural communities to remain on the land and to continue producing food for themselves and for domestic markets.

Source: Pedro Regato, extracted from: www.parquedelapapa.org and www.earthlore.ca/clients/WPC/English/grfx/...2/Colchester.pdf.


Planting potatoes, Peru (SL. Mathez-Stiefel)

There is a growing recognition of the need to develop policies and appropriate economic incentives, often in the form of subsidies or other environmental programs, to support the role that sustainable land uses play in the long-term conservation of environmental services, and to influence the behaviour of land users and compensate them for the cost of maintaining, recovering or shifting into sustainable management practices that have a positive impact on the conservation of natural resources.

Payments for environmental services (PES) are relatively new schemes that seek to support positive environmental externalities through the transfer of financial resources from beneficiaries of certain environmental services to those who provide these services or are fiduciaries of environmental resources (144). The basic principle behind PES is that communities that are in a position to provide environmental benefits should be compensated for the costs of these services, while the beneficiary sector of the society should pay for them (143). PES schemes strive to establish appropriate pricing, institutional, and redistribution systems that will eventually lead to behavioural changes and sustainable and socially optimal land use.

Over the last decade, PES schemes have been developed for environmental services such as water regulation, carbon sequestration, biodiversity and culture conservation, for which there is an increasing market demand, or for which such demand can emerge under appropriate conditions. From an assessment of current PES schemes undertaken by Mayrand & Paquin, a profile of the PES schemes that tend to work best has been drawn (Box 13) (144).

The existence of strong and undisputed tenure is a prerequisite for the creation of successful PES (144). The inequitable distribution of property rights or the persistence of unclear land tenure regimes, due to the disruption/collapse of traditional communal systems, can prevent the establishment of PES, as it may exacerbate conflicts over resources and make the distribution of payments to land users problematic. In such regions, securing access to the resource base through land tenure reforms remains a considerable challenge.

Box 13 | Elements of workable PES schemes

- Clear definition of the environmental services to be provided.
- Clear and consensual scientific evidence of the links between land uses and provision of services.
- Proper and acceptable value assigned to environmental services, based on sound economic analysis and extensive consultation with beneficiaries.
- Payments exceed the cost of providing services and are balanced: enough to compensate the costs to land users, and within the margins that beneficiaries are willing to provide.
- Payment mechanisms are designated to deliver monetary and non-monetary (i.e. capacity building, infrastructure, revenue diversification, or market development) benefits for land users.
- The transaction contracts should be flexible and open-ended, so as to allow the adjustments needed to improve effectiveness and adapt to changing conditions, and bear clear obligations for land users (i.e. acceptable land use type, management plan).
- Low transaction costs through collective negotiations and contracts that guarantee equity (i.e. solid cooperative institutions and local associations).
- Effective monitoring of compliance and the provision of services.
- Stable and continuous flow of revenues to ensure long-term sustainability of the system (i.e. taxes, state subsidies, direct contributions, grants, loans, or donations).
- Establishment of a governance structure that oversees, gathers and manages the funds from beneficiaries.
- Facilitated access to start-up financing.
- Solid understanding of the market for the environmental service to be sold.

Source: Pedro Regato, extracted from Mayrand & Paquin (144)

Since its inception, the GEF has funded 42 projects where PES was the core objective. Very few projects among them address environmental services from dryland mountains, in most cases with an overall national perspective. This is the case of the environmental services programmes in Argentina and Mexico, and the project to remove obstacles to direct private sector participation in in-situ biodiversity conservation in Bolivia (157).

Watershed services

The potential for developing markets for watershed services is a very promising one, when considering the critical role of these services in securing the water supply for millions of people. In fact, there is an increased willingness of the beneficiaries to pay for services, as awareness is growing of the importance of conserving upper watersheds for the maintenance of water services (145). Markets for watershed services usually involve users' fees to finance the improved management of upstream land uses that generate watershed benefits and meet the demands of downstream users (farmers, hydroelectric producers, and domestic water users in urban areas) (146). According to Mayrand & Paquin (144), the nature of the local demand and the presence of a limited number of well-organised beneficiaries (e.g., water or hydroelectric utilities, irrigation commissions) make it relatively easy to mobilise downstream beneficiaries and involve them in PES schemes.

Watershed PES schemes have been put in place in parts of Mexico, the US, and the central Andes. One such example is the *Fondo Nacional del Água* (Fonag) of Ecuador, which collects contributions from water users – the city of Quito and a hydroelectric power company – to fund conservation practices in the upper water-

Urbanisation in mountains, La Paz, Bolivia (S. Brüschweiler-Muster)

shed that provides drinking water for the capital (147). Also in Ecuador, the municipality of San Pedro de Pimampiro, in the province of Imbabura, is developing a pilot project to protect drinking water sources by paying land users in the upper basin to improve forest management in the watershed (148).

The Mexican programme on hydrological services (particularly watershed protection and aquifer recharging) provided by natural forests includes a number of rural areas from dryland mountains. The programme has a strong social target, focusing on *ejidos* (peasant communities that own land in common-property structures) in the poorest rural areas of Mexico, and payments are made to the community, not to individual peasants (158). For the period 2003- 2006, payments for the conservation of natural forests were between US$ 27 and 38 per ha per year, based on five-year contracts. During these same years, approximately 300 *ejidos* per year have signed on, bringing an additional 150,000 hectares per year into the programme. An assessment of the programme found that a significant portion of these contracts were paying for the protection of forests that actually faced low deforestation risks, identifying the need for better targeting the areas and fine tuning the payments to the real opportunity costs of landowners.

A GEF project approved in 2006 will provide a follow-up to the Mexico Environmental Service Programme. With a budget of US$170 million, this is by far the largest PES project in the GEF portfolio, from which 90% of the GEF money will go to (a) try to develop new market-based sources of PES, mostly for carbon sequestration, water regulation and tourism related conservation, (b) capacity building; and (c) capitalise on a Biodiversity Conservation Endowment Fund (158).

In Bolivia, Robertson & Wunder (149) have analysed the 'Water Sowing Project' (Siembra del Agua, in Spanish), a pioneer PES effort led by ICO (Eastern Training Institute), which addresses the needs of over two thousand water users in a number of semi-arid micro-watersheds of the provinces of Santa Cruz, Florida and Vallegrande, and promotes the creation of conservation areas[26] around headwaters to


Expedition on Aconcagua, Argentina (HP. Liniger)

improve water quality and quantity, and prevent increasing scarcity and deterioration due to intense irrigation, cattle ranching, deforestation and population growth. Several communal agreements were signed, following different options – including cash payments for water services, donated transfer of properties from private owners to the communities, secession of private property for the protected area while maintaining private formal owners, and complete expropriation by the community. According to ICO (1999), the water flow actually increased in the whole region since the establishment of the protected area, to the benefit of local farmers and their crops. However, it seems that more thorough hydrological studies are needed to confirm this positive effect. Land use change led to improved water quality and consequent positive environmental and users' health effects that are likely to persist.

Provisioning and cultural services
Among the best emerging practices, the diversification of revenues for communities involved in PES schemes through the creation of new markets for environmental goods and services (non-timber forest products, organic food, ecotourism) appears to be one of the most promising (144). PES schemes can play a significant role in supporting such diversification, by including specific support measures for market development and income generation in their compensation packages (Box 14).

Robertson & Wunder (149) have analyzed payments for cultural services in the Eduardo Avaroa Reserve, located in the arid highlands (4000- 6200 m) of southwest Bolivia, the most visited protected area in the country – with 45,000 visitors in 2003 and a visitation increase rate of approx. 15% per year. The region is home to unique desert landscapes, and two famous coloured lakes – the Laguna Colorada and Laguna Verde. The Eduardo Avaroa Reserve provides an interesting example of payment for landscape identity and beauty, because a considerable portion of tourism-related benefits are actually transferred to the local communities. The Nature Conservancy (TNC) promoted the establishment of an entrance fee system – the first of its kind in Bolivia – that has generated additional resources for park management, as well as explicit provisions for a benefit-sharing system that facili-

Box 14 | Using tourism and non-wood forest products to build a sustainable economy in the Shouf Biosphere Reserve, Lebanon

The Shouf Cedar Biosphere Reserve (SBR) was set up by the Lebanese government and UNESCO to protect the outstanding mountain ecosystem, which hosts one of the last strongholds of the Cedar of Lebanon. The region is the most important freshwater-generating hotspot in the Middle East: precipitation in the watershed is the source of both surface stream flow and groundwater, which supply hundreds of thousands of people and the agriculture of the Beqaa Valley and the Lebanese coastal plains.

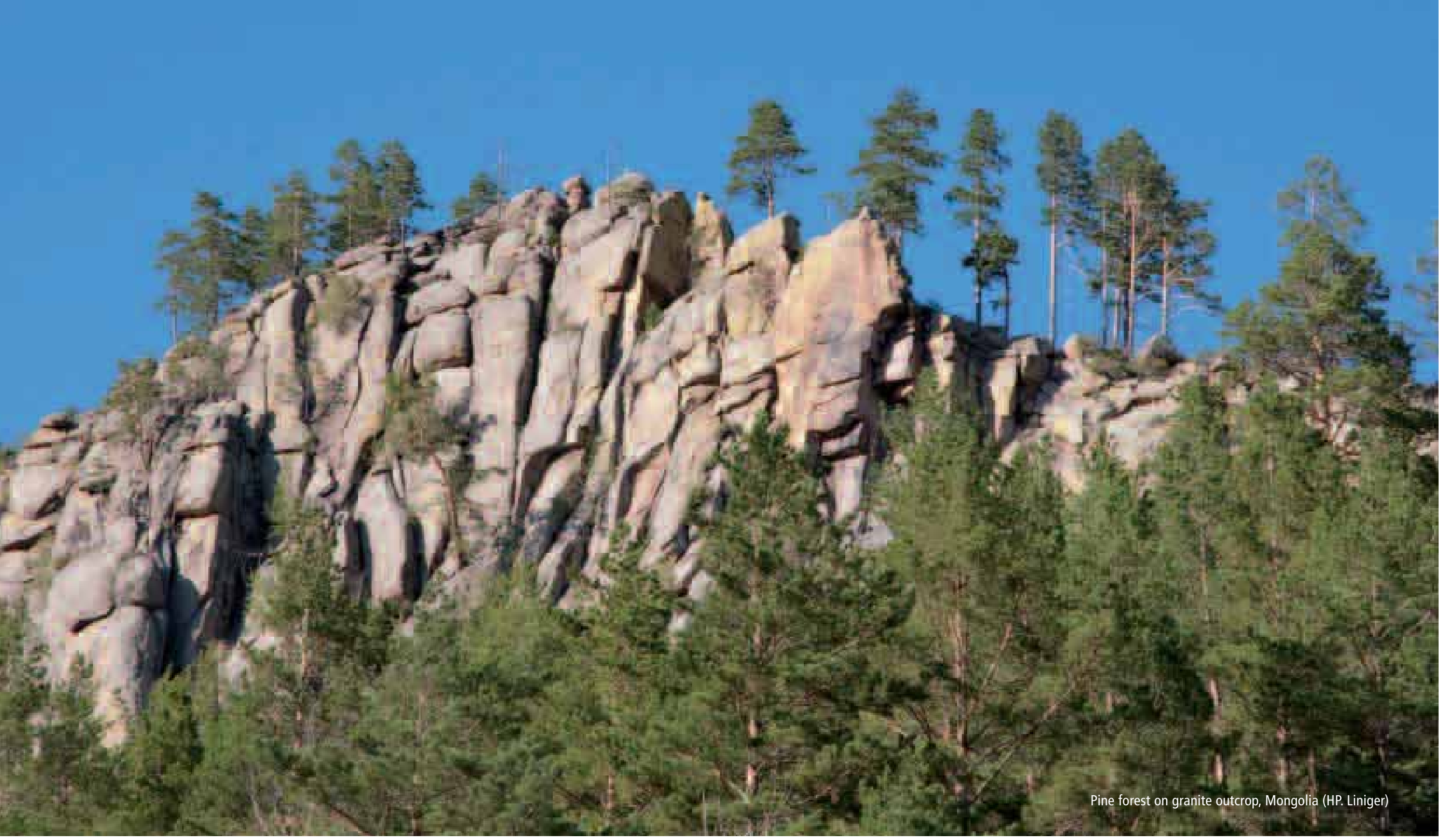
The approx. 70,000 people who live in the surroundings of the Reserve are currently facing severe economic challenges, mainly due to the loss of traditional occupations such as farming and low job opportunities, lack of proper investment and low quality services, and the low competitive edge of the local agriculture produce on the markets. The lack of employment is leading to increased migration to the cities and abroad.

Since its foundation in 1994, Al Shouf Cedar Society (ACS, www.shoufcedar.org) – the organisation specifically created to manage the Reserve – has supported initiatives aimed at improving the livelihoods of the communities living around the SBR, and the creation of a new economy, based on the sustainable exploitation of the outstanding natural resources of the region. ACS decided to focus its efforts on two promising lines of work: nature tourism and Non-Wood Forest Products (NWFP).

ACS's Eco-Tourism Programme is designed to facilitate a rewarding visitor experience through the establishment of adequate facilities managed by the Reserve, and by supporting small enterprises run by members of the local community, for the provision of high-quality services geared to the over 20,000 tourists (60% Lebanese nationality and 40 % various foreign nationalities) who visit the area every year. Thanks to this programme, SBR has become a leading eco-tourism destination in the Middle East, offering a wide range of activities and experiences, including hiking and trekking, bird watching, biking, climbing, rope games, educational activities, etc. A network of privately run guesthouses is being established throughout the protected areas, and five of them are already running a successful business. One of the strengths of ACS's eco-tourism programme is that of being developed in coordination with other, similar initiatives in the country. One of them is the Lebanon Mountain (LMT, www.lebanontrail.org) – the first long-distance hiking trail in the country. The LMT is a 440-km long path that extends from the north to the south of Lebanon, transecting more than 75 towns and villages at altitudes ranging from 600 to 2,000 meters above sea level. The LMT showcases the natural beauty and cultural wealth of Lebanon's mountains, bringing communities closer together and expanding economic opportunities in rural areas through environmentally and socially responsible tourism.

SBR harbours a rich flora with over 520 species of plants, and its scrublands and high mountain pastures which are particularly rich in aromatic, edible, and medicinal herbs and plants. The Rural Development Programme launched by ACS in 1999 builds on this natural treasure, and encourages the members of the local community – especially women – to make use of raw materials and produce a wide array of goods based on non-timber forest products, such as marmalades and jams, dried herbs, beverages, distilled waters, oils and craftwork. So far, the programme has granted aid to 40 families, facilitating the set up of several small family-based enterprises and the commercialisation of more than 70 products that are available on sale at the main entrances of the Reserve.

Source: Marco Pagliani[27]


Pine forest on granite outcrop, Mongolia (HP. Liniger)

tates payments to local communities. The system has created an incentive for the local community to take care of the tourist attractions: the end of egg collection, for instance, has led to a recovery of the flamingo population. Further changes have already been proposed to unlink community payments from the number of visitors and prevent undesired effects, such as the opposition of the community to regulations that restrict tourist access in sensitive areas.

Carbon sequestration services

Thanks to their large surface area, drylands hold 36% of total carbon stocks in terrestrial ecosystems. This figure explains the global significance of dryland ecosystems in carbon sequestration (150), and the importance of developing payment schemes to prevent the degradation and loss of forests, scrubland pastureland and agriculture in dryland mountains. Modelling studies suggest that, within the structure of current dryland farming systems, alterations can be made that will result in annual carbon sequestration in the range of 0.02–0.29 mg per ha per year (162). According to Wilkes (2008) (152), if reductions in livestock rearing rates in the Tibetan plateau of China could increase carbon sequestration by just 0.5 t C/ha/year, then at current carbon prices each herder household might be able to receive payments of over $7,000 per year, more than twice their current annual income.

So far, the climate change mitigation objective to increase carbon sequestration has focused on forest carbon storage through afforestation and reforestation initiatives. Nevertheless, as a major source of greenhouse gases, agriculture and rangelands also represent substantial potential for mitigation through soil carbon storage. There are a number of different land management options for carbon sequestration, such as soil erosion control, afforestation and reforestation, forest restoration, sustainable management and conservation of natural ecosystems, maintaining and increasing trees on agriculture land, farmyard manure, no-till farming, incorporating green residues and increasing composting, sustainable livestock densities, etc. Such options are in harmony with the aims of dryland mountain farmers and agro-pastoralists and are being widely promoted.


Homestead, Tibet (D. Maselli)

Payment mechanisms for carbon sequestration through afforestation and reforestation were initially established in the Kyoto Protocol's Clean Development Mechanism, allowing industrialised countries to set up carbon offset projects in developing countries. At the 2007 UNFCCC Conference of Parties (COP) in Bali, it was agreed to develop a mechanism to compensate reduced emissions from avoided deforestation and degradation. Reducing emissions from deforestation and forest degradation (REDD) became REDD + when conservation, sustainable management and enhancement of carbon stocks were added to the original concept at Bali. At COP 15, the significant potential of agriculture to mitigate emissions and sequester carbon was discussed. As a result, REDD + is considering the prospects for including agriculture in a REDD ++ mechanism to determine how agriculture can contribute to food security and secure livelihoods, while simultaneously building resilience to climate change and reducing emissions. Such agriculture programmes were further discussed during COP 16.

At the workshop on "Forests and Forest Ecosystems: Promoting synergy in the implementation of the three Rio Conventions", (Viterbo, Italy, 5-7 April 2004) organised by the UNCCD and CBD secretariats, in cooperation with the UNFCCC secretariat, it was emphasised that countries could achieve synergistic effects in afforestation/reforestation activities by formulating projects according to basic principles contained in the objectives of the three Rio Conventions. This would ensure that appropriate attention is paid to the environmental goals of conservation and sustainable use of biodiversity, combating desertification, carbon sequestration and other environmental goals and socio-economic aspects, including fair and equitable benefit sharing and poverty eradication. In this context, dryland mountains can benefit from combined actions on afforestation/reforestation activities under the CDM and voluntary carbon market, on reduction of forest deforestation and degradation under REDD, on sustainable forest management and conservation under REDD +, and hopefully on sustainable agriculture management under REDD ++. However, the relationship between carbon sequestration, livelihood requirements and environmental services protection can be controversial, so a final


Blue Nile Falls, Ethiopia (K. Hurni)

compromise should consist of adequate built-in provisions concerning local environmental and social factors, with relevant local participation in decision-making and benefit sharing.

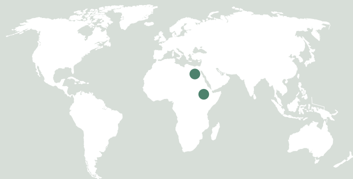
Carbon credit buyers are often interested in the presence of a CDM project portfolio and a well-defined national project approval procedure to become interested in a host country. Mainly countries that have received technical assistance for capacity building in CDM are better positioned to satisfy these requirements. A good example from dryland regions is Morocco, with an overall CDM portfolio consisting of 34 projects, of which 4 are afforestation and reforestation projects, with an estimated potential for emissions reduction of more than 4 million tons per year. With this dynamic capacity-building effort, Morocco is currently ranked in the top 10 of Point Carbon's CDM host country rating, the first African country to achieve this status (163).

It is predicted that financial flows for greenhouse gas emission reductions from REDD+ could reach up to US$30 billion a year. This significant North-South flow of funds could reward a meaningful reduction of carbon emissions and also support new, pro-poor development, help conserve biodiversity, and secure vital ecosystem services. The Global Environment Facility (GEF) for the first time will make available a separate funding envelope for SFM/REDD+ for countries willing to invest portions of their allocations from biodiversity, climate change and land degradation in more impactful Sustainable Forest Management/REDD+ projects. Altogether, the GEF may provide up to $1 billion for SFM/REDD+ funding throughout the course of GEF-5. All types of forests, ranging from tropical and sub-tropical forests to woodlands, will be eligible for funding and a wide spectrum of options for countries will exist: forest policy (re-)formulation, forest protected area creation and management, forest inventory and carbon measurement and monitoring, reduced-impact logging, certification of timber and NWFPs, and payment for ecosystem services, among others. In addition, the GEF will strongly support work with local communities to develop alternative livelihood methods to reduce emissions and sequester carbon. Under special circumstances, the GEF may also finance REDD+ Readiness activities.

4.6 International cooperation

Because mountain ranges often cross national borders, their management frequently involves trans-national cooperation efforts. Transboundary work is especially important in mountain watersheds shared by neighbouring countries, such as the Nile basin (Box 15), where this international cooperation is becoming a must not only for the wise and equitable use of water resources, but also to prevent future armed conflicts and political disputes.

Box 15 | Water governance in the Nile Basin



The River Nile, a vital resource for Egypt and Sudan, draws its waters mainly from the sub-Saharan countries at the head of its watershed. The Ethiopian highlands provide by far the largest share of this contribution – more than 80% of all the runoff to Egypt and Sudan. Water is one of the most under utilised resources in the Ethiopian highlands, although the agriculture that supplies food to the 80 million citizens of Ethiopia is mainly rainfed. Since ancient times, most runoff generated in the Ethiopian highlands has been used for irrigation schemes in lowland Egypt and Sudan.

Once endowed with rich natural resources, the Ethiopian and Eritrean highlands are now seriously depleted from millennia of agricultural activity. Scientists have demonstrated that soil degradation caused by expanding agriculture in the highlands has led to an increase in immediate surface runoff and decreased groundwater retention. As a consequence, crop production has been suffering increasingly from water stress, and the effects of drought have become more pronounced in recent decades.

Water conservation and supplementary irrigation at the field and farm levels can improve yields and food security in Ethiopia and Eritrea, and at the same time conserve the degrading soils. Researchers observe that even if soil and water conservation measures are fully implemented, total runoff from the watersheds will not be significantly reduced. Good water management can thus boost agricultural production, generate hydropower, and benefit lowland neighbours who closely follow developments in the highlands.

Over the past several decades, the Ethiopian state has been pursuing a policy of better regulating and using its waters for hydropower generation, before eventually releasing it to the lowlands. Meanwhile, irrigated areas are being expanded, but their overall effect on lowland water availability needs to be observed, and negotiated in schemes of benefit sharing with the neighbouring countries and in mutual agreements between water users and deliverers.

The current contribution of water to the lowland neighbouring countries, Sudan and Egypt, must be carefully observed. The Nile Basin Initiative (NBI) has been established for this purpose. A recent agreement was reached by the contributing states in order to improve the equitable sharing of water resources. Egypt so far has not signed the agreement, but may do so in the near future.

Source: Hans Hurni (i), Berhanu Debele (ii)[28]

The current trend of combined climate and socio-economic changes is gradually threatening the ability of dryland mountain regions to provide critical goods and services to both mountain inhabitants and lowland communities. International and regional cooperation have the task of facilitating the exchange of information and know-how about common problems and alternatives that may be applicable or adapted to different mountain contexts (Box 16). The Potato Park of Peru is supporting South-South cross-cultural and horizontal learning about the design, planning, implementation and management of Agrobiodiversity Conservation Areas: within this framework, farmers and scientists from Ethiopia and Peru met in the Potato Park in September 2009 to exchange experiences and learn about the Park's experience.

Box 16 | Creation of South-South learning and knowledge exchange platforms to deal with mountain development in Central Asia

The magnificent mountain ranges of Tien Shan, Pamir and Alay in Central Asia are part of the unique mountain system stretching into neighbouring Hindu-Kush, Karakorum and Himalayas. According to the IPCC projections for Central Asia, the whole region is going to be severely affected by climate change. Global warming will result in up to a 30% decrease in crop yields, while it is estimated that the demand for agricultural irrigation will increase by at least 10%. Summer precipitation will likely decrease in Central Asia, while higher temperatures could lead to an increased probability of events such as mudflows and avalanches that could adversely affect human settlements.

Central Asian countries share many ecological and socio-economic similarities, and may thus benefit from similar solutions and practices. For this reason, the Hindu Kush Himalayan countries – with the technical assistance of international and regional organisations such as ICIMOD – have come together and made some impressive progress in terms of regional efforts to understand the ecosystem services and goods, major drivers and impacts leading to socio-economic and environmental changes in the region. There is a wealth of knowledge and expertise, with many good practices in Central Asia worth tapping into, learning from and scaling up, although this patrimony is largely fragmented and found within individual countries. This learning and exchange process requires a supporting infrastructure, the commitment of financial and human resources, and a true will to learn.

The Joint Initiative of Mountain Partnership members from Central Asia on Raising Awareness & Advancement of the Sustainable Mountain Development Agenda is promoted by the Mountain Partnership Secretariat - Asia Pacific Decentralised Hub hosted by ICIMOD (Nepal), in partnership with Central Asia-based members from Uzbekistan, Kyrgyzstan, Tajikistan and Kazakhstan. The aim of the initiative is to raise awareness and create South-South learning and knowledge exchange platforms to deal with mountain challenges. The initiative decided to build on the shared cultural identity and traditional knowledge of local communities related to sustainable natural resource use, based on analysis of the interdependence between traditional management and nature conservation and on traditional governance systems such as common property systems, access and rights of natural resource use, etc.

The plan introduced innovative participatory pasture management efforts, including a joint exercise in pasture carrying capacity and assessment of grazing land conditions, which was previously conducted solely by specialists and eventually approved by the local councils. This approach made the assessment methods more user-friendly and easily applicable by herders themselves, and enhanced the engagement and stewardship of herders in the pasture management process. The herders were thus able to combine and integrate traditional knowledge and know-how inherited through generations into such novel methods as rapid assessment, participatory mapping, and cultivation calendars for fodder crops.

As part of the conservation measures, with the help of FAO funding, two demo plots were fenced and used for awareness-raising about overgrazing and a 5-km long irrigation system used for 160 hectares of arable land was repaired. Roads and mountain bridges to some 5000 hectares of underutilised pasture have been fixed in order to enable access to remote pastures. Capacity building support has been one of the main focus areas for the project, targeting the local capacity for growing winter fodder species. Technical training for veterinarians was provided and an experience-sharing trip was organised for residents of the Naryn and Chui regions. Gender aspects were considered by setting up and supporting six self-help groups for local women in alternative income-generation activities for purposes of revenue diversification.

Sources: Mountain Partnership Secretariat-Asia Pacific Decentralised Hub (Nepal). In partnership with Central Asia-based members of the Mountain Partnership: Eco-Forum (Uzbekistan); CAMP[29] Alatoo (Kyrgyzstan); CAMP Kuhiston (Tajikistan); AGOCA (Kyrgyzstan/Tajikistan/Kazakhstan)

Hamlet in the mountains of Tajikistan (S. Eugster)

At a regional and trans-boundary level, cooperation can foster the establishment of shared, long-term visions for the sustainable development of dryland mountain regions. The regional strategy for the conservation and sustainable use of the high Andean wetlands,[30] promoted by the Ramsar Convention, and the regional cooperation scheme on wetland conservation in the high mountain areas of Himalaya and Central Asia are good examples of regional cooperation.[31] The latter supports exchanges of know-how and experiences among wetland managers, through workshops organised in collaboration with international organisations like the International Centre for Integrated Mountain Development (ICIMOD), and with the active participation of scientists and officials from the countries of the region.

The UNCCD 10-Year Strategy (10YSP) is fostering partnerships at all levels and within the framework of an integrated approach that recognises and improves territorial governance (which is compatible with Agenda 21) and aims to contribute to the introduction of sustainable development practices that focus on dryland countries affected by land degradation. Under this framework, water scarcity policies are being fostered by the UNCCD secretariat, reflecting the importance of mountain ecosystems in water management issues, which includes the use of traditional technologies as part of these advocated water-scarcity policies.

For dryland mountains, international cooperation for risk reduction and management is crucial. The International Strategy for Disaster Reduction (ISDR) is a strategic framework adopted by United Nations Member States in 2000 that guides and coordinates the efforts of a wide range of partners to achieve a substantive reduction in disaster losses. The Hyogo Framework for Action (HFA) is the key instrument for implementing disaster risk reduction (DRR), adopted by the Member States of the United Nations. Its overarching goal is to build the resilience of nations and communities in the face of disasters by achieving substantive reduction of disaster losses by 2015 – in lives, and in the social, economic, and environmental assets of communities and countries. The HFA offers five priority areas for action (make DRR a national and local priority; know the risks and take action; build understanding and awareness; reduce risk factors; preparedness to act), guiding principles, and practical means for achieving disaster resilience for vulnerable communities in the context of sustainable development.

Since the adoption of the HFA, many global, regional, national and local efforts have addressed disaster risk reduction in dryland mountain regions in Central and West Asia, Mexico, Central Andes and Sub-Saharan Africa.[32]

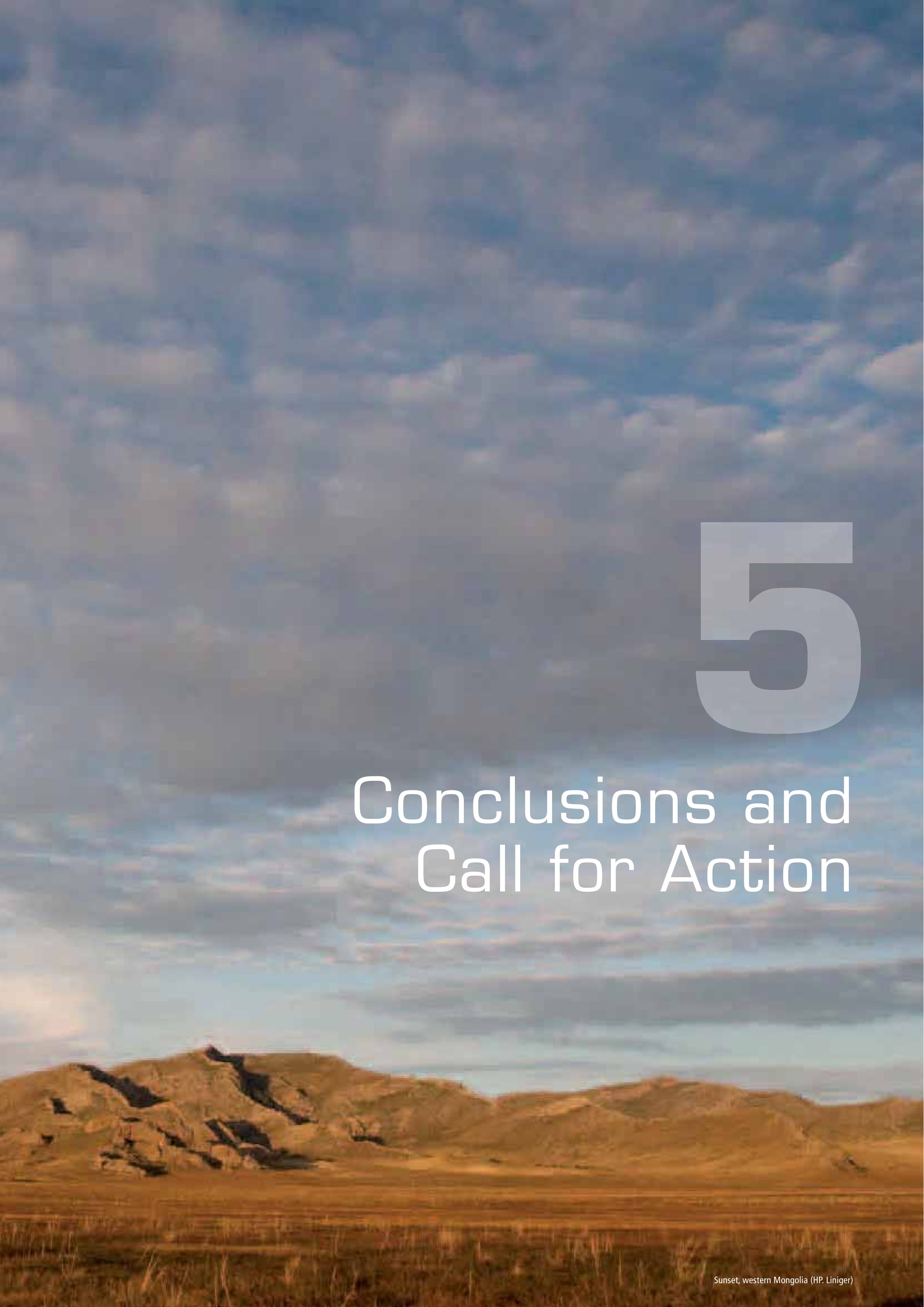
Realizing the relationship between desertification and biodiversity loss and between sustainable livelihoods and the conservation and sustainable use of biodiversity, the fifth Conference of the Parties to the CBD in 2000 adopted the Programme of Work (PoW) on Dry and Sub-Humid Lands (DSHL) in order to fill knowledge gaps and promote conservation. Moreover, at its seventh COP the CBD adopted the programme of work on mountain biological diversity (decision VII/27) as a set of actions addressing characteristics and problems that are specific to mountain ecosystems. The overall purpose of the programme of work is the significant reduction of mountain biological diversity loss by 2010 at global, regional and national levels. The implementation of the programme of work aims to make a significant contribution to poverty alleviation in mountain ecosystems and in lowlands dependent on the goods and services of mountain ecosystems. The status and trends of mountain biological diversity are being updated and various networks are collecting information for long-term monitoring of threats to mountain biological diversity; as of 2009, about 14.4% of the mixed mountain system biome and 27.9% of montane grasslands and shrublands biome were protected, exceeding the 10% target and contributing to achievement of the 2010 target (2).

The interlink between desertification and biodiversity loss in the world's drylands induced the secretariats of the CBD and UNCCD to agree a Joint Work Programme (JWP) in 2003, focusing on the biological diversity of dry and sub-humid lands. An agreement was reached that the first phase of the implementation of the Programme would focus on assessing the status and trends of biodiversity in DSHL and the effectiveness of conservation measures; identifying specific areas of value and/or under threat; and further development of indicators of the biological diversity of DSHL and its loss, for use in the assessment of status and trends.

The UNCCD National Action Programmes to Combat Desertification (NAPs) and the World Bank Poverty Reduction Strategic Papers (PRSPs) are prerequisites for accessing the financial instruments and hence are indispensable in driving economic opportunities for dryland mountain regions (164). NAPs include measures for enabling legislation and social and economic policies, and for reducing duplication of efforts through cooperation between economic sectors and by joint synergetic implementation of the different Multilateral Environmental Agreements (MEAs).

5

Conclusions and Call for Action



Sunset, western Mongolia (HP. Liniger)

Moving towards action

The challenge posed by climate change and by desertification and degradation of the natural environment and human societies in dryland mountains can only be met through the introduction of significant changes in management practices and governance.

Cape Verde (HP. Liniger)

The required adaptation for sustainable land management implies the adjustment of ecological, social, and economic systems to stop and reverse negative processes and practices, and to increase their ecological and social resilience. There is strong evidence that such resilience is greatly enhanced in complex, structured ecosystems with broad genetic diversity, species-rich habitats and culture-rich societies – the so-called mosaic landscapes.

Preserving and enhancing the ecological and cultural diversity of dryland mountains is thus the best strategy for building their resilience and viability. This challenge will require the adoption of flexible policies, governance and management systems and, in most cases, the restoration of institutional arrangements, co-management patterns, and communal approaches developed by local societies through the past centuries. This adaptation will also require the devolution of power – authority and responsibility – from centralised states to local community groups.

Achieving sustainable land management and adaptation measures will necessarily involve the development of innovative solutions, including new technologies, workable economic incentives, payments for environmental services, and the adoption of adaptive management decisions in forestry, agriculture, and water and soil protection policies. International and regional cooperation will require strengthening, and new mechanisms for mutual learning and networking will have to be established, with the participation of all concerned stakeholders.

These recommendations are discussed in more detail below:

1. Engaging all concerned stakeholders in a learning process aimed at filling current information gaps, exchanging know-how and monitoring global changes in dryland mountain ecosystems.
    - Research organisations working in the ecological, social and climate sciences should join forces to develop more accurate scenarios and predictions about the combined impact of climate change, desertification and

biodiversity loss on dryland mountain ecosystems, and monitor their effects at a representative number of sites in all regions. A large array of 'climate change watchers'—foresters, farmers, shepherds, etc.— should play a key role in the implementation of monitoring programmes.

- A minimum set of indicators to monitor impacts and the performance of sustainable development measures are recommended by the Rio conventions, combining elements of both population and ecosystem wellbeing. Countries with dryland mountain regions need to be more active in the UNEP/GEF Capacity Building Partnership to enable stakeholders to implement actions and monitor their effectiveness in reversing the synergetic effects of desertification, biodiversity loss and climate change.
- Regional learning networks involving all relevant stakeholders should be promoted and strengthened by international cooperation programmes. These networks should focus on covering major information gaps, sharing experience and exchanging traditional and scientific know-how between 'nodes of expertise' and less-favoured areas. The experience of regional networks led by international organisations such as ICIMOD in the HKH region in Asia should be promoted in under-represented regions with important gaps, such as the mountains of North Africa and the Middle East.
- Community groups should take the lead in developing locally-adapted solutions. International cooperation programmes should provide direct support to such groups and promote more South-South cooperation on how to design, plan, implement and manage agro-biodiversity conservation areas.

2. **Governments should incorporate climate change adaptation in all sectoral policies; this is especially urgent where long-standing or large investments are planned, such as large-scale irrigation systems, some of which already deplete available water resources, and will be at high risk under climate change predictions.**

    - Meanwhile, researchers should obtain more accurate and precise information on the likely effects of climate change at the detailed regional level, and grass-roots organisations should be able to test adaptation options in all development sectors through specific pilot actions and regional networking.
    - Governmental policies should also promote awareness of climate change as a factor in land use planning at the farm and regional levels. Moreover, major efforts by NGOs and intergovernmental organisations should be made to increase the awareness of individual land users and decision makers about the issues of climate change and the need for adaptation of farming, pastoral and forestry practices.

3. **Effective solutions to address global change trends and meet the targets of the Millennium Development Goals in dryland mountains will only be possible if governments act to restore the commons, and favour the devolution of power – authority and responsibility – from centralised states to local community groups.**

    - Intergovernmental organisations and aid agencies should grant priority to interventions that help revive past experience of flexible policies and institutional arrangements, identifying new forms of dialogue and participation in decision-making, innovative technologies, and adequate policy incentives to effectively support sustainable land management and adaptation measures, including forestry and agriculture, energy, water, urban and other land use sectors.

Women spinning, Shangrila, China (HP. Liniger)

- Communal institutions need the collaboration of external agents – NGOs, international research and development organisations – as allies with privileged access to policy processes who can facilitate the adaptation of traditional systems to the current socio-economic and political contexts.
- A move towards decentralised local governance is the most effective mechanism for achieving the MDGs, so governments need to recognise the relevance of their human rights obligations, encourage broader people's participation and develop rights-based accountability mechanisms. There is a need for more effective aid and substantial up-scaling of aid investments in countries with dryland mountain regions, to tackle governance reforms according to the recommendations of the 7th UN Global Forum on Reinventing Government (156).

4. Intergovernmental organisations and aid agencies should give priority to the urgent need to improve knowledge and preserve the outstanding ecological and cultural diversity of dryland mountain socio-ecosystems, as the best strategy to cope with the intricacies of climate change, desertification, and biodiversity loss.
   - Priority should be given to international research programmes aimed at increasing knowledge about species and genetic diversity in all ecosystems and agronomic systems.
   - Intergovernmental organisations and NGOs should support national governments in the need to rethink protected areas, so as to allow species adaptation needs (i.e. along altitudinal gradients) and to secure the preservation of genetic reserves.
   - Intergovernmental organisations and NGOs should promote and support the establishment of other kinds of protected areas, such as sacred sites and community conserved areas, as these areas have demonstrated effective contributions to the conservation and sustainable development of

Discussing solutions (S. Eugster)

dryland mountains; decisions about whether this should be done inside the official protected area system or as a new form of preserving wider landscapes should be made by governments, local communities and religious authorities on a case-by-case basis.

5. Governments should promote more flexible policies supporting large partnerships from the grass-roots to the national and international levels (see decision 3 UNCCD COP. 9). Intergovernmental organisations and NGOs should circulate information on lessons from successful experiences with integrated natural resource management over large territories, with a special focus on integrated water management, and advocate for the official adoption of this policy instrument by all governments in dryland regions.

   - New methodologies should be tested to involve all the players in the functioning of upland-lowland interactions in dryland mountain territories.
   - Researchers, development organisations and local users' associations should investigate into, and revive proven traditional water management systems, and check what alternatives there are in water-stressed mountain regions. More efforts are needed to identify, conserve, and restore the numerous water management systems belonging to ancient sophisticated cultures and adapt them to modern conditions by improving labour conditions and providing new technological solutions when needed.
   - There is a need to develop integrated water demand strategies that help reduce water consumption and allow more efficient use through concerted decisions on the conjunctive use of all existing sources of water. Intergovernmental agencies should give priority to dryland mountain regions where adaptive water management is concerned – in terms of capacity building and development of representative case studies on integrated water management through the UN Water programmes.

Olgas Rocks, Australia (HP. Liniger)

6. National governments should participate more actively in regional policy frameworks for disaster prevention, especially those on hydrologic disruption and increase in the frequency and intensity of forest fires.
   - Regional funding programmes should promote transdisciplinary exchanges of knowledge about hydrogeology, local perceptions and livelihood strategies to evaluate the nature and scale of glacier recession impacts, and provide information on adaptation strategies, and plan future water uses.
   - Restoration, reforestation and afforestation programmes should be developed based on a landscape approach, integrating human needs and environmental constraints (such as drought) and opportunities (such as species and genetic diversity, good practices).
   - Priority should be given to the effective communication of scientific "usable results" to grassroots organisations, land managers and decision makers. This should be enhanced through cross-cultural collaboration and educational workshops and communication.
   - Strict laws for the protection of high mountain glaciers and lakes in dryland mountains should be passed and effectively implemented. Participatory impact assessments should be required for all major infrastructures and industrial plans affecting dryland mountain regions.

7. Government policies should support measures to increase the competitiveness and sustainability of the mountain economic sector. The international community – UN Aid Agencies, NGOs, and the private sector – are called upon to support national and local governments aiming at improving the livelihoods of inhabitants in dryland mountains through the intensification of sustainable land, water and forest management, as well as through sustainable investments that include the value-chains of such ecosystems and their populations. Priority should be granted to funding measures such as:

- The diversification of farming activities through the encouragement of diversified economic systems based on non-timber forest products, agricultural products and tourism services, aiming to ensure overall sustainable development.
- The establishment of agri-environmental incentives and compensation to support land uses linked to mountain biodiversity and to environmental risk reduction.
- Investment support to innovate, diversify and strengthen the mountain farming sector, with a special focus on the production of quality food products for foreign and local consumption or as a service to tourism.
- The development of new marketing opportunities, including certification and labelling, which can support high-quality products linked to cultural values.
- The development of community-based small enterprises for the sustainable harvesting, processing and marketing of Non-Wood Forest Products.

8. **The socio-economic progress of dryland mountain communities should be promoted in a sensitive way, with special consideration for the less favoured groups such as women and the young unemployed. Development and rural support policies to raise living standards, increased working opportunities and improvement of people's livelihoods in mountain regions should obviously not impact the environment, lifestyles and cultures, as these values represent the very basis of the competitive advantage of mountains.**
    - Considering that desertification in dryland mountains often leads to an increase of responsibilities assumed by women, special attention should be given to strengthening the capacity of women – organisational and business skills, availability of new technologies – and to facilitating more equal access to resources and involvement in decision-making.
    - The recovery, recognition and enhancement of traditional cultures and know-how on soil, forest and water management contributing to soil carbon storage can help develop effective measures to combat the synergetic effects of desertification and climate change in dryland mountain regions. Direct benefits for farmers and herders are expected to occur through increased soil fertility and crop yields that, in turn, will contribute to improved livelihood and food security at the national scale.

9. **National and international research programmes to improve knowledge about the economic value of most goods and services in dryland mountain regions should be promoted. The diversification of revenues for communities should be supported through the creation of new markets for environmental goods and services, such as non-timber forest products, organic foods, and ecotourism. Payments for ecosystem services (PES) schemes can play a significant role in supporting such diversification of revenues by including specific support measures for market development and revenue diversification in their compensation packages.**
    - Pilot projects to demonstrate the benefits of payment schemes for watershed protection, biodiversity conservation and cultural services should be enhanced.
    - Opportunities for carbon markets linked to reduction of emissions from deforestation and degradation, and the enhancement of carbon stocks through conservation and sustainable management of forests, are very

promising. Intergovernmental organisations, aid agencies and NGOs should support pilot initiatives in all dryland mountain regions, as part of the REDD+ negotiation process.

- The promotion of agriculture practices that enhance food security and livelihoods for the poor, improve resilience to climate change and reduce emissions was debated in Copenhagen (UNFCCC COP 15). As agreement on REDD+ is yet to be reached, it is still possible to consider the link to agriculture and to develop a REDD++ mechanism during COP 16 in 2010.

10. Water treaties are important for the good governance of shared river basins in dryland mountain regions, and can be pathways to peace. Transboundary initiatives should be encouraged in all major shared watersheds to support the joint management of water resources as a tool to achieve sustainable development and regional stability, under a sound legal and institutional framework agreed to by all parties.

- More inclusive forms of cooperation options adapted to each context should be developed and promoted in all regions based on the participation of actors representing the public administration, civil society and the private sector, from grassroots to the highest political level. This will facilitate the setting-up of a coordinated effort on adaptation options to enhance mountain environmental and social resilience to global change and prevent future geopolitical conflicts.
- Among priorities to reduce the chance of conflict in transboundary initiatives there is the need to build capacity among civil society groups to ensure that they can meaningfully contribute to basin-wide initiatives, and enable local users to demand access to benefits governed by interstate agreements while ensuring that they buy into basin-wide initiatives.
- In spite of the difficulties encountered by partners where there are armed conflicts (e.g. the Lebanon mountain range), it is advisable to address environmental risk issues and identify cooperation possibilities that involve civil society, as it may be more receptive than government actors.
- Transboundary cooperation on mountain tourism represents a good opportunity to strengthen socio-economic and environmental links between mountain communities in neighbouring countries.

Endnotes and authors of text boxes

[1] A social and ecological system can be defined as a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner (159).

[2] The part of West Asia with a Mediterranean climate, from Turkey to Egypt, is included in the Mediterranean Basin.

[3] A closed drainage basin that retains water and allows no outflow to other bodies of water such as rivers or oceans.

[4] A Vavilov Centre (aka Vavilov Centre of Diversity) is a region of the world first identified by Dr. Nikolai Vavilov as an original centre for the domestication of plants.

[5] An extended and cold winter that can prove devastating for livestock in Central Asia.

[6] www.fao.org/nr/giahs

[7] Information extracted from www.biodiversityhotspots.org

[8] www.eoearth.org/article/Biological_diversity_in_the_mountains_of_Central_Asia

[9]www.timesonline.co.uk/tol/news/world/asia/article6571287.ece

[10] http://news.bbc.co.uk/2/hi/business/7707847.stm

[11] http://en.wikipedia.org/wiki/Uranium_mining

[12] www.eurasianet.org/node/61446

[13] Gangwar, A. Living on top of the mountain. *In:* www.indianfolklore.org

[14] http://www.fao.org/newsroom/en/news/2007/1000570/index.html

[15] The Chinese Meteorological Administration predicts that the north-western mountains of China will lose over a quarter of their current glacier coverage by 2050. These glaciers supply 15-20% of the water to over 20 million people in the Xinjiang and Qinghai Provinces alone.

[16] http://www.gloria.ac.at

[17] Fynbos is the natural shrubland vegetation occurring in a small belt of the Western Cape of South Africa, mainly in winter rainfall coastal and mountainous areas with a Mediterranean climate.

[18] Fynbos Programme (CAPE) and Succulent Karoo Programme (SKEP); South African National Biodiversity Institute.

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[20] www.miningenvironmental.com/legal-brief/argentina-vetos-glacier-law

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[24] UNCCD Secretariat. *In:* "Women Pastoralists: Preserving traditional knowledge, facing modern challenges."

[25] UNCCD-IFAD 2007. Initiative for People Centered Conservation (IPECON).

Mountains or Apus are sacred beings that represent the most important expression of human aspirations

[26] Private Reserves of National Heritage, a new legal category recently formalised.

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[28] (i): Dr. phil. nat. Dr. h. c., Professor of Geography and Sustainable Development, University of Bern, Switzerland; (ii) MSc in Soil Science, Coordinator, Regional Coordination Office, NCCR North-South, Addis Abeba, Ethiopia.

[29] http://assets.panda.org/downloads/humedalesaltoandinosingles.pdf

[30] www.ramsar.org/pdf/mtg/mtg_himalaya_4th.pdf

[31] CAMP, the Central Asian Mountain Program financed by the Swiss Agency for Development and Cooperation, was succeeded by the CAMP Network of non-profit and non-governmental grassroots organisations working on the concept of practical sustainable mountain development in 3 Central Asian countries, namely Kyrgyzstan, Kazakhstan and Tajikistan.

[32] www.unisdr.org

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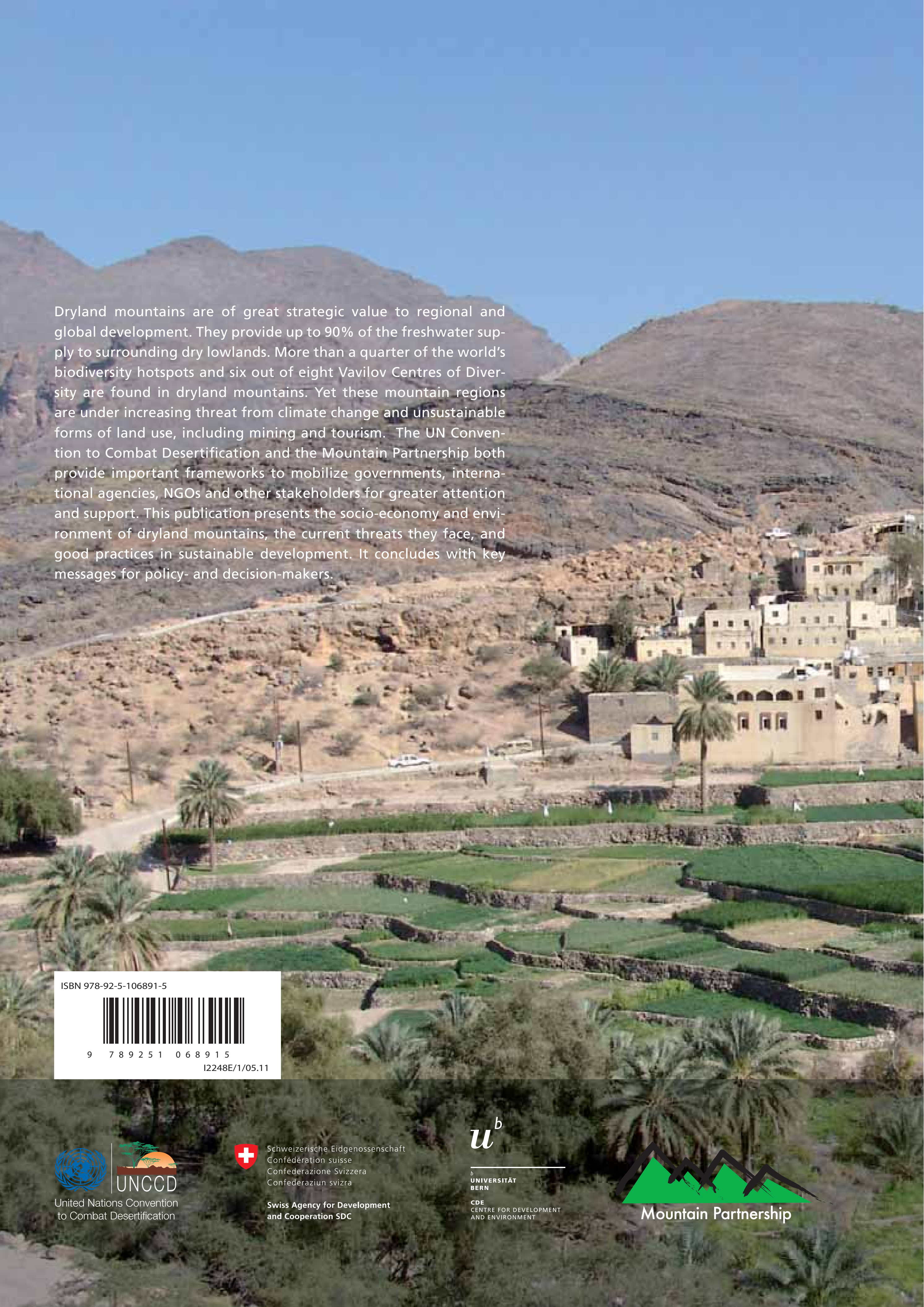

Dryland mountains are of great strategic value to regional and global development. They provide up to 90% of the freshwater supply to surrounding dry lowlands. More than a quarter of the world's biodiversity hotspots and six out of eight Vavilov Centres of Diversity are found in dryland mountains. Yet these mountain regions are under increasing threat from climate change and unsustainable forms of land use, including mining and tourism. The UN Convention to Combat Desertification and the Mountain Partnership both provide important frameworks to mobilize governments, international agencies, NGOs and other stakeholders for greater attention and support. This publication presents the socio-economy and environment of dryland mountains, the current threats they face, and good practices in sustainable development. It concludes with key messages for policy- and decision-makers.

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