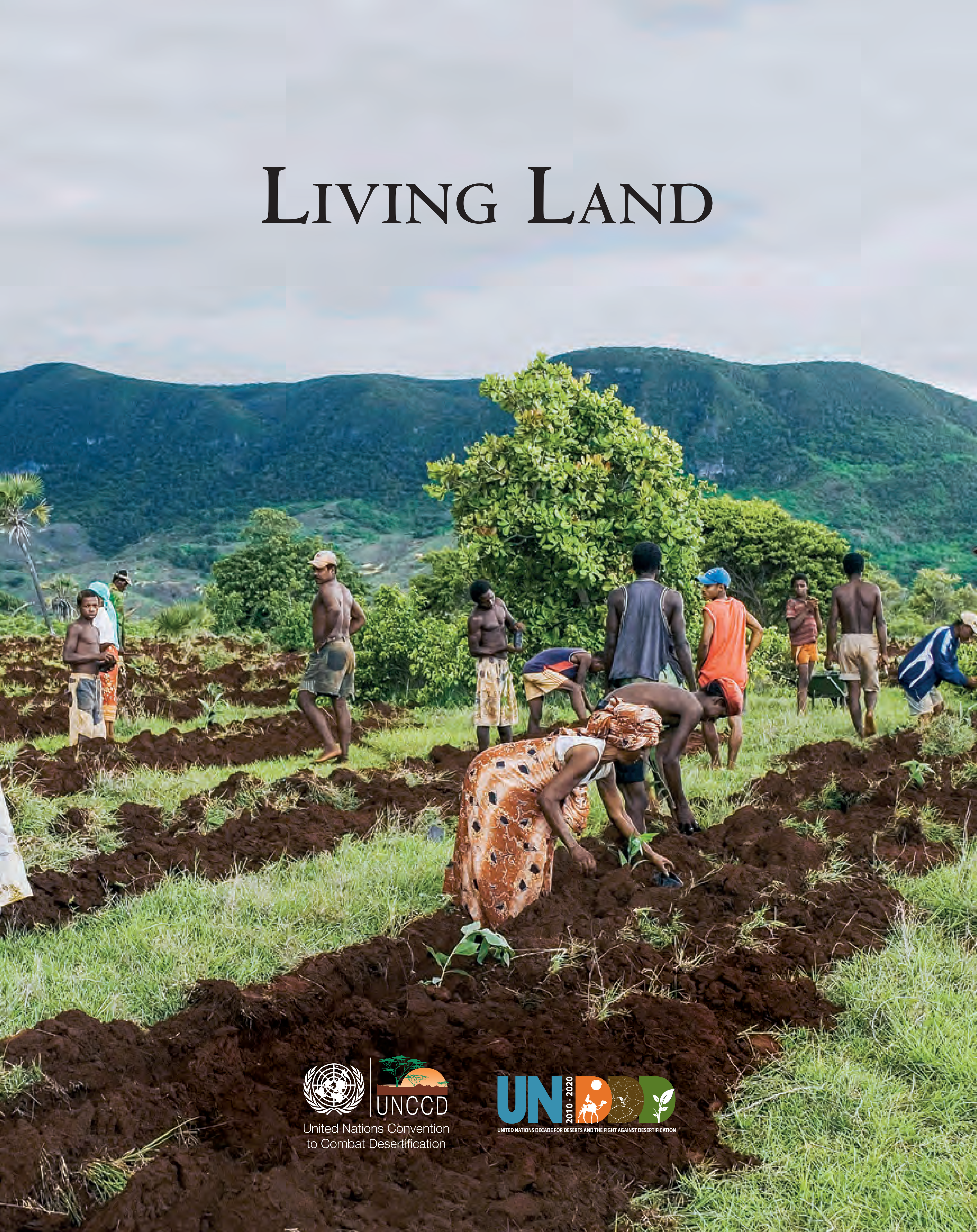
Living Land



United Nations Convention
to Combat Desertification

UNITED NATIONS DECADE FOR DESERTS AND THE FIGHT AGAINST DESERTIFICATION
2010 - 2020

Living Land

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Cover photo: Mechanical labour of the soil, common nurseries and planting of the trees directly by the beneficiaries are key elements of the afforestation approach "village – individual reforestation" which was developed by the German development cooperation in Madagascar resulting in about 9,000 ha rehabilitated land so far. © GIZ/ECO
For the full story please visit https://youtu.be/fM7RQZKOB40

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Foreword

MONIQUE BARBUT, EXECUTIVE SECRETARY, UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION

The number of migrants taking dangerous risks to cross borders is a signal of an emerging challenge. But if the number of Europe-directed migrants is significant, their origin is even more so. The main countries of origin are Afghanistan, Eritrea, Gambia, Iraq, Nigeria, Pakistan, Senegal, Somalia, Sudan and Syria. Civil war or terrorism may explain the outflow of migrants in many of these countries, but what about Gambia and Senegal? If you look below the surface, you can trace the origins of migration, even in these war-torn countries, to deepening poverty in regions where naturally fragile lands are experiencing sharply declining fertility, and infertility creates unemployment, hunger, lack of opportunity and, eventually, political breakdown.

Migration isn't just a European problem. Every year, 700,000 people migrate from Mexico's drylands to other regions. But the greatest injustice is faced by the communities forced to migrate. For many rural people in the developing world, the land and its natural resources are still the primary sources of livelihood — from employment to meeting such basic needs as food, water, energy and medicine. More than 2 billion people live in the driest regions of the world and are already touched by the effects of climate change. Droughts and floods are more frequent and extreme. In the last 10 years, the number of natural disasters globally has doubled from 200 to 400 per year. The push to migrate will only grow if we do not act to address its root causes.

Living Land tells inspiring stories about tackling the challenges of land degradation and climate change, and doing so affordably. These stories show how land degradation occurs, and that it is now a threat beyond the Sahel and other dryland regions. They explain what we can do, and what is already being done. Investors, policymakers and activists who have longed to do something about land degradation but have found the subject daunting and incomprehensible will find this publication highly useful. This is a book by experts for everyone who cares about our planet's future.

Less than a decade ago, Professor Norman Myers from Oxford University projected that by 2050 at least 200 million people would migrate due to the impacts of climate change. Myers' estimates were highly contested — and still are. However, the political uproar in Europe over the influx of just 300,000 migrants in 18 months shows how the future could unfold if we continue to ignore land degradation and drought elsewhere. The political consequences are far-reaching and global. *Living Land* shows that to stem the flows of migration, we must create solutions for its environmental push factors. Inaction is by far the more costly option, and as *Living Land* shows, the solutions are cost-effective and produce real change in the first few years.

Monique Barbut
Executive Secretary,
United Nations Convention to Combat Desertification

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IZABELLA TEIXEIRA, MINISTER OF THE ENVIRONMENT, BRAZIL
TEREZA CAMPELLO, MINISTER OF SOCIAL DEVELOPMENT AND FIGHT AGAINST HUNGER, BRAZIL

Brazil has sought constant innovation and improvement of national policies to simultaneously promote social and economic development and environmental conservation. Emergency initiatives that previously had a focus on combating the most visible effects of drought and desertification processes were replaced by structuring actions in order to improve the living conditions of the local people and to promote a productive and decent coexistence with drought. Environmental conservation as well as water, food and energy security have been guaranteed with the use of locally developed technologies that are adapted to the conditions of the areas susceptible to desertification, and aimed at the needs of the poorest population. The policies and cases presented here give a sample of the results of participatory management that involves different levels of the Government and civil society to preserve the environment and overcome extreme poverty. Such a model has been generating innovations that contribute to combat desertification, conserve biodiversity and to promote adaptation to climate change in our country.

Izabella Teixeira
Minister of the Environment, Brazil

Tereza Campello
Minister of Social Development
and Fight against Hunger, Brazil

PROF. DR. VEYSEL EROĞLU. FORESTRY AND WATER AFFAIRS MINISTER, TURKEY

Global warming, climate change, desertification and drought are the most relevant global issues of our days. Desertification, land degradation and drought that is threatening directly around 1.2 billion people in more than 110 countries and in 4 billion hectares in the world is not only an environmental issue, but it also has a negative impact on economy, security and development.

Rapid demographic increase and industrialization worldwide is causing intensive pressures on natural resources. Issues such as deforestation, soil and water resources pollution, desertification, climate change, biodiversity extinction risk, hunger and migration emerging from these pressures were opened to discussion in a more intensive way in international platforms after Rio Summit held in 1992.

The only way to confront this threat for humanity is to ensure that countries use their abilities to act together and that they realize efficient cooperation.

In this context, the 12th Conference of the Parties for the United Nations Convention to Combat Desertification to be held at Ankara, capital of our country, between 12-23 October 2015, will offer a very important opportunity.

Turkey is aware of the responsibility given to country Parties according to United Nations Convention to Combat Desertification objectives fulfillment.

Our country is playing an active role in combating desertification and its negative effects both in national and international fields.

In this scope our **National Desertification Combating Strategy** was prepared, and the current **National Desertification Combating Action Plan** was updated in the light of the new **National Strategy Document.**

Furthermore, in the scope of **Erosion Combating Action Plan** prepared for years 2013-2017, **Upper Watershed Flood Control Action Plan, Mine Sites Rehabilitation Action Plan** and **Dam Watersheds Afforestation Action Plan** land degradation is prevented and watersheds protection is ensured so that it contributes to decrease desertification and climate change effects on our country.

I hope that worldwide public opinion will consider environmental worries not only as scientific reality but also as an ethical question and will notice their personal responsibilities.

As the host country for United Nations Convention to Combat Desertification, we express our satisfaction to share with the entire world this relevant publication entitled *Living Land* with Turkey's experience and successes.

Prof. Dr. Veysel EROĞLU
Forestry and Water Affairs Minister, Turkey

JORGE RESCALA PEREZ, DIRECTOR GENERAL, NATIONAL FORESTRY COMMISSION OF MEXICO

A healthy environment is a fundamental human right that means a binding responsibility with future generations. Far from being a burden it should be seen as an opportunity to generate employment and value and, as a consequence, economic development and poverty reduction.

Economic growth and sustainability are not conflicting tasks; instead, they should be complementary.

Consistent with its commitment to combat desertification and land degradation, Mexico was the first country in the world to subscribe to and ratify the United Nations Convention to Combat Desertification in 1995, one year after its adoption. Furthermore, Mexico was the first country to submit its Action Plan to Combat Desertification in 1994.

At the Third Scientific Conference of the United Nations Convention to Combat Desertification, hosted by Mexico in 2015, experts from around the world gathered to discuss the role of science, technology and traditional knowledge and practices to fight desertification and land degradation. They recognized that, due to the cross-cutting nature of land degradation, climate change and biodiversity loss, there is a need to promote integrated landscape management approaches to address those challenges simultaneously, supported by the generation, diffusion and exchange of scientific, technical and traditional knowledge.

The Government of Mexico has established clear policies and is advancing to conserve soil and reverse land degradation. In doing so it seeks to maintain the provision of a wide range of benefits such as fertility, the productive capacity of soils, regulation of the hydrological cycle, control of floods and landslides, climate change mitigation and adaptation, and the conservation of Mexican terrestrial ecosystems which are among the world's richest in terms of biological diversity.

To lead Mexico to its full potential, the Government is implementing political actions aimed to promote and strengthen the sustainable use of its natural resources in order to contribute to poverty eradication, maintain livelihoods of local communities and increase the quality of life of Mexico's population while avoiding environmental degradation.

Jorge Rescala Perez
Director General, National Forestry Commission of Mexico

Living Land: an introduction

Wagaki Wischnewski, Focal Point, United Nations Inter-Agency Task Force of the United Nations Decade for Deserts and the Fight against Desertification

Global understanding of climate change has undergone a sea change since 1992, when the public became aware of the issue. Worldwide, policymakers, the public and the private sector, all the way down to the household-level are taking measures to secure their assets against the impacts of climate change. Less noticed, until recently, is the sea change taking place on the issues of desertification, land degradation and drought.

In 1992, governments began international negotiations on a convention to combat desertification, land degradation and drought. This was never viewed as an issue facing all developing countries, much less a global community. Most negotiators understood it as an African problem, primarily, and gave it an apt title to signify this fact: the United Nations Convention to Combat Desertification, in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (UNCCD).

This perception has shifted dramatically over the last 20 years. In a 2011 review by the UNCCD, 169 of the 194 countries that are party to the convention claim they are now affected by desertification, land degradation or drought. *Living Land* presents a range of initiatives from around the world on the fight against desertification, land degradation or drought. They stretch from Australia in Asia, through the Middle East, Western Europe and Central and Eastern Europe, all the way down to Chile and the Cuban islands in Latin America. Underlying this is an important lesson: land degradation is not a threat to Africa alone. It is a global threat that manifests itself in a variety of ways.

The land's vulnerability to degradation is driven by human and climatic factors, and global collaboration is required to address the issues

Image: Chetan Soni & UNCCD 2009 Photo Contest

The land's vulnerability to degradation on a global scale is driven by a coincidence of two factors — one is human and the other is climatic. On the climatic side are the weather conditions that expose the land to conditions — harsh wind and water effects — that erode the soil. The science shows that erratic and extreme weather events are becoming more regular and intense. But governments cannot control these climatic conditions on their own; it requires global collaboration.

On the human side are the inappropriate land use practices that make the soils fragile. Governments can limit the damage done to the land by creating the incentives that promote the take-up of sustainable land use practices. Thus, it should come as no surprise that most of the authors present sustainable land management practices as their key interventions. They reveal a wide range of approaches being used in different parts of the world, a wide range of the actors involved and the roles they play, as well as a wide range of tools available and in use to support these efforts; some of which are highly sophisticated, such as satellites, while others are as basic as the manual installation of stone bunds. This publication highlights some of the challenges national governments that are parties to the convention face in their efforts to combat land degradation and manage drought.

Why another publication?

Clearly, these dimensions have all been covered before. So what is the valued added of *Living Land*?

It responds to a knowledge gap that is vital in the mobilizing of the global public in the efforts to combat desertification, land degradation and drought. *Living Land* provides technical knowledge on the subject of land degradation in a language that is accessible to the general public, policymakers and activists that do not know the subject. Unlike many publications that focus on the problem or assessment of desertification, land degradation or drought, *Living Land* is about implementation. It is about experts showing what governments are doing, how they are doing it, where they are doing it and why they are doing it. Simply put, through *Living Land*, the technical experts that implement sustainable land management are reaching out to the public.

The first assessment of land degradation on a global level was carried out in 1991.[1] Known as the *Global Assessment of Human-induced Soil Degradation*, the study was based

More than 1.5 billion people depend on degrading lands, but land degradation is not fated, where there is political will

Image: Ricardo Spencer & UNCCD 2013 Photo Contest

on the expert judgement of scientists. It produced a world map of human-induced soil degradation and concluded that 15 per cent of the land surface was degraded. But it got outdated quickly.

The first comprehensive assessment of the status of desertification, land degradation and drought on a global level is the 2005 *Millennium Ecosystem Assessment* (MEA). It is a well-researched presentation of the status and the economic, social and cultural values of the dryland regions of the world. It brought to the attention of the international community the consequences, at the global level, of failing to combat land degradation or mitigate the effects of drought. The MEA remains a valuable resource for policymakers, activists and the scientific community. But it focuses on drought and land degradation in fragile ecosystems only, that is, the arid, semi-arid and dry-sub-humid zones of the world. Thus, it does not tell us the status of land degradation worldwide. And the publication is still fairly technical, which has kept it inaccessible to the general reader, in spite of its immense value.

The *Global Assessment of Land Degradation and Improvement* (GLADA) was published in 2008 and offers a deeper analysis of land degradation.[2] It reveals the scope of land degradation in all types of ecosystems and the global population affected, but also probes where land is improving. Indeed, a fair assessment of the status of land degradation must take into account the amount of degrading land and the unproductive land being restored back to health.

According to GLADA, 24 per cent of the global land area is degrading. Some of these are new areas and not just in Africa. Land degradation was also evident in Australia, Asia, Latin America and North America. In short, this is a global phenomenon. GLADA uncovered other significant results. About 78 per cent of the degrading land is not in the dryland areas, but in the humid areas; 16 per cent of the land area is improving; and 1.5 billion people depend directly on degrading land. The study also drew attention to the release of greenhouse gasses through land degradation. In spite of the study's groundbreaking data, its highly scientific orientation means it didn't capture the imagination of the general public.

At about the time the study was released, the international community celebrated the International Year of Deserts and Desertification. In light of a persistent lack of awareness about the scope and causes of desertification and the solutions to the problem, the United Nations General Assembly declared 2010 to 2020 the United Nations Decade for Deserts and the Fight against Desertification. The purpose of the decade is to raise global awareness of desertification, land degradation and drought at all levels. This year, 2015, marks the half-way point of the decade.

What has changed?

The adoption of the 10-year (2008-2018) strategic framework for the implementation of the Convention was a watershed moment in the global efforts to combat land degradation. It embraced science as the guide to policymaking in the global efforts to combat land degradation and drought. The science is today more robust and growing, and the Science and Policy Interface (SPI) established in 2013 is facilitating dialogue between scientists and policymakers.

Image: Jorge Valenzuela & UNCCD 2009 Photo Contest

More than 2 billion people will be living in water-scarce regions in the world and rehabilitating degraded lands is a pathway to water security

Three scientific conferences have shaped how governments are implementing the convention. The first conference put forward 11 impact indicators to assess changes in the productivity of the land. Two of the indicators are mandatory for 194 governments when they report on the progress they are making to combat land degradation.

A database of the sustainable land management techniques used around the world was also set up to facilitate the exchange and diffusion of knowledge. Known as the Scientific Knowledge Brokering Portal, the database has a lot of information and knowledge for use by land managers and policymakers.

The second scientific conference examined the economic benefits of sustainable land management versus the costs of inaction. The results persuaded governments that it is possible and necessary to pursue a land degradation neutral world. That is, for every hectare of land that is degraded an equal amount of degraded land is restored back to health in the same timeframe and in the same ecosystem. This idea is now part of the Sustainable Development Goals, particularly goal 15.3, which the international community will strive to achieve by 2030. The importance of this conference is reflected in the ongoing work of the *Economics of Land Degradation* (ELD) initiative, a platform for policymakers and the private sector that is now building data on the economic benefits of land and land-based ecosystems. ELD's aims are to establish a common approach for robust economic analysis of land management and to highlight the benefits of adopting sustainable land management practices.

The scientific conference held earlier in 2015 considered the role land use systems can play to mitigate climate change. *The Impulse Report* was the basis for this discussion at the conference. The international community recognizes that the available technologies on alternative energy and carbon capture and storage are not enough to keep the temperature rise to below 2 degrees Celsius. But the trees, soils, forests, wetlands and other land-based resources that absorb carbon can store more than half of the remaining excess carbon emissions. The scientific community is urging governments to adopt these carbon sequestering measures as part of the Paris 2015 Climate Change Conference because of their added value. Degraded lands and declining groundwater levels would recover. Ecosystems would provide the resilience needed during floods or droughts, for instance.

Other types of assessments of land degradation are also underway. The SPI is working on evidence to show that efforts to combat land degradation also address the issues of climate change and biodiversity loss. It is also identifying how sustainable land uses effectively manage soil carbon. The Intergovernmental Platform on Biodiversity and Ecosystem Services is carrying out an assessment on land degradation and restoration. It will focus on the global status of and trends in land degradation in each region and for different types of land cover; and ecosystem restoration and options.

The *Global Land Outlook* is a flagship publication that will be issued every four years from 2016. It is targeting a much broader audience; an educated general public, non-governmental organizations and civil society, and decision makers in the private and public sectors. Its aim is to promote the mainstreaming of sustainable land management in both policy and investment decisions. The publication is set up as a communications platform for strategic analysis to address the future

Image: Nimai Ghosh & UNCCD 2013 Photo Contest

Sustainable land management — an untapped source of employment that can transform livelihoods in some of the poorest regions of the world

land management challenges in the context of sustainable development. These include food, water and energy security; climate action and biodiversity conservation; urban and infrastructure development; land tenure, gender and governance; and migration, conflict and human security.

Several important scientific assessments to support decision-making are in the pipeline. The consensus and policy cooperation they are mobilizing are pointers of success. What is lacking, however, are specific products aimed at the public. Products that show, in practical terms, what it means to restore or rehabilitate degraded land; where success has been achieved; and how the public can get involved.

As one of the few publications that have endeavoured to fill this gap, *Living Land* is a powerful outreach tool for sensitizing the public about the problem, and mobilizing action globally. It is also an important tool for sensitizing policymakers and decision makers who are not well versed in the subject, but whose work is related to the issues of land degradation and drought.

Living Land targets the same audience as the *Land for Life* series of publications but its approach is different. It tells the story of fighting land degradation from the perspective of the actors with a duty to ensure good land stewardship — governments. By contrast, the *Land for Life* publications tell the same story from the perspective of other stakeholders — intergovernmental, non-governmental organizations and community-based organizations.

How to use this publication

Living Land is written in a style that is suitable for anyone interested in this issue. Therefore, readers who are simply curious about the subject or who wish to understand the issues of land degradation will find this book particularly useful.

But the book is also very rich in content and will be particularly useful for educators who are looking to understand the subject and for teachers of environmental sciences, including at the undergraduate level. Other potential users are journalists, activists, researchers and extension works who need a comprehensive publication to introduce them to the subject and to provide pointers in the direction the subject is moving.

The third category is the practitioners who are interested in doing something about land degradation. Funding agencies, the private sector, humanitarian and other non-governmental organizations and military personnel will all find this publication an important source of knowledge about different regions of the world, the main drivers of desertification and land degradation in different regions, the variety of tools available to address the different challenges, and the key and range of actors involved in this issue.

Each of the articles is written as a stand-alone piece, therefore readers can start with any article of their choice. Nevertheless, the articles are clustered around particular themes, for instance, water or food security.

Still, many of the articles cut across several themes. For instance, an article highlighting the link between land degradation and water scarcity may also speak to a unique sustainable land management technique used or an innovative financing mechanism employed as part of the solution. Therefore, educators need to invest some time to select the most suitable articles for their purpose. Skimmers can read the first paragraph (in bold text) of each article to find out the central message of each piece.

Reversing land degradation in the drylands: scaling out and monitoring proven sustainable land management options

Feras Ziadat, Nora Berrahmouni, Uwe Grewer, Sally Bunning and Louis Bockel, Food and Agriculture Organization of the United Nations, and Theib Oweis, International Centre for Agricultural Research in the Dry Areas

Promising sustainable land management (SLM) options are available to reverse land degradation. Yet, land degradation and desertification are threatening people's livelihoods and food security, particularly in the dry areas with unfavourable climate variability and change. We propose a guiding opportunistic approach to reverse this trend. The approach helps in identifying target areas where adaptable SLM options have high potential of success. This is possible when coupled with an implementation and scaling-out campaign supported by proper policies and financial mechanisms. It requires continuous monitoring and evaluation to assess the impact and guide the fine-tuning based on future fluctuations.

Land degradation is causing serious economic, social and environmental problems in the arid areas. It directly affects the livelihoods of the rural population by reducing the productivity of land resources and adversely affecting the stability, functions and services derived from natural systems. Land degradation and desertification are driven by unfavourable natural factors and are aggravated by misuse and overexploitation of the natural resource base, particularly through inappropriate and unsustainable agricultural practices, overgrazing, deforestation and forest degradation.

The types and causes of land degradation and desertification vary from one site to another, even within a short distance. Therefore, to propose workable solutions, the dry areas should be classified based on specific challenges, then suitable SLM practices are implemented and adopted for each class. Four dominant agroecosystems are considered in the dry area in general and in the Near East and North Africa in particular. These are the pastoral (rangeland) agroecosystems, rain-fed agroecosystems, irrigated agroecosystems and forests and agroforestry.

Image: Ethiopia/ICARDA

Implementation of SLM in farmers' fields by the whole community

The challenge in pastoral (rangeland) agroecosystems is to enhance productivity and halt/reverse land degradation through rehabilitation and improved management of the natural resources, particularly the most limiting resources, land and water. By concentrating (collecting) the run-off into target areas, water harvesting increases water availability to plants, controls soil erosion, reduces the impact of drought, improves the productivity and vegetation cover, and increases rainwater productivity. Within the International Centre for Agricultural Research in the Dry Areas (ICARDA) led rangeland benchmark site in the Badia of Jordan, innovative methods to select and implement water harvesting interventions were developed and the willingness of farmers to adopt these technologies has significantly increased.

In rain-fed agroecosystems, production is dependent on a low and extremely variable rainfall and, therefore, productivity is low and unstable. This is further affected by frequent droughts and continuing land degradation. One option that has the potential to provide large productivity gains is the use of supplemental irrigation for rain-fed crops, provided there is water available for irrigation. This is done by using and optimizing limited water resources in supplemental irrigation to increase and stabilize yields and water-use efficiency. In the ICARDA-led rain-fed benchmark site in Tadla, Morocco, work in the farmers' fields has shown that wheat yields are doubled with limited supplemental irrigation while increased by 30 per cent with the application of only 50 mm of water to advance the sowing date by few weeks. Water productivity is nearly doubled (exceeding 2 kg of grain per cubic metre of water).

In irrigated agroecosystems, increasing water productivity/efficiency in irrigated areas is a top priority almost everywhere in the world; but it is of particular importance in the dry areas where water scarcity is high and is rapidly increasing. Increasing water productivity in irrigated agriculture requires reducing water losses and improving water management and cropping patterns at the farm, field and basin levels. In the ICARDA-led irrigated benchmark site in Egypt, an alternative option to the inefficient furrow irrigation followed by farmers was introduced. The raised bed system and package was developed and mechanized. It has resulted in 30 per cent lower water use by farmers, along with correspondingly lower pumping and labour costs, without reduction in yield. Farmers' incomes have been increased by 15 per cent and water productivity by 30 per cent. Net return per unit of water was increased by 20 per cent.

Forests and agroforestry systems in drylands play crucial ecological, social and economic roles while improving environmental sustainability and resilience in the wider landscapes. They harbour species that are particularly

Proven interventions

Image: ICARDA Benchmarks – Jordan

Macro- and micro-catchment water harvesting practices are a proven intervention against land degradation

Among the proven interventions/packages to help in fighting land degradation and secure more food in the dry areas are:

- **Rangelands:** macro- and micro-catchment water harvesting practices (contour ridges and semicircular bunds using the Vallerani mechanized system), rooftop and courtyard water harvesting
- **Irrigated areas:** water-saving techniques (raised beds and deficit irrigation)
- **Rain-fed areas:** supplemental irrigation and early sowing
- **Forests and agroforestry:** innovative water harvesting techniques, use of treated wastewater, sand dune fixation, conserving soil fertility, controlling erosion, using vegetative strips in farmland, assisted natural regeneration, community forestry and development of community-based small and medium enterprises.

The World Overview of Conservation Approaches and Technologies (www.WOCAT.net) is acknowledged by the United Nations Convention to Combat Desertification as the primary database for SLM best practices to support the 194 signatory countries in recording their own SLM best practices and using the SLM knowledge of stakeholders worldwide.

The Global Soil Partnership

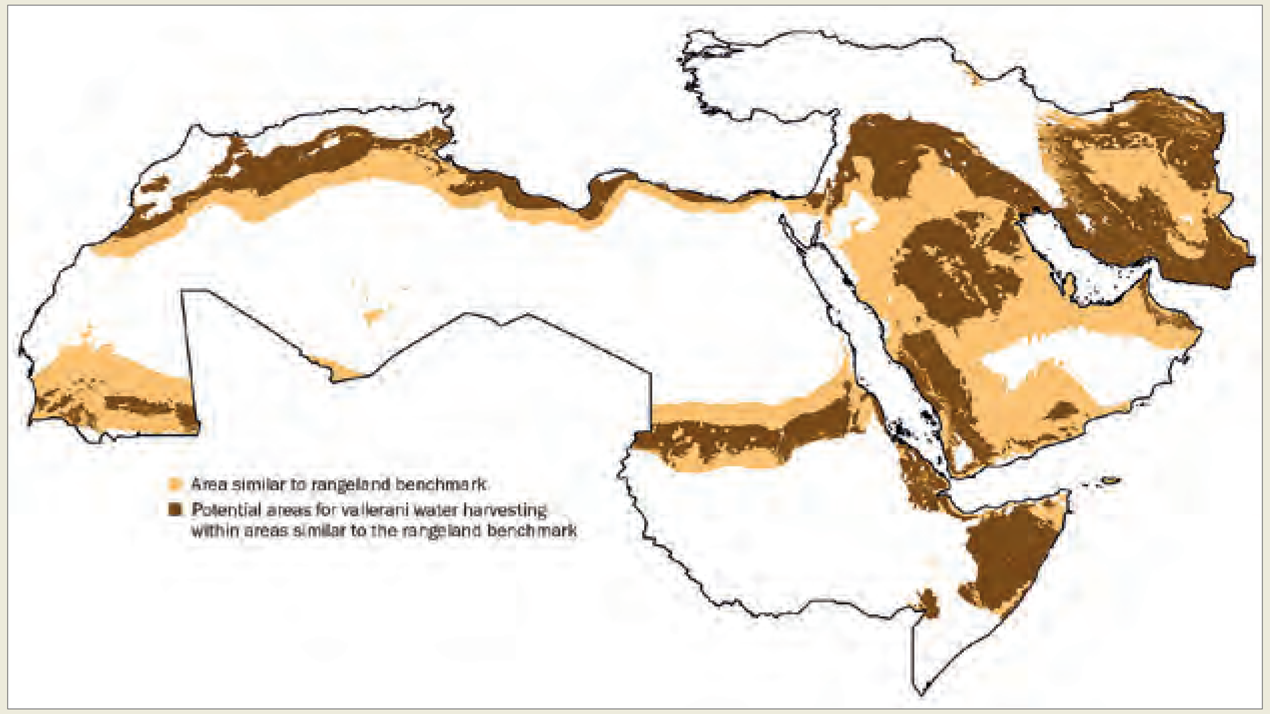
Five pillars of action:

1. Promote sustainable management of soil resources for soil protection, conservation and sustainable productivity
2. Encourage investment, technical cooperation, policy, education awareness and extension in soil
3. Promote targeted soil research and development focusing on identified gaps and priorities and synergies with related productive, environmental and social development actions
4. Enhance the quantity and quality of soil data and information: data collection (generation), analysis, validation, reporting, monitoring and integration with other disciplines
5. Harmonize methods, measurements and indicators for the sustainable management and protection of soil resources.

The implementation plans for the regional soil partnerships are in an advanced stage of development based on regional challenges, gaps and priorities and are expected to substantively strengthen partnerships for promoting sustainable soil management and restoring degraded soils worldwide.

www.fao.org/globalsoilpartnership

Areas similar to the rangeland benchmark research site in Jordan and potential areas for scaling out mechanized water harvesting intervention



Source: Similarity and Suitability Analysis to Assist the Out-Scaling of Sustainable Water and Land Management Practices in West Asia and North Africa. ICARDA

adapted to extreme ecological conditions and provide essential goods and ecosystem services. However, forests and their associated ecosystems are facing serious and multiple threats, ranging from deforestation to degradation, fragmentation and desertification. Nevertheless, if well managed and properly valued, forests and agroforestry landscapes in drylands can help alleviate poverty and contribute to food security and sustainable livelihoods for 2 billion people worldwide. Many drylands countries are developing and piloting approaches and technologies to support sustainable management and restoration of dryland forests and agroforestry systems.

Over the past several years, these technical practices were fine-tuned and tested and a number of packages for the best management of water and land, including reducing land degradation, were developed. However, to achieve better adoption by farmers and ensure positive results from their implementation, suitable techniques/technologies need to be disseminated on a large scale to similar dry areas. Identifying areas similar to those of the benchmark research sites where technologies are developed is a tool to facilitate the scaling-out process.

In many countries, the dissemination of improved technologies does not usually take into consideration the specificities of the agroecosystems. Consequently, the efficiencies of the technology transfer programmes remain low. Benchmarking has provided an approach that helps identify areas similar to those where the improved technologies were developed. This starts with the selection and characterization of a benchmark site in an agroecosystem; then improved technologies are developed and evaluated in this site and, finally, similar areas to the benchmark site are identified and mapped to better target the out-scaling on a large scale.

Similarity analyses are used to find areas with certain characteristics that match those where technologies were tested and fine-tuned. Similarity maps were generated at the regional level using expert criteria, defined by an interdisciplinary team and using the available datasets. Among the factors used to develop these criteria are the soil, climate, land use and water resources. Suitability analyses are used within the similar areas at the national level, to identify areas where the water and land management packages developed can be applied with a high probability of success. Professionals, planners and decision makers can use the information and products generated from these analyses to target the scaling-out of improved and adaptive technologies.

The purpose of these analyses was to identify geographic locations for scaling out. A follow-up socioeconomic analysis would be needed at the community level before interventions can be implemented. This should be supported by a proper enabling environment to enhance adoption by the communities.

The joint use of similarity and suitability analyses/maps can guide the targeting of areas within the four agro-ecosystems for the dissemination and promotion of the implementation of sustainable water and land management interventions. It is anticipated that these will be used by decision makers, planners and donors who seek to identify areas for the scaling out of sustainable water and land management interventions.

Implementing sustainable options to manage agriculture, forestry and land use change in targeted areas is expected to reduce land degradation, improve productivity and contribute to reducing current levels of greenhouse gas emissions and increasing carbon sequestration. Many of the technical options for climate change adaptation are available and often provide central co-benefits for carbon sequestration and reduced greenhouse gas emissions. For example, in dryland ecosystems, decreasing the rate of cropland and grassland degradation and halting the process of desertification as part of a sustainable landscape approach will reduce the vulnerability of small-scale farmers to climate variability and extreme events and likewise prevents high amounts of soil and biomass carbon loss.

The Ex-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by the Food and Agriculture Organization of the United Nations (FAO) providing estimates of the impact of agriculture and forestry development projects, programmes and policies on greenhouse gas emissions and carbon sequestration. The net balance of a project or policy is expressed in CO_2 equivalent and considers all greenhouse gases that were emitted or sequestered due to its implementation compared to a business-as-usual scenario. The tool helps project designers estimate and prioritize activities with high benefits in economic and climate change mitigation terms and requires only a limited set of time and data resources that fit well to investment project and policy design processes. Up to 2015, EX-ACT analyses have been carried out in over 40 countries as part of cooperation with a wide range of stakeholders, including the World Bank, Agence Française de Développement, the International Fund for Agricultural Development (IFAD) and the United States Agency for International Development.

Sustainable agricultural practices in drylands that conserve and increase carbon stocks in soils and biomass lead thereby to especially strong synergies between positive livelihood and environmental outcomes. The EX-ACT tool has been used for estimating the mitigation impacts of the FAO-supported IFAD Family Farming Development Programme in Niger. Within the project area, small-scale farming systems are under pressure from prolonged periods of soil degradation that are further intensified through wood logging at unsustainable rates as well as low organic matter inputs to annual croplands that experience extended periods without soil cover. In order to reverse the soil degradation dynamic and increase agricultural productivity, the project invests in the scale-up of Assisted Natural Regeneration practices that conserve and propagate naturally occurring shrubs and trees on agricultural land. This practice provides important benefits for maintaining a continuous soil cover, supplying organic matter to soils and reducing soil temperature through shading. Besides, degraded annual cropland is rehabilitated through the practice of half-moon pits or demi-lunes that increase plant nutrient availability as well as water storage close to the plant root zone. Practices of improved cropland management, afforestation of dunes and the establishment of living hedges are further project components.

The FAO EX-ACT analysis indicated that through these project actions a total of 6.9 millon tonnes of CO_2-equivalents will be mitigated over a period of 20 years. This is equivalent to annual mitigation benefits of 1.4 tCO_2-eq per hectare. Thereby the project component on Assisted Natural Regeneration provided the strongest mitigation benefits due to its large scope. This analysis identifies thus also in quantitative terms the strong climate change mitigation benefits from sustainable management practices in drylands.

Another example of the use of EX-ACT is the ex-post analysis of the FAO Transboundary Agro-ecosystem Management Project for the Kagera River Basin (Kagera TAMP) in Burundi, Rwanda, Tanzania and Uganda. The Kagera TAMP project lead to the scale-up of sustainable land management practices such as agroforestry systems, sustainable management of annual cropland, erosion prevention on hillsides, and the increased use of soil and water conservation structures. The EX-ACT analysis was integrated as part of the general project monitoring framework and required the monitoring and evaluation staff to indicate the total area of achieved land management objectives after project finalization. The EX-ACT tool was then used to indicate the total mitigation benefits generated by the outlined activities, and allowed comparison of the mitigation benefits of the various different project components: Thereby agroforestry and afforestation practices could be identified as the most important carbon sinks that are generated through the project, while also improved management of annual croplands and grasslands contributed to the overall provision of GHG benefits.

Support for long-term solutions

Since 2010 FAO, with the European Union and the Global Mechanism of the UNCCD, has been supporting the implementation of the African Union Initiative Great Green Wall for the Sahara and the Sahel Initiative aimed at improving the resilience of human and natural systems and to find long-term solutions to desertification, land degradation and drought, climate change and biodiversity loss. As a follow-up to this successful cooperation, a new project, Action Against Desertification, was recently approved under the EU-ACP (European Union African, Caribbean and Pacific countries) collaboration programme, to support implementation of action plans in selected countries and expand activities to the Caribbean and Pacific regions. Examples of success on the ground are many: farmers from hundreds of villages, including men and women, have been able to turn their degraded land to production using native plants; guidelines and successful practices are compiled and being disseminated for scaling up action within drylands.

Enhancing water resources management in irrigated agriculture to cope with water scarcity in arid regions

Bakhodir Mirzaev, Shehzad Akram, Liban Ali Yusuf and Abdul Basit Jam, Islamic Development Bank Group

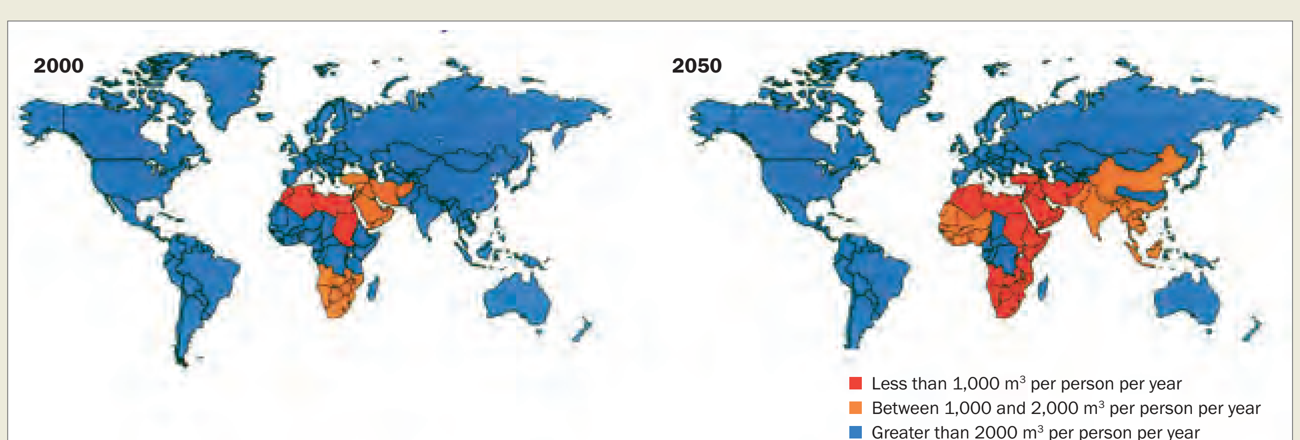
Global water resources are becoming scarce and are already a source of competition in all sectors of the economy in the arid regions. Competition exists between sectors that depend on the same water sources such as river basins. Rivers and lakes that cross international boundaries generate competition, as one country can limit another's access to the water resource through over-extraction or pollution. According to the United Nations World Water Development Report,[1] 263 river basins are shared by two or more nations, indicating that international competition for shared water bodies could be a serious source of international debate in the upcoming decades. Competition exists between various water use sectors and societies — between urban and rural water users, between hydropower demand and agriculture users, between upstream and downstream areas. Moreover, most current water management systems undervalue environmental and ecosystem water needs.

The population tends to grow as a geometric progression in developing countries that face water scarcity problems. The water sector lacks the infrastructure and institutional set-ups needed to provide water services and effective water management. Countries with less than 2,000 m^3 annual per capita freshwater availability are located in Africa, the Middle East, and South-East and Central Asia.

The Islamic Development Bank Group (IDB) is a south-south multilateral development finance institution. It was established to foster the economic development and social progress of its member countries and Muslim communities, individually and collectively in accordance with the principles of Shari'ah. IDB has a critical milestone in its five-year programme (2011-2016)[2] to "Enhance cooperation, alliance and partnership; establishing regional dialogue for facilitation and supporting agreements on management of common natural resources as well as land and water resources."

In the water sector, the programme envisages providing advisory support and technical assistance, leading member countries' dialogue on the development of water resources management planning at river basin scale, and providing decision-making and financial support. The plan should include integrated approaches such as knowledge management and investments in infrastructure with innovation and advanced technologies which are socially, economically and financially viable.

Global water scarcity



Source: Fischer and Heilig

Images: IDB

The Dasht e Abbas irrigation scheme carries water to farms through a network of mains and distribution pipelines

IDB is directly involved in natural resources management with integrated rural development; water resources management and environmental protection; and agriculture and food security team members. IDB strengthens member countries' capacities to better respond to environmental challenges in current climate constraints. At the same time, it assists member countries in dealing with river basin (transboundary) water resources management issues at national and regional levels. IDB strives to promote sustainable natural resources management, increase agricultural productivity, enhance capacity development, promote inclusiveness and equity, encourage rural development, and facilitate farmers' access to agricultural technologies and support services.

Improving water use efficiency will require accurate measurement of water supplied to farmers' fields. However, irrigation water application is not measured due to a lack of simple measuring devices. Also, farmers do not have an incentive to save irrigation water and have insufficient knowledge about the negative impacts of over-irrigation. These problems have been accumulating for more than half a century. They were insufficiently studied at the initial stages, and the effects of many technical solutions were not as obvious at the outset as they are today. Now it is necessary to find feasible ways out of this difficult situation.

Surface and subsurface drainage are required in arid irrigated agriculture to ensure crop development and to manage soil salinity. Surface drainage from furrow irrigation is often discharged into drainage ditches and lost for future use on the farm. Subsurface drainage is discharged into large open drains to be disposed of later in surface water bodies. Improving irrigation management will reduce the total volume of drainage water being discharged and provide additional water supply for irrigation.

During the past decade technologies in irrigation have improved tremendously and the modernization of irrigation methods at the farm level has opened many opportunities for farmers.[3] However, in order to arrive at this stage, farmers face many difficulties. Improvement of irrigation methods includes converting from a low-efficiency irrigation system (such as furrow irrigation) to a high-efficiency system such as sprinkler, drip and micro-irrigation. As mentioned above, over the past decade the countries located in arid regions that face water scarcity have already made a considerable investment to assist farmers to convert from conventional irrigation practices to high-efficiency sprinkler, drip and micro-irrigation systems.

Dasht-e-Abbas irrigation scheme

The development objective of the Dasht-e-Abbas irrigation scheme was to improve food security and alleviate poverty by increasing agricultural production and productivity through the development of about 32,750 ha of irrigated land. The project contributed to increasing income and living standards of the rural population of the region by generating employment for about 6,500 people in the agriculture, fish farming and animal husbandry sectors.

The Dasht-e-Abbas irrigation scheme is located in the South-Western province of Ilam, which includes the Doyraj River catchment area. The newly developed scheme carries water through a network of mains and distribution pipelines up to on-farm level. In the on-farm plots, advanced irrigation technologies such as pressurized sprinkler and drip irrigation are introduced. The project achievements include:

- a 32,750 ha irrigated area developed for pressurized irrigation, including 7,210 ha by drip irrigation and 25,540 ha by sprinkler irrigation where water efficiency increased from 67 per cent to 92 per cent
- conversion of a 270 km main water delivery canal to a pipeline system, increasing water efficiency from 74 per cent to 98 per cent
- 88 km of primary/secondary drainage channels put in place to drain field plots towards natural flood ways and on to the Doyraj river.

Image: IDB

The Chókwè irrigation scheme rehabilitation project aimed to enhance agriculture productivity and farmers' income in the area

Rehabilitation of Chókwè irrigation scheme

The development objective of the Chókwè irrigation scheme rehabilitation project was to enhance agriculture production and productivity and consequently farmers' income in the Chókwè irrigation scheme area. This contributed to the rehabilitation of the existing 50-year-old irrigation scheme covering 7,000 ha as well as enhancements to agriculture productivity.

The Chókwè irrigation scheme is located 250 km from Maputo, the capital city of Mozambique. It is in the Gaza Province, downstream of the Limpopo river and extended along the eastern side of the river. Rehabilitation of the irrigation scheme has improved the livelihood of the 5,000 smallholder farmers, enabling them to come out from subsistence farming and become small commercial farmers. The rehabilitation of the scheme improved the secondary and tertiary canal network with flumes up to on-farm level. Improved furrow irrigation was introduced on farms after levelling the land. The project achievements include:

- existing water supply facilities were increased from 1,200 ha to 7,000 ha
- investment in irrigation facilities improved the socioeconomic status of more than 5,000 smallholder farmers and provided them with access to irrigated lands
- agriculture production increased, with main crop rice yield increasing from 1 t/ha to 5 t/ha
- 2,120 km of water delivery canal was rehabilitated to the flume system, increasing water efficiency from 62 per cent to 96 per cent.

In the irrigation sector the main challenges are related to poor management of irrigation and drainage systems, low levels of land preparation and operation and maintenance costs which affect agriculture productivity.[4] The main and primary irrigation canals are running well, but secondary and tertiary canals are still not rehabilitated. The tertiary canals, especially, are seriously damaged as they were built in the late 1950s.

The local smallholder farmers are challenged with the operation and maintenance of the on-farm scheme, which identified a shortage of agricultural machinery and proper agro inputs such as improved seeds, fertilizers and land preparation. Thus, the irrigation area is developing slowly and farming efficiency and crop yields are low. This area has very productive soil, but a lack of agricultural investment and low levels of agricultural technology has led to a great waste of local agricultural resources and obstacles to the further development of the regional economy.

The local smallholder farmers lack technical knowledge of modern agronomic and irrigation practices as a result of outdated or missing technology and a lack of technology transfer infrastructure. Insufficient technology and information are further exacerbated by the institutional setting in which irrigators operate. One example of a water management problem is the basis for determining the irrigation water requirement for crops. Both irrigation systems and crop varieties have changed considerably over time as farm field sizes have decreased, groundwater levels and mineralization have increased, cropping patterns have diversified (particularly as centralized planning was abol-

Images: IDB

Investment in the Chókwè irrigation facilities has improved the socioeconomic status of more than 5,000 smallholder farmers

ished in peasant farmland) and awareness of the limitation of water withdrawals has increased. However, no corrections have been introduced to address these changes.

Water resources management challenges have increased significantly in the past two decades. Continuing population growth and rising incomes have led to greater water consumption as well as more waste. Rural populations in developing countries are growing dramatically, generating demand well beyond the capacity of already inadequate water and sanitation infrastructure and services and food security. Overcoming these issues requires more effective and integrated, intersectoral water management, enhanced capacity at all levels and better welfare for rural people.

It is the view of many development agencies that even very sophisticated water management technologies at all levels of the system will not solve the water supply problem without increasing water use efficiency in the field. Better water use efficiency is described as increasing the yield while maintaining existing water application. Every cubic metre of water saved in the field (when efficiency of the irrigation network is 50-60 per cent) reduces the need for water delivery by 50 per cent without any reconstruction of the canal network. However, efficiency of furrow irrigation is also affected by several external factors:

- poorly levelled field surfaces
- fluctuations of water supply flow during irrigation
- use of non-optimal irrigation technique elements that do not correspond to specific natural conditions
- lack of interest among land users in using improved methods of irrigation
- lack of a real cost for water delivery.

In addition to these factors, irrigation quality still depends on the availability of water in the right quantity and at the right time. Areas with water supplied through irrigation systems are better supplied, while areas with pumped water often suffer from delayed water supply due to pump capacity or insufficient electricity.

Several lessons have been learned, with potential for wider applicability. For example, the implementation of advanced irrigation technologies (more efficient sprinkler, drip and micro-irrigation systems) can be used in the most arid regions.

In order to be able to invest to advanced irrigation technologies, cropping patterns should be changed from field crops (such as cotton, alfalfa, rice, wheat) to high value crops such as trees, fruits, nuts and vegetables. The production value and market values of field crops are lower than those of high value crops, while the water use and acreage is much higher.

In addition to generating improved farm incomes, perennial crops require year-round maintenance and tend to provide stable employment at higher wages. Spring and fall vegetable crops, although seasonal, are labour-intensive and generate strong on-farm revenues that support regional economic growth.

In particular, water management institutions play an important role in their interaction with farmers to introduce different programmes at local level. Low-interest loans or microfinance programmes have been created to enable farmers to change from traditional irrigation methods to advanced irrigation technologies.

Sustainable smallholder agriculture, food security, agricultural policy and the role of smallholder farmers

Umar I. Kamarah, Islamic Development Bank Group

Increasing prices for agricultural commodities offer a historic opportunity to intensify production systems for small-scale farmers in many developing countries. But without agricultural policies supporting them in making use of this opportunity, many of them would lose their access to land and income, resulting in aggravated food insecurity. Hence, an agricultural policy guided by the objectives of food security, poverty reduction and sustainability, taking into account the dynamics of rural growth, must ensure: increased supply of agricultural products (including, but not exclusively, food) based on intensification; broad-based income/livelihood opportunities for the rural population; environmentally friendly, sustainable land use.

There is some debate over what a 'development and food security oriented' agricultural policy actually means. Should it focus on the potentials of existing smallholder farms, or on the efficiency of commercial scale large-scale farms? Should it embark on high external input technology based on chemicals and fuel, or give preference to sustainable land use practices? Should it go for a 'food first' policy, or should all agricultural commodities receive the same attention? Should smallholder farmers be promoted by public or private services? Moreover, there is disagreement on the appropriate approaches of promotion: are smallholder farmers helped most effectively by a farming/livelihood systems approach or a value-chain approach? And there is debate about who is responsible for ensuring sustainable and climate-smart land use practices and adaptation of farmers to climate change. However, the overarching question is whether there are general global answers to these questions or whether the answers depend on the specific local context. The answers to these questions must be guided by the policy objectives above.[1]

Although some of the dynamics are of global nature and demand global answers, specific local conditions have to be considered to find appropriate policy responses.[2] Consequently, there cannot be any general rule on whether small or large farms, low or high external input solutions, or private business, civil society or the government will do better. Rather than embarking on dogmatic debates on what is preferable in general, the first rule for designing agricultural policies is to follow the principle of context specificity. This principle has far-reaching implications for the process of policy design. Policies need to be drafted on the basis of local-level analysis and experience and with the participation of people with local knowledge. Such a process has to be adequately resourced.[3]

Smallholder farmers (SFs), given the opportunity, can intensify their production methods and thus increase productivity considerably. Especially in low-wage countries, SFs dispose of

Image: IDB

Gender empowerment is smart economics: Sierra Leone's SAGs play a vital role in enhancing economic efficiency and improving development outcomes

Image: IDB

Watershed management and environmentally-sound water-harvesting help to improve food security and conserve the natural resource base in Mont Bpabit

competitive advantages in the production of many commodities regarding quality requirements (African hand-picked cotton, for example), while they suffer from disadvantages in managing access to markets and services due to limited economies of scale. Taking their potentials into account SFs should, for the sake of food security and poverty reduction, be given preference by agricultural and land policies wherever smallholder farming is the predominant mode of production. Thereby not only can agricultural production be increased, but the masses of the rural poor, who still rely on farming as a source of income or subsistence, will have access to food. The disadvantages of smallholders in accessing markets and services can be compensated by making use of the capacities of agribusiness to facilitate contract farming arrangements. To become strong and reliable partners within contract farming systems on the one hand and empowered negotiation partners on the other, SFs need to be organized.[4]

According to the International Fund for Agricultural Development, support for smallholders will be crucial to future food security.[5] In emerging markets, three out of four low-income people depend directly or indirectly on agriculture for their livelihoods. Indeed, the World Bank suggests that supporting smallholder farming is the most effective way of stimulating economic development and reducing poverty.[6]

Sierra Leone: strengthening communities, reducing poverty

The development objective of the Islamic Development Bank Group (IDB) financed Sierra Leone Community Driven Development (SLCDD) project was to assist war-affected communities to reduce poverty and build local capacity for collective action, thus contributing to the country's stability, peace and sustainable economic growth.

The specific objectives of the project were to:

- improve the socioeconomic conditions of the communities in the targeted areas, especially the women and youth, through improving physical and social rural infrastructure, providing health education and preventative care and facilitating economic growth and livelihood development
- support capacity-building at the local level through skills training and strengthening of linkages between communities, local and chiefdom councils and the National Commission for Social Action.

Given the depth and severity of poverty across geographical niches in the country, the project benefited 675 communities spread across 12 districts of Sierra Leone, namely Bombali, Port Loko, Kambia, Tonkolili, Bo, Moyamba, Bonthe, Pujehun, Kono, Kenema, Western Rural and Western Urban. The project sought to empower local communities and improve the Government's capacity to reach out to stakeholders in the project areas such as SFs, fishermen, pastoralists and poor and vulnerable groups, including women and unemployed youth.

Importantly, the strategy represents a shift from public sector domination to a community-driven development (CDD) approach. With this project, IDB was able to induce a paradigm shift in Sierra Leone by empowering local communities to follow a socially inclusive and participatory process for the preparation and implementation of their own development plans. The project introduced an innovation in the formulation of local development plans, which brings all

Image: IDB

Adopting high-yield varieties has helped Mont Bbapit's small farmers to increase crop productivity by up to 70 per cent

the participating economic interests together in a socially inclusive process of collectively identifying the development priorities of their respective communities and translating these priorities into investment activities managed by the communities themselves. This participatory process resolved conflicts and ensured that funded subproject activities represent the interests of the group.

Income-generating activities supported by the project have helped communities to achieve tangible benefits and results including increased income and reduced rural poverty through access to better livelihood opportunities. At project completion in 2014, the real income of 50 per cent of the 675 communities covered by the project is estimated to have increased by 63 per cent.[7]

The SLCDD project has succeeded remarkably in organizing women into self-help affinity groups (SAGs) of 10-15 members, empowering them to save and loan money to each other, developing their skills and making them attractive clients to commercial banks and large-scale social safety net programmes. By definition, SAGs are generally homogeneous and related by affinity. Their members use savings, credit and social involvement as instruments of empowerment — pro-poor capacity-development relating to the rural poor themselves and building their local institutions for sustainable rural economy. Currently there are 118 SAGs covering the four provinces of Sierra Leone. As the Sierra Leone case shows, gender empowerment is smart economics — it can enhance economic efficiency and improve other development outcomes in three ways. First, improving women's absolute and relative status feeds many other development outcomes, including those for their children. Second, levelling the playing field — where women and men have equal chances to become economically, socially and politically active, make decisions, and shape policies — is likely to lead over time to more representative, and more inclusive, institutions and policy choices and thus to a better development path. Third, removing barriers that prevent women from having the same access as men to economic opportunities and productive inputs can generate broad productive gains which are increasingly important in a competitive and globalized world.

The SFs face high transaction costs in accessing credit, markets and public entitlement programmes. Small groups were ineffective, hence the need to aggregate and build institutions of the poor from the grass-roots level. The institutional platform of smallholder farmers created a local source of finance and organization that the rural poor need to start enterprises, gain job skills, increase incomes and try innovative solutions to their problems — including food security and nutrition centres.

Key lessons were learned during the project. Rural credit programmes, particularly in remote areas, require innovative mechanisms that adapt to constraints on financial institutions and beneficiaries. Following the success of SLCDD Phase 1, the Government of Sierra Leone was strongly committed to the CDD approach and requested a follow-on project, SLCDD Phase 2, which has been processed and approved by IDB's Board of Executive Directors. In June 2015 a financing agreement was signed by IDB and the Government at the IDB Annual Meeting in Mozambique. SLCDD Phase 2 will scale up on the results of SLCDD Phase 1. It relies on demand-driven investments and the empowerment of local communities to improve productivity and is specifically focusing on technology improvement, enabling SAGs to leverage collaboration between project and research and extension systems and improve the quality of livelihoods.

Ensuring sustainable rural livelihoods in Cameroon

Cameroon's poverty rate remains at 20-25 per cent and is a disproportionately rural phenomenon. With limited irrigation potential, natural resource management (NRM) issues are critical to sustainable economic development, especially in more marginalized rural areas such as the Mont Bpabit region.

The rural poor, who make up 85 per cent of the population in the area, rely on rain-fed agriculture and herding. Given that the population in this area is expected to increase by more than 20 per cent between 2012 and 2020, the sustainability of such livelihood systems is in question. The Government of Cameroon has sought to maximize agricultural potential in dryland areas while managing natural resources in a sustainable manner, but there have been several problems as the tribes and agricultural producer organizations have tended to remain isolated, and the Government has had little experience addressing these rural concerns.

The development objective of the IDB-funded Rural Land Development Project was to help reduce rural poverty and improve food security in the Mont Bpabit region through the development of 1,200 ha of lowlands, and improvement of agricultural production and NRM. The project components were designed to achieve this objective through lowland development and construction of socioeconomic infrastructure; water harvesting and watershed management, which would introduce several environmentally-sound water-harvesting interventions; adaptive research implemented on a demand-driven basis; and extension and training, which would provide funding for establishing effective agricultural extension services.

All activities are implemented within the framework of traditional community-based structures/tribal organizations, resulting in a demand-driven development process. This tribal framework ensures that government personnel become sensitized to rural community needs and concerns and it mobilizes local populations to manage natural resources in a sustainable manner. To incorporate tribal systems into their management framework, community groups which determined their own composition and structure were established.

With the objective of conserving the natural resource base, 1.2 million cubic metres of water storage facilities have been constructed, exceeding the estimated target by about five times and representing a 45 per cent increase in water availability. The project also established 150 rangeland management units, and established fodder trees and shrubs on approximately 2,000 ha. In terms of poverty reduction and improving livelihoods, construction of safe drinking water storage facilities resulted in agricultural and health benefits for the local rural population. Increased fodder availability and genetic improvement led to increased income from livestock and the adoption of high-yield varieties led to increases of 27-70 per cent in the productivity of vegetables and other crops. Overall, socioeconomic conditions of 10,440 households have been improved. In addition, the project built a good foundation for local capacity in resource management through training and support for project staff, farmers and community representatives.

Engaging an isolated group in a broad NRM project through the incorporation of existing community-based institutions was an innovative approach. Core project beneficiaries include farmers — especially SFs, farmers' associations, cooperatives, rural producer organizations (RPOs), private sector and value chain actors at the local, district and national level. Overall, these RPOs represent about 10,000 farming households, of which 1,200 produce cassava, 2,050 produce maize, 3,000 produce vegetables and 4,000 produce rain-fed upland and lowland rice.

The project illustrates that a multisectoral/multidisciplinary approach in NRM and poverty reduction projects is more likely to achieve objectives than single-sector projects. Participatory project implementation requires flexible budgeting that is not constrained to predetermine outputs, but relies on a demand-driven identification of activities. And adequate initial training and capacity-building is a prerequisite to the start-up of activities requiring beneficiary participation.

Future direction for smallholder farmers

The question serious analysts would pose is: which sectors of the economy in Sierra Leone and Cameroon need urgent attention? Agriculture is the motor of the economy and is therefore a priority. There is also the issue of illegal migration, which sees African youth migrating to Europe only to perish in the Mediterranean. This is of concern to their countries of origin as well as recipient countries. In order to make agriculture attractive to the youth, there is an urgent need to invest in activities that are likely to create employment; to invest massively in labour-intensive infrastructure projects and transform agriculture from subsistence-based production to business; and to reform the land tenure system and improve farming practices. Agriculture has to be a rewarding business. Not only will this automatically earn rural farmers more money, but it will also make agribusiness a more viable proposition.

Combating desertification: introducing integrated ecosystem management in the People's Republic of China

Frank Radstake and Bruce Dunn, Asian Development Bank, Manila, Philippines[1]

The People's Republic of China (PRC) is on the frontline of combating one of the most important global environmental challenges of the twenty-first century — the growing degradation and desertification of dryland ecosystems that cover more than 40 per cent of the Earth's land surface. More than a third of the world's population lives in dryland ecosystems. About 90 per cent are citizens of developing countries. Many of them are poor and primarily depend on land for their livelihood and consumption.

A dryland farmer in Gansu province, one of the areas most affected by desertification

In the PRC more than 250 million people, including several large ethnic minorities, live in the dryland ecosystems that cover much of the northern and western regions of the country. The provinces of Gansu, Qinghai, and Shaanxi and the autonomous regions of Inner Mongolia, Ningxia Hui, and Xinjiang Uygur are the worst-affected areas. These dryland ecosystems are home to approximately three-quarters of the country's rural poor, and house over 5,000 species of wild animals and plants. Many rural people have benefited only marginally from the country's spectacular overall economic growth over the past three decades. The economic loss caused by desertification is reportedly estimated to be about 1.4 per cent of the PRC's annual gross domestic product (GDP) and over 23 per cent of the annual GDP of the main affected provinces of Gansu, Qinghai, and Shaanxi and the autonomous regions of Inner Mongolia, Ningxia Hui, and Xinjiang Uygur.[2]

The PRC Government has long recognized the potential ecological, economic and social crises building in its dryland areas. It can ill afford droughts, and it cannot allow more vast tracts of its territory to be stripped by wind and water of topsoil and productivity. The effects already spread beyond the dryland ecosystems themselves. Distant cities as far away as Japan have been affected by the more frequent and severe dust storms that rise in north-west PRC and Mongolia.

The PRC also recognized that its past efforts, although impressive, were hampered by an uncoordinated, piecemeal approach. A wide variety of national government agencies planned and carried out their own narrowly-focused activities with little or no consultation. Conflicts arose between the responsibilities, priorities, goals, methods and regulations of the institutions involved. They also duplicated efforts and wasted resources. This lack of cohesion diminished the impact of the Government's work.

Since the ratification of the United Nations Convention to Combat Desertification (UNCCD) in 1997, the PRC has progressively intensified its efforts to combat land degradation as a matter of national priority. In 2002, the Asian Development Bank (ADB) agreed to a lead role to support the PRC to rethink, restructure and strengthen its dryland management programme. Led by the Ministry of Finance and the State Forestry Administration, the Government's decision to establish the Global Environment Facility (GEF)-PRC Partnership for Combatting Land Degradation in Dryland Ecosystems (the partnership) reflected the Government's growing commitment to addressing the country's deepening problems. The partnership aimed at promoting good farming practices, land preservation, and water and soil conservation with strategies for rural development that reach, include and benefit the poor.

A 10-year country programming framework (2003-2012) was prepared, introducing an effective integrated ecosystem management (IEM) approach through a portfolio of new

Pilot projects: alternative agricultural solutions

Image: Frank Radstake

Greenhouses in Qinhai province

In Guohan County, Inner Mongolia autonomous region, subsistence farming livelihood and access to land and water resources were adversely affected by the arrival of environmental refugees from a village whose dryland ecosystem had been destroyed. With the partnership support, villagers built greenhouses to grow higher value cash crops. As a result, their incomes rose.

Growing industry in nearby Wuhai City had depleted local groundwater resources. To save water, farmers adopted a drip irrigation system, which increased water efficiency by 40 per cent and helped control pests and diseases. Twelve sites tested drip irrigation, canal repairs or rainwater collection to conserve water.

In Qinghai province, villagers in Huangyuan County undertook greenhouse and mushroom farm trials and increased their annual incomes. With more than 500 greenhouses on pilot sites, farmers are now ready to set up a cooperative to sell directly to the provincial capital.

Minhe County, in Qinghai province, was among several sites that introduced courtyard vegetable gardens, thereby adopting a traditional architectural feature that has been rarely used for vegetables. The gardens have improved household nutrition, reduced expenses, and led to small-scale experimentation with new crops.

investment and capacity development projects, with cofinancing by ADB, GEF, the International Fund for Agricultural Development and the World Bank. The IEM approach provided new ways to plan and manage dryland natural resources by combining knowledge and experiences from diverse disciplines.

The PRC's adoption of the IEM concept was unprecedented. It was the first time that the Government had established such a high-level, cross-sectoral, national and provincial institutional coordination mechanism for natural resources management. It allowed a wide array of national, provincial and local institutions and agencies (such as those operating in the areas of agricultural and rural development; land, forestry and water management; environmental protection; finance and planning) to work together on building the foundations to combat land degradation. This included the introduction of new policy, legal and institutional concepts and frameworks, the development of provincial strategies, implementation of pilot projects, and sharing of information.[3] All along, the PRC sought to learn from countries that have wrestled with similar problems.

In the initial stages of its work, the partnership placed heavy emphasis on critical groundwork. It developed and disseminated the policy, legal, institutional and technical concepts and frameworks of IEM through the central and provincial government agencies involved in dryland activities. This effort included the building of knowledge, skills, laws and regulations, policies and legislation, organizational and institutional abilities, and the communications and relationships necessary to put IEM into practice in the six hardest-hit dryland jurisdictions. The work of six legal teams added substantially to PRC's knowledge base on the subject.[4] New local laws were put on the books, including, for example, the Xinjiang Uygur Autonomous Regional Wild Plants Conservation by-laws, the Forest Resources Management and Protection Regulation in Beijing, and the Regulation for Implementation of Law on Combating Desertification in Gansu.

Pilot projects: clean energy, conservation and salinity control

Images: Frank Radstake

Clean energy for cooking: biogas (left) and solar

The partnership supported significant household-level investments in alternative and renewable energy systems to reduce dependence on wood, manure, straw and crop stubble. New heating and cooking technologies like solar, biogas and electromagnetic stoves and pressure cookers allowed villagers to make better ecological use of straw for penned animal fodder, crop stubble for protecting topsoil and seedlings, and manure for fertilizer. More efficient traditional stoves are being tested.

The Naiman Women's Federation in Inner Mongolia worked closely with the local government in promoting conservation agriculture and reducing tillage. Women in dryland ecosystems have become increasingly responsible for agriculture while men work away from farms. The women's federation reported that by keeping animals off fields and leaving straw and stubble on the land, farms have reduced wind erosion, protected seedlings and improved soil quality. Penned animals also increased in weight. The trial area has been expanded.

In Minhe County, Qinghai province, villagers contributed to the purchase of 35 new units of agricultural machinery for conservation agriculture and reduced tillage. They shared maintenance expenses and developed a roster system for sharing the machines among the 270 beneficiary households. These farm machineries and tools greatly reduced labour hours for tractor ploughing, and even made tractors available to be hired out.

Gansu province adopted institutional and physical measures to combat soil degradation in eight sites that suffer from severe primary or secondary salinity. In former wetlands, Gansu province has instituted grazing bans to restore the natural ecology. To biologically rehabilitate areas severely affected by salinity due to too much irrigation, the province also pioneered the use of Chinese wolfberry, also known as Goji berry, which is resistant to drought and salt and is a highly profitable crop. The partnership provided wolfberry farmers with field training in pruning and in the use of organic fertilizer to replace chemical fertilizer, which is known to increase salinity.

The partnership helped the six provinces and autonomous regions formulate individual IEM strategies and action plans. Until then, individual provincial agencies had followed narrow strategies, each focusing on a fraction rather than the whole of the wider problem. The governments have integrated the strategies into their five-year planning cycles, and pay particular attention to the sensitivity of the ecological environment, levels of poverty in affected areas, and the potential environmental, social and cultural benefits of prospective IEM projects.

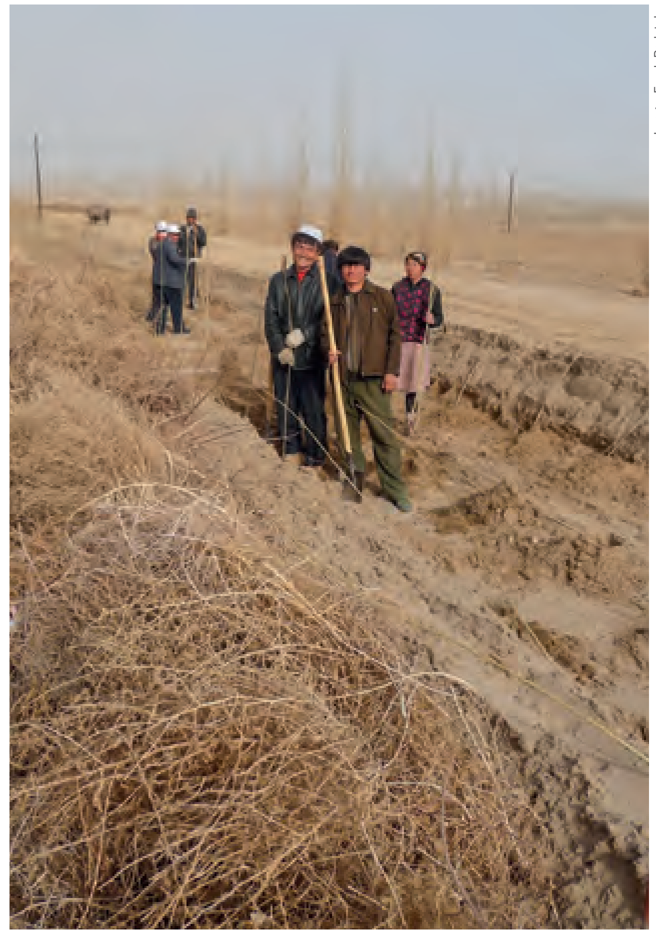
The partnership implemented pilot projects to give the PRC's central, provincial and local agencies and dryland stakeholders field experience in the adoption of the IEM approach. These pilots provided examples and guidance for a growing number of larger, more widespread investments in subsequent years. The pilots have also proven the ecological and development value, cost-effectiveness and sustainability of the IEM approach on the ground.

Pilots focused on specific challenges in each province or autonomous region. The sites were representative of prevailing soil, vegetation, water and other natural resource conditions. Villagers collectively helped choose the IEM interventions they felt would best address their challenges. GEF provided catalyst funding, but provincial and county governments were co-financiers. Beneficiary households contributed in kind and cash. Government officials, like the mayor of Huangyuan County, Qinghai province, said they welcomed the knowledge and hands-on experience of planning and implementing IEM pilots, even more than the GEF financing.

Through the piloting of new technologies, the PRC Government was able to document best practices to be added to the database of the World Overview of Conservation Approaches and Technologies, (WOCAT).[5] WOCAT is a global network that collects, compares, disseminates and uses information on soil and water conservation technologies and approaches.

In parallel, the pilot experiences have been integrated into larger-scale sustainable land management investment projects in Gansu and Shaanxi provinces and in Ningxia Hui and Xinjiang Uygur autonomous regions. For example, ADB is currently supporting the implementation of the Ningxia

Replacing annual crops with perennial and more climate resilient economic trees in Gansu province



Planting shelter belts in Xinjiang Uygur autonomous region

Integrated Ecosystem and Agriculture Development Project, the Forestry and Ecological Restoration Project in three North Western Provinces, and the Shaanxi Weinan Luyang Integrated Saline Land Management Project. Total investment by all partners for assistance, grants, and investment projects under the partnership is about US$800 million.

Since 2014, the partnership has entered a new phase as it seeks to build on successful capacity and institutional development. With the support of ADB, a new *Integrated Strategy for Sustainable Land Management in Western PRC for 2014-2023* has been prepared. Critical new challenges include adapting to climate change, developing public-private partnerships and innovative financing mechanisms, keeping updated with new sustainable land management concepts, and improving coordination with other programmes such as the PRC-GEF Biodiversity Partnership Framework and the UNCCD.[6] A key lesson learned is that scaling up sustainable land management is a complex process, and time, patience and persistence is needed to embed cross-sectoral cooperation across government agencies. Furthermore, greater levels of investment are needed and resources will need to be channelled and supported through innovative cooperation mechanisms that have been initiated over the past decade. With this approach the partnership will continue to strive towards its long-term goal of improving sustainable land management in dryland areas that benefit poor people.

Pilot projects: better animal husbandry and sustaining biodiversity

Among the major causes of land degradation in the pilot sites are the conversion of marginal land to pasture and overgrazing by goats and sheep. Because penning animals can have significant socioeconomic and environmental benefits, the partnership helped to popularize new breeds, feeding methods, weight-gain technologies and the use of animal manure for biogas and fertilizer. Farmers were encouraged to enrol in vocational training and to rehabilitate their grazing areas. In response to declining fodder and rainfall, livestock owners reduced their number of sheep and fattened the remaining animals.

Jingbian County, Shaanxi province, was given 50 sheep of an improved breed whose lambs can be weaned in two to three months instead of the usual 10 months, and can reach an average weight of 80 kg in four months, instead of eight. Villagers anticipated high demand for the improved lamb and stud services. Farmers began focusing on the quality of their livestock rather than quantity.

The Hudan watershed in Huangyuan County, Qinghai province, was confronted with upstream and downstream water conflicts, dying local tree species, significant reduction in biodiversity and inappropriate agricultural and grazing practices. Hillside grazing was partially banned and steps were taken to restore vegetation. The partnership trained farmers in sound ecological practices and the use of renewable energy and helped them start alternative livelihood activities. The quality of local soil and water improved, and native plants have regrown. Villagers participating in monitoring activities reported the return of several species of native birds for the first time in many years.

Reclamation and sustainable development of degraded lands in the Niger basin

Seyni Seydou, Project Coordinator, Niger Basin Authority and Laouali Garba, Principal Environment Officer, African Development Bank

The catchment area of the Niger River covers 2.2 million km² (with an active basin of 1.5 million km²), crossing four agroclimatic zones successively in nine West and Central African countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria. The entire basin is characterized by a generalized degradation of its natural resources and it is affected to varying degrees by water and wind erosion and siltation.

In this highly differentiated bioclimatic context lives a population estimated at 113 million inhabitants in 2005, more than half of the population of the nine countries of the Niger basin. The Niger River is therefore of vital importance to the socioeconomic advancement for the nine basin countries. The realization off this is unfortunately compromised by climatic and anthropogenic factors.

Four parallel stripes are commonly distinguished in the climate from south to north of the basin. These are the humid tropic zone, with over 1,200 mm of average annual rainfall; the subtropical zone in the dry season, called the 'Sudanian zone', with an average annual rainfall between 800 and 1,200 mm; the long dry season subtropical zone, called 'Sahel', with an average annual rainfall between 100 and 800 mm; and the subtropical desert, called 'Sahara', with very irregular or near absent annual rainfall of less than 100 mm.

The physical and chemical constitution of the geological bedrock of the Niger basin is the basis of arenization and sand. Transported and deposited by water and wind paths, it is the major cause of the silting up of the Niger River. The climate is the main factor in the production of sand by dissolving rocks with moisture, through their cracking with temperature differences, by their disintegration (soil)

An awareness session in Sembé village, Mali

Dune fixation in the Gao region, Mali

Glaze treatment methods include benches to control erosion, like these ones at Yettoré Allah, Niger

with drought and from their wear with hydraulic transmission and wind. The intensity of the weathering of rocks and strong pedogenesis is dependent on weather conditions (temperature, humidity). Indeed, under hot and humid conditions, chemical weathering promotes dissolution of the silica igneous rocks or carbonate limestone elements. The silting processes are more important and more visible especially in a hot and dry climate.

These processes have led to three major erosion systems in the Niger River basin:

- the Guinean system consisting of a feed head, high erosive power and a spreading and settling zone (Delta basin of Mali), connected by a transport zone (between Bamako and Segou), representing 13 per cent of the basin area
- the Sahelo-Saharan system corresponding to the Niger loop and having a reduced internal power supply network, unsustainable under dependence of the outlet of the Delta basin of Mali, representing 58 per cent of the basin area
- the Nigerian system composed of two well-watered feed heads with high erosive power (Jos Plateau and Plateau Yoruba for Niger River, Jos Plateau and Adamawa for Benue river) and a wide application and sedimentation area (confluence of oceanic region and delta), representing 29 per cent of the basin area.

With an annual average growth rate of nearly 3 per cent the population of the Niger basin, estimated at 113 million in 2005, will reach 160 million in 2020, including 90 million urban and 70 million rural. The average population density is 55 inhabitants per km² and rural population density is 37 inhabitants per km². The areas with higher population densities (30-50 inhabitants per km^2) register intense agricultural activities, often centred on the double production of food crops and cash crops, including cotton. In the Niger basin it was found that the high population densities and poor agricultural practices accelerate the silting process.

The main anthropogenic factors of land degradation in the basin include: rapid population growth (3 per cent per year), increasing urban consumption of natural resources (40 per cent of the population live in cities), extensive agriculture (about 50 per cent of the active area of the Niger basin is cultured), overgrazing (UBT 31.3 million with an annual growth rate of 2.4 per cent), overexploitation of wood energy and the expansion of mining activities.

Approach and intervention techniques

To cope with the accelerated land degradation process of in the Niger basin, the Niger Basin Authority (NBA) member countries have adopted different strategies and policies for sustainable management of natural resources. This political will has led to the commitment of the NBA in a shared-vision process with a main component, the development of the Sustainable Development Action Program (SDAP) including an investment plan. Three core areas of actions were defined in the SDAP: the preservation of ecosystems in the basin, development of socioeconomic infrastructure, and capacity-building and stakeholder participation.

The African Development Bank and the West African Economic and Monetary Union (UEMOA) funded a project (2006-2014) called the 'Fighting siltation programme in the Niger River Basin' (PLCE/BN). The major aim is to effectively

Thresholds of gabion and dry stone in the Tillabery region, Niger

and sustainably undertake actions/activities against silting in the Niger River. The PLCE is a multinational programme with a regional integration ambition. It includes the involvement and consultation of the nine NBA member states through the implementation of national components in Mali, Niger and Burkina Faso. The total cost of the programme is US$51.1 million including contributions from the NBA, member states and beneficiaries.

A participatory approach was adopted for the implementation of activities for siltation control in the Niger basin. It included the generation of the required information, creation of awareness, and the training and organization of communities and other stakeholders to develop their capacity and commitment through their significant involvement and accountability to implement the programme's activities. The participatory approach was deployed in six major steps:

- inform/raise awareness on the programme content
- establish democratic community organizations
- conduct a participatory diagnosis to define the communities' landscape and identify resources, problems, possible solutions and associated costs
- record the commitments of each stakeholder through a signed memorandum of understanding with each community organization
- supervise the communities in the implementation of activities based on an Annual Work Plan
- conduct a participatory evaluation of the activities carried out.

This approach generated, among other things, a massive and voluntary membership of the beneficiaries (farmers, breeders, fishermen, loggers, youth and women) in all activities of the programme, and better learning conditions to internalize technical and organizational approaches.

Land recovery/restoration techniques used during the PLCE implementation are grouped into three methods: glaze treatment, dune fixation and correcting ravines. The glaze (which refers to degraded land with impermeable crust) occupies a significant part of the Sahel basin. This degradation makes the rain wash over the soil and results in the decline/denial of crops and the disruption of socioeconomic activities of the communities. To reverse this situation emphasis was put on the recovery and recycling of glaze with the objective to reduce run-off speed, promote infiltration, increase the clay-silt-sand deposits, and thus help to achieve improved soil fertility which in turn leads to increased productivity and production with the associated revenue. In addition, this effort also led to the restoration of biodiversity. The methods used for glaze treatment are mechanized subsoiling, making erosion control strips (half-moons, benches and trenches), the Zaï or Tassa, stone barriers and dry stone thresholds. The mechanical works are reinforced by biological treatment (direct sowing, planting trees and grasses, agricultural and fodder speculations).

Dune fixation entails stabilizing dunes through a combination of mechanical (wattle using plant-based materials) and biological actions (planting trees and herbaceous cuttings with species suited to the environment).

Ravine correction is done by building filter works (thresholds of stone or gabions) through the ravines to block run-off, retain solids (sand and detritus) and let off the water without

Bench restoration in the Tillabery region, Niger

solid fillers. These structures must be strengthened by biological plantation to ensure durability.

Results achieved

The implementation of this first phase of PLCE has yielded very encouraging results. These include the development and adoption of a master plan for siltation control in the Niger basin including an action plan and an investment programme; the implementation of actions to protect and fight against the siltation of 41,600 ha in Burkina, Mali and Niger; beneficiaries' use of technical and planning tools to protect and fight against erosion and silting through a participatory approach; training of 100,000 farmers in the different technical areas for degraded lands restoration; and the installation and supervision of 217 Village Committees for Natural Resources Management.

The PLCE programme implementation has generated other positive environmental and socioeconomic effects including restructuring and improving the texture and fertility of soil, revegetation (grass and trees) and the reduction of rural youth exodus in the basin. The main lessons learned are that:

- reversing the trends of land and water degradation is possible if you put in adequate human, financial and technological package resources
- fighting against desertification and Niger River siltation should be a cross-border/multinational and multisectoral issue with strong involvement of all the stakeholders which augers well for accountability in the whole basin.

The implementation of PLCE in the Niger basin helped to achieve the desired results for all the planned activities. This performance reflects the effectiveness of an intervention strategy based on a participatory approach that enabled the empowerment of benefiting communities through an effective decentralization of financial resources and of natural resources management.

In order to consolidate the significant benefits and to bring actions across the entire basin, the African Development Bank and other NBA partners (including UEMOA, KfW, the Global Environment Facility and the West African Development Bank) commenced, in 2014, the formulation of an ambitious (scaled-up) siltation control programme covering all nine countries of the basin. This is called the Integrated Development and Adaptation to Climate Change Program in the Niger Basin (PIDACC/BN). Its overall objective is to contribute to the improvement of livelihoods and resilience of people in the rural communities through sustainable management of natural resources in the basin. Specifically it aims to reduce the silting process of the Niger River, improve communities' adaptive capacity to climate change, and improve the integrated management of natural resources in the Niger basin. PIDACC/BN will focus on developing the resilience of ecosystems and natural resources through the protection of natural resources and ecosystems and the strengthening of shared management of water resources; and on developing the resilience of rural communities through the construction of multipurpose infrastructure and social protection. The estimated cost is US$300 million. The programme preparation is to be finalized in 2016 for effective implementation in 2017.

The right to water in the semi-arid region: managing Brazilian areas susceptible to desertification

Ministry of the Environment & Ministry of Social Development and Fight against Hunger, Brazil

In Brazil, areas susceptible to desertification (ASD) cover 1.3 million square kilometres of the national territory. The semi-arid area in the north-east region is the largest of such areas, with a total extension of 980,000 km^2 and a population of 22 million people. Better known in Brazil as 'Sertão' (backlands), this region has most of its territory covered by Cerrado and Caatinga, biomes rich in endemic species.

In contrast to other ASDs, the semi-arid area has relatively high average rainfall, but with precipitation levels unevenly distributed in time and space. Some droughts may last particularly long, as a result of the El Niño phenomenon and other weather factors. Recently, the region has endured the longest drought in 50 years.

The persistence of drought in the ASD led to the mobilization of various civil society stakeholders for the promotion of the fundamental rights of vulnerable populations, including the right to water and the right to a sound environment. In response to this popular mobilization, the Brazilian Government designed a policy to mitigate the effects of drought. Governmental actions related to ASDs have an integral approach and also aim at the mitigation of poverty and inequality; the sustainable expansion of production capacity; and the conservation and sustainable management of natural resources.

Emergency initiatives that were previously focused on combating the most visible effects of drought gave way to a set of structuring actions, jointly promoted by the Ministry of the Environment (MMA) and the Ministry of Social Development and Fight against Hunger (MDS). The National Commission to Combat Desertification gathers government agencies, members of civil society and stakeholders to discuss the implementation of the National Action Plan to Combat Desertification, with particular emphasis on access to water. The Brazilian policies also put emphasis in the provision of credit lines for projects that combine innovation and local knowledge.

The construction of cisterns has positively affected the lives of more than 4 million people in the semi-arid area

Image: João Vital

Successive sediment containment barriers, ensuring water retention in the soil and a productive environment

Water access

In the Brazilian backlands better access to water is promoted, in particular, through improving the storage of water in the soil and maintaining the vegetation cover. These objectives are reached through technologies such as:

- Retention terraces — transversal channels built in the direction of the declivity of the terrain, reducing the speed of the flood and its destructive potential on the soil.
- Contour stone barriers — applied on small farms, in areas where the use of agricultural mechanization is difficult. These also reduce the volume and speed of floods.
- Successive sediment containment barriers — structures built with loose stones in small inflowing rivers or streams, with the objective of retaining the sediments generated by erosion in cultivated areas.
- Underground dams — the use of a plastic canvas in the underground to create a barrier that will prevent the accumulated water in the soil continuing to flow during the dry season. Such underground water reservoirs are therefore used as a moist substrate for growing crops and as a support for water supply.
- Sustainable forest management — the planned use of forests, allowing for natural regeneration. It protects the soil and ensures the conservation of species and of vegetation cover. The planned use of dry forests allows for taking advantage of their forage for cattle farming, as wells as providing sustainable and legalized forest biomass to meet energy demands and enhancing the use of non-timber species. Other positive outcomes are favouring beekeeping and better regulating the water supply.

Besides the above-mentioned technologies, the construction of cisterns based on the traditional knowledge of the local population has positively affected the lives of more than 4 million poor people in the semi-arid area. Cisterns are a low-cost technology, which allows for the capture and storage of rainwater. The implementation of cisterns is funded and coordinated by the Federal Government in partnership with civil society organizations, state and local governments. Since 2003, over 1.2 million cisterns have been built. Labour is chosen preferably within the local community, lowering costs and generating job opportunities. Beneficiary families and bricklayers are trained both for the construction and for the proper use of correspondent technology. Each cistern is monitored for the assessment of its results.

Increasing access to water in this region generates profound changes in the lives of families: it reduces the incidence of diseases and liberates women and children to other activities. This experience strengthens the enormous capacity of local dwellers to cope with the hardship of the Sertão. In addition, it releases families from dependence on tank trucks and other forms of political patronage.

Overcoming extreme poverty

Food security is recognized as one of the top priority issues for Brazil. Initially, with the Zero Hunger Programme and later with the main Brazilian conditional cash transfer programme — called 'Bolsa Família' — Brazil managed to considerably reduce extreme poverty. Currently the Bolsa Família programme reaches 14 million households. Public sponsorship for the construction of cisterns is specifically devoted to that goal. In 2011, the Brazil without Extreme Poverty Plan was released to further promote social rights.

Image: Mr. Ubirajara Machado

José Nivaldo with the pavement cistern, built with funds from the Brazil without Extreme Poverty Plan

Image: Paulo Araújo - ASCOM/MMA

Brazil has been promoting programmes to foster community and family forest management

In recent years, small farmers in the semi-arid area have benefited from nationwide policies that are designed to facilitate domestic market access to agricultural products. One is the Food Purchase Programme (PAA), through which the Government purchases food produced by family farmers and distributes it to people in areas of nutritional insecurity. PAA also contributes to the formation of public stocks of food produced by family farmers. Furthermore, the programme strengthens local and regional commercial networks. It also values organic food production, encourages healthy eating habits and fosters cooperatives and associations. Today, the semi-arid population is better prepared to face prolonged droughts with low to no migration to cities, hunger or unemployment. The consolidation of these new public policies, which combine overcoming extreme poverty and adaptation to climate change, will bring progressively more positive results. During the more favourable seasons, the families can improve their productive assets so that they are better suited to resist the expected periods of hydric crisis.

Case study: security for small farmers

José Nilvaldo and Maria Aparecida dos Santos raised four children on their small farm in rural Areal, State of Paraiba. They are beneficiaries of the Bolsa Família and made their own water cistern for drinking water. In 2013, with funds from the Brazil without Extreme Poverty Plan, the family could also count on the 'cisterna calçadão' (pavement cistern). The calçadão cistern captures rainwater on a 200 m² paved surface. Surrounded by a curb, the construction is made on a slope. Water is fed to a settling box and then to the reservoir which can store 52,000 litres. Covered and closed, the cistern is protected from contamination caused by animals and evaporation.

The improvement in production, made possible by irrigation, opened other opportunities for income generation. The couple is part of an association of agroecological farmers which sells their production to the Federal Government's PAA. The programme buys food from family farmers and provides for people in situations of vulnerability. In 2014, the family received US$3,000 from sales to the PAA. The product of their work, organic and locally harvested food, was used in school meals. "I am happy that my children do not go hungry as I did," Aparecida recalls. In the past, they had to walk 12 kilometres to get water to drink. "There were times when I would leave at 4 a.m. and would return around noon." Nilvaldo says that "Today, I eat meat every day. In the past, the poor people only ate meat on Sundays". On the property, they have 24 kinds of agricultural products, and breed geese, turkeys, chickens and pigs. The family also has its own bank of native seeds. Working in partnership with the Brazilian Semi-Arid Articulation non-governmental organization (NGO), the Brazilian MDS supports community seed banks on several farms in the region, including in Areal.

Forest management

As part of its policies related to the sustainable use of forest resources, Brazil has been promoting programmes to foster community and family forest management. Those contribute to job and income generation in rural areas.

This set of benefits is essential to the conservation of watersheds in ASDs. Sustainable forest management, coupled with the legal protection of forests — Legal Reserve and Permanent Preservation Areas — enables a community to maintain forest cover over 50 per cent of its total area. The combination of

Image: Mr. Ubirajara Machado

José Nilvaldo and Maria Aparecida dos Santos on their farm in rural Areal

sustainable use and conservation policies allows for a productive activity with low environmental impact.

The MMA promotes the Community and Family Forest Management Federal Programme, with special focus on ASDs and in partnership with NGOs such as the Northeastern Plants Association and the Araripe Foundation, and with financial support from development institutions such as Caixa Econômica Federal and Banco do Nordeste. More than 5,000 families have benefited in an area of approximately 85,000 hectares, generating an average monthly income supplement of US$70 per family. The forest management activities in ASDs maintain an area of 350,000 hectares, providing jobs and income for over 7,000 farmers in dry periods and contributing to the permanence of families in the countryside.

Case study: Baixa Grande

There are 115 farming families living in the Baixa Grande settlement, city of Jati, Ceará State. They all benefit from the Federal Programme of Community and Family Forest Management. In an area of approximately 8,500 hectares, agriculture and livestock are developed as main activities, and forest management in a complementary way. The forest area is divided into production plots ranging from 74 to187 hectares, in a 20-year production cycle.

The commercialization of this sustainable forest production generated an average annual family income of US$1,000 during the first year of implementation of the programme. Now it brings an average income of US$2,000 per family per year. Sustainable forest management in Baixa Grande settlement became an important instrument for environmental management, promoting water, food and energy security with benefits to biodiversity and vegetation cover. The testimony of José Rodrigues, President of the Association of Settlement Baixa Grande, illustrates the success and benefits of management practice for the community: “The Forest Management Plan brought about only good things to our association. Families that did not have a fixed income or had low income, are now able to guarantee their livelihoods with sustainable management. To those people who already had any kind of small fixed income, such as low retirement pensions, the wood production provides an extra income and helps every month. After the implementation of this project, there was a change in people’s way of thinking with regard to deforestation. Before that, there was much more illegal deforestation, use of fire and other activities that are not allowed. Today, there is more awareness about the need to preserve the environment and respect environmental laws. Our community is 100 per cent stronger.”

The Afforestation and Erosion Control Mobilization Action Plan in Turkey

M. Abdullah Yurtoglu, Ministry of Forestry and Water Affairs, General Directorate of Combating Desertification and Erosion, Department of Combating Desertification, Turkey

The effects of a rapidly growing world population and the extension of the global economy mean that the stress on natural resources is increasing day by day. As a result of overconsumption, fundamental indicators of the environment are gradually being degraded.

Forest areas shrink, the water level decreases, erosion leads to soil loss, wetlands disappear, rangelands are degraded, rivers dry up, the average temperature increases, coral islands are dying, and species of plants and animals become extinct. The global economy, which is continuously developing and extending, will eventually destroy its own life-support system, Earth’s ecosystem, unless necessary precautions are taken. The world needs to solve this problem by designing a system that can provide for the basic needs of all people without self-destruction.

Turkey is among the countries facing a high level of land degradation and erosion due to topographical structure, climate and improper agricultural practices, overdestruction of range and forest lands and the sensitivity of most of the lands to erosion. The problems caused by climate change and global warming as a result of greenhouse gases released into the atmosphere are continually increasing. Our country is among those that would be affected severely by these problems. In order to re-establish the greenhouse gas balance in the atmosphere, we need to decrease greenhouse gas releases and increase carbon sinks.

Immediate rehabilitation of infertile forests and afforestation wherever possible are among the most efficient precautions to be taken against global warming and the climate change it causes. To achieve this, a cooperative project was implemented by Turkey’s Ministry of Environment and Forestry (now the Ministry of Forestry and Water Affairs) and public institutions and organizations, municipalities, non-governmental organizations and the community assigned by National Afforestation and Erosion Control Mobilization Law no. 4122.

Our greatest aim was to increase the forest lands, which are important carbon sink areas, in order to achieve a balance in the greenhouse gases in the atmosphere. At the earliest opportunity, forest assets should be increased, degraded forests should be rehabilitated, and soil loss through lakes, dam reservoirs and seas should be prevented by combating erosion. Therefore, we felt the need to mobilize the resources of our country and accelerate the works in order to achieve this aim as soon as possible.

The National Afforestation and Erosion Control Mobilization Action Plan prescribed the need for coordinated work among

Image: Min. of Forestry and Water Affairs, Turkey

Afforestation and rehabilitation of forests is one of the most efficient precautions against global warming and climate change

Image: Min. of Forestry and Water Affairs, Turkey

Roadsides were among the areas afforested, with planting on 8,135 km of highways and 2,262 km of village road

Image: Min. of Forestry and Water Affairs, Turkey

Each year of the mobilization, 300,000 people were employed for seed and seedling production, afforestation, rehabilitation and erosion control work

public bodies and institutions as well as all the parties of the community. The action plan was applied from 2008 to 2012. During its five years, the plan detailed the undertaking of afforestation, rehabilitation and erosion control and rangeland rehabilitation works on an area of 2.3 million hectares. The Ministry of Environment and Forestry aimed to accomplish the work on 2.16 million hectares of this area and other bodies and institutions on 136,000 hectares. The total cost of these works was estimated at more than TL 2.7 billion.

In order to assume that a country is self-sufficient in terms of its forests, at least 30 per cent of its land should be covered with forest. In 2004, 27.2 per cent of Turkey's land was covered with forest. This figure was close to the world norms.

However, 49 per cent of our forest lands are degraded, and these should be converted to productive forests as soon as possible. Our target for 2023 is to reach 23 million hectares of forest area, which means 30 per cent of the country's area.

Some parts of Turkey's degraded forest lands are stony and rocky so they cannot quickly be made economically productive. Nearly 4.2 million hectares of degraded forest can be converted to productive forest areas by afforestation, rehabilitation and erosion control works. Furthermore, there are nearly 1 million hectares of treasury land suitable for afforestation and erosion control works.

According to the results of the forest inventory works, there has been an increase of nearly 1 million hectares in the area of forest lands in Turkey during the past 30 years:

- 1963-1972: 20.2 million hectares (26.1 per cent of the total area)
- 1997: 20.7 million hectares (26.6 per cent of the total area)
- 2004: 21.19 million hectares (27.2 per cent of total area).

The National Afforestation and Erosion Control Mobilization Action Plan had several objectives:

- Rehabilitate forest and 10 per cent of canopy closures in Turkey and make them productive again with minimum effort and minimum cost through a forestry approach close to the nature.
- Restore the balance of nature to establish a liveable environment and minimize the potential effects of global warming, climate change and desertification in the country.
- Prevent floods and overflows, which are seen frequently in the river watersheds and lead to loss of lives and goods; regulate water run-off in the watersheds and improve water quality.
- Reduce the current pressure for wood production on the forests by establishing forests in order to meet the country's need in for wood raw materials.
- Raise community awareness of the importance of caring for saplings, trees and forests by initiating afforestation mobilization, and establish the planting of saplings as a common tradition practised by citizens every year. Through a love of nature, the concept of beautification of the environment will be established in citizens' hearts.
- Look after each sapling planted and prevent our country's soil from being carried away by erosion to the lakes, dams or seas, so Turkey's citizens can live in a greener and cleaner environment.

Today, humankind frequently experiences various types of disasters such as drought, desertification, erosion, floods, avalanches and famine. Each year, many humans and other creatures die due to natural disasters in Turkey and across the world. The people

Image: Min. of Forestry and Water Affairs, Turkey

Green belt afforestation was important to address a growing need for recreational space in urban areas

that have been destroying nature are unconsciously paying for it. Trees and forests are our biggest resources to prevent these disasters. We should look after these resources and their assets should be sustained and accelerated. This can be achieved by mobilizing everyone to plant saplings and re-establish the forests.

Potential afforestation areas cannot be established by the Ministry of Environment and Forestry's financial and physical capability alone. One of the biggest services that can be provided to our country is to say: "stop erosion" by planting saplings. Everyone should have this spirit of enthusiasm. Therefore, agencies and institutions, bodies of troops, local authorities and non-governmental organizations in Turkey should provide financial and physical support to this afforestation mobilization.

Countrywide afforestation mobilization began in 2008, with the goal to afforest and rehabilitate 2.3 million hectares by 2012. The soil that had been carried from these areas to dams and seas due to erosion would be conserved. The most effective and permanent precautions against climate change and global warming have been taken.

While the forests are decreasing constantly, Turkey is one country that is increasing its forest asset. Our forests covered 20.2 million hectares of land in 1973, and had reached 21.7 million hectares in 2012.

During the five years in the scope of the mobilization, we achieved afforestation of 210,169 hectares; soil protection afforestation in 315,889 hectares; and private afforestation in 49,385 hectares. Some 1.75 million hectares of degraded forest were rehabilitated and rangeland rehabilitation was achieved in 37,880 hectares.

Roadsides, schools, hospitals, health centres, sanctuaries and cemeteries were afforested in action plan works in addition to afforestation, rehabilitation, erosion control and rangeland rehabilitation work. Planting was done on 8,135 km of highways and 2,262 km of village road, in 27,000 school yards, 1,095 health centres and hospital orchards and 9,826 sanctuaries and cemeteries. In the scope of the 'Schools get life' initiative, works are being conducted and school orchards are being planted.

Green belt afforestation has also been achieved around cities. As a result of migration from rural to urban areas, the population's need for recreational space in cities has increased. To address this need, green belt afforestation around urban areas was undertaken and urban forests were established.

During the mobilization, the works received support from every walk of life. Seedlings were planted on the behalf of supporters and memorial forests were established. In this context banks, firms, real and legal entities have contributed TL 20.6 million (US$11.5 million) in financial support, 15.2 million seedlings were planted on the behalf of supporters and 79.288 hectares were afforested. Over the five years of the action plan, 109 million seedlings were distributed to the population free of charge.

Action plan implementations also provided employment opportunities to the rural population. Every year during the plan's implementation, 300,000 people were employed for six months in the production of seeds and seedlings, afforestation, rehabilitation and erosion control work.

The Turkish Government's decision to initiate mobilization resulted in Turkey's greatest project to achieve afforestation and combat erosion. Turkey is among the countries which will be affected by climate change and desertification because of its geographical location. There is active erosion in 59 per cent of its agriculture lands, 54 per cent of its forest lands and 64 per cent of its rangelands, while 48 per cent of its forests are degraded. To address these issues, the Afforestation and Erosion Control Mobilization Action Plan focused on key goals to increase forests, improve degraded forests, prevent erosion and minimize the effects of these in Turkey. During the five years of action plan activities, all parts of society have participated in achieving those goals and carrying out afforestation, rehabilitation, erosion control and rangeland rehabilitation work.

The original target of the action plan was to afforest and combat erosion across 2.3 million hectares of land within five years. This target has been exceeded, with 2 billion seedlings planted to establish more than 2.4 million hectares of forest plantation between 2008 and 2012.

The mobilization of afforestation has been achieved and its effects continue to be seen. Between 2003 and 2014 afforestation, erosion control, rehabilitation and rangeland rehabilitation works were realized on 4.2 million hectares of land and a total of 3.25 billion seedlings met with soil.

Building on partnerships and strong stakeholder involvement to tackle land degradation

Thorunn Petursdottir, Soil Conservation Service of Iceland
and Hreinn Oskarsson, Hekla Forest Project & Icelandic Forest Service

Iceland is ecologically the most damaged country in Europe. The story of its ecosystem degradation stretches as far back as to the Norse settlement, or approximately 1,100 years ago when the Vikings discovered this pristine volcanic island located just south of the Arctic Circle in the Atlantic Ocean.

At the time of settlement, around two-thirds of Iceland was vegetated with at least 25 per cent woodland cover. Due to a harsh climate and erodible volcanic soils, the Icelandic ecosystems were highly vulnerable to the year-round livestock grazing and woodland utilization practised by the settlers. Over the following centuries, unsustainable land use triggered ecosystem degradation resulting in extreme loss of fertile soil and vegetation. Today, around half of the original vegetation cover is lost including almost all the woodlands; leaving approximately 42 per cent of Iceland desolated. Furthermore, considerable to very severe erosion still occurs on about half of the remaining ecosystems. Most of the desertification can be directly related to mismanagement of natural resources, but in a few cases the deserts were formed solely by volcanic eruptions or they are located beyond vegetation limits.

Organized work aiming to halt soil erosion and further degradation and to protect the remaining woodlands started nationwide in 1907 when the Icelandic Government approved the first Act on forestry and protection against soil erosion. It was followed up by the establishment of two governmental agencies, the Icelandic Forest Service (IFS) and the Soil Conservation Service of Iceland (SCSI). Ever since, the two agencies have actively practised and facilitated ecosystem conservation and ecosystem restoration through diverse reclamation and forestation projects. Furthermore, in recent decades most of their projects have centred on stakeholder involvement and participatory approaches in order to ensure social acknowledgement and local support for the conservation measures implemented, and to secure the long-term ecological maintenance of treated areas post implementation.

Image: Johann Thorsson

Severe erosion still occurs on about half of the remaining ecosystems in Iceland

Image: Hreinn Óskarsson

Natural colonization of birch woodlands in the Hekla forest area

Image: Hreinn Óskarsson

Successful restoration of birch woodlands in Goðaland south Iceland. The remnants of birch woodlands were protected from grazing in 1925 by IFS

The Icelandic Forest Association (IFA) non-governmental organizations (NGOs), dedicated to forestation on deforested areas, were established by 1930. In the following decades, several regional branches were established under the IFA umbrella. From its establishment, IFA has provided profound support to the forestation and woodland protection practised directly by IFS. In 1969, increased public discussions about the poor condition of Icelandic ecosystems compared to past ecological richness led to the establishment of conservation NGOs; Landvernd. These new NGOs were meant to provide voluntary support to soil conservation activities comparable to what IFA, the forest NGOs, provided to forestation projects. Around 1970, a number of small individual NGO groups that annually worked on land reclamation on a voluntary basis were also established. The increased environmental awareness was also reflected at the governmental level, for example through a major revision of the laws on soil conservation and through a parliamentary resolution that substantially increased the public funds available in the 1980s for ecosystem restoration and for promoting methods of sustainable land management.

After 1990 the prevailing methodology driving governmental ecosystem restoration practices was substantially changed. Instead of the previous top-down approaches, the governmental agencies responsible for soil conservation and forestation adopted new participatory strategies for their restoration measures. Furthermore, instead of continuing to promote the use of agronomic methods, the agencies increasingly adopted the ecosystem approach in their restoration activities. Today, governmentally driven ecosystem restoration projects are based on strong stakeholder involvement and participatory approaches throughout the project lifetime and preferably afterwards as well.

In recent years the diversity of restoration projects has increased significantly, with a stronger focus on multiple integrated outcomes. Their goals are, for example, related to raising awareness about how soil conservation and the processes driving climate change are inevitably interconnected and how to enhance the socioecological resilience of degraded ecosystems to increase the livelihood of local communities. Currently, a number of restoration partnership programmes and projects exist, managed by governmental agencies, NGOs or as independent projects funded by the state and by businesses. There follows a short description of the main programmes. A complete summation of all restoration measures was published in a report titled 'Ecological Restoration in Iceland', released in 2011.

Farmers Heal the Land (FHL) is a cost-shared governmental restoration programme established by SCSI in 1990. It is based on collaboration between farmers and SCSI. It is the largest programme of its kind, with around 600 participants working individually on lowland restoration projects at their own farmsteads. The programme was established to increase rangeland restoration and improve grazing management; however, its main underlying target was to ease cooperation and build mutual trust between farmers and SCSI, as this had been perceived by the correspondence as lacking. The programme provides direct and indirect incentives to participants in the form of minimum subsidy payments and regular in-person field visits by restoration experts located at the nearest extension SCSI office. The FHL programme has facilitated the restoration of approximately 300 km^2 (3 per cent) of degraded areas below 400 m elevation. Furthermore it has substantially eased communications and strengthened trust between SCSI and farmers, as hoped for in the beginning. The majority of the farmers practise restoration to extend the size of grazing land. Participants also claim that the restoration of degraded lands is their moral responsibility; to 'pay the debt to the land' and return it to their descendants in a better condition than it was in

Image: Hreinn Óskarsson

Volunteer groups plant birch seedlings in the Hekla Forest project

when they received it. Economic factors do not play a substantial role in that context; neither do governmental policies.

Regional afforestation projects are state funded and implemented by farmers and landowners. The first regional afforestation project was established by the state in 1991. Later on it was followed by the establishment of comparable projects in other regions of Iceland. Each project operates at an individual level and runs its own regional advisory office. Nevertheless, they work in close cooperation under the same umbrella association. These projects provide maximum subsidies to farmers and other landowners who want to practice commercial forestry on their land, but they also support those who want to practice forestry using only native species. The projects are based on strong partnership and, in addition to regular in-person field visits by experts from the regional office, they offer participants a variety of forestry-related seminars and courses. In total approximately 450 farmsteads are currently participating in these projects.

The regional *Gróður fyrir fólk í landnámi Ingólfs* (GFF) NGO was established in 1997. The main aims of the organization are to halt soil erosion and ecosystem degradation in the vicinity of Iceland's capital city Reykjavik and adjacent towns, and to enhance the ecosystem services these systems can provide to increase the quality of life of inhabitants in the area. GFF uses only organic residues, such as hay litter, livestock manure or gurry in its restoration projects. The NGO is funded by the state, local authorities, governmental agencies and various types of business. The organizations work closely with school pupils who take an active part in the restoration work and use it for educational purposes. Furthermore, each year GFF coordinates restoration activities practised by several groups of volunteers. Substantial changes can be seen within the restoration areas but the greatest success lies in the public awareness-raising that the project has engendered since its establishment.

The United Nations University (UNU) Land Restoration Training Programme was founded in 2007 by the Icelandic Ministry for Foreign Affairs in partnership with the Agricultural University of Iceland and SCSI. It was formally approved as a UNU programme in 2010. The programme provides training for specialists from developing countries in the field of ecosystem restoration and sustainable land management, focusing on strengthening institutional capacity and gender equality. The fellows stay in Iceland for six months and get extensive professional and vocational training, given by a large variety of experts. Around 70 specialists from Africa and Asia have already graduated with a diploma from the training programme.

The Mount Hekla forestry project was founded in 2007, with the main objective to restore birch (*Betula pubescens*) woodlands near the active Mount Hekla. Only few hundred years ago the Hekla forest area was mostly covered with extensive birch forests and woodlands. Historical records show that prior to settlement, deposits of volcanic ash and pumice from eruptions in Mount Hekla were mostly stabilized on the forest floor, preventing secondary distribution. After more than a thousand years of farming in the area, both grazing and forest clearing had devastated the woodlands and today the areas near the Hekla volcano are some of the most severely degraded ecosystems in Iceland. These areas are quite fragile with low resilience, and ash deposits from nearby volcanoes such as the active Mount Hekla cause heavy damage to the remaining vegetation following each eruption. Currently most of the area is eroded, the soil is poor in nutrients and water-holding capacity, and frost heaving is extensive. Erosion is extensive; primarily wind erosion but also water erosion the during the spring thaw. Therefore, natural establishment of seedlings is limited.

Image: Hreinn Óskarsson

Birch seeds are collected in September and sowed in the autumn

Local farmers or landowners, SCSI, IFS, regional afforestation projects and local forestry associations have been working on stopping the erosion and restoring the vegetation in the area since the nineteenth century. The early efforts were mainly focused on protecting local farmhouses and hayfields from the sand and creating grazing areas. Later the work dealt with protecting larger areas from sheep grazing; spreading fertilizer, especially nitrogen and phosphorus; and seeding grasses and nitrogen-fixating species, mainly Nootka lupine. Trees have been planted or sown in reclaimed areas with good success, and natural colonization of birch can be found around both the old remnants of the birch forests and younger plantations, which suggests that tree planting is a feasible method in the area.

The eminent results from these restoration activities were the main arguments for the establishment of the Hekla forest project. Its primary goals are to increase the resilience of the ecosystem to deposits of volcanic ash during eruptions in the volcano and to prevent secondary distribution of the ash by wind and water. Other goals are the restoration of ecosystem function and biodiversity, carbon sequestration and improved options for future land use.

From the very beginning, the project was based on building effective partnerships and the involvement of various stakeholder groups in the process. Local farmers, governmental organizations and NGOs formed a collaboration committee for the project. They contributed actively to planning and promotion until the project was officially approved by the state as an independent governmental project, run by the state with funding from the business sector. Since then, the committee's role has changed to be mainly advisory.

Local landowners and other volunteers participate actively in the project, mostly by planting birch seedlings provided by the project. The project area extends over 90,000 hectares. Due to the size of the area, low-cost methods are essential. Therefore, the restoration of woodlands will mostly rely on colonization of birch and willows rather than large-scale planting. Birch seedlings are planted in small groves or woodland islets, from which these species will colonize surrounding areas during the next decades. However, stabilizing the soil in the nearby areas is needed to create favourable conditions for woodland expansion by seed. This is done by spreading inorganic or organic fertilizer onto the land in order to facilitate the establishment of soil crust and local flora. Sowing a mixture of grass species is also needed in some areas.

Since the Hekla forest project started in 2007, all planting, spreading of fertilizers and sowing of grass has been mapped and stored in a GIS database. Several research projects have been conducted in the area and some are ongoing, looking at both ecological factors and cultivation techniques.

In 2015, 215 landowners had joined the project and more than 2.5 million seedlings had been planted. The afforested area covered more than 1,300 hectares, divided into numerous small patches throughout the area which have already started to facilitate self-seeding. The project has been successful and will be a model for other similar projects in Iceland in the years to come.

Sustainable land management in Mongolia

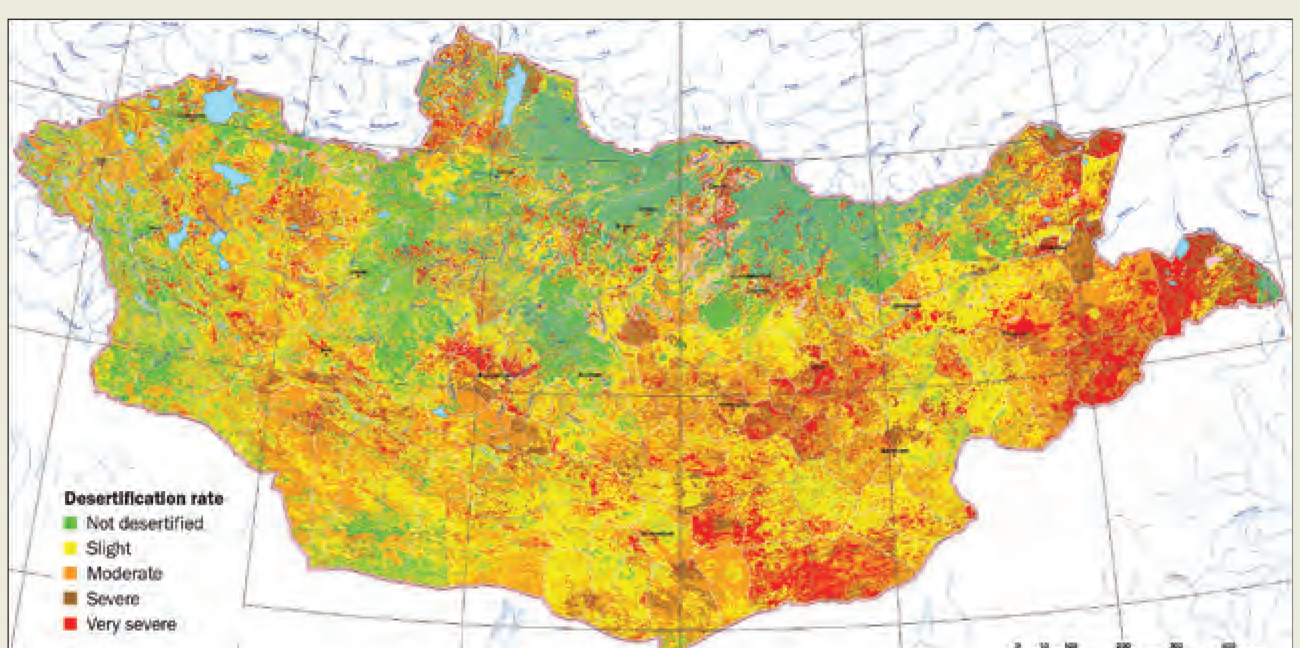
Bayarbat Dashzeveg, Ministry of Environment, Green Development and Tourism of Mongolia

Mongolia is one of biggest inland countries in Asia with an area of 156.65 km^2, most of which is arid and semi-arid land. It lies at a fairly high elevation (approximately 1,580 m) above sea level, completely separated from oceans and seas (500 km from the Atlantic Ocean, 1,600 km from the Yellow Sea) and surrounded by high mountain ranges. It borders on China in the east, west and south and on Russia in the north. According to the definition provided in the United Nations Convention to Combat Desertification (UNCCD), 90 per cent of Mongolia's landmass is highly vulnerable to desertification and land degradation.

Mongolia has a typical continental climate and average temperature of 1.56a. The lowest temperature is -50^{0}C in winter and in the Gobi area the highest temperature can reach 40^{0}C. The topography of the land largely influences the geographical distribution of climate characteristics, and is to some degree reflected in the soil and vegetative cover properties where it has created a distinctive distribution pattern. On the other hand, Mongolia has one of the region's most arid climates and its ratio of precipitation to evapotranspiration fluctuates in most territories between 0.05 and 0.65, therefore it is highly vulnerable to desertification.

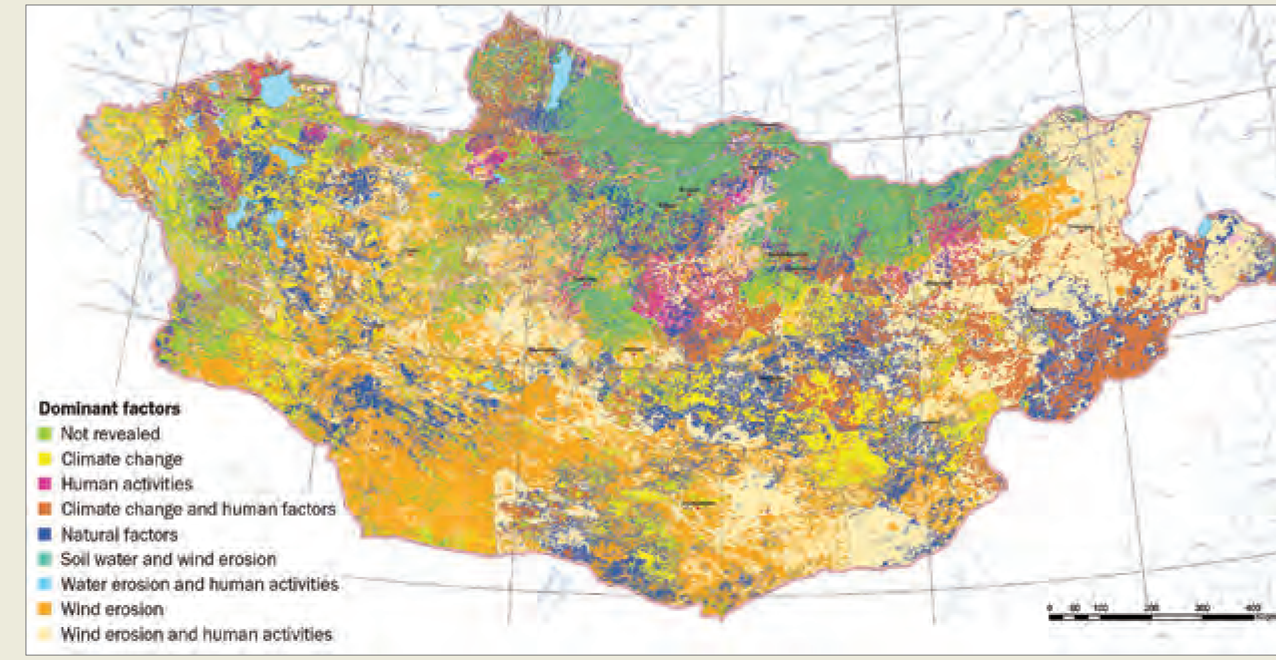
The main characteristics of Mongolia's climate are its distinctive four seasons, high fluctuations in air temperature, low precipitation, and notable climate differences in latitude and altitude zones. Results from continuous studies based on official data from the National Meteorological and Hydrological Observation Network demonstrate that the mean annual air temperature in the Altai, Khangai, Khentii and Khovsgol mountainous regions is colder than 40^{0}C, while the valleys between mountains and major river valleys are colder than 6-8^{0}C, the desert steppe zone is warmer than 2^{0}C, and southern Gobi is warmer than 6^{0}C. The mean annual air temperature corresponds with the northern edge of Mongolia's desert steppe zone, at latitude approximately 46° north. Permafrost occurs at territories with a mean annual air temperature lower than -2^{0}C.

Desertification rates in Mongolia



Source: Min. Env. Mongolia

Dominant factors affecting desertification in Mongolia



Source: Min. Env. Mongolia

From meteorological observation data since the 1940s, the lowest recorded air temperature was -55.3^{0}C in the Zuungovi *soum* (district), Uvs *aimag* (subdivision), in December 1976. According to data from nearby aerological stations, surface temperature inversion occurs or develops diurnally at 600-1,000 m depth and 6-17^{0}C. This is why in winter the river valleys and depressions have the coldest temperatures compared to the nearby higher terrains or open plains.

The evapotranspiration level is less than 500 mm at the high mountain belt region; 550-700 mm at the forest steppe zone; 650-750mm at the desert steppe; and 800-1,000 mm at the desert zone. Mongolia receives about 230-260 days and 2,600-3,300 hours of sunshine per year.

Mongolia's steppe and desert steppe zones are very windy. The annual average wind velocity in these areas is 4-6 m/s. Wind velocity is 1-2 m/s in the Altai, Khangai, Khovsgol and Khentii mountain areas and mountain valleys, and 2-3 m/s in all other areas. According to data from the meteorological observation stations near aimag and soum centres around the country, wind velocity of higher than 4 m/s was recorded in one quarter of the country's territory.

Mongolia's precipitation is several times less than the potential evapotranspiration and the territory is lacking in humidity. The level of precipitation in the Khangai, Khovsgol and Khentii mountains is 300-400 mm, in the forest steppes and Mongolia Altai zones it is 250-300 mm and in the steppe zone it is 150-200 mm, while in the desert steppe and desert zones it is 50-150 mm.

The Gobi desert steppe and desert zone accounts for about 41.3 per cent of Mongolia's territory and its soil is loose and fragile, with high winds causing sand and dust storms for 30-100 days a year, compared to 120 days in southern parts of Mongol Els. Meteorological observation data indicates some 300-600 hours of sand and dust storms a year.

From the results of studies on the impacts of global climate change on Mongolia's territory, it is evident that the mean annual air temperature has increased by 1.9^{0}C between 1940 and 2004. Taking the period 1961-1990 as a base, it is evident that the warming trend in Mongolia started in 1989, intensifying in the later twentieth century and the beginning of the twenty-first century. Studies show that the mean air temperature increased by 1.6^{0}C between 2000 and 2010 compared to the period 1961-1990. In those 10 years 2001, 2004 and 2007 were the warmest and the mean annual air temperature was 1.3-2.7^{0}C higher than that of the base year.

Climate warming is evident in all seasons. According to records from the meteorological stations in Mongolia in the last 20 years the mean annual air temperature in the winter (November-January) increased by 0.5^{0}C, in spring (February-April) and fall (August-October) by 1.3-1.7^{0}C, while the summer temperature (May-July) increased by 4.3^{0}C.

Grassland is the major ecosystem in Mongolia, and is very important to the country's economy and eco-environment. Farming is a pillar industry, contributing more than 30 per cent of Mongolia's gross domestic product. Typical grassland, shrubberies with large areas for pasture, desert and the Gobi with little vegetation or bare land make up 83.2 per cent of the country's land area of 1.3 million km^2. The pasture is distributed in the south-west, south and north-east of the country, joining with Inner Mongolia and China, constituting the fringe area of

Image: Min. Env. Mongolia

The high-yield results encourage herders from 'Bayantuhumiin Uguuj Horshoo' group to make their desert area green

European-Asian grassland in north-east Asia with a lot of human activity. Now most of the grassland in Mongolia has degraded and is in the process of desertification because of overgrazing, overcultivation, overdeforestation and open-pit exploitation.

In the past 40 years, 42.5 per cent of the country's land has been desertified, with desertified lands increasing by 13-18 per cent per year. Potential arable land has decreased quickly, from 130x104 ha in the 1990s to 90x104 ha in 2004. Now, 44.5 per cent of grassland is influenced by desertification. The East Gobi province has the most severe desertification in Mongolia. Its area is about 11.5x104 km^2, of which 17.6 per cent is light desertified, 41.7 per cent moderate desertified and 40.5 per cent severe desertified land.

Mongolia is united with UNCCD, and the Mongolian Government promulgated national action programmes, called 'Green Belt', in 1997 and 2005 to combat desertification. The Government has implemented programmes to protect against land degradation, combat desertification and soil erosion, and improve ecological structure, costing an estimated Tog 200-300 million per year. However, it could not achieve satisfactory results in combating desertification. There are eight nurseries in arid areas and the 150-500 thousand seedlings they grew every year before transition to a market economy satisfied demand. In the market economy, however, most nurseries do not have active work and only 3-10 thousand seedlings are grown in a year.

The Mongolian Government is implementing the Green Belt programme and the National Programme to Combat Desertification, and aims to build national capacity for preventative measures in view of the global trends and the present economic situation.

In the summer of 2013, herder communities involved in the United Nations Development Programme's (UNDP's) Sustainable Land Management for Combating Desertification project harvested high yields of hay. This was the result of several years of effort to improve the soil condition in their localities, representing arid and semi-arid regions.

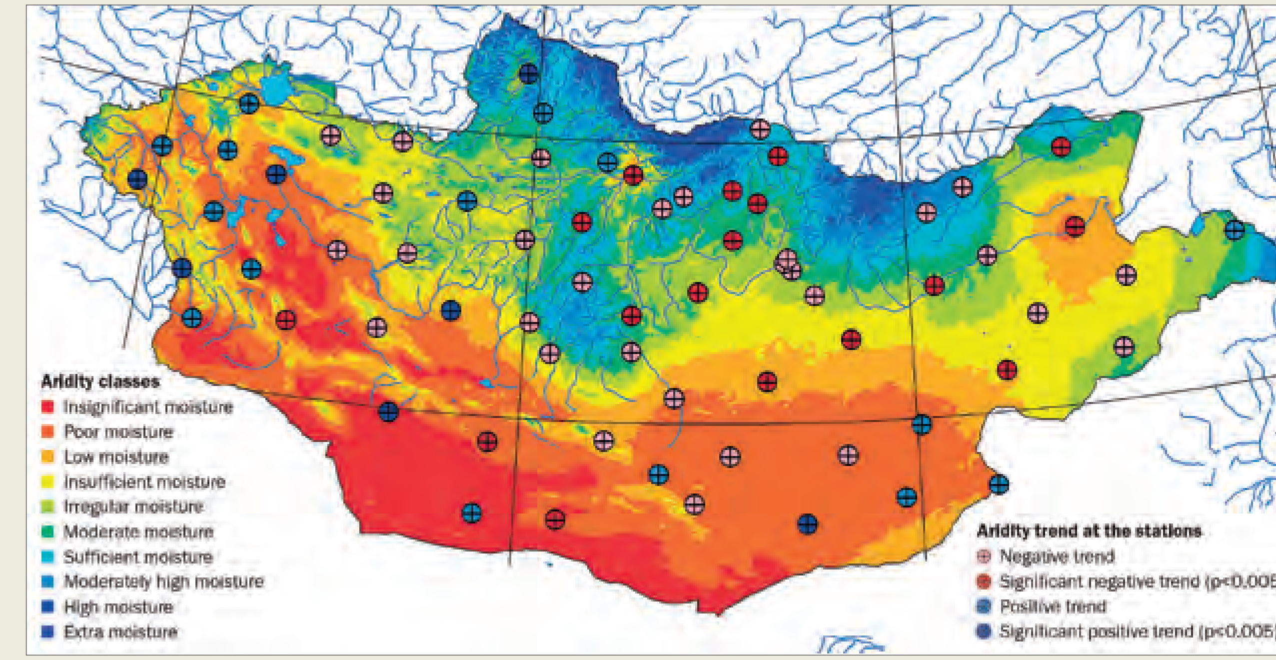
With funding from the Netherlands and Switzerland governments and UNDP, the Sustainable Land Management (SLM) project started in 2008 and operates in 13 soums of four provinces representing different ecological zones of Mongolia. It aims to introduce and promote sustainable land management practices, adjusted to local soil and climatic conditions and livelihoods. Herder communities involved in the project have fenced new hayfields to prevent livestock movement and obtained abundant harvests by improving irrigation and applying organic fertilizers.

Mongolia is located in an arid and semi-arid zone of continental Asia, characterised by hot and dry summers, low soil fertility and scarce vegetation cover dominated by few species. Nomadic herders rear sheep, goats, cattle, horses and camels as their main source of income. They often face insufficiency of hay and fodder in winter and spring seasons, which is a major obstacle in sustainable livestock husbandry. In recent years, herders have become less mobile, leading to overgrazing and hindering plant seed maturation, which in turn leaves pastureland barren and prone to wind and water erosion.

With the collapse of the socialist system and the dismantling of state-owned cooperatives in the 1990s, livestock was privatised but not the land itself. Although the number of livestock has been steadily increasing, the practice of collaboration between herders was lost and the rearing of excessive numbers of livestock which exceeded the pasture's carrying capacity has largely degraded the land during the past two decades.

Before the start of the SLM project, 70 per cent of Baruunbayan-Ulaan soum in Uvurkhangai province was degraded with increased sand invasions, the main reason for which was unsustainable use of pasture exceeding the carrying capacity. 'New generation' herders have poor knowledge of pasture use, and have limited experience in haymaking and pasture rotation and fencing to support natural regeneration.

Aridity trends measured by Mongolia's meteorological observation stations



Source: Min. Env. Mongolia

The UNDP project provided support for the formation of herder groups and a series of training opportunities with field demonstrations on pasture management, hayfield fencing, soil quality improvement and maintenance techniques, and methods of planting alfalfa and barley. In 2009, the training courses organised by the UNDP project enrolled over 2,600 participants, 60 per cent of whom were women. After the training, with the project's support, herder communities fenced off 12 hectares of pasture in the Taats river valley in 2009. The project also provided technical assistance in restoring old water ditches and establishing a borehole well to be used in case of severe water shortage. The plot was used by a former state collective farm to grow barley and for haymaking over 20 years ago. However, due to irrigation difficulties caused by continuously declining water levels, herders had slowly abandoned crop farming.

In 2009, under the technical guidance of the UNDP project, the 'Bayantuhumiin Uguuj Horshoo' herder group planted alfalfa in 2.2 hectares, barley in 1 hectare, and 10 ha of land was used for haymaking. Due to their collaborative efforts to maintain hayfields, fencing and improved irrigation, herders were able to once again harvest crops and prepare their own hay for winter. The herder community harvested 2.5 tons of alfalfa, 2 tons of barley and 80 tons of hay that fully meet their needs.

The herders who worked on the hayfield established a formal herder group involving 10 households and 23 members in 2010. The group leader, Mr D. Tumurchudur, says: "We worked as one to rest our field from livestock, irrigated and used organic fertilizers, which rewarded us with a good amount of hay. Because of the hay we reserved, we did not lose a single lamb in the past severe winter. Neighbouring herders now come to us to learn from our experience."

He also stated that herders can harvest five times more hay from one hectare by merely supporting natural regeneration. Initially, the herders were pessimistic about planting new crops. However, after seeing the first results, the community was very much inspired. Herder group women made barley flour and as well as using the flour for household needs, the excess was sold on the provincial market generating a revenue of Tog 500,000 (approximately US$385). The herder group won first place by participating in the brand product fair of Uvurkhangai province.

Following the experience of the Bayantuhumiin Uguuj herder group, five new groups with 43 households were established in 2010, all working on soil improvement and pasture management. With UNDP support, the herders have created added value and alternative income opportunities aside from livestock husbandry through small-scale vegetable farming, diversified diary and wool products.

With UNDP support, the annual soum-wide pasture/land management plan is developed and implemented with herder community participation, which will be the basis for significantly reducing degraded land towards the end of the project. The UNDP-supported herder groups have pioneered a revival of collective action for pasture management and the prevention of land degradation.

Participatory saline soil management in Thailand

Apichart Jongskul and Pranee Srihaban, Land Development Department; Worapong Waramit and Wisit Ngamsom, Focal Point Office of Thailand to United Nations Convention to Combat Desertification and Land Development Department

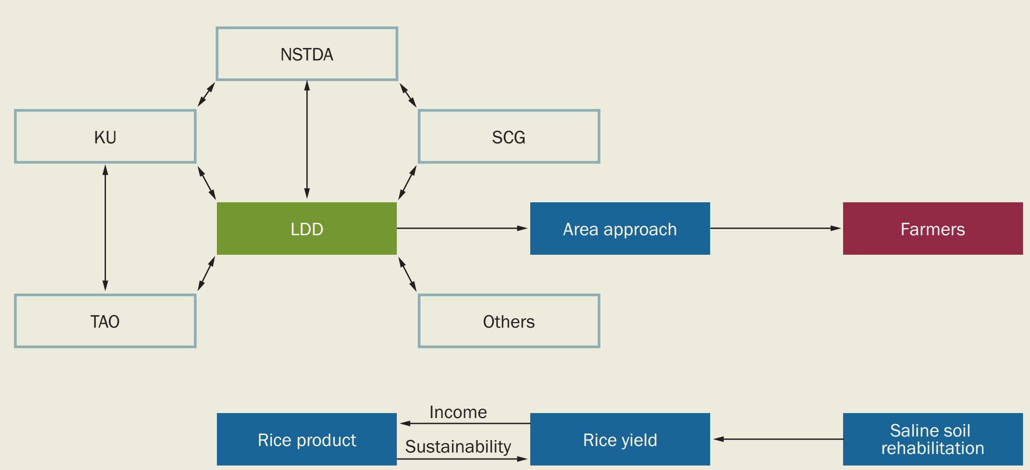
The United Nations Convention to Combat Desertification has indicated that the world population is estimated to increase to 9.6 billion by the year 2050 and there is a need to clear 3 million hectares of new land every year for food supply. Promotion of sustainable land management to reclaim degraded land and turn it into a robust foundation for food security is an urgent priority.

Participatory saline soil management in Thailand is an approach to reclaim degraded land and enhance food security through farmer participation. Saline soil, a prevailing problem in agriculture land, covers 2.84 million hectares or 29 per cent of the area of north-eastern Thailand. Soil salinity levels have been categorized into three classes: severely saline, moderately saline and slightly saline. The saline causes unfavourable soil structures and degrades the ecosystem, particularly the system that supports rice cultivation. Leaching of saline soils by rainwater deteriorates natural water resources, irrigation and underground water.

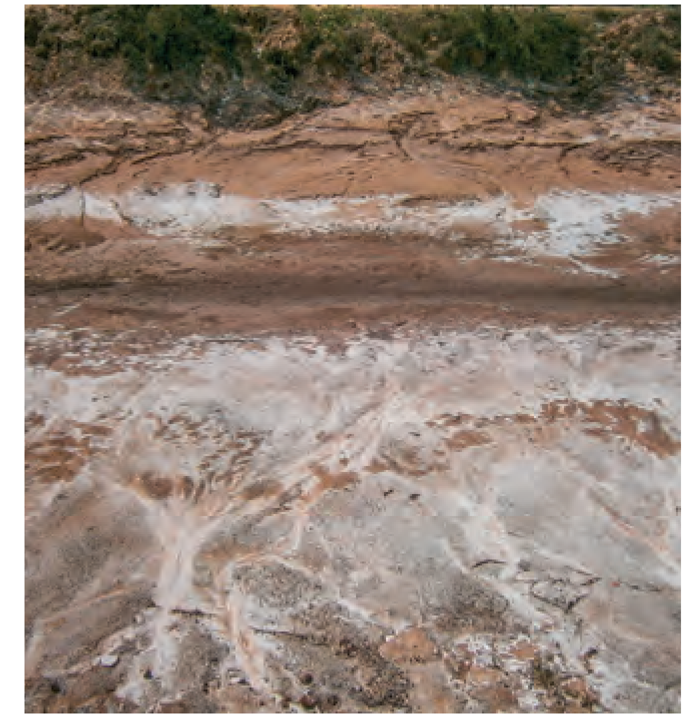
The Land Development Department (LDD) of the Ministry of Agriculture and Cooperatives in Thailand has tried its best to rehabilitate saline soil to return it to agricultural purpose, particularly in severely affected sites in Tung Muang Pia in the Ban Pai district of KhonKaen province. The project area covers approximately 122,880 hectares where most farmers depend on rice cultivation. Saline affects both on-site and off-site agriculture areas. The former limits the area for cultivation and causes low productive yield due to its toxicity to the root system of rice and degradation of the soil's physical properties. The latter causes saline water contamination in natural streams. As a result, it initiates the expansion of areas affected by saline soil. Paddy rice is vulnerable to soil salinity conditions. It has been reported that the rate of germination of paddy rice in saline soil is lower compared to non-saline soils. Seedling and root systems will be unhealthy and the budding rate will be low. The rice plant will become dwarfed, with low weight and low protein in the grain. When the paddy field becomes dry, the level of saline concentration will increase and the risk of rice plants dying will be higher.

LDD rehabilitates saline soils according to its category of severity. In severely saline soils, it introduces both mechanical and vegetative measures for the instant installation of drainage systems (open drains and sub-drains) to permit rainwater to leach the saline from soils. The salt-tolerant plant *Acasia ampliceps* is grown to pioneer and generate the plant ecosystem in the affected area. In moderately saline and slightly saline soils, LDD constructs soil and water conservation systems for instant land levelling and extensive water storage in paddy fields; incorporating green manure crops, growing salt-tolerant trees on the dykes along paddy fields, and adding rice straws to paddy fields to increase organic matter in the soil.

The concept of participatory saline soil management



Source: LDD



Images: LDD

LDD works with farmers to rehabilitate saline soil, which covers 29 per cent of the area of north-eastern Thailand

The approach used to improve saline soil begins with providing knowledge to farmers on how to use rainwater to leach saline in paddy fields. This entails storing water in paddy fields for two to three days until its colour turns brown, then discharging the water to the installed drainage system. After repeating the same leaching step two or three times, the farmers can grow paddy as usual. LDD also recommends that farmers use organic substances such as rice husk, compost and farmyard manure together with green manure such as *Sesbania rostrata* to incorporate into the soils after harvesting for 100-120 days to increase organic matter, help retain moisture in the soil and prevent upward migration of saline to the soil surface by capillary water. To reduce utilization of chemical fertilizers and ensure the use of organic substances, LDD promotes the use of microbial activators in making composts and liquid fertilizers for the improvement of saline soil on individual farms. Agricultural residues are locally available for this purpose. Thus, saline soil will be improved through leaching out the saline and increasing organic matter in the soil.

Rehabilitating saline soils takes time. Salinity levels will not decrease much in the first and second year, so a better yield cannot be fully expected in this period. Apart from the focus on technical and biophysical aspects of saline soil rehabilitation, the area approach has been used to implement the project, and its potential to improve farmers' incomes and sustainable livelihoods has been considered. Therefore, farmers in the reclamation areas receive technical assistance and other support from various government agencies and institutions including local government and the private sector. The concept of participatory saline soil management has been introduced, with LDD as the main agency that coordinates and works with other relevant partners in the area. The partners have a shared goal to increase rice productivity and enhance the value added to rice products in order to raise farmers' income in the project area. Biophysical rehabilitation helps to improve soil properties and the capacity for rice production, while other supporting activities from partner agencies contribute to increasing knowledge of other development techniques, such as rice production techniques to achieve premium-grade rice with a unique aroma when cooking, as well as marketing. As a result farmers' incomes have increased.

Participatory actions have been introduced since the first year of the rehabilitation project. Apart from soil improvement gained from applying green manure crops (*Canavalia ensiformis* or Jack Bean) and growing *Sesbania* on paddy field dykes, farmers also earn additional income from selling seeds. SCG Paper, a public limited company taking part in the project, supports the provision of seedlings of eucalyptus, a fast-growing and salt-tolerant tree species, to farmers. After a period of three to three-and-a-half years, the trees can be harvested and sold to the company for about B22,000 per rai (6.25 rai = 1 hectare).

At the very beginning, though the rehabilitation project was taking place, the rice yield was apparently very low. Productivity was only about 300-320 kg/rai while the cost of production was as high as B4,600 per rai. Instead of gaining profit, farmers lost. The question was how to improve both production and the price of the rice. Then LDD coordinated with the National Science and Technology Development Agency (NSTDA) and provided capacity-building to farmers on improving rice yield and quality. The training focused on soil and seed-bed preparation; identification and selection of good quality, salt-tolerant rice seeds; appropriate growing techniques and water management; harvesting and post-harvest techniques; rice-mill processing for good quality grains, and packaging. Under the training programme, farmers gained more knowledge about saline soil improvement and techniques for quality rice production. Additionally, many workshops had been organized by NSTDA to identify and select groups of skilled

Image: LDD

Rice growing in saline soil: capacity-building has helped farmers to improve rice yield and quality

Image: LDD

Rice produced from the participatory saline soil management project attracts a higher price and market demand due to improved quality

farmers. Then skilled farmer groups and networks were established for good quality rice production. Rice yield produced by the groups and networks is high, the quality is acceptable and there is demand from consumers and markets.

Rice produced from the participatory saline soil management project receives a higher price and market demand than normal due to the improved quality. SCG supports the project in terms of market development for selling 'saline soil rice products' and facilitates the sale of rice products for farmers' groups.

Regarding research and development of saline soil rice products, the Sakon Nakhon Campus of Kasetsart University has conducted research and promotes the improvement of rice quality and value through improving the quality of aromatic rice varieties. In addition, the Tumbon Administration Organization (TAO) fulfils the coordination between relevant agencies, institutions, the private sector and farmers in the project area. TAO also contributes in terms of disseminating information, performing public relations activities, facilitating and hosting technical training, and raising awareness among farmers.

It is now 14 years since LDD implemented the participatory saline soil management project. The transformation from abandoned bare land with crust surface soil to an outstanding rice cultivation area is remarkable. Between the years 2000 and 2014 the rice growing area has been expanded to 4,320 hectares or 60 per cent of the total 7,200 hectares of the development area. Average rice production is approximately 430 kg/rai, and its total value in 14 years is approximately US$5.6 million or US$414,643 per year. In this regard, if member agencies, institutions, organizations, the private sector and farmers continue to integrate their work in a cooperative manner and invite new partners to fulfil other required improvements in saline soil rice productivity, quality and added value, enabling an increased supply to meet market demand, it is possible that farmers' income could reach four times their present level or US$1.7 million per year.

To provide backstopping services, LDD has established a land development centre where farmers can look for most of their required materials, various best practices, and recommendations on sustainable saline soil management. The centre facilitates the sharing of knowledge and experience and technology transfer. It encourages the adoption of saline soil rehabilitation techniques and promotes collaborative working among farmers. It is hoped that with full support and knowledge gained from their participation in the project, farmers will be strengthened and will be able to manage the saline soil sustainably. The project has been designed to be a model for saline soil management in other salt affected areas of north-eastern Thailand as well.

In 2014, the project received the Excellence Award for achievement in delivering integrated public services from the Thailand Public Service Awards organized by the Office of Public Sector Development Commission. The key learning experience from this saline soil management project is how to overcome the challenges to farmers' adoption of saline soil improvement techniques. There is a need to understand farmers' problems and their needs as well as other related contexts by working closely with farmers and relevant stakeholders in the area, and to bring about cooperation among them including influencing people and local agencies to become fully involved in the project in order to achieve the desired goals. The project turns an idle, degraded land into a fertile outstanding place for high quality rice production. Its impact not only generates better and sustainable income and livelihood to farmers, but also enhances sustainable agriculture and food security as a whole.

Securing the upper end of the water value chain in South Africa

Christo Marais, Chief Director, Natural Resource Management Programmes, Department of Environmental Affairs, South Africa

On 30 November 1993 a group of researchers, planners and natural resource managers met to discuss the impacts of invasive alien plants on water resources and biodiversity in the Fynbos Biome, or Cape Floristic Region, the smallest of the world's six plant kingdoms. Two resolutions were made at the meeting: to present to local decision-makers the threat that invasive alien plants pose to the country's scarce water resources (the initiative that developed into the 'Working for …' programmes); and to approach 'the rich north' for support in the battle against invasive alien plants and their impacts on biodiversity. The latter is the forerunner to the landscape planning programme, Cape Action for People and the Environment and later programmes funded by the Global Environmental Facility of the World Bank.

Hydrological research going back as far as 1943, when Professor C. L. Wicth published the first scientific papers showing that *Pinus* plantations have a negative impact on streamflow, provided the initial rationale for the clearing of invasive alien plants. This was confirmed by further research between the 1960s and 1980s[1,2]. The idea of also creating jobs while containing the spread of invasive alien plants to improve water security was presented to the late Professor Kader Asmal, the then Minister of Water Affairs and Forestry, in June 1995. In October 1995 the Working for Water (WfW) programme was launched by Professor Asmal, a multidepartmental programme with a budget of US$6.9 million (R25 million based on the exchange rate at the time). The programme has since seen phenomenal growth, with a budget increasing to US$1,317.3 million (around R9.88 billion based on the mean exchange rate for 1995-2015) and peaking with an expenditure of US$105.3 million (R1.263 billion) during 2014/15, while also giving part-time employment opportunities to more than 40,000 people over the last few years.

Initially the primary focus of WfW was on the management of invasive species known to have negative impacts on streamflow. It was soon realized, though, that WfW cannot operate in isolation. When invasive alien plants are cleared from riparian zones and wetlands there is still the imperative for restoration of the wetland to improve water purification and retention, and ultimately to improve dry season flows. In 2004 the Working for Wetlands (WfWet) programme, initially run as a sub-programme of WfW and implemented by the South

Image: Christo Marais

Pinus species invading the Southern Cape Mountains where 8 per cent of streamflow is lost due to invasive alien trees

Image: Christo Marais

Workers restoring a highly degraded wetland in the Baviaanskloof

Images: Christo Marais

Images: Christo Marais

Top: WoF has more than 30 per cent women in its employment and over 90 per cent of the fire fighters are younger than 35
Bottom: To date some 2.8 million hectares of invasive alien plants have been treated. Invasive alien plants cover around 20 million hectares of South Africa

African National Biodiversity Institute (SANBI), was formally established. During the same period there were a number of devastating wildfires across the fire-prone biomes of South Africa. Often the most devastating ones were associated with high fuel loads, the result of dense stands of invasive alien plants which caused very hot fires that not only threatened infrastructure but had devastating impacts on topsoils and biodiversity. In September 2004 Working on Fire (WoF) was established, again as a sibling programme of WfW.

The Subtropical Thicket Restoration Programme — the forerunner of what would become Working for Ecosystems — was also established in 2004 to develop a scientific platform for catalysing public and private sector investment in the restoration of more than 1 million hectares of degraded subtropical thicket in the Eastern Cape of South Africa. After some years the project was expanded to the grasslands and savannah areas of the Maloti-Drakensberg range in the northern parts of the Eastern Cape, KwaZulu-Natal and the other northern provinces, more specifically Limpopo.

With the establishment of Working for Ecosystems there was now an integrated programme in place for the implementation of restoration and maintenance of ecological infrastructure and the delivery of ecosystem services. It completed the family of programmes that could address challenges related to water security, climate adaptation and mitigation, improved productive potential of land, natural disaster risk management and most importantly, restoration of biodiversity.

Image: Dr. Bennie van der Waal

The silted-up dam at Mount Fletcher

Image: Christo Marais

Large-scale degradation in the catchment of the Mount Fletcher dam

Furthermore, over the last 20 years the Working for… programmes have succeeded in mainstreaming ecological restoration into the employment and rural development debates. South Africa has a number of socioeconomic challenges, the toughest of which arguably include unemployment, safety and security, education, health, rural development and water and energy security. The natural resource management programmes contribute primarily to addressing unemployment, rural development and water security, but have the potential to make more tangible contributions to primary health (water quality of run-of-river water extractions in rural areas), education and energy.

Strong political buy-in and active support for programmes started with Professor Asmal in 1995 and continues today under Minister Edna Molewa, with the programmes having the full support of every minister responsible for water and environmental affairs since its inception. Political support, though, cannot be sustained without substance. The magnitude of the natural resource management programmes today is not to be underestimated. Its socioeconomic impacts, the areas cleared of invasive alien plants, degraded land restored and fires suppressed are very significant contributions not only to the economy but also to environmental resilience and the mitigation of, and adaption to climate change

Since the inception of the WfW programme the family of natural resource programmes has together created more than 227,100 person years of employment across South Africa. The programmes grew from just over 6,100 employment opportunities to more than 50,000 on average over the last three years. During that time, consistently around 50 per cent of these were female and more than 60 per cent were younger than 35 years old. WoF, a programme where one would expect a very low percentage of women, has more than 30 per cent women in its employment, arguably the highest for any fire management institution in the world. More than 90 per cent of the fire fighters are younger than 35.

To date some 2.8 million hectares of invasive alien plants have been treated. To put this in context, one has to compare it to the extent of such plants in the country. Invasive alien plants cover some 20 million hectares of South Africa to a lesser or greater extent. If compressed to 100 per cent density, they would cover around 1.9 million hectares, an area bigger than the Gauteng Province or the Kruger National Park. Although on the surface it looks as if WfW is making progress, research has shown that invasive alien plants may be spreading by between 7.4 per cent and 15.6 per cent, necessitating additional investment.[3] To curb the rate of spread and improve the sustainability of the labour-intensive clearing programmes WfW is investing around US$4 million of its annual budget in biological control.[4] Biocontrol is known to drastically reduce seed set and in some cases even kill its host species.

WfWet has invested in the restoration of 970 wetlands since its inception. Despite this being a substantial number, investments in wetland restoration will have to be increased significantly if the impact on countrywide water quality and retention for improving dry season flows is to show a marked improvement.

To date Working for Ecosystems has nearly 22,000 hectares under restoration for improving watershed services, sequestering carbon, improving the productive potential of the land and improving biodiversity. WoF has fought more than 13,100 fires since its inception. On average it has contributed to the suppression of around 15 per cent (expressed as a percentage of estimated area burned) of all veld and forest fires since its inception, with a high of 27 per cent during the 2014/15 fire seasons.

It is important, though, to put these achievements into context. Arguably the biggest investment in the restoration of ecological infrastructure and the delivery of ecosystem services has been done through WfW. It is estimated that invasive alien plants reduce streamflow by around 3 per cent. This might sound small but it represents 1,443.56 million m^3 of water per year. In the high yield catchments that are important water sources for economic growth in the country, the reduction in streamflow exceeds 5 per cent of

Image: Mike Powell (left), Christo Marais (right)

The slope facing up the valley at the Cambria site (left) shows hardly any above-ground biomass in 2004; (right) the view of the slope from the top of the valley in December 2014

mean annual run-off with a high of 8.4 per cent in the Southern Cape. The catchments with the highest impacts all fall within the Maloti-Drakensberg range, the 'water tower' of South Africa that supplies water to KwaZulu-Natal and Gauteng Provinces, and the Southern and Eastern Cape mountain ranges that supply water to the Nelson Mandela Metropole (Port Elizabeth), the economic hub of the Eastern Cape, the Garden Route (one of the country's ecotourism draw-cards), the catchment areas of Cape Town and the wine lands in the Western Cape.[5,6] Not all the water used by invasive alien plants is utilizable by humans though. In 2007 it was estimated that invasive alien plants in high-yield catchments and along riparian zones reduced usable water (registered water use) by more than 4 per cent and if left unchecked this could increase to more than 16 per cent. A water-scarce country like South Africa simply cannot afford this.[7,8]

Large-scale desertification is mainly caused by abandoned croplands, overgrazing and unsustainable use of timber and other fibre resources. Other contributing factors are unsustainable fire regimes — short fire return periods, burning during the wrong season and then grazing the land too soon after the last burn. These can all lead to major erosion, especially in the high-yield catchments. Five of the country's large dams have been silted up by more than 60 per cent and the worst of them, the Welbedacht dam, is silted up by more than 90 per cent.[9] Such figures don't represent the full picture, though, as many smaller dams are also silted up but this information is not captured in the national records. One such example is the municipal dam of the small rural town of Mount Fletcher in the Eastern Cape. The dam, which has a catchment of 77,100 hectares and a storage capacity of 500,000 m^3, was completed in 2008. Within five years it was more than 80 per cent silted up.

From the above it is clear that not only does land degradation have a major impact on water security, it also impacts negatively on our ability to adapt to climate change. All climate change models point to an increase in the intensity of both droughts and floods, combined with extreme temperatures. South Africa simply cannot afford not to invest in the restoration of its ecological infrastructure. In the Eastern Cape Subtropical Thicket Restoration Programme, of which more than 11,000 hectares is already under restoration, not only does restoration have the potential to increase carbon capture by around 80-100 tons of above-ground and soil carbon per hectare, but intact thicket also increases infiltration significantly.[10,11,12] Research has shown that more than 100 times lower infiltration in soils associated with degraded thicket, relative to the soils under intact vegetation, results in lower levels and less retention of soil moisture, almost double the amount of run-off and an almost six-fold increase in sediment load.[13] The increased run-off might sound positive but it all happens as part of flood flows and leads to a reduction in dry season flows. Water-scarce South Africa cannot afford to lose dry season flows.

At the moment it is estimated that the South African Government invests around US$166 million per year overall, of which the Natural Resource Management Programmes contribute about US$147.6 million. In order to get on top of the challenge though, the country will need to invest around US$1 billion per year, adding around 100 000 jobs to the economy.[14] Footing such a bill is unaffordable for the South African Government alone. All enterprises depend on water and energy; it is therefore a logical imperative that the private sector increases its commitment to the restoration of the country's ecological infrastructure and the delivery of ecosystem services. Once the private sector has internalized the impacts of catchment degradation on profitability, sustainability and risk reduction, investments in ecological restoration could be absorbed into companies' investment in enterprise and supplier development. The restoration of ecological infrastructure not only improves water security, contributing to economic growth and livelihood security; it is also a critically important contribution to managing climate change. To unlock resources the country will need a legislative platform allowing for incentives to restore and disincentives to degrade, backed up by appropriate institutions to facilitate investments in ecological infrastructure.

Translating policy into action — efforts to combat desertification, land degradation and drought in Namibia

Teofilus Nghitila and Bryn Canniffe, Department of Environmental Affairs, Ministry of Environment and Tourism, Namibia

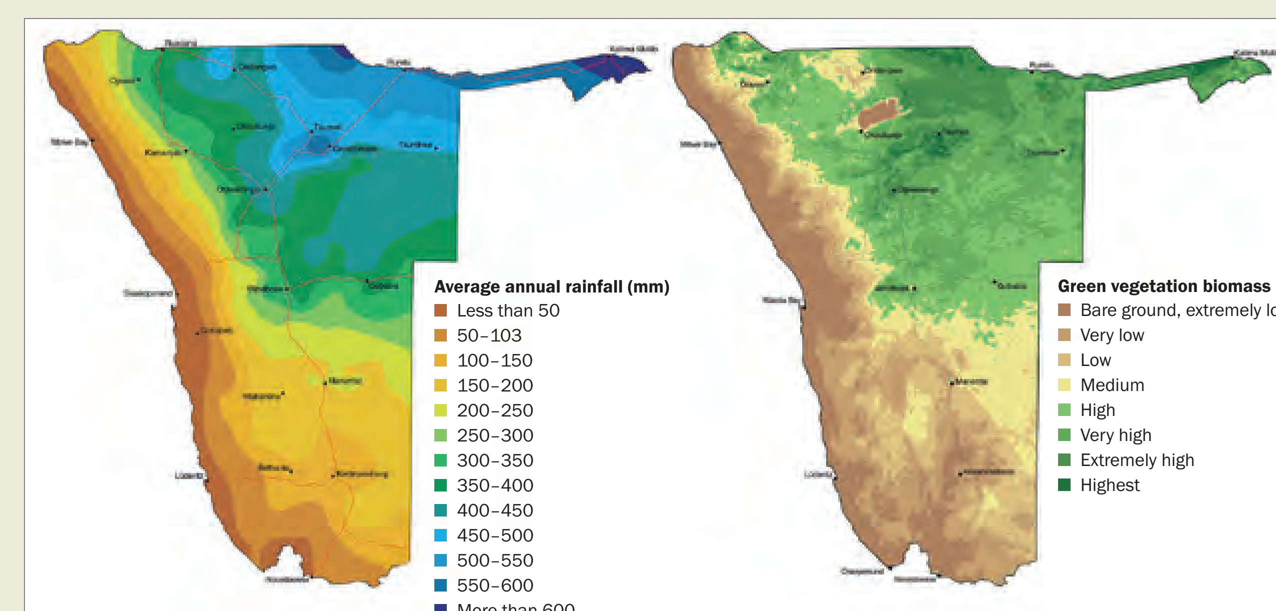
Issues of desertification, land degradation and drought are particularly important to Namibia. Known as the land between two deserts, Namibia is the driest country in sub-Saharan Africa, with over 90 per cent of its landmass classified as hyper-arid, arid or semi-arid. Annual rainfall varies from just 10 mm in the south-west to some 700 mm in the more tropical north-east. In all parts of the country rainfall is highly variable and unpredictable.

This situation is expected to worsen under the climate change scenario with increasing temperatures, an increased number of drought and flood events and even greater rainfall variability expected. Namibia already experienced its worst drought in 30 years in 2013 and rainfall is also well below average in 2015, which is a major threat to water and food security in the country.

In spite of these harsh conditions, almost 70 per cent of the population relies on agriculture to some extent for their livelihood, while approximately 71 per cent of the land surface is used for agriculture and mainly livestock farming. This high level of dependence on the land exists despite the predominance of infertile soils and harsh climatic conditions.

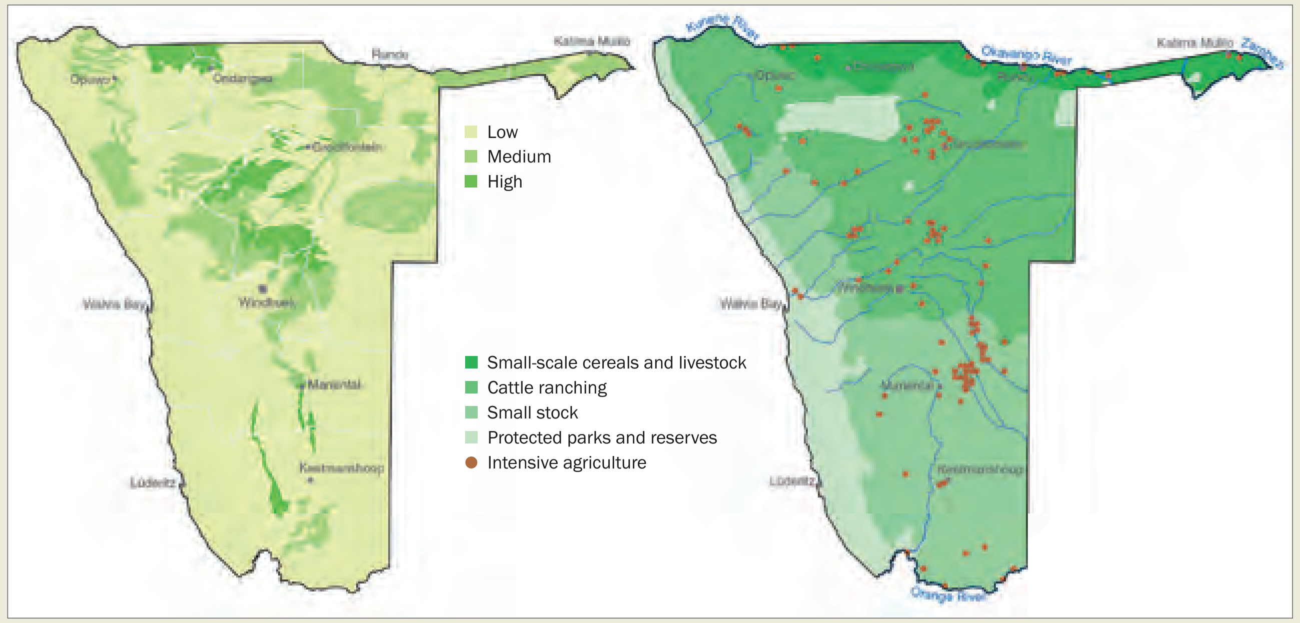
These factors make the United Nations Convention to Combat Desertification (UNCCD) highly important for Namibia, particularly the first two strategic objectives of the UNCCD 10 Year Strategic Plan — to improve the living conditions of affected populations and to improve the condition of affected ecosystems. The bottom-up approach of the UNCCD also resonates with Namibia, which aims to empower communities, especially women, as these are the custodians and day-to-day managers of the land and its resources.

Average annual rainfall and average plant production in Namibia



Source: Mendelsohn 2002[1]

Maps showing suitability of soil for crop cultivation (left) and the types of agricultural land uses practised



Source: Mendelsohn 2002[2]

In line with its Presidency of UNCCD Conference of the Parties (COP) 11 and the Namib Declaration, which was adopted at COP11, Namibia has sought to provide national-level leadership in the implementation of the UNCCD and to tackle issues of desertification, land degradation and drought head-on.

A number of manifestations of desertification and land degradation are commonly found in Namibia. These include:

- overgrazed and overstocked land
- bush encroached land
- deforested land
- soil degradation
- water degradation.

Overstocking and overgrazing has led to loss of ground cover and land productivity as well as increased vulnerability to drought. This problem is particularly acute in Northern Namibia and in a number of other scattered places, typically around large settlements. Open access to land and unsuitable distribution of watering points, including boreholes, is a major driver for overstocking.

Bush encroachment refers to the invasion of undesired woody species in rangeland environments, which leads to an imbalance of the bush to grass ratio, depletion of underground water sources, a decrease in biodiversity and decreases in carrying capacities. It occurs predominantly on commercial agricultural land in the central and eastern areas of the country. Overall, it is estimated that around 26 million hectares of land is affected and economic losses incurred have been estimated to be up to N$1.6 billion per year. It is believed to result from a number of complex interacting factors such as overgrazing and reduced browsing in favour of cattle production, exclusion of veld fires, and climatic and soil moisture conditions caused by prolonged droughts.

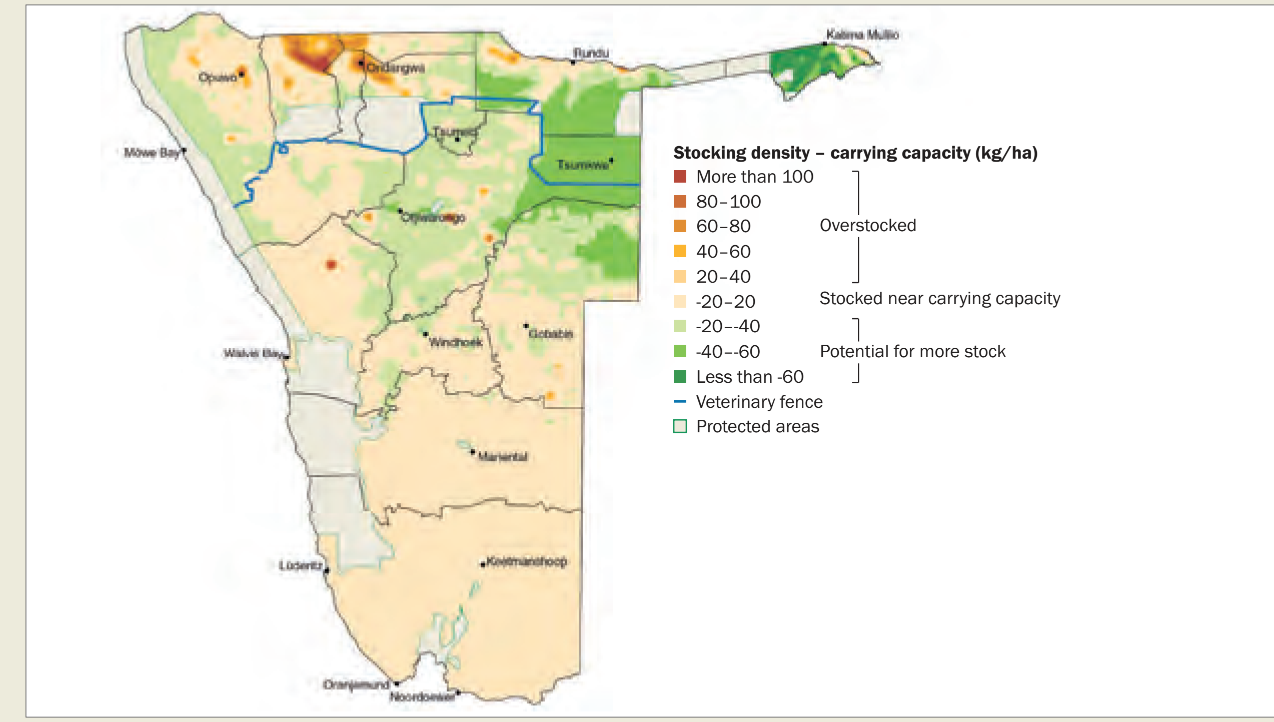
Deforestation is most prevalent in the more densely-populated northern regions of the country and is due largely to the unsustainable uses of trees to build houses and provide fuel, clearing of land for dryland cropping, and unsuitable fire management. It is estimated that wood is still the primary energy source for at least 60 per cent of Namibia's population.

Soil degradation is considered an increasing problem, caused by erosion from wind and water, and associated with declining fertility and loss of organic matter on both commercial and subsistence cropland. However soil health is not systematically monitored throughout Namibia. Impoverished soils and cases of soil compaction have been identified in northern Namibia due to dryland cropping over many years with limited nutrient inputs or soil fertility management under subsistence agriculture and through unsuitable tillage methods.

Water degradation refers to decreased water quantity and quality. Strong population growth, rapid urbanization and industrialization and expanding national economic output all place increasing demands on a resource already under stress and have the potential to jeopardize the quality of the resource. Current land management practices are also leading to water degradation through:

- over-abstraction of water through dams and boreholes
- inappropriate irrigation management which can cause salinization
- lowering of water tables and desiccation of springs through invader bush species
- inappropriate provision of artificial water points.

Stocking density in carrying capacity in terms of kg/hectare in Namibia



Source: Mendelsohn 2002[3]

The identification of desertification as a threat to national development and the need for the sustainable management of land has been a leading priority for the Government ever since independence in 1990.

The Government, in partnership with non-governmental organizations, donor agencies, academic institutions and the private sector, embarked on a National Action Programme to Combat Desertification (NAPCOD) in 1994, a full three years before it ratified the UNCCD. Namibia was one of the first developing countries to implement a national action programme and it laid a lot of the groundwork for tackling challenges at the national and local level. It systematically addressed a number of shortcomings in the areas of policy, institutional and individual capacity, awareness-raising, monitoring and community engagement in land degradation issues.

NAPCOD came to an end in 2005 but its pioneering work and lessons were built on through the Global Environment Facility-funded Country Pilot Partnership Programme for Integrated Sustainable Land Management, which ran from 2007 to 2012 and included the following four subprojects.

The Integrated Sustainable Land Manage¬ment Support/ Adaptive Management Project had a mission to find innovative ways of manag¬ing land in a way that restores the natural en¬vironment and increases income-generating opportunities for communities.

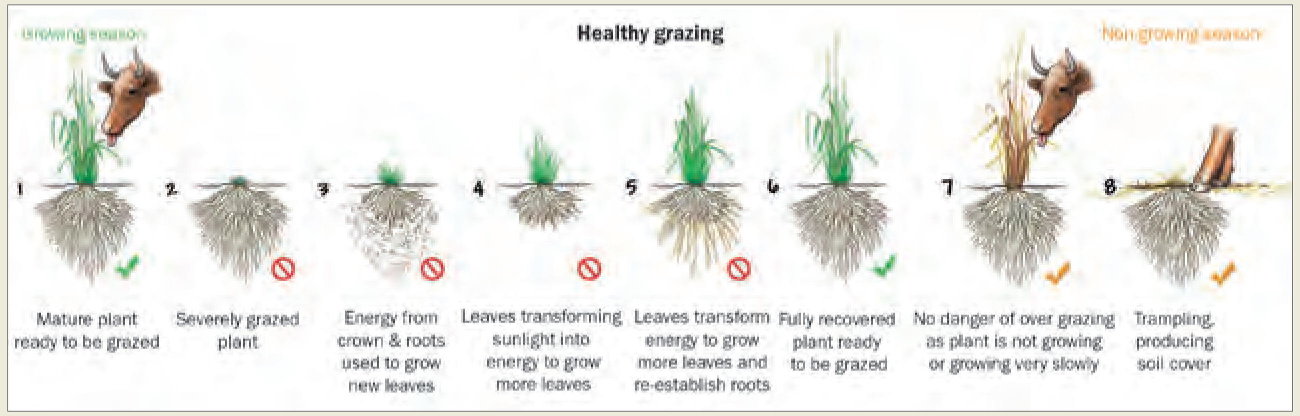
The Climate Change Adaptation Project, through improvement of traditional crops and livestock farming, developed and piloted a range of effective coping mechanisms to assist farmers in Namibia's North-Central regions to better cope with climate change.

The CALL-C Project: Enhancing institutional and human resource capacity through local-level coor¬dination of integrated rangeland management and support tested ways for communities to work together with government and other bodies to better manage grazing lands in the North-Central regions.

The Kalahari-Namib Project is a transnational project involving Namibia, Botswana and South Africa to implement sustainable land management practices in the Molopo-Nossob basin area. The implementation of this project in Namibia was delayed and it is now being implemented in the period 2013-2016.

In 2014, Namibia's Third National Action Programme (NAP3) to the UNCCD was launched as an overarching strategic document aiming to "prevent and reverse desertification and land degradation in affected areas and to mitigate the effects of drought in Namibia in support of poverty reduction and environmental sustainability." NAP3 contains six desired outcomes for the period 2014-2024 and is fully aligned with the UNCCD 10 Year Strategic Plan. A national sustainable land management committee, involving different line ministry representatives, non-governmental organizations, donor agencies, academic institutions and the private sector, is spearheading the implementation of NAP3.

The NRMPS promotes new approaches to rangeland management based on an improved understanding of the rangeland ecology



Source: Ministry of Agriculture, Water and Forestry 2014[4]

Years of testing and piloting of good practices have resulted in enhanced policy frameworks for the sustainable management of rangelands and croplands at the national level. This includes the National Rangeland Management Policy and Strategy (NRMPS) of 2012 and the Comprehensive Conservation Agriculture Programme for Namibia (2015-2019). These complement the National Drought Policy and Strategy of 1997, which seeks to promote the long-term on-farm management and diversification of risk and preparedness for drought events.

The NRMPS seeks to ensure that rangelands are managed so that productivity and biodiversity are restored and maintained. It identifies eight principles for sound rangeland management:

1. Know your resource base
2. Manage the rangeland for effective recovery and rest
3. Manage the rangeland for the effective utilization of plants (grasses and shrubs)
4. Enhance soil condition
5. Address bush encroachment
6. Plan for droughts
7. Monitor your resource base — including rangeland condition, stocking densities, water levels etc.
8. Plan infrastructure developments — especially water points.

The NRMPS is currently under implementation through a dedicated national task force team and has resulted in a number of innovative approaches to rangeland management, which bring together modern range management science and traditional and indigenous knowledge and practices. Addressing the frequency of grazing through combining herds and herding all livestock from a single or several water points to a different patch to graze each day, based on an agreed grazing and land use plan, is a key feature of these approaches, which have been found to have positive effects on perennial grasses. These also allow for increases in stocking rates, which is important when one considers the cultural significance of maintaining large herds.

Conservation agriculture is identified in Namibia's fourth National Development Plan as a priority strategic initiative and this led directly to the development of the Comprehensive Conservation Agriculture Programme for Namibia (2015-2019). This programme is now building on a range of conservation agriculture practices and techniques appropriate for specific farming systems and agroecological zones. These include approaches to land preparation such as ripping and minimum tillage as well as soil moisture conservation, agroforestry and crop rotation. There is considered to be great potential for these approaches, particularly in the subsistence farming sector in the northern regions, as part of an overall shift towards climate-smart agriculture.

A striking feature of NAP3 is its intention to move Namibia on a pathway towards land degradation neutrality (LDN). This is also in line with commitments laid out in Namibia's COP 11 Presidency Strategy and the Namib Declaration from COP 11, which called for a bolder agenda to secure the 'Future We Want'.

Namibia is one of 14 countries engaged in a pilot project to implement the concept of LDN at the national level. The first phase of the project has developed draft targets in a range of areas such as forest cover, cropland productivity and bush encroachment for Namibia to achieve LDN. A national working group on LDN was also established and pilot sites were identified across the country for testing of the LDN principles.

Phase two of the project is currently under development and will consider:

- the further integration of LDN into the national development agenda
- setting up/strengthening of existing monitoring mechanisms for land degradation
- implementation of needed intervention/restoration activities identified for the pilot sites
- production of an updated land degradation risk assessment map for Namibia, that will be used for planning purpose.

Networks to combat desertification in Portugal

Maria José Roxo, Universidade NOVA de Lisboa; Eugénio Sequeira, Liga para a Proteção da Natureza and Lúcio do Rosário, Institute for Nature Conservation and Forests

Portugal adopted the United Nations Convention to Combat Desertification (UNCCD) on 17 June 1994, some time before it came into effect on 26 December 1996. After 16 years, and having reviewed the National Action Programme to Combat Desertification (NAPCD) with a new version in December 2014 to align it with the goals of the UNCCD Strategy 2008-2018, the problems of desertification remain a reality in Portugal. Despite significant progress with the inclusion of desertification in its main territorial management instruments, the adoption of a communication strategy to increase public awareness of the gravity of this phenomenon continues to be one of the biggest challenges of this new national action plan.

Portugal faces a troubling scenario based on the evidence of global warming and climate change, in which there is an increase in the occurrence of extreme weather phenomena (droughts, floods, heatwaves and cold waves, among others). It is crucial that governments and citizens are aware of the causes and consequences of desertification. Both should seriously look for solutions to mitigate and combat it, as there are clear direct and indirect relationships between human activities, climate and the dynamics of ecosystems.

Considering the increasing problems related to natural resources scarcity, such as soil and drinking water, one method for calling attention to this situation has been to organize a programme of events during the last five years. This included conferences, workshops, photo exhibitions and documentaries, developed particularly in the areas affected or susceptible to desertification.

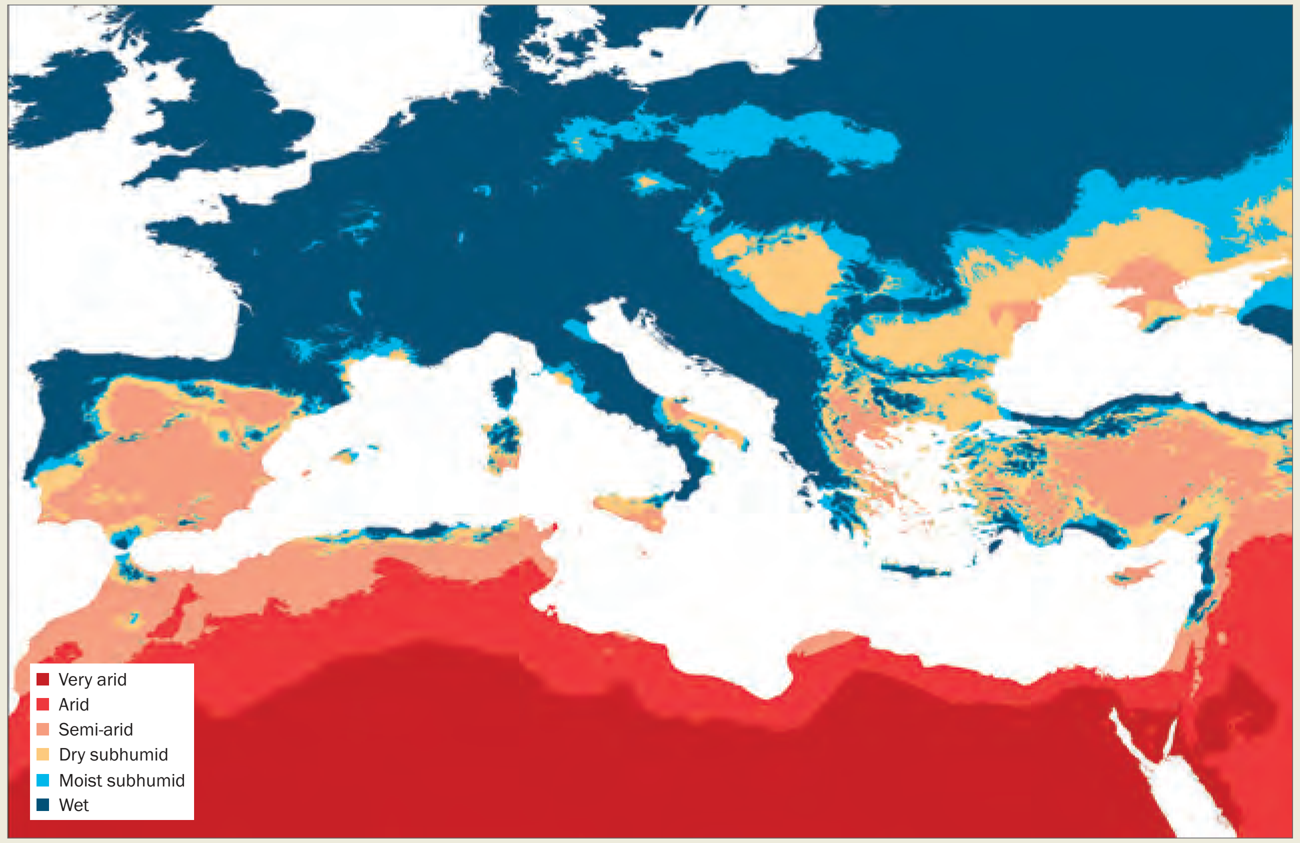
During this period several crucial steps were taken. In its first phase the programme focused mainly on recognition of the main causes of this serious environmental problem, with particular attention to natural factors (soil, water, vegetation, climate). In the second phase it was necessary to integrate human factors (social, economic and cultural issues) for a better understanding of such a complex phenomenon.

The research undertaken enabled a knowledge of the deep natural causes which have contributed to the genesis of the desertification phenomenon, including climatic extreme events and droughts. Climatic extreme events include intense precipitation periods that can cause the loss of organic matter and destroy soil structure (erosion). Droughts are character-

Image: Photo M.ª Roxo

The landscape of desertified areas in the Mértola region (south-west Portugal), one of the most arid areas of the country

Aridity index for the Mediterranean region, 1950-2000



Source: Lúcio do Rosário, based on FAO (PM) CGIAR-CSI

ized by the occurrence of below-normal precipitation values, recorded during an extended period, associated with a change in the distribution of rainfall, with significant reduction of precipitation in spring and an increasing period of water deficit. This affects the normal development of vegetation and weakens soil resources and agricultural production.

However, other major causes of desertification can be seen in all the unsustainable activities linked to the use of natural resources and agriculture, including agricultural bad practices. These include deep and continuous crop farming on greater slopes; monoculture that leads to loss of soil nutrients and its breakdown; the use of species not suited to the climate or soil; contamination of soil by overuse of fertilizers, herbicides and pesticides; use of heavy farm machinery, and use of poor-quality water with the consequent risk of soil salinization and sodization.

Activities related to livestock may also cause severe soil/water degradation, such as grazing or excessive livestock density in a given area resulting in the appearance of tracks favouring shallow seepage and soil compaction by excessive cattle trampling. We should also mention the extensive destruction of shrubland for land use changes, deforestation and the excessive consumption of water (tourism and agriculture irrigation) that lead to the reduction and depletion of groundwater, which often contains excess salts and causes soil salinization. Last but not least, soil sealing by the creation of infrastructures, equipment and urbanization also have an effect.

One of the main goals of NAPCD 2014 was to develop cartography and indicators to help decision makers find appropriate solutions to the management of resources in the dry territories and at the same time favour and encourage the recovery of degraded lands areas.

Considering the cartography of the aridity index (the ratio between precipitation and potential evapotranspiration) for Portugal it is clear that the area susceptible to desertification has increased in the last half-century. This is most evident when comparing the periods of 1970-2000 and 1980-2010, and even more relevant when looking only at the decade 2000-2010, which had some particularly severe annual droughts.

Therefore, the aridity or the equivalent susceptibility to desertification have affected 58 per cent of the territory of continental Portugal in the last three decades (1980-2010), while in 1960-1990, 36 per cent was affected. In this context the areas of the south, central and northern interior were included, but it should be noted that at a national level it is also necessary to consider the arid areas of south-eastern Madeira Island and the islands of Porto Santo, Desertas and Selvagens.

The indicator of land productivity relates to the services provided by the ecosystem and includes information about the

Sustainable land management and fire prevention on the Estrela mountain, central Portugal, promoted by the URZE forest association (Dryland Champion 2013)

Sustainable landscape management on Portugal's first private natural reserve (north-east Portugal) promoted by Transumância e Natureza (Dryland Champion 2013)

dynamics of the quality and quantity of land productivity. It is based on the long-term fluctuations of the factors that affect the conditions of standing biomass, specifically its productivity and phenology. In this context, for Portugal, such features are approaching the Food and Agriculture Organization concept of 'land quality', which synthesizes the cartography of the Land Quality/Land Degradation Index (LDI) developed for continental Portugal for 2000-2010.[1] This map shows that:

- LDI classes are distributed heterogeneously between the various regions of Portugal
- with respect to soil conditions the residual frequency pattern suggests that the northern region comprises the most important part of the degraded lands
- regarding the regressive trends in the land quality Alentejo is the region most affected.

For the period 2000-2010 the set of results also shows geographic variation of the conditions and trends of land quality, with settings that can be associated with 'hotspots' and 'green spots' of desertification in the Portuguese continent. A synthetic analysis found that:

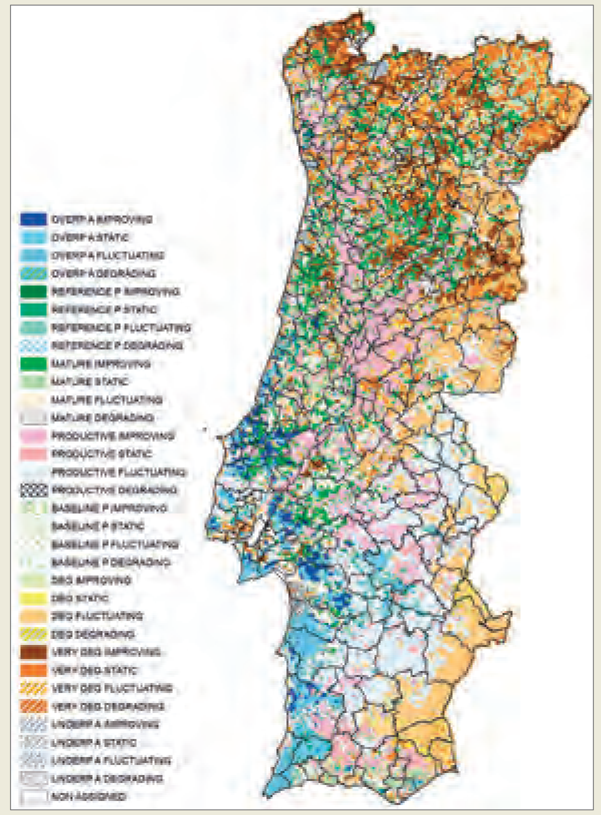
- in terms of the land conditions 32.6 per cent of the continental territory is in a degraded situation and 60.3 per cent is in reasonable/good condition
- in 67.8 per cent of the territory the vegetation is resilient to inter-annual climate variations or accumulates biomass over time
- the lands with static trends where primary productivity remains without evolution represents 30.8 per cent of the territory, thus corresponding to a high frequency of occurrence
- processes with a regressive trend in the land quality only persist in 1.5 per cent of the total area of the continent.

The strategic objectives of NAPCD 2014 include the promotion and sustainable management of ecosystems in areas susceptible to desertification and the recovery of areas affected by desertification or land degradation. In this context, it is important to stress a set of specific objectives and associated operational actions undertaken concerning the Mediterranean region, and particularly the Iberian Peninsula, which is one of the regions most threatened by climate change. Therefore, special responses are requested regarding mitigation and adaptation, while also aiming to generate global benefits and enhance synergies with the processes of nature conservation and biodiversity.

Specific actions for soil protection and conservation, especially those resulting of the national implementation of the Thematic Strategy on Soil Protection for the European Union, include:

- implementation of support measures to increase the resilience of ecosystems in areas susceptible to desertification through specific interventions aiming at the conservation of vegetation, soil and water, and particularly in the headwaters of watersheds more prone to erosion slopes or the surroundings of water lines of torrential regimes
- promotion of soil drainage, when appropriate
- cultural interventions aiming at increasing carbon sequestration in agricultural soils and forests
- monitoring of the physical and chemical characteristics of soils with adequate periodicity
- promotion of a cartography (reference types and soil quality) at national and regional scale
- assessment of the situation and evolution of national agricultural reserve and erosion issues and others related to the soil conservation of the National Ecological Reserve, at local level (municipal).

The Land Degradation Index for continental Portugal, 2000-2010



Source: Gabriel del Barrio et al, 2011

Encouragement and support for environmental restoration and landscape rehabilitation in land affected by desertification and/or with degraded soils focuses on several areas. These include areas that are affected by uncontrolled rural fires including forest fires; land where soil has been degraded by overexploitation, particularly areas with misfit herds of cattle; land with woody invasive alien formations; land with inert extraction areas; and all other land affected by erosion, saline influence or that is degraded overall.

The promotion and development of sustainable production methods and certified management takes into account soil conservation. This includes:

- efforts to promote the application of best practices in land use and soil conservation (such as minimal mobilizations, direct sowing, minimum anchor between rows and cover, and crop rotation)
- integration of production, organic farming and extensive grazing
- application of cross-compliance standards, specific environment commitments for agriculture and forest, and restrictions in vulnerable areas (such as nitrates-vulnerable zones)
- maintenance or increase of organic matter levels and soil biodiversity.

Other interventions that promote climate change mitigation include activities that help to reduce emissions and increase sinks (such as the management of livestock effluents through energy recovery; increased carbon sequestration in agricultural soils by direct sowing and installation of permanent improved and biodiverse pasture; increase in forest carbon sequestration through improved forest management and afforestation of new areas). These interventions also include getting to know, recognize and develop other technologies, practices and processes to reduce emissions or increase carbon sinks in a rural context.

Interventions aimed at adaptation to climate change include the development of activities that improve the resilience of agricultural and forestry systems. These focus on the knowledge of species and adapted crops; the relationship between activities and their exposure to climatic effects; technologies, practices and processes that increase resilience and their respective application; recovery of native species for priority use, including xerophytics for the establishment of improved pastures and trees and/or shrubs formations; and the adaptation and fitting test of non-autochthones xerophytics Mediterranean species where and when suitable.

On the other hand, PANCD 2014 considers two networks as basic structures for the monitoring and evaluation of the different action lines. The Pilot Areas to Combat Desertification network should include administrative units defined as priorities for interventions. The Thematic Reference Centres in Combating Desertification network will encompass management units for the study, development, demonstration and expanse of actions and good practices to combat desertification, land degradation and drought, and must be in possession of a specific measurement infrastructure for the subjects to be evaluated. These networks should eventually be integrated in other equivalent Iberian and Mediterranean networks.

It is also important to consider the Dryland Champions Programme created by the UNCCD in 2013 to recognize and relieve projects, initiatives and activities of individuals and/or organizations that promote or develop, at national or local level, useful contributions for sustainable management in arid regions and systems.

As a result, every year since 2013 Portugal has submitted to the UNCCD Secretariat a list of the organizations and individuals awarded as Dryland Champions. So far it has distinguished 27 entities with interventions not only in different regions affected by desertification in the country, but also with cooperation projects in arid areas of other Portuguese-speaking countries. Among the distinguished Portuguese Dryland Champions are representatives of different organizations working for local or cooperative development of the environment, farmers, forestry and indigenous breed producers' associations, scientists, technologists, public administration, companies and financial institutions.

The establishment of local pilot areas to combat desertification in the affected regions was considered essential for the systematization of effective solutions to mitigate and combat this phenomenon by sharing experiences and information. However all the entities named as Dryland Champions in Portugal represent, individually and as a whole, a very important component of the National Reference Network for combating desertification, because they have been selected as an example for national or global relief.

Seizing opportunities for sustainable land management through targeted policies and strategies — German engagement

Christina Seeberg-Elverfeldt, German Federal Ministry of Economic Cooperation and Development (BMZ)

When addressing environmental challenges, three conventions at the global and international level must be considered: the United Nations Framework Convention on Climate Change addressing climate change, the Convention on Biological Diversity addressing biodiversity, and the United Nations Convention to Combat Desertification (UNCCD) addressing sustainable land management. These too often work in separate ways; however there is also a need to look at cross-cutting themes. When it comes to the national level, an array of policies and initiatives exist which need to consider overlaps, synergies and trade-offs between the challenges. Especially at the local level when implementing programmes and projects, local realities usually need an integrative approach, considering several challenges.

Therefore, with Germany's commitment towards implementing UNCCD, we contribute to overcoming a silo approach and seize opportunities to promote sustainable land management at different levels, in synergy with different multilateral agreements. Germany's support to the implementation of UNCCD has been very pronounced from the early days of the convention. During the biennium 2012/2013, the Federal Government invested €425 million into combating desertification, which went to over 800 projects worldwide. Most of these projects operate at national and local level, many within regional frameworks and some at international level. Generally sustainable land management is an integral part of German development cooperation (DC) projects and programmes in the fields of food security and rural development, watershed management and biodiversity conservation, preservation

Image: Klaus Ackermann

The initiative 'One World — No Hunger' aims to overcome hunger today and secure the conditions for future generations to feed themselves

Image: Klaus Ackermann

Reforestation of degraded land for sustainable wood energy production is among the measures enabled by German DC

Image: Michael Martin

Increasing the productivity of agricultural lands is one key element for achieving food security

of ecosystem services, and climate change mitigation and adaptation. The majority of these projects (267) are implemented in Africa, 162 in Asia, 132 in Latin America and the Caribbean, 13 in the Middle East and seven in Europe. Approximately 20 per cent of the funding has gone to 52 supra-regional projects.

As a signatory to UNCCD and as the host country of the convention's Secretariat, Germany is committed to support the achievement of UNCCD's objectives. We work closely with the Secretariat on technical and political matters and support the implementation of the 10-year strategy.

The inspirational target of land degradation neutrality (LDN) was born out of the United Nations Conference on Sustainable Development (Rio+20) and guides the formulation of a target under the Sustainable Development Goals (SDGs) and the post-2015 development agenda. The idea behind this is to motivate all countries concerned by the loss of ecosystem services through land degradation to invest in maintenance and improvement of their land resources. UNCCD has started preliminary work on implementing LDN in a pilot project with 15 countries. Their national action plans will be oriented towards the LDN objectives. Germany is actively supporting this process in two countries to assess at an early stage the implications and necessary actions required for the LDN implementation. Furthermore, within our support of the SDG process we want to firmly establish soil protection as a vital part of the future agenda for sustainable development.

In 2014, the German Federal Ministry for Economic Cooperation and Development (BMZ) launched the special initiative 'One World — No Hunger', which aims to address some of the greatest challenges facing humankind. The two key goals are to overcome hunger and malnutrition among today's population and to create and secure the conditions for future generations of a growing world population to feed themselves. The initiative's multisectoral approach addresses six fields of action, expanding its activities in food security, resilience, food security in crises and conflicts, agricultural innovation, structural change in rural areas, sustainable use of natural resources and responsible land use. We have provided additional funds of around €300 billion in 2014 and 2015 and further funds will probably be provided in the next two years.

Under the initiative, various global programmes have been initiated. The Global Programme on Soil Protection and Soil Rehabilitation for Food Security is among these. It supports five partner countries with the broad-scale implementation of field tested approaches for soil conservation

Image: Klaus Ackermann

Access to land rights for women is often difficult. Promoting gender equality is important for food security

and rehabilitation of degraded soils. At the same time, the aim is to improve the policymaking framework with a view to establishing incentives for sustainable soil use. To support capacity-building, active exchange of lessons learned between partner countries will systematically be enriched by state-of-the-art science. The programme includes six measures in Benin, Burkina Faso, Ethiopia, India and Kenya and specifically addresses smallholders who are affected by soil degradation and food insecurity. Experts and decision makers in ministries, private sector associations, local government, service providers and education bodies will be exposed to innovative approaches and technologies.

The legal environment is also important for encouraging investment in land. In Burkina Faso, we contribute to the implementation of a land reform process. In many contexts farmers are willing to invest in preserving soil fertility, but cannot afford to do so unless property rights are settled. As gender equality is one of the most effective innovations against hunger, we particularly support women, who often have no access to land rights.

The programme will be accompanied in the partner countries by research from the Institute of Advanced Sustainability Studies, which will identify entry points for processes through which the known challenges to sustainable land management may be overcome in the respective local contexts. In this regard, processes of social learning, dialogue and collective action will play a central role.

The costs of land degradation are largely ignored by governments and private businesses, and decisions are often taken without taking into account the services provided by healthy soils and sustainable land management. Therefore, together with the European Commission, UNCCD and other international partners, BMZ launched the Economics of Land Degradation (ELD) Initiative in 2011. It cooperates with the scientific community, the private sector and policymakers to analyse the economic costs associated with non-sustainable land use. The results of sound economic arguments can then be used to demonstrate to the public and the private sector, the costs of inaction versus action on sustainable land management. This approach is especially important in the case of actors who are not directly involved with land use and soil issues, such as decision makers from finance departments who are responsible for allocating funds from a limited budget. The initiative aims to ensure these decision makers are aware of the strong economic arguments in favour of investment in measures to combat land degradation. It should be made clear that avoiding land and soil degradation is generally much less expensive than the damage and losses incurred by allowing it to continue. Providing information on the economic impacts of land degradation and desertification thus enables politicians to reach informed decisions.

The initiative is attracting widespread interest and expanding its human capacity development activities. Apart from providing workshops and training courses for interested parties in various countries, along with substantive and strategic support for the Soil Leadership Academy established by UNCCD and the private sector, a sequence


Image: GIZ/ECO

Sustainable land management and the rehabilitation of degraded land are an integral part of German DC projects and programmes around the world

of Massive Open Online Courses (ELD-MOOC) has been carried out.

Raising awareness on soil conservation and food security and promoting action also in Germany is a central element of Germany's commitment to combating soil and land degradation. Within the earmark of the International Year of the Soil in 2015, BMZ has funded a media campaign in Germany entitled 'Soil. Sustains life.'. Different formats of communication such as a web page, thematic newsletters, an exhibition and media outreach are used to raise awareness among the general public on the importance of soil, its functions and interrelations with many facets of our life. Within the Global Soil Week 2015, we also supported the 'One Hectare' installation to illustrate the topics of soil and land on one hectare in a central park in Berlin.

Some practical examples

Most people in sub-Saharan Africa cook and heat with wood. During the decades to come, charcoal will continue to be the key source of energy in the ever-growing cities. As charcoal is almost always produced illegally, the consequences are forest degradation and land degradation.

In northern Madagascar, therefore, German DC has developed an approach which combines the large-scale reforestation of degraded land for sustainable wood energy production with improved property rights, innovations in transformation technologies and economic benefits for the population. Some 9,000 hectares of plantation already supply a quarter of the charcoal used by the regional city

Soil protection in concrete terms: promoting soil fertility in Ethiopia

In the country's upland areas, the Government is promoting a national programme geared to sustainable land management. Success is being achieved here in combating erosion and making more effective use of rainwater for agriculture. The Global Programme on Soil Protection and Soil Rehabilitation for Food Security will complement this approach. Utilizing integrated fertility management measures, soil fertility will be increased in land areas which have been protected but remain low in nutrients. A key factor in this is the improved biomass management, use of organic fertilizers and crop husbandry measures, complemented by the targeted use of mineral fertilizers.

Soil protection in concrete terms: sustainable land management in Benin

Two-thirds of arable land in Benin is now affected by soil degradation. This poses a threat in terms of food and livelihood to the population of predominantly small crop and livestock farmers. To combat this, the Beninese Government promotes tried-and-tested practices of sustainable land management at local, regional and national level. The Global Programme on Soil Protection and Soil Rehabilitation for Food Security supports the use of site-adapted and mainly organic fertilizers on smallholdings as well as the safeguarding of access to land. Curricula are being prepared for farmer field school services with a view to training personnel. At national level, the programme supports integration of the soil conservation issue into national strategies and exchange with international knowledge networks.


Image: Michael Martin

Cooperation projects help to enable food security, rural development, watershed management, preservation of ecosystem services, and climate change mitigation and adaptation

of Antsiranana. This project is an impressive example of how combating desertification also contributes to climate protection, biodiversity preservation — among other things, by reducing the pressure on natural forests — and rural development. To ensure that the impact of such innovative approaches is as widespread as possible, German DC is also carrying them over to other countries.

Desertification, climate variability and population growth are drivers of poverty and resource degradation in Niger. Competition for shrinking areas of fertile land is leading to conflict and forcing local people to migrate. Through its 'Promotion of productive agriculture' programme, German DC is providing support in reclaiming degraded land for agriculture, forestry and pasture farming. This involves retaining and harnessing the fertility of floodplains threatened by soil erosion through the construction of water-spreading weirs. During the rainy season these constructions, similar to dams, act to slow and spread the flow of rainwater through the valleys and allow it to be used to irrigate a larger area of agricultural land. Having greater control over the floodwaters also helps to prevent soil erosion and replenish groundwater reserves. Reclaiming degraded arable land and improving irrigation enables higher crop yields to be achieved and thus improves food security and the general economic situation of the local population.

In the Piura region of northern Peru the local population, associations and the regional government decided to collectively tackle the problem of desertification which was severely affecting the area. In the context of an Economics of Land Degradation initiative study, the partners received advice on integrating strategies of sustainable land management and desertification control in development and public budget plans. The results of the study showed that the economic cost of soil loss amounts to approximately 14 per cent of agricultural gross domestic product, with a total loss of around US$100 million. This strong argument convinced all stakeholders to jointly develop innovative approaches for the sustainable use and reforestation of dry forests. This was the significant motivation behind the Peruvian Government's decision to introduce a mechanism for payments for ecosystem services into national legislation in 2014.

Combating desertification and land degradation in the forestry sector

Mexico's National Forestry Commission

Mexico has a unique biodiversity; this is why the Government of Mexico is promoting the protection and conservation of its natural resources, which are the basis for a healthy economy and a decent life for a large number of people.

Mexico has 138 million hectares of forest vegetation, equivalent to 70 per cent of the national territory. More than 64 million hectares are covered by forests, rainforests and other ecosystems dominated by arboreal life forms.

In addition to its important role for biodiversity conservation, forest vegetation is extremely important in the provision of ecosystem services. It is related to the regulation of the hydrological cycle, biodiversity conservation, soil formation and protection, and climate change mitigation and adaptation.

The social relevance of forest ecosystems in Mexico is significant. It is estimated that over 11 million people live in forest areas, which heavily rely on these ecosystems to meet their daily subsistence needs.

Degradation processes of forest ecosystems have major consequences. These include reducing ecosystem services such as those related to regulation of the hydrological cycle (for example the quantity and quality of water provision; flood and landslide control) as well as loss of fertile agricultural land and increased desertification by the presence of erosion, increasing greenhouse gas (GHG) emissions through the loss of forest biomass and the decreased capacity of forest ecosystems to adapt to the effects of climate change, besides the loss of biodiversity.

Among the most visible causes of degradation of forest ecosystems in Mexico are overgrazing, illegal logging, land use change of forest lands, wildfires, presence of forest pests and diseases and unsustainable exploitation of forest resources, whether for domestic or commercial purposes.

As part of Mexico's strategy to combat desertification and land degradation, since 2001, when the National Forestry Commission (CONAFOR) was created, national forest policy and programmes have aimed to promote good land management practices through sustainable forest management, restoration of degraded ecosystems and the conservation and protection of forest from disturbance factors such as forest fires, pests and diseases. In order to revitalize the economy of the forest sector and improve the quality of life of inhabitants of forest areas, CONAFOR provides direct technical and financial support to forest landowners to carry out actions for sustainable use, conservation and restoration of forest ecosystems.

Results to date are encouraging; in Mexico's report for the Food and Agriculture Organization's Global Forest Resources Assessment 2010, a reduction of 34 per cent in the annual net deforestation rate was registered, decreasing from 235,000 hectares per year in the period 2000-2005 to 155,000 hectares per year in 2005-2010.

The observed reduction in the rate of forest loss has also been reflected in a lower contribution to national GHG emissions. According to Mexico's National Communications to the United Nations Framework Convention on Climate Change, GHG emissions from the land use, land use change and forestry sector have substantially declined, reducing its contribution to Mexico's total GHG emissions from 14 per cent in 1990-2002 to only 6.3 per cent in 2010.

CONAFOR is conducting actions to restore 1 million hectares in the period 2014-2018, under a scheme focused on priority microwatersheds. Through the Priority-Watershed Restoration Programme, CONAFOR provides direct support to landowners to convert agriculture and grazing lands to

Image: National Forestry Commission archive

CONAFOR provides direct support to landowners to carry out activities such as soil conservation, and restoration

Image: Fabricas de Agua del Centro de Sinaloa (FACES)

The PES programme helps to finance soil restoration measures

Living Land

Cutzamala and La Marquesa priority watersheds

Image: National Forestry Commission archive

Landowners in the Cutzamala and La Marquesa watersheds participate in forest restoration activities

The Cutzamala system stores, conveys, treats and distributes fresh water, benefiting 5 million of the nearly 20 million people in Mexico City. It has been working for 20 years and is the most important external source of water supply to Mexico Valley. Water comes from seven reservoirs located in rivers in the states of Mexico and Michoacan and is channelled through pipelines, and treatment and pumping plants.

Current problems in the watershed largely originated with a decline of vegetation cover. In the last 40 years, 13 per cent of forest cover has been lost, mainly by land use change for agricultural purposes. This has caused increased erosion, decreased infiltration and groundwater recharge, gradual loss of soil fertility and increased sedimentation in reservoirs that reduces their lifespan.

A restoration programme for Cutzamala and La Marquesa watersheds was launched in 2009 as a pilot programme aimed at changing the traditional restoration model for forest ecosystems. It was the first to integrate soil conservation and restoration practices and reforestation activities under a granting scheme of economic incentives and technical assistance to participating landowners. Implementation mainly focuses on priority areas to improve the provision of hydrological environmental services.

Forest restoration actions are intended to increase the catchment and infiltration of rainwater, reduce soil erosion and decrease risks of floods and landslides, in order to reduce maintenance costs and extend the lifespan of the hydraulic infrastructure. The programme also focuses on promoting employment and income generation in local communities, contributing to diversification of productive activities through collaboration with other government institutions working in the rural sector in order to create synergies between programmes.

From 2009 to 2015 soil restoration and reforestation activities in degraded land were carried out in 105,556 hectares with an investment of almost US$160 million.

Community involvement in Santiago de Anaya

Image: National Forestry Commission archive

The local community in Santiago de Anaya were involved in planning and carrying out conservation and improvement measures

Santiago de Anaya is located 140 kilometres north of Mexico City in the Mezquital Valley, which is characterized by its semi-desert climate.

This was once an important mining region, but today the population is engaged in rain-fed agriculture and extensive livestock farming. High levels of desertification have been caused by overexploitation of its timber resources to supply the mining industry and by overgrazing.

The community has 'Otomí' origins, a native indigenous group organized through 'mayordomías' (stewardships) and 'faenas' (tasks) to perform welfare duties, including those related to protection and conservation.

Reforestation and soil conservation activities in the region started in the 1980s. In 1998 a community development programme was launched to strengthen organization, training, technical assistance and inter-agency support, in order to create a transferrable model for the protection, conservation and improvement of the natural environment.

Through a model of participatory planning, areas were defined for reforestation; plant species, planting methods, soil and water conservation activities were determined; and projects to diversify productive activities were identified. Soil was prepared in contour lines using machinery, and individual terraces, trenches, dikes, stone dams, gabion retaining walls or other land structures for water storage were constructed, allowing an increase in the survival of planted trees to 80 per cent.

Thanks to various institutional programmes over the past three decades, a semi-compact area above 1,800 hectares was restored with the plantation of introduced and native forest species. Currently, pine trees reach up to 8 metres high. The soil has been stabilized from erosion and at least three water springs are maintained in the restored areas.

The conservation of wild flora and fauna, increased infiltration of water, soil conservation, use of non-timber forest products, lower consumption of wood through the use of efficient stoves, improved landscape and wildlife management areas are some of the benefits obtained by the community.

The achievements and organizational model for community involvement provide an example for replication on a larger scale, and the community was awarded the National Forestry Merit Prize in 2005.

forest lands, as well as for carrying out activities for soil conservation and restoration, reforestation and fertilization, and protection and maintenance of reforested areas within a three-year implementation period.

An innovative element of this programme is the payment granted to landowners as compensation for the land opportunity cost. This ensures landowners will have no reduction in income while reforested areas are established, and encourages actions for protection and maintenance in order to ensure a greater survival of planted trees.

An important aspect of forest resources in Mexico is the collective nature of land tenure. Ejidos and communities (both forms of collective ownership) own 62.6 million hectares of forests, rainforest and arid forest vegetation, equivalent to 45 per cent of the total forest area of the country. Management of common-use forest resources in Mexico has been analysed in various studies, which concluded that in many cases these have been managed in a sustainable way providing various social, economic and environmental benefits to the population, especially for the most vulnerable (indigenous people, women and the poor).

CONAFOR strengthens forest governance and promotes mechanisms for social engagement to support planning, consultation and dialogue, ensuring representation of the

Image: National Forestry Commission archive

CONAFOR strengthens forest governance and promotes mechanisms for social engagement to support planning, consultation and dialogue

owners of forest lands, including rural communities and indigenous peoples, in order to improve the effectiveness of forest programmes in general.

Since 2003, CONAFOR has successfully implemented a national Payment for Environmental Services (PES) programme to compensate the owners of forest lands for the actions taken for conservation, restoration and protection of their forests that allow maintenance or improvements to the provision of ecosystem services related to regulation of the hydrological cycle, biodiversity conservation and climate change mitigation. PES is financially supported by resources collected through fees for water use (provided by the National Water Commission), fiscal resources annually allocated by the Congress and voluntary contributions by direct beneficiaries of environmental services.

Since its beginning, PES has shifted from a passive conservation scheme to one in which integrated land management is promoted for its conservation in a compatible manner with productive activities.

From 2003-2015, CONAFOR has invested over US$660 million to enrol over 5 million hectares in this innovative protection scheme in order to maintain forests' soil and water protective functions and biodiversity conservation, benefiting more than 7,652 ejidos, communities and small landowners across the country.

In order to increase the flow of financial funds and thus extend the area under PES, CONAFOR promotes the matching-funds mechanism to involve the direct users of environmental services in local schemes for compensation of forest landowners where the services are produced. Currently, over 118 matching-funds agreements are signed by CONAFOR and direct users of environmental services, committing joint contributions of almost US$67 million.

Protecting water infrastructure through local mechanisms of payment for environmental services

Sanalona reservoir, located in the Tamazula river 24 kilometres from the city of Culiacan, began operation in 1948 to irrigate 95,000 hectares in the Culiacan Valley. In 1963, a hydroelectric plant was established with a capacity to generate 14 megawatts of power. The reservoir supplies drinking water to 675,000 people in the Culiacan Valley and is a place of recreation and relaxation.

Concerned by the siltation of the dam due to erosion in the recharge zone of the reservoir basin, in 2009 a group of citizens, farmers, entrepreneurs, industrialists and water users formed an organization called Fabricas del Agua Centro Sinaloa (FACES), to promote actions for the hydrological restoration of watersheds in central Sinaloa.

FACES signed a five-year collaboration agreement with CONAFOR for the provision of matching funds to develop a local mechanism of payment for environmental services, which would allow it to finance forest restoration actions in the catchment basin of the Sanalona reservoir.

Between 2009 and 2014, financial contributions to the project were over US$940,000, of which over US$510,000 came from farmer contributions, US$330,000 from CONAFOR and US$100,000 from the Monsanto Foundation. The project generated 2,500 wages per year; 740,000 trees were planted; 500,000 cubic metres of filter dams (stone and gabions) were built; and a nursery with a capacity production of 200,000 plants was installed.

This project has directly benefited 120 people of the Imala ejido and 200 temporal workers involved in fieldwork activities. It indirectly benefited 314 ejido inhabitants. Social benefits include construction of a multipurpose hall and a doctor's room in the health centre and the installation of roofing, libraries and air conditioning in basic education centres. Environmental education activities were conducted, aimed primarily at children to promote improved solid waste management in order to prevent it from reaching the reservoir.

FACES obtained the National Forestry Merit Award in 2014, awarded by the Government of Mexico through the National Forestry Commission in the category of Civil Society Organizations.

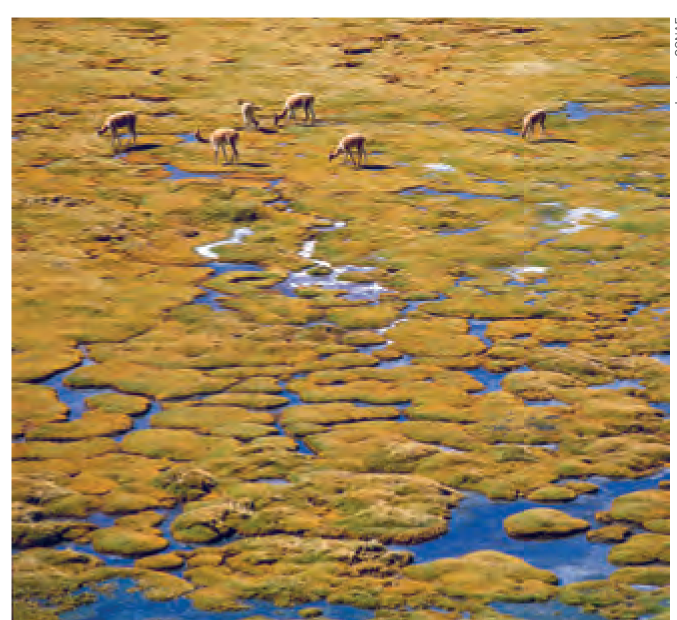
Synergies in the fight against desertification for mitigation and adaptation to climate change

Angelo Sartori, Chief & Wilfredo Alfaro, Forestry Engineer, M.Sc., Climate Change and Environmental Services Unit, Forest Development and Support Management Office, National Forestry Commission, Chile

Chile is severely affected by the impacts of climate change on desertification, land degradation and drought. Rainfall has decreased by 20-50 per cent in the Central Zone during the last century[1] and a reduction in precipitation in this zone is very likely during the present century.[2] Chile has an area of 75 million hectares, with 47.3 million hectares affected by desertification, land degradation and drought[3] from which 36.9 million hectares are affected by land degradation.[4] Moreover, Chile has 341 counties in total, with 290 counties affected by desertification, land degradation and drought, 26 per cent of them to a severe degree and 37 per cent to a moderate degree.

Since 2007, the longest drought period on record has affected the whole country with a water crisis that is without precedent. The Ministry of Agriculture has declared 268 counties to be in a state of 'agriculture emergency due to drought'; 32 counties have been declared as 'water shortage areas' by the Ministry of Public Works, and 20 counties have been declared as affected by 'catastrophe of constant drought' by the Ministry of the Interior. Most of the Central Zone has been declared as an area under prohibition, restriction or depleted to new water rights.[5] Land use change in the country is close to land degradation neutrality (LDN); nevertheless, the area of land with no vegetation cover has expanded from 24.7 million hectares to 48,587 hectares during the period 2000-2010.[6] The extent of forest cover is 16.7 million hectares; nonetheless, there is a significant area under forest degradation, mainly from forest fires and firewood production.

The National Action Programme to Combat Desertification (PANCCD-Chile) was implemented in 1997. As a result, since the year 2000 a total area of 4.2 million hectares has come under sustainable land management plans and a public investment of US$1,578 million has benefitted an average of 50,000 people per year by supporting Ministry of Agriculture incentives for afforestation, soil reclamation and irrigation.[7] To foster implementation, priority on synergies led to the integration of PANCCD-Chile into the National Strategy on Climate Change and Vegetation Resources (ENCCRV). This national strategy is led by the National Forestry Commission (CONAF) of the Ministry of Agriculture of Chile, as the national focal point for both the United Nations Convention to Combat Desertification (UNCCD) and the mechanism for Reduction of Emissions



Images: CONAF

Andean camelids face displacement from some wetlands like these in the arid ecoregion of the Andean High Plateau, due to activities such as intensive agriculture and mining

Image: CONAF

The 'Tambillo' Prosopis forest is an example of the high biological diversity in the Atacama Desert (arid ecoregion) providing local people with animal fodder and charcoal

Image: CONAF

Rain may be absent for centuries in the Atacama Desert (semi-arid ecoregion), but when it occurs plants such as this *Bomarea ovallei (Phil.)* create the 'Flowered Desert' phenomenon

from Deforestation and Forest Degradation (REDD+) of the United Nations Framework Convention on Climate Change (UNFCCC). The purpose of this national strategy is to design and apply public incentives that may provide landowners of xerophytic vegetation and forests with access to benefits from the ecosystem services they provide.

Strategic activities of the ENCCRV emerge as priorities from local and indigenous communities, and they are implemented as pilot projects and as part of the commitments to the UNFCCC and UNCCD. Strategic activities are also integrated into a proposal for Intended Nationally Determined Contributions to the UNFCCC, as well as the process for aligning PANCCD-Chile to the 10-year strategic plan of the UNCCD funded by the Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP), and to the Global Land Degradation Neutrality Project where Chile participates in a voluntary modality. Pilot projects have been funded by international cooperation such as the United Nations Development Programme (UNDP), the European Union, GEF, the World Bank, UN-REDD, the Government of Switzerland, the Chilean Government, the Forest Carbon Partnership Facility (FCPF) and private companies, with a total investment of US$13 million. A system for the distribution of benefits and safeguard systems has been fully developed with funding from FCPF. Strategic activities are implemented in six major ecoregions in Chile: arid, semi-arid, Mediterranean, temperate, austral and island oceanic territories.

In the arid ecoregion, the United Nations' Millennium Ecosystem Assessment initiative in 'Salar de Atacama' developed a unique sub-global assessment for desertification located at the heart of the Atacama Desert, the oldest and driest desert in the world. The Atacama Desert in Chile includes part of the American Puna High Plateau, the living scenario for the Andean cultures Aymara, Quechua and Likan-Antai or 'Atacameños' that built up the landscape to set in production this extremely fragile land through an outstanding irrigation system and extensive terrace system known as 'andenes', which gave its name to the Andean high mountains. In 2003-2005, this initiative assessed the provision of ecosystem services from drylands for human well-being through a participative process in a Linkan-Antai (Atacameños) ethnic community. The process related to water resources, tourism, minerals, biodiversity, Likan-Antai cultural heritage and desert air as a window for astronomy. As a result, CONAF developed a typology of projects and a joint administration agreement with the Likan-Antai people for co-management of the national parks within the Likan-Antai territory.

In the semi-arid ecoregion, the 'Peñablanca' Fog Catchment Project is the flagship project on innovative systems for fog harvesting. The agriculture community has a special legal regime of common property unique to this region. Peñablanca is one of these communities that until the early twentieth century provided wheat and livestock for the whole region and exported its products to the northern part of the country during the golden age of nitrate production. Intensive use fully exhausted the land, and since 1993 wheat has not been sowed in this community because it had become impossible to obtain a good yield. In 2004, the community received funding from GEF, UNDP and European Union through the Small Grant Programme to Combat Desertification to install a set of fog collectors to provide water for afforestation and tourism activities. The commitment of the community during the mega-drought, which began in 2002 in this region, made it possible to use water collected in many innovative ways, including production of a local beer named 'Atrapaniebla' ('Fog Collector'). Other demonstrative initiatives in the region include the 'El Sauce' Soil and Water Conservation Project implemented by CONAF and the Coquimbo Regional

Image: CONAF

The O'Higgins Glacier in the Bernardo O´Higgins National Park (austral ecoregion) has retreated 16 km during the last century, affecting ecosystems that depend on it

Government. The project was located in the centre of the water crisis in a town that fully depends on groundwater for water supply. CONAF established different soil and water conservation and rainwater harvesting works in a nearby catchment to improve the water regime and the level of groundwater in surrounding wells. These works included infiltration trenches, check-dams and afforestation with appropriate species, among other interventions. In this scenario, CONAF also implemented the Sustainable Land Management in Chile initiative to determine best practices based on territorial planning, in particular tree species appropriate for afforestation. The typology of projects developed for this ecoregion aims to improve carbon stocks and to restore degraded land, as a strategy to foster the role of forests in rainfall processes such as the provision of nuclei for cloud formation, air humidity and change in albedo and local energy balance.

In the Mediterranean ecoregion, the Small Grant Programme to Combat Desertification provided funding to the 'La Aguada' water harvesting project, located 100 km south-west of Santiago city. In this area water also became very scarce to people and 'Navidad' county administration had to provide water by tank trucks. This community received funds to install rainwater harvesting systems, roof water collectors and cisterns to benefit from scarce rainfall for drinking water, the production of vegetables under greenhouses, fodder for cattle and trees for firewood. To address another relevant issue, the 'Peñuelas' Preventive Forestry for Forest Fires Project funded by the international cooperation agency of the Government of Switzerland addressed the burden of forest fires occurring in the city-forest interface in 2014, which devastated 76 hectares of urban area near Valparaiso city, the greatest forest fire in an urban area ever recorded in Chile. CONAF deployed demonstrative activities to explore forestry treatments for carbon sequestration, management of distribution of combustible material and control of fire dispersion, such as firewalls, density management and mixed forests of species containing extractable organic compounds with a lower fusion point.

The temperate ecoregion concentrated on application of the supporting mechanisms of the Ministry of Agriculture contained in PANCCD-Chile. Since 1931 Chile has enacted several laws to establish incentives for afforestation as a mechanism to restore degraded land. Examples of this are: Decree No. 4363/1931 known as 'The Forest Law'; Decree Law No. 701/1974 on forest support; Law No. 20.283/2008 on

Image: CONAF

Protected areas, like the Torres del Paine National Park in the austral ecoregion, help to address land degradation

Image: CONAF

Rapa Nui, in the island oceanic territories ecoregion, is both a wonder of the world and an example of the threat from land degradation

native forest restoration, and especially Law No. 19.561/1998 on forest support for the restoration of degraded land and land under desertification processes, which was included as a goal in PANCCD-Chile. These legislations have provided 'net zero deforestation' in Chile. In other important matters, forest fires are also a first class driver for degradation in this ecoregion. During 2015, forest fires in the Araucanía region, 900 km south of Santiago city, affected two national parks of the National System of Protected Areas of the State administrated by CONAF, causing public commotion. The area affected contained significant stands of *Araucaria araucana*, a symbolic tree for Chilean, Mapuche and Pehuenche ethnic people. CONAF carried out a participative process with representatives of the community, especially Mapuche and Pehuenche people, to elaborate a restoration plan for the China Muerta National Reserve. The strategic activities included afforestation with seedlings from local genetic material, soil and water conservation works and management of remaining vegetation. Another project in the entire temperate ecoregion is the Forest Water Catchment Restoration Project. Within this ecoregion Valdivia city was one of the rainiest places in Chile, but since the 1960s rainfall has decreased by 30 per cent in this region. During the severe drought which began in 2007, sources of drinking water were severely affected so counties in the region had to deliver water to people in tank trucks, something fully unexpected for this region. This project was funded by the targeted support of UN-REDD and UNDP, and its strategic activities aimed to increase carbon sequestration and improve the water regime in catchments for drinking water supply.

In the austral ecoregion, CONAF developed a Sustainable Firewood Production Pilot Project funded by FCPF. Almost 20 per cent of national energy consumption is provided by the country's forests, accounting for almost 15 million tons per year. Firewood production is a huge driver for degradation in Chile. Firewood has been a subsistence productive activity performed by small producers, normally in an informal scheme of production and trade. Forests subject to firewood production barely have an authorized management plan, so the project provided access for small landowners to technical assistance assuring forest sustainability, as well as gathering points and drying systems for firewood and support on trade chains. In addition CONAF, through the Sustainable Land Management in Chile project, developed a pilot project on an Early Warning System for Illegal Logging to demonstrate strategic activities aimed at the conservation of existing stocks of carbon and improving the sustainability of forests subject to inappropriate management practices, especially illegal logging.

In the island oceanic territories ecoregion, Rapa Nui (Easter Island) located in Polynesia 4,000 km west of the continent, has a unique world culture heritage. The 'Moais', sculptures of paramount dimensions, have captured the imagination of people through the ages and their meaning remains hidden. Rapa Nui has also been a global example of what land degradation can provide for mankind, setting the stage for extinction. It is supposed that the population reached 12,000 people at its maximum. They depleted natural resources to provide food for such an enormous population in such a tiny space. The Easter Island Palm disappeared along with many other symbolic forest species like 'Toromiro' (Sophora toromiro), the tree that provided wood for another mystery yet not solved, the 'speaking tables' containing the written language of Rapa Nui. CONAF developed a project typology for Rapa Nui to determine best management practices appropriate for afforestation on the island, to improve carbon stocks and to restore degraded land, as a strategy to foster the role of forests for the provision of ecosystem services for human well-being.

The continuing fight for the rights of Pachamama — Mother Earth — in Bolivia

Ole Thonke, Ambassador and Camilla Lodberg Holck Madsen, Royal Danish Embassy in La Paz, Bolivia

In 2012 the Bolivian Government passed a new law that gave special rights to Mother Earth. The law is considered the first of its kind, and gives all nature equal rights to humans. With the law, the Bolivian Government and society hoped to embrace the traditional indigenous respect for Mother Earth, also known in Bolivia as Pachamama, and the law was considered vital to prevent ongoing climate changes, which have already caused drastic consequences in the country. One of the most severe is the melting of glaciers in the high Andes, which have caused both draughts and floods in Bolivia in recent years.

The passing of the law marks a new direction in Bolivian politics towards the environment, which began when Evo Morales won the election in 2005 and entered the presidency. As the first Bolivian president from the indigenous population, Morales' politics have focused especially on improving the rights and living conditions of the indigenous groups in Bolivia with politics that respect their lifestyle, culture and traditions, among them respect for nature. However, Morales and the Bolivian Government face a major dilemma between the desire to expand extractive industries in order to fund social programmes and provide employment, and the desire to protect the country's environment and nature from pollution caused by these industries. Therefore, it is a challenge for visions and practice to go hand in hand in Bolivia.

For the people living in Bolivia's forests, the choice between clearing the forest to make way for their agriculture or making use of the resources of the existing forest has not been difficult to make. The former option has traditionally been by far the most profitable one — and the fastest way to earn a living. Therefore, deforestation in Bolivia has been increasing since the 1990s and is one of the country's biggest threats to the environment, to the climate and to the local people, who experience the direct consequences of the deforestation.

Image: Carlos Pinto/FAN

One of the sad consequences of deforestation in Amazonas — the increasing spreading of forest fires

Image: Edmond Sanchez/FAN

Clear evidence of deforestation in Bolivia

Image: Kathrine Dalsgaard

Local communities are the prime beneficiaries of the different development programmes in Bolivia

Bolivia is the fifteenth richest country in the world in forest cover, and the eighth richest in biodiversity. In 2010, the estimates for surface covered by different types of forest in Bolivia reached 46 million hectares. However, recent studies by the Bolivian non-governmental organization (NGO) Fundación Amigos de la Naturaleza (the Union of Friends of the Nature), show that between 2000 and 2010 1.8 million hectares of wood was cleared in Bolivia. Even though deforestation has decreased since the 1990s, when 250-300 million hectares were lost each year especially due to the expansion of agriculture, the yearly rate between 2000 and 2010 was still as high as 200 million hectares per year.

Bolivia has a wide system of protected areas, which covers around 15 per cent of the country. The national parks and areas cover the full range of the different terrains and ecosystems to be found in Bolivia, but unfortunately most of the country's valuable resources are hidden in their grounds. Therefore, the protected areas are also exposed to deforestation.

The Bolivian Government has taken different approaches to reducing deforestation and helping the local people to obtain a sustainable way of living in harmony with the country's forests. The Royal Embassy of Denmark in Bolivia has assisted in the Government's focus on reforestation through the Danish development cooperation, Danida.

A new way to support local capacity building are the programmes financed by Danida to strengthen the civil society in order to promote sustainable forest management. The Civil Society Fund for sustainable forest management (FOSC, its acronym in Spanish for the Fund Manager in Bolivia), finances three Civil Society Organizations in three prioritized regions of Bolivia: Northern La Paz, Pando/Riberalta and Chiquitanía. It aims at strengthen the civil society to adapt to and mitigate climate change in the 3 regions and to improve their livelihoods and incomes. The purpose is to develop local capacities for sustainable forest management to reduce deforestation. The three programmes began in May 2015 and will last 30 months until October 2017.

The programme in Northern La Paz takes place in the middle of the national park Madidi, where the Wildlife Conservation Society (WCS) has been working since the late 1990s. The park is over 15,000 square miles, and covers the tropical Andes in Bolivia. The landscape and ecosystems in the park vary from moist tropical rainforest to grasslands and montane forests. The biodiversity also shows the vast diversity of the park: here reside 1,100 bird species and 300 mammal species, among them jaguars and Andean bears. WCS finds that the biggest challenges in the park in regard to deforestation are the building of roads, hydroelectric projects, illegal logging, mining and agriculture.

The sustainable production of different agroforest fruits in Amazonas keeps deforestation at bay

The important citrus fruits of the San Juan community

The programme is carried out by WCS in cooperation with different regional institutions and corporations and is especially focused on different indigenous territories, which are particularly threatened by the different consequences of climate change and deforestation. The logging already done in this area has giving rise to the threat of severe forest fires and flooding of the indigenous lands, which is why the project seeks to help the local community in the continued fight against deforestation. To do this, the different organizations seek to help the locals in getting knowledge about the possibilities to exploit the forests' own resources in a sustainable way, for instance by producing agroforest fruits such as coffee and cacao, by using better farming practices in already cleared areas, and by improving the practice of collecting wild-growing products such as incense and palm trees for building rooftops. The forests in Madidi offer good possibilities for different productions in a sustainable way, but it is necessary for the local communities to get a code of practice to make sure they do not overexploit nature. Therefore, the programme seeks to make sure local societies get a sustainable platform for production — and all the work is carried out in close cooperation with local people to make sure their knowledge of the forests does not get lost in the process. An important part of the production of agroforest fruit is the commercial potential of the products, which is why an essential part of the programme is for the NGOs to help the local communities find interested buyers and markets for their goods.

Since the programme is still in its early stages, the final results of the efforts are not yet known. However, the expected results are that 540 families, which include approximately 3,000 people, will benefit directly from the programme. The families' incomes are expected to increase by at least 30 per cent due to the better, more efficient production techniques they will gain knowledge of. In addition, 12,000 inhabitants in the indigenous lands are expected to benefit indirectly. Thanks to the sustainable agroforestry implemented by the project, a total loss of 10,000 hectares of forest in Madidi is expected to be avoided by 2017. The programme derives from earlier experiences of similar programmes, but with a bigger focus on the development of products and the participation of the local community. Therefore, the experiences behind the programme are old, but the programme itself is new, and that is also the reason why the organizations behind the programme are certain that the expected results will be achieved.

Another project in Bolivia to reduce the deforestation is in the Amazon jungle, which is particularly exposed to logging as a result of the expansion of agriculture and cattle farming. Here, the forest is cleared constantly to make way for crops like rice and yucca. However, the soil of the Amazon is not

Bolivia's rich biodiversity is threatened by deforestation and climate change — luckily, the Bolivian Government has taken measures to stop both

made for agriculture and this creates a continuous need to expand the area, therefore also increasing deforestation. Luckily various projects are addressing the issues and promoting sustainable solutions. One of these projects is fruit production in San Juan, supported by Danida, where already cleared land and degraded soil is used for growing citrus fruits, pineapples and beans. This project has various advantages. Firstly, already cleared land, unfit for further production of e.g. yucca, is used for production purposes instead of being left unfertile. Secondly, the combination of growing beans, pineapples and citrus fruits provides a continuous income to the local community both on a short-term and a long-term basis. The citrus fruits need 5-10 years to produce a profit, and therefore the local society needs the income of the yearly harvest of pineapples to make a living. Additionally, the leguminous plant like beans helps produce ammonium-ion that brings nutrition to the otherwise unfertile soil. Altogether, the combination of beans, citrus fruits and pineapples make sure that the community does not need to expand its areas of agriculture and thereby does not contribute to further deforestation. And thirdly, if left fallow, the soil will rapidly be covered with grass increasing the risks of uncontrollable fires during the dry season (June to October). The burning of grass easily and frequently leads to uncontrollable forest fires which result in bigger areas of deforestation and the burning down of villages. Furthermore, in order to reduce the risks of forest and field fires, the local communities are working on constructing firebreaks consisting of areas of less flammable vegetation in between the fields and the forest. This work is undertaken in cooperation with local universities putting the research of the students into practice in combination with the year long experience of the local farmers. Hence, alternative production of citrus fruits and pineapples in San Juan is a way to reduce the risks, secure economic stability for the local community and contribute to the reduction in deforestation.

In Bolivia, the fight against deforestation and other threats to the environment goes on. With the juridical acknowledgement of the rights of Mother Earth, the Bolivian Government has taken a big step against the exploitation of nature. However, with about 45 per cent of the country's population still living in poverty according to the World Bank, the dilemma between respecting nature and make use of it in a sustainable way, or making fast and easy income using nature's resources unsustainably, continues both on a national and a private level.

Controlling shifting sands in Kuwait: an approach for sustainable development

Professor Doctor Raafat Misak, Environment and Life Sciences Research Center, Kuwait Institute of Scientific Research; Member of the National Committee for Combating Desertification at the Kuwait Environment Public Authority

Kuwait covers about 17,800 km^2 and consists of two main ecosystems: the terrestrial (about 85 per cent) and the coastal and marine ecosystem (15 per cent). The harsh environmental conditions of Kuwait (including prolonged drought), as well as land degradation, are major impediments for the real development of its terrestrial ecosystem. These two major elements represent serious threat to national economy and quality of life.

The main challenges facing sustainable land management (SLM) in Kuwait are:

- reversing the various processes of land degradation and land misuse through serious and sustainable measures
- managing drought through long-term monitoring, forecasting and preparedness
- managing the hazards of shifting sands
- modification of the national Greenery Plan (1995-2015) to cover desert areas
- setting up sustainable land use plans considering environmentally sensitive areas
- establishment and implementation of the National Action Plan for combating land degradation (Article 10 of UCCD).

The rainfall in Kuwait is scanty and irregular and the rainy season extends between October and April. The average annual rainfall is about 110 mm. During the last 40 years, Kuwait experienced a number of dry seasons with below-average rainfall. These include: 1963/1964 (28.mm total rainfall); 1972/1973 (39.7 mm total rainfall), 1988/1989 (31.6 mm total rainfall) and 1993/1994 (28.3 mm total rainfall). In addition to dry seasons, Kuwait experienced drought periods lasting more than three seasons, for example 1962-1967 (28.1-87.7 mm of rainfall) and 1987-1990 (31.6-84 mm of rainfall). During the last eight years (2007-2015), Kuwait has experienced a long period of drought.

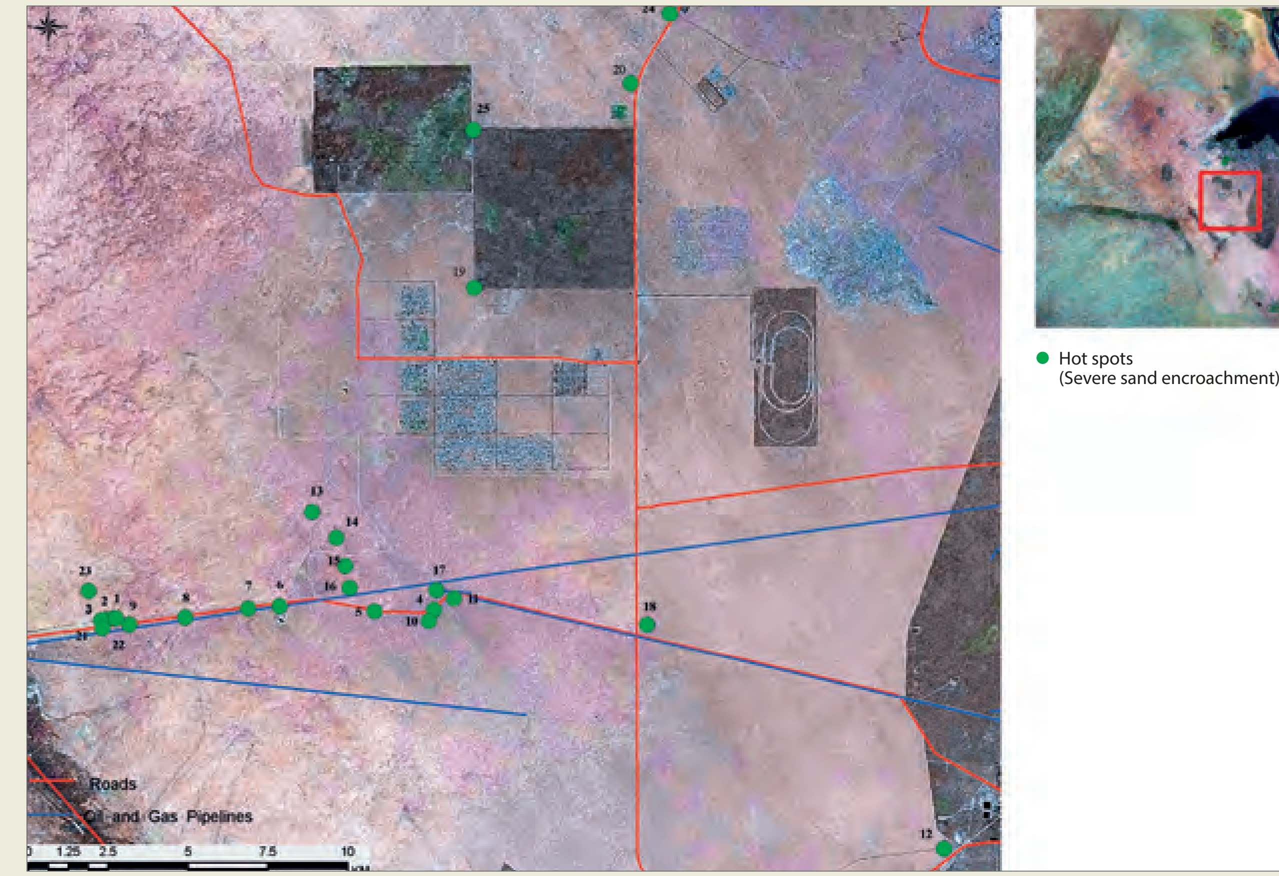
A map showing highways under threat from shifting sands: red arrows indicate prevailing winds, dotted lines indicate proposed mobile sand control systems

Source: National Committee for Combating Desertification in Kuwait (Kuwait National Focal Point, KEPA, 2015)

An image of Kuwait showing the locations of the proposed mobile sand control system

Source: National Committee for Combating Desertification in Kuwait (Kuwait National Focal Point, KEPA, 2015)

A satellite image showing facilities influenced by shifting sands (1-25) in the Kabd area



Source: National Committee for Combating Desertification in Kuwait (Kuwait National Focal Point, KEPA, 2015)

Classes of drought are:

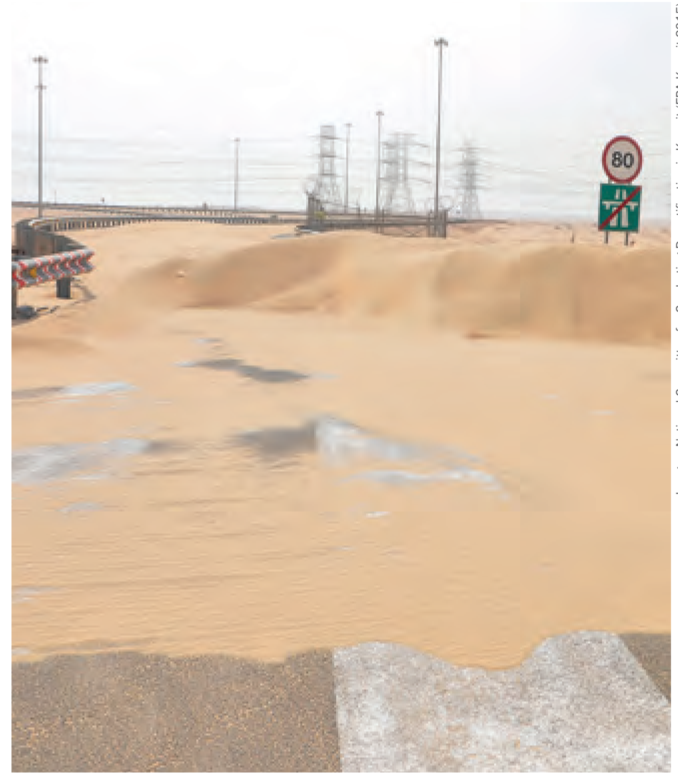
- very severe: total annual rainfall less than 25 mm (seasons 1963/1964 and 1993/1994)
- severe: 25-50 mm total annual rainfall (seasons 1972/1973, 1976/1977 and 2007/2008)
- moderate: 50-75 mm total annual rainfall (seasons 1966/1967, 1991/1992 and, 2008/2009)
- slight: 75-100 mm total annual rainfall (very common seasons 1964/1965, 1996/1997).

In Kuwait, current land use is environmentally classified into three categories. Extremely destructive land use covers 10-12 per cent of Kuwait with damage extending 1-5 m from the ground surface. Destructive ground use affects about 75 per cent of the country with damage restricted to 50-75 cm of the soil. Non-destructive land use, where damage is not observed and natural recovery prevails, affects 12-15 per cent of Kuwait.

Land degradation processes prevail in the majority of the terrestrial environment of Kuwait. Three classes of land degradation are identified: almost non-degraded (12-15 per cent), moderately degraded (75 per cent) and severely degraded (10-12 per cent). Land degradation processes include soil salinization and water logging, loss of topsoil (through both wind and water erosion), soil crusting, sealing and compaction, vegetation degradation and loss of biodiversity. In the open desert areas (close to 51 per cent of Kuwait), where livestock grazing is the major land use type, indicators of soil, vegetation and hydrological degradation as well as loss of biodiversity are prevailing. In the agricultural areas (about 2.7 per cent of Kuwait), depletion of soil productivity, water logging and soil salinization are recorded.

The terrestrial environment of Kuwait, especially its central part (about 60 per cent of the total area), is an open theatre for extremely active aeolian processes. Wind erosion (soil drifting) is very common in the areas of fragile sandy soils which cover more than 50 per cent of the land. Soil drifting is a major cause of land degradation and field measurements indicate that the 2007/2008 dry season (less than 40 mm rainfall) resulted in severe soil losses through wind erosion. In wide stretches, winds removed 10-15 cm of topsoil (around 1,000 m^3 per hectare).

In the Kabd area (about 35 km south-west of Kuwait City), hotspots (sites severely attacked by shifting sands) were recently recorded. These include segments of roads, water wells, industrial facilities, farms and other infrastructures. Drifting sands from deflated substrates encroach on existing facilities.



Two field photos showing severe sand encroachment along Sabiyah Road

Images: National Committee for Combating Desertification in Kuwait (EPA Kuwait,2015)

In the last few years, several types of eco-friendly materials have been successfully used to control shifting sands, such as ecomat and coir mats. Ecomat is environmentally friendly mulching mat, fully biodegradable and made from 100 per cent natural oil palm residues. These residues supply nutrients to both the soil and the plants. The ecomat contains elements such as Potassium, Magnesium and Nitrogen which enhance soil quality and plant growth. Ecomat was tested in Kuwait in the Burgan oil field, Kabd and at sites in Al-Liyah.Coir mats are 100 per cent biodegradable mulching blankets made up of coir products. These mats are fast binders of soil. They provide an excellent medium for quick vegetation, holding seeds and saplings in place. The mats are excellent for air and water permeability. This product was tested at the Burgan oil field.

Three scenarios are proposed to manage the hazards of shifting sands in the terrestrial environment of Kuwait.1

The first scenario is the establishment of two green belts, each with at least 10 rows of *Prosopis juliflora, Ziziphus spina christi* and *Tamarix aphyllae* trees. The first belt (25 km length) is in the Al Huwaimiliyah area and the second (130 km length) is at Ras As Sabiyah-Al Salmi. The selection of sites for the two belts is based on information gained through field surveys and remote sensing imagery interpretation of the area. The aim is to stabilize active sandy bodies between the two belts as well as some active bodies in the south, using environmentally friendly materials such as ecomat, coir and plant residues.

The second scenario involves afforestation, specifically the plantation of *Prosopis juliflora, Zizpiphus spina christi* and *Tamarix aphyllae* trees along the Huwaimiliyah-Al Wafra corridor. The areas proposed for afforestation cover about 615 km^2. Treated sewage water has the potential to be used to irrigate these plantations for at least one year. The scenario also includes the revegetation of native shrubs such as *Haloxylon salicornicum* and *Rhanterium epapposum* which are very effective in trapping shifting sands, and the stabilization of active sandy bodies along segments of the Huwaimiliyah-Al Wafra corridor using greenery residues of Abdaly, Kabd, Wafra and urban areas in Kuwait (recycling of greenery residues).

In the third scenario, green belts will be established in the northern and central parts of Kuwait. In southern parts, there will be revegetation of native plants such as *Rhanterium epapposum*. There will also be immediate stabilization of active sandy bodies and local sources of dust using greenery residues and mulching sheets such as ecomat and other environmentally friendly mulching materials

The cost, efficiency and environmental sustainability of the proposed scenarios should be assessed by a multidisciplinary team of experts. For the final design of the green belt, wind tunnel experiments will be conducted and the most cost effective and environmentally sound scenario will be selected.

Case study: Kuwait's highways

The main threat facing most of the development facilities and public utilities in the Kuwaiti desert is the sand encroachment problem. Military camps, air bases, oil fields, agricultural areas, animal production facilities and desert highways are severely influenced by shifting sand. Managing the sand encroachment problem along highways will secure safe and high-speed transportation as well as sustainable control measures in the country.

Characteristics and cost of the proposed mobile sand control system

Components	Sustainability	Cost per 1,000 m length *	Durability
Integrated mechanical- biological: double impounding fences (about 100 m apart and 2 m high) with three rows of drought-resistant trees in the middle	Very high (integration between mechanical and biological)	KD60,000:40,0000 (2,000 m of chain-link fence)KD20,000 (cost of 600 trees and irrigation for one year)	25-30 years[4]

* Cost includes labour and materials. 1KD = US$3.5

Source: EPA Kuwait

Active aeolian processes including abrasion, transportation and accumulation are prevailing in wide areas of Kuwait's terrestrial ecosystem. These areas constitute 40-50 per cent of the country. Assessment and monitoring programmes for aeolian processes through ground stations and remote sensing are basic requirements for designing action plans for controlling encroaching sands. In addition, deep understanding of the mechanisms of sand transport and their relation to current land use are essential for identifying the magnitude and general trends of sand encroachment problems. Based on that, the best approach and techniques for mitigating sand encroachment problems is selected.

The National Committee for Combating Desertification in Kuwait[2] discussed the feasibility of reducing land degradation from about 72 per cent in 2015 to 0-5 per cent in 2030. For this purpose, a 20-year land degradation neutrality scheme is proposed. It consists of five programmes: land degradation monitoring, mapping and assessment (ground and remote sensing investigations); GIS-based knowledge support system; restoration/rehabilitation (for soil, vegetation, wildlife and water supplies); sustainable land use; and public awareness and human development. Managing the hazards of shifting sands falls under the umbrella of programme number four, sustainable land use.

Proposed mobile sand control for the Wafra area: red arrows indicate the direction of sand transport

Source: National Committee for Combating Desertification in Kuwait (Kuwait National Focal Point, KEPA, 2015)

In Kuwait the network of roads consists of six highways: the Sabiyah, Salmi, Abdaly, Wafra-Mina Abdullah, Wafra-Azour and Kabd highways. The magnitude of sand encroachment along the highways is remarkably variable. It is controlled by both local and regional conditions. In general the most significant controlling factors are:

- road extension in relation to the main natural NW-SE corridors of shifting sands (Huwamiliyah-Wafra and Umm Qaser-Ras As Sabiyah)
- land use types in the upwind side of the roads (such as open desert areas, protected areas, farms, buildings, bundwall and green belts)
- availability of local sources of drift sands (dry wadis, dissected hills, sabkhas, playas, sand sheets and sand dunes)
- local geomorphologic and topographic conditions
- vegetation cover (density and types).

Based on recent field measurements, three degrees of sand encroachment are identified along highways. Very severe encroachment, where close to 50 per cent of the road is vulnerable to sand encroachment, is represented by the Al Salmi and Sabiyah roads. Severe encroachment means that close to 30 per cent of the road is vulnerable, and this category is represented by the Wafra-Mina Abdallah, Wafra-Azour and Kabd roads. Moderate encroachment, where close to 10 per cent of the road is vulnerable to encroachment, is represented by the Abdaly Road.

An action plan has been proposed to manage the sand encroachment problem along highways in Kuwait. It consists of an integrated system of mobile sand control. This system was successfully tested by the Kuwait Institute for Scientific Research in the Kabd Experimental Station in 2004. It comprises two impounding fences (2 m high, chain-link type with slats) situated 100 m apart. Three rows of drought-resistant trees will be planted in the middle distance between the two fences. The total effectiveness of this system is estimated to be around 28 years.[3]

Combating desertification under climate variability, climate change and reduction of water resources in India

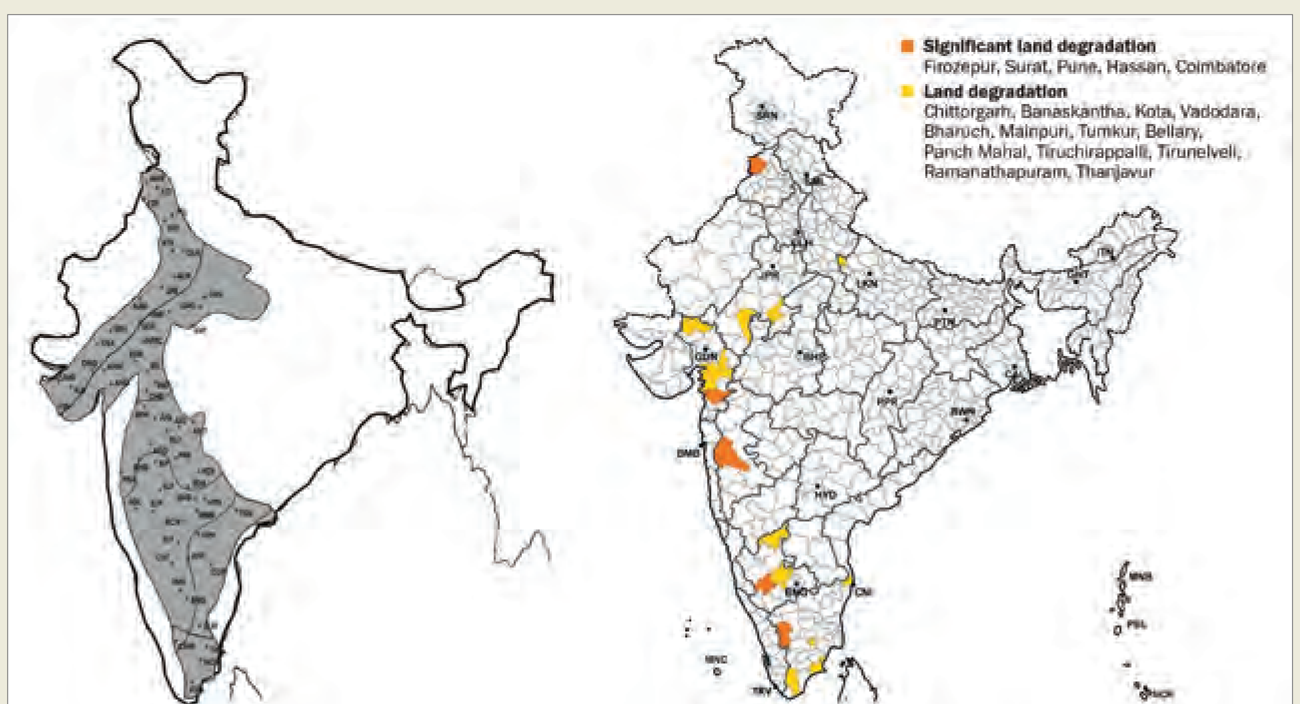
L. S. Rathore, N. Chattopadhyay and S. D. Attri, India Meteorological Department

A big part of the world's area is arid and prone to desertification. Over the past few years, it has become increasingly clear that desertification is one of the most pressing global environmental challenges threatening to reverse the gains in sustainable development in different parts of the world.

Various assessments by United Nations Environmental Programme have continued to show that desertification results from complex interactions among physical, chemical, biological, socioeconomic and political problems that are local, national and global in nature. In India, 25 per cent of the total land area is undergoing desertification while 32 per cent is facing degradation for various reasons such as climate variability, leading to extreme weather like drought, floods and heatwaves, and the trend of different climatic parameters, leading to reduction of water resources. This has affected the productivity of crops and ultimately the livelihood and food security of millions across the country. Thus the dryland areas are more prone to desertification in India. Desertification and loss of biological potential restricts the transformation of drylands into productive ecosystems.

Dryland areas in India comprise annual rainfall between 40-100 cm and practically no irrigation facilities. They cover 87 districts spread over Haryana, Punjab, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu. Agriculture in this region is largely dependent on rainfall. In arid regions of India, more than 90 per cent of annual rainfall occurs during the monsoon season, and any changes in monsoon rainfall will strongly impact agriculture. Climate variability has had an adverse effect on the production of major crops such as pulses, oilseeds, coarse grain crops and cotton along with wheat and rice in dryland tracts. About 228 million hectares (mha) or 69 per cent of the total geographical area (about 328 mha) is under drylands in arid, semi-arid and dry sub-humid areas of the country. Rajasthan accounts for the most desertified land (23 mha), followed by Gujarat, Maharashtra, Jammu and Kashmir (13 mha each) and Orissa and Andhra Pradesh (5 mha each). According to reports, 68 per cent of the country is prone to drought and this will be further heightened because of the impact of climate change, particularly in drylands. Land degradation caused by multiple forces including extreme weather conditions (particularly drought) and human activities are also affecting food production, livelihoods, and the production and provision of other ecosystem goods and services.

India's dry farming tract (left) and regions of land degradation (right)



Source: India Meteorological Department (left), NCC report, India Meteorological Department (right)

Desertification in India is projected to be severely compromised by climate variability and change. Monsoonal and other weather conditions are unstable, causing major droughts, floods, cyclones and other natural disasters. Recently, the years 2002, 2005 and 2009 proved to be drought years, 2010 was the warmest year and 2002/03 was an extremely cold winter. In addition, 2014 and 2015 have brought hailstorms in Maharashtra, north and central India. Hailstorms in 2015 caused crop loss in states such as Maharashtra, Karnataka, Telangana, Madhya Pradesh, Chattisgarh, Uttar Pradesh and Bihar. Thunder squalls over southern states have affected standing crops. In 2014 Cyclone Hudhud affected states including Andhra Pradesh, Orissa, Bihar, Jharkhand, West Bengal, Uttar Pradesh, East Madhya Pradesh and Chhattisgarh, while Cyclone Nilofar affected Gujarat. In spite of a general increase in temperature over recent decades, extreme rainfall events also increased over the west coast of India.

Desertification, along with climate change and loss of biodiversity, were identified as the greatest challenges to sustainable development during the 1992 Rio Earth Summit. In addition to climatic variability, climate change will further challenge the livelihoods of those living in this sensitive ecosystem and may result in higher levels of resource scarcity. Using a number of climate models, different scenarios have been generated for future climate change in India. It has been projected that average surface temperature will increase by 2-4 degrees Celsius during the 2050s, with marginal changes in monsoon rain during the monsoon months (June, July, August and September) and large changes in rainfall during non-monsoon months. The number of rainy days is set to decrease by more than 15 days and the intensity of rains is likely to increase by 1-4 mm/day. An increase in the frequency and intensity of cyclonic storms is projected. The hydrological cycle is predicted to become more intense, with higher annual average rainfall as well as increased drought.[1] An annual mean area-averaged surface warming over the Indian subcontinent is predicted to range between 3.5 and 5.6 degrees Celsius over the region by 2080.[2] These projections show more warming in the winter season over the summer monsoon. The spatial distribution of surface warming suggests a mean annual rise in surface temperatures in north India by 3 degrees Celsius or more by 2050. A marginal increase of 7-10 per cent in annual rainfall is projected over the subcontinent by the year 2080. However, the study suggests a fall in rainfall by 5-25 per cent in winter with a 10-15 per cent increase in summer monsoon rainfall over the country. Because of these projections of future climate change, there will be increased land degradation owing to droughts, and increased soil erosion caused by heavy rainfall events. In addition, climate change may exacerbate desertification through the alteration of spatial and temporal patterns in temperature, rainfall, solar radiation and winds.

Although the effects of climate change from anthropogenic forcing on the use of water resources in the world remain

Climate variability in India, 2000-2014

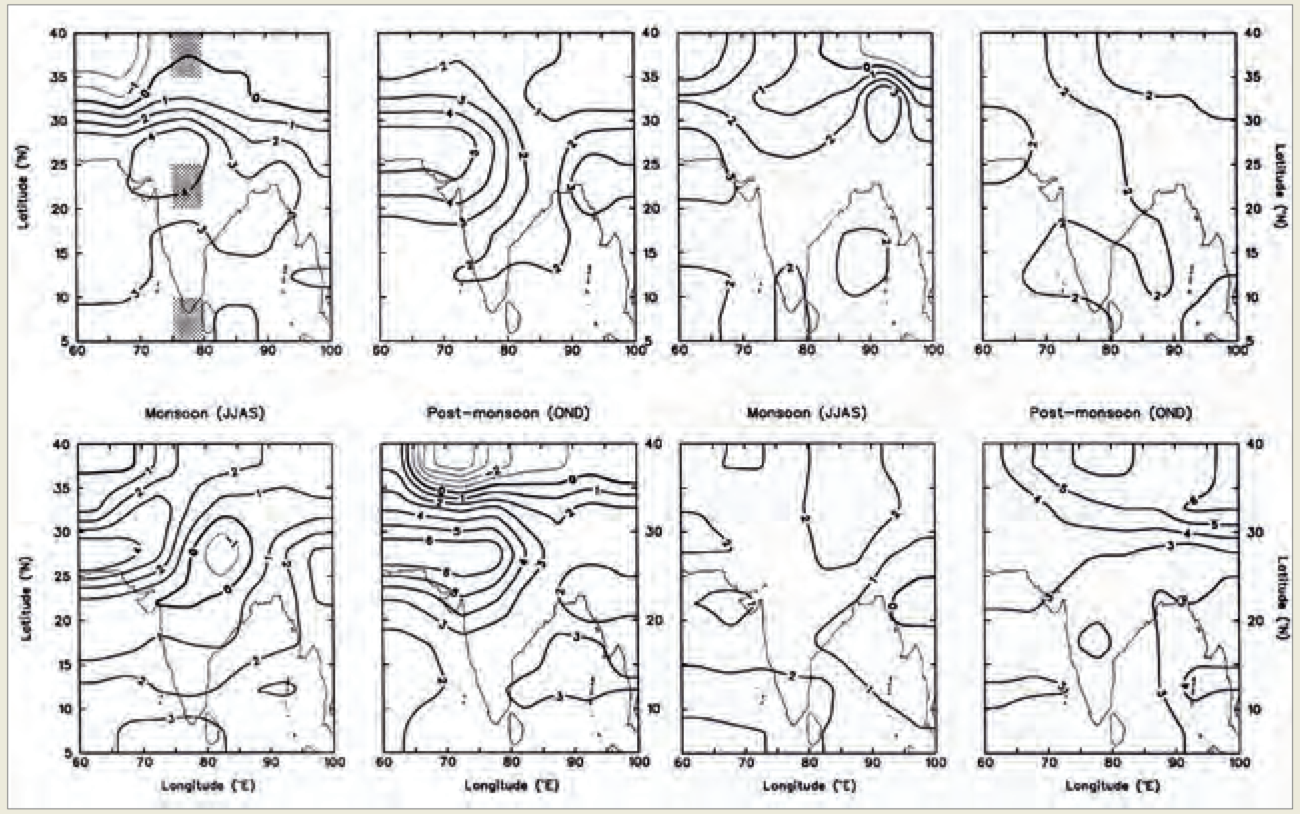
Southwest monsoon rainfall departure			
Year	%	Year	%
2000	-8	2008	-2
2001	-8	2009	-23
2002	-19	2010	+2
2003	+2	2011	+1
2004	-13	2012	-8
2005	-1	2013	+6
2006	-1	2014	-12
2007	+5		

Extreme events in India

- 2002 drought
- 20-day heatwave during May 2003 in Andhra Pradesh
- Extreme cold winter in 2002/03
- Drought-like situation in India in July 2004
- Abnormal temperatures during March 2004 and Jan 2005
- Floods in 2005
- Cold wave 2005/06
- Floods in arid Rajasthan and Andhra Pradesh and drought in northeast regions in 2006
- Abnormal temperatures during third week of Jan to first week of Feb 2007
- All India, severe drought 2009
- 2010 — One of warmest years
- 2011 — Failure of September rains in Andhra Pradesh
- 2012 — Early season drought
- 2013 — Floods and landslides in Uttarakhand
- 2014 — Hailstorms in Maharashtra

Source: India Meteorological Department

Calculated change (per cent) in mean seasonal PE for for 10C of global warming: (left) the Canadian Climate Centre experiment and (right) the Geophysical Fluid Dynamics Laboratory experiment



Source: Chattopadhyay & Hulme, 1997

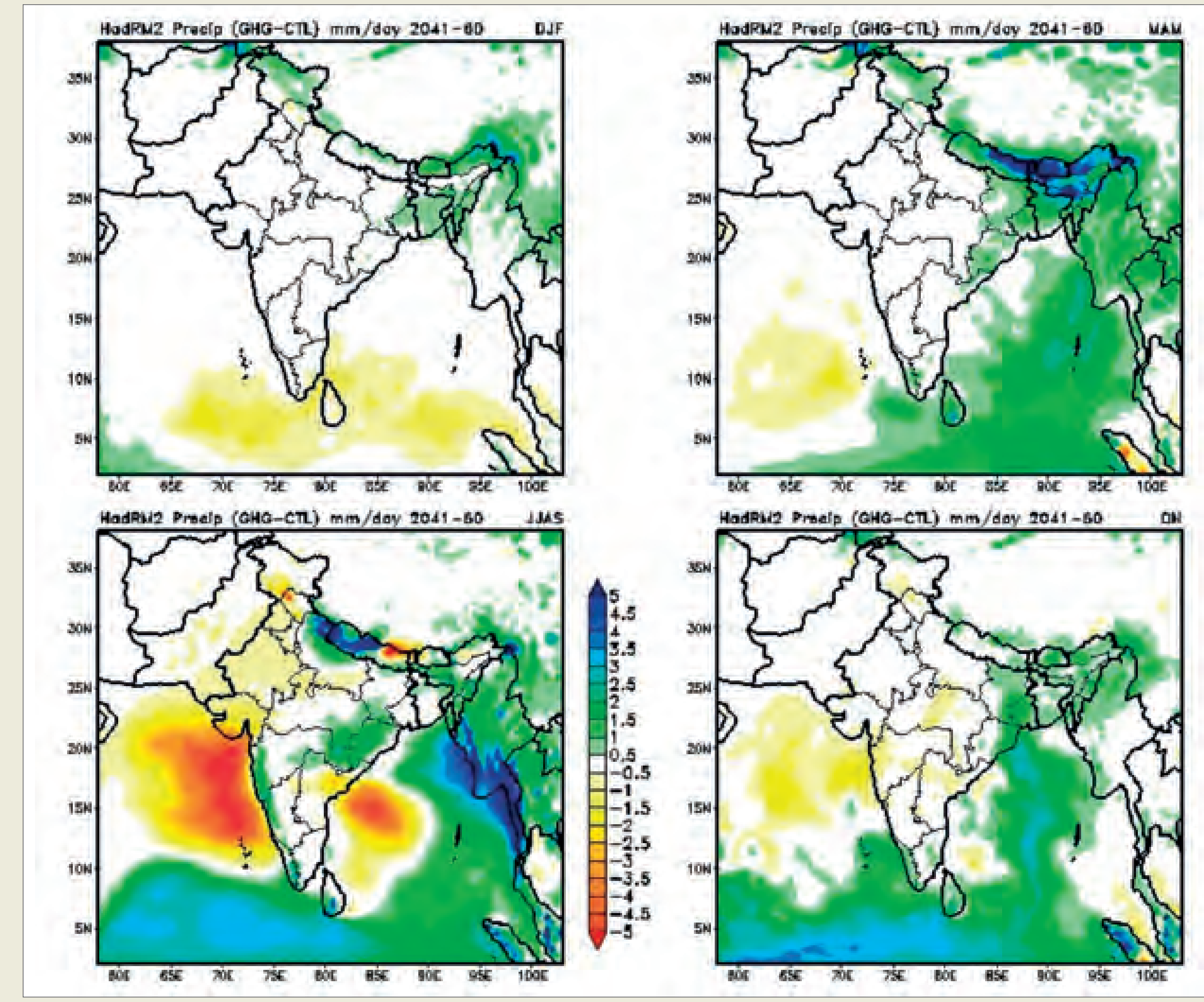
difficult to project, anticipated climate change combined with other drivers of change is likely to intensify current agricultural water management challenges in India. Higher temperatures and more frequent droughts are expected to reduce water availability, hydropower potential and crop productivity in general. The effects of population growth and increasing water demand, which are often, but not always, coupled, are likely to be a more significant source of water stress than climate change when considering changes to mean precipitation and run-off. Increasing temperatures in all regions are expected to intensify evaporative demand, which would tend to increase the amount of water required to achieve a given level of plant production if crop phenology and management are to be held constant. However, if cultivars and planting dates were to remain unchanged, accelerated crop development in response to temperature increases would tend to have the opposite effect on water requirements. Rising temperatures are also expected to increase evaporative losses of surface water resources.

Future changes in potential evapotranspiration (PE) over India and adjoining countries project an increase in all the global climate models. In the monsoon season the maximum increase in PE is over north-western India. The interrelationship between PE and rainfall was assessed by mapping the number of global climate model (GCM) experiments which yield increased P/PE ratio for the monsoon season. A number of GCMs agree that the P/PE ratio becomes more favourable over north-eastern India and that changes in this ratio are less favourable in the post-monsoon season and in the extreme south in the country.[3]

Presently, the India Meteorological Department has taken up an extensive modernization programme to enhance weather services in the country and for combating desertification through the induction of advanced technology for observational systems (including automatic weather stations, Doppler weather radars, advanced satellites and upper air observations network), installation of a centralized information processing system and its link with the national meteorological centres. The outcomes of these modernization programmes are district-level forecast services, nowcasting of severe weather events, extended range (10-20 days or a month) forecasting, increased accuracy of short, medium and long-range forecasts, multi-hazard early warning, real-time data availability, improved spatial and temporal coverage and better service delivery.

Thus, it is advisable to focus on prevention of desertification in dry farming tracts of India along with the other regions. The following adaptation strategies are being

Rainfall projections for different seasons in India



Source: Bhattacharya, 2006

prepared in a systematic and planned manner, based on climatic and water resource information:

- nationwide climate monitoring programme
- improved methods for accounting of climate-related uncertainty for decision-making processes
- reassessment in the new climate scenario of water availability and demands in all regions, particularly in water-scarce regions
- re-examination of water allocation policies and operating rules
- proper coordination among concerned organizations so as to freely share the data, technology and experience for capacity-building.

In addition, strategies such as the planning of land use, especially in new land developments, are being considered. Areas where water supply priorities are low can be planted with drought-resistant varieties of trees. Knowledge of water requirements for various crops and planting dates is integrated systematically with water supply probabilities to develop planting strategies. The selection of cropping patterns according to the availability of water will reduce the adverse impacts of drought on potential water-consuming crops. Plants suitable for water-scarce areas could be those with a shorter growth period, high-yielding plants requiring no increase in water supply, plants that can tolerate saline irrigation water, plants with low transpiration rates, and plants with deep and well-branched roots.

India became a signatory to the United Nations Convention to Combat Desertification (UNCCD) on 14 October 1994 and ratified it on 17 December 1996. The Ministry of Environment, Forest and Climate Change is the nodal ministry in the Government of India for UNCCD and the Desertification Cell is the nodal point within the ministry to coordinate all issues pertaining to the convention.

Functional rehabilitation of desertified ecosystems in Israel: ecological and socioecological perspectives

David Brand, Chief Forester, Head of the Forest Department, Keren Kayemeth LeIsrael — Jewish National Fund; Itshack Moshe, Deputy Director Southern Region, Keren Kayemeth LeIsrael — Jewish National Fund; and Moshe Shachak, Ben Gurion University of the Negev

The multifunctional cultural landscape in the southern arid and semi-arid region in Israel (the Northern Negev), has been shaped by human activity over the millennia. These anthropogenic ecosystems, common to the Northern Negev, are degraded systems that regularly lose soil and water resources necessary to support the ecosystem in its entirety.

Desertification processes in Israel are caused by uncontrolled land-use such as grazing, vegetation removal, cultivation and the neglect of ancient agricultural sites. The results include decreased landscape diversity and primary productivity, increased flood intensity and soil erosion, degradation of water resources, and harm to native flora and fauna.

Keren Kayemeth LeIsrael — Jewish National Fund (KKL-JNF), a national organization responsible for afforestation and land reclamation in Israel, has accumulated rich experience and advanced knowledge through years of research and day-to-day field management, and can offer a unique set of tools for confronting these desertification processes.

KKL-JNF rehabilitates desertified areas in Israel based on long-term research that combines, measures and quantifies ecosystem processes and feedbacks which have changed due to desertification. This knowledge base enables KKL-JNF to

Image: David Brand

A typical view of degraded areas in the arid zone of Northern Negev

Living Land

Image: Itshack Moshe

Water harvesting plays a major role in sustainable afforestation in Northern Negev's arid zone

develop theoretical and practical frameworks for restoring ecosystem functions in highly depredated areas in order to improve ecosystem services.

This framework views desertification and rehabilitation as part of a complex socioecological system in which human activities shape the cultural landscape and create desertified and rehabilitated novel ecosystems. The framework includes an ecological perspective that identifies the drivers of desertification and rehabilitation processes in the Northern Negev and a sociological-landscape perspective that integrates desertification and rehabilitation concepts with cultural landscape and ecosystem services concepts.

Desertification processes, in the past and present, are caused by human activities and overexploitation of natural resources in conjunction with climatic extreme events such as prolonged drought. The results of these processes are desertified ecosystems, seen in Israel in the Northern Negev region, characterized by a high level of system degradation as determined by indicators for soil erosion, water loss and primary productivity.

Research in earth and ecological sciences discovered the key processes that shift water-limited ecosystems from the state of desertification to rehabilitation. In a healthy and functional state, the main mechanism by which water-limited ecosystems conserve and use water, soil and biological resources is through redistribution of rainfall via changes to surface run-off absorbed in woody plants patches. The woody plant patches, which capture and retain surface run-off, function as localized 'resource sinks' and create resource-enriched patches. These patches, enriched with water and soil resources, exhibit relatively high biological productivity and diversity.

Desertification drivers, such as grazing and drought, cause a significant reduction in run-off 'sinks' made of woody vegetation, resulting in reduced water conservation and increased water leakage. As a consequence of changes in the water flow and its spatial distribution, soil erosion increases and biological productivity and diversity decreases. This trajectory in ecosystem dynamics — the transition from conservation to loss of resources — leads to a state of ecosystem degradation.

The degradation state affects landscape functions which provide ecosystem services in the Northern Negev by creating a novel set of ecosystems in which the dominant component is a biotic soil crust that replaced the woody plants. This component prevents water conservation in the form of soil moisture and leads to increased water loss as surface run-off. The novels ecosystems differ in form and function from the woody dominated ecosystems that existed prior to human habitation in the Northern Negev. The current degraded ecosystems were formed over thousands of years, and were affected by the physical and biological changes that resulted from diverse and wide-ranging human activities. These novel desertified ecosystems function, but human history has shaped them to a low functional level as expressed by their reduced ability to store system resources and transport them to the biotic elements for ecosystem production. Presently, desertified ecosystems in the Northern Negev are characterized by a high

Image: 'Albatross' — KKL Archive

Hiran forest after rehabilitation activities

level of system degradation as determined by indicators for soil erosion, water loss and primary productivity.

Ecological models describing the functional attribute of ecosystems in the Northern Negev reveal that an increased rate of system degradation can be expected due to the following trends: increased urban development and its associated demographic pressures (increased built-up areas); high-intensity cultivation of agricultural lands; lack of maintenance of ancient agriculture sites, and increased grazing pressure. In addition, predicted trends in global climate change may result in more extreme weather events (incidences of unusual droughts and storms), thus exacerbating degradation processes.

Identification of the pathways and trajectories of desertification processes enables formulation of the pathways and trajectories for functional rehabilitation of the ecosystems, where functional rehabilitation implies restoring the ecological functions of the system prior to desertification. This necessitates reversing the system functioning from a system that loses water and soil to one that conserve these resources. When the system conserves resources its cascading functional responses are an increase in biological productivity and diversity.

KKL-JNF acts to functionally rehabilitate the desertified ecosystems in the Northern Negev by landscape modulation through the construction of a mosaic of 'mini run-off catchments' for harvesting the surface run-off generated by the soil crust. This rehabilitation framework restores the pre-desertification functions of rainfall water redistribution and creates a landscape of soil moisture enriched patches that conserve resources and enhance biological productivity. In reshaping landscape structure, the human-made rehabilitated ecosystems regain the ability to preserve their scarce resources while renewing their ability to supply ecosystem services for human welfare.

System rehabilitation and the reversing of degradation processes by management intervention by KKL-JNF is based on a scientific understanding of the connections between hydrological processes and ecosystem structure and function in water-limited zones. This includes understanding the rainfall/run-off/soil moisture relationship on the slope and watershed scales, as well as the connection of water flow to ecological processes such as productivity and diversity on the landscape level.

Viewing rehabilitation as a management intervention to regulate ecosystem functions is the road map that directs KKL-JNF management actions and is translated into specific activities, such as:

- alteration of the ecosystem's physical infrastructure — constructing various measures for run-off harvesting on slopes and valleys as well as measures to stabilize erosion processes such as gully heads; facilitating in-situ storage of scarce water and soil resources, and encouraging the regeneration of biotic components on site
- afforestation — tree plantation to supply ecosystem services for human welfare.

The functional rehabilitation of an ecosystem restores the integrity of fundamental hydrologic, edaphic and ecologic processes, which are directed towards creating a novel,

Images: Itshack Moshe

Bicycle trails, native flowering sites, parks and community forests are just some of the cultural services which improve the life quality of inhabitants

highly functional and sustainable ecosystem. The integrity of the ecosystem is restored because the following key processes are regulated by management:

- redistribution of on-site rainfall through changes to surface run-off harvesting patterns
- enhancement of natural soil patches and the creation of artificial ones which capture and retain surface run-off, thus functioning as localized resource sinks.

These patches, enriched with water and soil resources, exhibit increases in primary productivity.

In sum, the aforementioned approach towards system rehabilitation to restore landscape heterogeneity involves the creation of artificial sinks on slopes and valleys, which collect and store run-off rainwater, thus producing patches enriched with water and nutrients. The infiltration of captured surface run-off into the soil creates water-rich microhabitats and improved soil quality, enabling the possibility to plant trees to create a novel ecosystem. The human-made novel ecosystem reinforces the system's ability to supply benefits to humans and other organisms living there. The choice of which tree species to plant and the configuration of the planting are adapted to landscape and soil moisture spatial heterogeneity, soil, site-specific topographic, and edaphic factors. The use of a diverse set of tree species guarantees resilience and durability of the novel ecosystems to the stresses of drought, grazing and human activity.

The historic long-lasting, widespread and large-scale human land use in the Northern Negev has result in a land surface which can be considered a mosaic of cultural landscapes, in which different stages of anthropogenic influences have been overlaid and refined, resulting in alternating periods in which desertification and of rehabilitation prevail. Therefore, the mosaic of ecosystems that form the cultural landscapes can be understood as the result of the dynamics of social-ecological systems, in which social, economic and environmental components are closely interwoven.

Cultural landscapes imply landscapes that are deliberately managed by humans and that their ecosystem services have been sustained through a long and complex history of human settlement, land use and misuse.

KKL-JNF adopted a cultural landscape framework that provides a new perspective on desertification and rehabilitation as interactions between man and nature, by understanding of the role of humans in landscapes and ecosystems transformation in the Northern Negev. In this view, landscape management means integrating natural processes and human engineering in a functional way, as described in the previous section, in order to provide ecosystem services. Functional rehabilitation is therefore a comprehensive framework that connects the cultural landscape with its ecosystem services.

Through its years of varied activities, KKL-JNF has found that integrating cultural landscape and ecosystem services approaches is a powerful tool in order to guide management activities of functional rehabilitation, such as water redistribution in a specific landscape unit. The ability to display ecosystem services for different land use within a

Images: Moti Kaplan (left); 'Albatross' — KKL Archive(right)

Green belts planted around cities and villages and along dry streams provide recreation and leisure sites for inhabitants

cultural landscape perspective is an important advantage of the integrated approach. The integrated approach provides a useful understanding of the cultural inputs, outputs and services in the context of ecosystem and landscape function. We suggest that this approach is particularly useful for environments heavily influenced by humans, for example in heavily grazed drylands.

Linking both ecosystem services and cultural landscape frameworks enables concentration on the human dimension of ecosystems and landscapes management, thus enabling the integration of rehabilitation interventions within a multifunctional landscape, including agricultural and urban ecosystems. The two frameworks are complementary in providing guidelines for combating desertification and together have proven successful in adding unique ecosystem services to the cultural landscape of the Northern Negev.

An evaluation of results from the functional rehabilitation of Northern Negev ecosystems, from the perspective of the cultural landscape-ecosystem services approach, indicates an increase in the diversity and level of ecosystem services supplied to humans. These ecosystem services comprise all types of services including:

- Regulating services, which regulate the water cycle to prevent resource loss and mitigate flood damages; regulate and prevent soil erosion; protect arable land, grazing land and urban areas from flooding and erosion; increase primary productivity as a driver in the ecosystem's energy and nutrient cycles; support populations of natural enemies of agricultural pests; regulate pollination services; and regulate carbon cycling through increased rates of carbon sequestration.
- Cultural services, which improve the life quality of inhabitants: the green belts planted around cities and villages and along dry streams supply recreation and leisure sites, native flowering sites, bicycle trails, parks and community forests. Rehabilitation of the ancient agriculture sites enables the preservation of historical and cultural heritage assets and supports forest-based tourism, thus encouraging visitors to use guest facilities at neighbouring communities and making an economic contribution to rural livelihoods.
- Provisioning services, which supply biomass and shade for sheep, goat and cattle herds owned by the local population, and supply firewood to the local population for cooking and home heating.

In conclusion, KKL-JNF's work in the functional rehabilitation of Northern Negev ecosystems provides an important contribution to the world's understanding of desertification and rehabilitation processes and the importance of an active multi-use approach to land management.

KKL-JNF's methods for the functional rehabilitation of Northern Negev ecosystems can be used as efficient and applied tools to rehabilitate desertified areas outside Israel, as well as for adapting to the expected influences of global climate change in water-limited regions.

KKL-JNF shares with other countries the scientific basis, applications and adaptations of its methodology for the return of functionality to degraded ecosystems, which are supported by long-term monitoring and research programmes. Results of the rehabilitative actions and management of rehabilitated areas are evaluated by their long-term effects and influences. Recent studies assessing the effects of decades-old rehabilitation works show that rehabilitation processes contribute to increased ecosystem integrity and functionality.

Rethinking the sustainability of Israel's irrigation practices in the drylands

Professor Alon Tal, Blaustein Institutes for Desert Research, Ben Gurion University

Israel's strategy to combat desertification includes a determined effort to expand agricultural production in the drylands. Two central components of this effort are the wide utilization of drip irrigation technologies and a complete commitment to 'marginal' water sources, in particular recycled wastewater. Initial results have been hailed as extraordinarily impressive, with dramatic growth in yields with practically no increased freshwater allocations. Yet, a growing scientific consensus suggests that Israel's approach to irrigation may be fundamentally unsustainable.

Israel began developing drip irrigation some 50 years ago. The technology was soon hailed as a breakthrough in agricultural efficiency. In the country's early years, furrow and gravity based flooding systems had been normative. By contrast, drip systems delivered tiny amounts of water and fertilizer directly to the root zone of plants and trees in a steady flow. The new technology immediately produced significantly "more crop for the drop" and offered farmers myriad operational and environmental benefits: reduced diseases, weeds, labour costs and nonpoint source pollution discharges. At the same time, nutrients and chemicals were more efficiently delivered directly to the root zones of plants.

The technical capabilities of drip irrigation quickly improved. Drip systems became more robust and durable, with emitters able to process lower quality waters without clogging. Subsurface irrigation systems were eventually developed to solve environmental problems, especially for systems utilizing treated effluents. Keeping wastewater underground adds an additional level of safety, preventing the likelihood of contact with produce or exposure among workers. It also allows for drippers to release water precisely where it is needed, in the root zones, 20 cm underground. Today, some

Image: Naty Barak

Israeli drip irrigation technology applied in Africa

Image: Alon Tal

Ben Gurion University researchers evaluate the efficacy of irrigation waters with different salinity levels

75 per cent of Israeli irrigation relies on drip systems, roughly half of which involve subsurface systems. Paradoxically, as the systems' sophistication increased, prices began to drop.

While Israeli agriculture was embracing drip irrigation, a parallel process took place in terms of irrigation water: treated sewage effluents became the predominant source of water for Israel's agriculture sector. Standards were set for reuse of effluents and in 1956 a national masterplan was adopted that envisioned the ultimate utilization of 150 million cubic metres by Israel's agricultural sector. Today, three times that amount of treated wastewater is recycled. As of 2015, the country recycles 86 per cent (400 million m^3) received at its treatment plants. This is a far greater commitment than other countries. For instance, Spain, the European leader in the field, reportedly recycles 12-17 per cent of its sewage; Italy and Australia roughly 10 per cent. Over half the irrigation water used by farmers in Israel today is recycled effluents (50 per cent at secondary treatment levels and 50 per cent tertiary), allowing for the cultivation of 130,000 hectares of agricultural lands.

Reuse of treated sewage can substantially expand water resources but is not without environmental and public health ramifications. Recycling sewage initially raised concerns about microorganisms: beyond affecting farmers deleteriously through direct contact, irrigated effluent can leave consumers exposed to produce with a range of harmful bacteria. Over the years, upgraded Israeli wastewater treatment levels largely eliminated this hazard. Improved compliance with the Ministry of Health's effluent irrigation standards, which stipulated increasingly high water quality standards for irrigating different crop types, also contributed to substantially reduced risk.

Not all contaminants are easily removed through treatment. For instance, boron is a critical element for plants but is toxic when concentrations are excessive. As conventional sewage treatment does not eliminate boron, its presence in effluents began to affect crop yields in the 1980s. Israel quickly moved to ban boron in laundry detergents and immediately improve the recycled wastewater quality provided to farmers.

Other 'microcontaminants' such as pharmaceutical residues, remain a problem. Hebrew University's Benny Chefetz's laboratory has identified high concentrations of pharmaceutical compounds such as lamotrigine (an anticonvulsant drug) in crops irrigated with secondary treated wastewater that cross the threshold of toxicological concern (TTC) level for a child (25 kg) who consumes half a carrot a day (60 g carrot/day). Consumption of sweet potato leaves and carrot leaves by a child (25 kg) would also surpass the TTC level for epoxy-carbamazepine (an epilepsy drug) at 90 g leaves/day and 25 g leaves/day, respectively. The risks associated with these 'contaminants of emerging concern' are only now being characterized, but they are probably of less concern than the oldest water pollutant of them all: salinity.

Salts, almost without exception are not removed during sewage treatment from wastewater streams. Wastewater by definition has higher salinity relative to its contributing background

Image: Alon Tal

Lysemeters measure the response of pepper plants to salinity at the Wyler Department of Dryland Agriculture, Ben Gurion University

Image: Alon Tal

Lysimeters measure the response of olive trees to different irrigation regimes at the Ministry of Agriculture's Gilat research station

sources. (Some treated effluents may actually have lower salinity than alternative freshwater sources with salinity levels. For example: wastewater in Israel that is derived from desalinated seawater has lower salt levels than fresh water removed from the Kinneret — Sea of Galilee.) Given the seasonal demand in Israel's Mediterranean climate, Israel stores effluents in reservoirs during the rainy months. The evaporation that takes place during storage invariably leads to higher salinity levels.

Some 15 years ago, there were already Israeli experts who questioned the wisdom of the country's aggressive promotion of effluent reuse. They argued that over time, using wastewater for irrigation would lead to the accumulation of sodium compounds in soils. While chloride is required in very small quantities for photosynthesis and enzymatic reactions, sodium, the other component of salt, makes little if any contribution to plant health or yields. Even modest quantities can be toxic to plants and cause damage to soil structure, making it unproductive for agriculture. Indeed, conventional fresh water used in irrigation can contain sodium at levels two orders of magnitude higher than the plant needs to develop.

With time, signs of salinity damage from long-term effluent usage in Israel were ubiquitous. A study in Israel by researchers in the Ministry of Agriculture's Volcani Institute compared yields in orchards on that been utilizing effluents via drip irrigation for 10 years: avocado and citrus yields were 20-30 per cent lower than trees in the same orchards that had been using fresh water. Soil damage from wastewater tends to be concentrated in the upper soil layers. But again, the plants themselves are affected: another recent analysis by leading expert Alon Ben-Gal and Eran Raveh shows clearly that as wastewater reuse in Israel has increased over the last 20 years so have sodium concentrations in soil and crops.

Traditionally, Israeli farmers have overcome salinity problems by applying high irrigation rates to crops, leaching excess salts out of the root zone to protect plant health. In an arid region, farmers may use an additional 30-40 per cent more water simply to manage salt levels in cultivated soils. This can solve the plant's problems but can contribute to contamination of the underlying aquifers. Recent experience in large olive tree plantations in Israel's Negev desert constitutes a cautionary tale.

The olive trees relied on drip irrigation with water from relatively saline, underlying aquifers. The salts were managed by applying water for leaching. During the rare winter storm of 30 mm or more, salts accumulating on the surface could dissolve and be delivered directly into the root zone. Facing perennially high evapotranspiration levels, the trees took in large quantities of the salty water and immediately showed signs of distress. Recently, when olive oil prices dropped, the cost of such massive leaching became prohibitive and the farmers reduced the magnitude of irrigation dramatically. It did not take long before the tree production began to significantly decline due to exposure to the salts.

The lesson is clear: in arid and semi-arid regions where there is not sufficient precipitation to flush salts out of soils, deficit irrigation will not work. This makes leaching imperative but economically and environmentally problematic.

In a recent article, two leading Israeli agricultural researchers with Alon Ben-Gal and Eran Raveh wrote: "Israel's policy of lower prices for salty water and absolute utilization of wastewater for irrigation without addressing salinity may have been reckless. Leaching, necessary in agricultural water management when using water containing salts, is of itself unsustainable, as the water leaving the root zone contains not

Image: Naty Barak

A Jojoba plantation at Hatzerim Kibbutz — 12 years of subsurface irrigation and going strong

only the salts that must be leached, but also various other contaminants, contained in the water, added in agricultural processes (fertilizers, pesticides and herbicides), or mobilized from soil and subsoil."

Other leading Israeli irrigation researchers, (such as Shmuel Assouline, David Russo, Avner Silber and Dani Or) also began to speak up about the issue, citing mounting evidence that various aspects of soil hydrology are negatively affected by wastewater reuse. Damage is the result of increased loadings of organic matter, surfactants, nutrients, and subsequent interactions with the soil.

Cognizant of the dangers, Israel continues to make significant efforts to reduce salinity in its drinking water sources. Regulations prevent the release of the salts used by kosher slaughter houses from reaching municipal waste streams; desalination provides an increasing fraction of drinking water, reducing the salinity in the resulting sewage. But wastewater is still a relatively saline source for irrigation, requiring copious amounts of water for leaching out residues. When Avner Silber and his colleagues compared irrigation with conventional water sources to irrigation with water where salts were removed via desalination prior to delivering to banana crops, the results were compelling: not only did desalination obviate salt leaching and the risk of salinization of underlying water resources — it also improved yields and fruit quality.

Based on this research, academic and government researchers are openly recommending that desalinated water be considered as a viable water source for irrigation. Given the high energy demands and greenhouse gas emissions associated with desalination, a truly sustainable irrigation policy may require solar energy systems to provide the electricity for desalination processes.

The question is: Can farmers afford to pay for such high quality water? Many agricultural experts argue that conventional crops will not be profitable if they rely on desalinated water, which in Israel ranges between 55 and 65 cents per cubic metre (1,000 litres). Onions, carrots and potatoes would be losing propositions; for tomatoes and peppers the economic calculous is tenuous. Surely orchards in the drylands cannot compete with groves that enjoy rain-fed conditions.

Based on Israel's experience, certain implications for other water-scarce countries are already clear: drip irrigation should be a central component in any agricultural production strategy. It is simply irresponsible to continue to use flood, furrow and sprinkler irrigation when drip irrigation systems offer such clear agronomic and environmental advantages. At the same time, if a country with croplands in arid or semi-arid regions wishes to sustain irrigated agriculture over the long term, it must ensure an extremely high quality of water and ultimately seek to utilize desalinated water sources. Sooner or later, massive utilization of effluents will lead to salinization and eventually force such a transition.

Farmers using desalinated water may not be able to compete on world markets, so countries will need to consider subsidizing water produced for irrigation. Moreover, if expansion of dryland agriculture is not to compromise climate change mitigation efforts, renewable energy should be integrated in desalination processes. Finally, the Israeli experience suggests that extensive wastewater reuse should only be seen as a temporary exigency and a transition stage in a country's agricultural evolution. The well-documented, deleterious environmental impacts are clear and disturbing, sending a clear message that effluent recycling in the drylands is fundamentally unsustainable.

Restoring lands and livelihoods in rain-fed areas through community watershed management

Suhas P Wani and Kaushal K Garg, International Crops Research Institute for the Semi-Arid Tropics, India

Ensuring food security and reducing poverty for a global population that will grow to 9 billion by 2050 is a challenging task.[1] Increased food production has to come from available, limited water and land resources.[2] Water scarcity is acute, particularly in developing countries like India, China and Thailand where population pressure is high, physical scarcity of water is expected and countries are struggling to eradicate poverty and improve quality of life.

Blue water availability in most of the river basins is declining as available water resources are already allocated among various sectors and no scope exists to harvest it further.[3,4] Moreover, significant uncertainty is arising on future water and food availability due to increased vulnerability of drylands. Extreme events like flash floods or longer dry spells; more dry or wet years; temperature change and pest/disease infestation are among the characteristics driven by climate change.[5] Use efficiency of land and water resources must be enhanced, especially in rain-fed systems which hold huge untapped potential to address present and future food security.[6,7,8,9,10]

A large percentage of rural families in Asia (60 per cent) and Africa (70-80 per cent) is largely dependent on agriculture and allied sectors. There are a number of challenges such as fragmentation of farmlands, low crop yields, water scarcity, land degradation and inability to access credit and markets.[11] However, crop productivity of these farms is two to five times lower than the achievable potential. Per capita availability of land is declining continually with the growing population.[12] Further, most of the cultivated lands as well as common property resource lands are degraded and continue to degrade further, particularly in Asia and Africa. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners have been working to develop various natural resources management technologies to bridge the yield gaps and to harvest the potential of rain-fed areas since 1976. For example, various *in-situ* and *ex-situ* soil and water conservation technologies to enhance/maintain land capability and green and blue water availability were developed at farm and community scale; their suitability was evaluated for different soil types and cropping systems; and they were demonstrated through on-station research experiments at ICRISAT and on-farm farmers' participatory trials along with consortium partners.[8,9,10] Based on the lessons learned from different evaluation studies, an ICRISAT-led consortium has developed a farmer participatory integrated watershed management approach adopting a holistic integrated genetic and natural resource management strategy to increase productivity, production and profitability through building partnerships. ICRISAT later expanded and strengthened the Inclusive Market Oriented Development strategy to link smallholder farmers to markets and ensure profits through innovative collective action using new information and communication technologies.

ICRISAT and its partners have established sites of learning (500-2,000 ha scale) in different rainfall and ecological regions, demonstrating the potential of rain-fed system through an integrated watershed management approach. The following case studies from India, China and Thailand represent different ecosystems, demonstrating the suitability of the integrated watershed management approach to minimize land degradation, overcome water scarcity and harness the potential of rain-fed agriculture in Asia.

Adarsha Watershed, southern India

The Adarsha watershed in Kothapally is located in the Shankarpally mandal of the Ranga Reddy district of Telangana (previously Andhra Pradesh). Before 1999, this village suffered acute water shortage, land degradation and poor agricultural and livestock productivity. Eighty per cent of its 462 ha of agricultural land was rain-fed with a monocropping system. The main crops were cotton, maize, sorghum and pigeonpea with productivity of 1,000-1,500 kg ha^{-1} of sorghum/maize and 200 kg ha^{-1} of pigeonpea. There were 62 open wells. Most of these dried up soon after monsoon and the women walked 2-3 km to fetch drinking water from February until the monsoon arrived.

At the request of the district administrator and the government Drought Prone Area Programme, ICRISAT and its consortium partners (the Government of Andhra Pradesh; MV Foundation, a non-governmental organization; the Central Research Institute for Dryland Agriculture; and the National Remote Sensing Agency) started implementing watershed technologies between 1999 and 2004. Various soil and water conservation practices, productivity enhancement, crop diversification and intensification work along with knowledge-based entry point activities were introduced. Groundwater availability increased from 3.5 m to 6.0 m due to various soil and water conservation interventions. Due to increased availability of water resources, the entire watershed transformed from degraded to more productive. Cropping intensity increased from 85 per cent to 150 per cent and large numbers of farmers shifted from low-value crops to high-value crops (Bt. Cotton and vegetables). Average crop yields of sole maize increased by 2.2


Images: ICRISAT

Top: Post-monsoon water levels in one of the wells of Adarsha watershed, (left) before and (right) after the watershed intervention
Bottom: Farmers in the Adarsha watershed adopted intercropping as an improved management practice and many moved to high-value crops such as cotton

to 2.5 times (3,800 kg ha^{-1} compared to 1,500 kg ha^{-1}); intercropped maize pigeonpea with improved management produced 6,000 kg ha^{-1} compared to 2,900 kg ha^{-1}; and pigeonpea yields increased to 900 kg ha^{-1} against 200 kg ha^{-1} in 1998. Moreover implementing such interventions has strengthened a number of regulating and supporting ecosystem services such as reduced soil loss (10 t ha^{-1} to 2 t ha^{-1}), reduced surface run-off (30-40 per cent), increased base flow, improved water quality (pesticide residue-free), increased green cover and carbon sequestration.

Parasai-Sindh, central India

The Parasai-Sindh watershed, comprising three villages covering 1,250 ha, was developed as a benchmark site in Jhansi district of Bundelkhand, being a hot spot of water scarcity, land degradation, poverty and vulnerability to the impacts of climate change. This watershed receives nearly 850 mm of rainfall with about 85 per cent from June to September. Agriculture and allied sectors are the main sources of livelihood for the rural people in this region who are largely dependent on groundwater resources for domestic and agricultural use. Due to hard-rock geology, groundwater recharge mainly takes place in shallow and unconfined aquifer which is characterized by poor specific yield. Water level in open/dug wells depletes very fast after the monsoon and communities suffer from water scarcity especially in summer. Women and girls were spending significant time and energy collecting water for domestic use, while men would migrate to nearby cities in search of livelihood during and after the monsoon. This left women and livestock further exposed to a number of socio-economic stresses and exploitation.

From 2012 onwards, ICRISAT along with national partners, Central Agro-Forestry Research Institute (CAFRI), district administration, government of Uttar Pradesh and local community started implementing watershed interventions in Parasai-Sindh watershed. Regular interactions with the community contributed to a strong trust resulting in effective planning and implementation of watershed activities. The village and the watershed committees identified potential locations where different soil and water conservation practices such as check dams and gully control structures could be made. *Ex-situ* water harvesting structures together developed 125,000 m^3 of storage capacity by the end of June 2015. Through state-of-the-art monitoring, it was estimated that these structures harvested around 250,000 m^3 of surface runoff and facilitated groundwater recharge in every monsoon season with the groundwater table increasing on average by 2.5 m compared to non-intervention stage. This has increased cropping intensity


Images: ICRISAT

Parasai-Sindh watershed, Bundelkhand region, central India: (left) over and base flow from a check-dam indicates increased groundwater and surface water availability; (right) farmer cultivating vegetable as cash crop

by 50 per cent especially during post-monsoon season (*rabi* season). Productivity of post-monsoon crop especially wheat has doubled after the watershed interventions. Wheat yield before the watershed interventions ranged from 1,500 to 1,800 Kg ha^{-1}. Despite the good establishment of crop, there was high chance of crop failure due to depleted water resources between January and February and supplemental irrigation was not possible due to drying wells. After implementing the watershed programme, farmers began harvesting wheat yield ranging from 3,000 to 4,000 kg ha^{-1} resulting in significant improvement in their income and livelihood. Farmers have shifted cropping pattern from low-income crops (chickpea and mustard) to high-income crops (vegetables and wheat) and fodder availability has increased significantly. Agro-forestry has strengthened by promoting tree plantation on farm bunds and wasteland with community participation. Improved varieties of chickpea and wheat were introduced and crop yields increased from by 30 to 50 per cent. In addition, various income-generating activities such as vermicomposting, nursery raising and other micro-enterprises helped farmers to earn additional income. Watershed interventions enhanced average annual family income from 50,000 INR (US$830) to 125,000 INR (US$2,080) in a period of three to four years clearly indicating the potential of science-led interventions to address the food security and rural livelihood issues in drylands.

Lucheba, China

Lucheba village in Pingba County, Guizhou province in southern China comprises a cluster of six villages with 340 households and 1,373 people. It was selected in 2003 for integrated watershed interventions by ICRISAT and its partners. Before this, the cropping system was largely maize, rice, soybean, sunflower and rapeseed. There was high pressure on women as they had to travel long distances to fetch drinking water due to water scarcity even for domestic use. Migration levels were high as people sought other livelihood options and men were largely engaged for labour work in the construction sector. In 2003, based on discussions with the village communities, two drinking water schemes were undertaken as an entry point activity with project funds and partial contributions from villagers. Spring water from the hilltop was tapped and brought down to the village through a pipeline system. Further watershed interventions such as soil and water management, improved cropping systems, crop diversification, integrated nutrient and pest management practices, along with other income-generating activities such as poultry and pig rearing, were introduced. Altogether 151 rainwater harvesting/irrigation water storage tanks of 5 m^3 capacity were constructed; nearly 133,000 trees were planted on 100 ha of wasteland, and a 4.8 km village approach road was built from the main road. Later a 6 km-long field road was also constructed with government support. Crop diversification was undertaken with high-value vegetable crops. More than 260 biogas plants were set up in village households to reduce pressure on fuelwood and protect the forests. Micro-enterprises for women were promoted along with forage production on bunds.

Watershed interventions completely transformed the livelihood of the people. Average annual income from agriculture has increased threefolds (from US$500 to US$1,650). The benchmark crops (rice, corn, rape, soybean, sunflower and kidney bean) were replaced with high-value crops like watermelon and vegetables like tomato, pumpkin, cabbage, chilli and eggplant using hybrid seeds and improved agronomical practices. Lucheba now boasts two animal health centres, an Internet-enabled farmers' training centre and one Vegetable Growers' Association. The whole village currently has biogas-powered street lighting. The migration level has been drastically reduced and those who had migrated to cities have returned to villages as the quality of life is better than the city with more opportunity to work in the village itself. The village's average per capita income is twice that of the province.

Images: ICRISAT

Lucheba watershed, China: (left) the landscape shows a large area under vegetable and cash crops; (right) Scientist observing staked tomato plants

Tad Fa, Thailand

Tad Fa watershed is located in Phu Pa Man district in the Khon Kaen province of Thailand. It was developed as benchmark site to address the issues of land degradation and poor agricultural productivity in 2003. The Department of Agriculture, the Land Development Department, Khon Kaen University and ICRISAT, along with the rural community, formed the consortium for implementing the programme. The watershed receives a good amount of rainfall (1,300 mm) but due to uneven distribution and lack of water harvesting structures, the village was suffering water scarcity even during the monsoon period. Nearly 80 per cent of the total agricultural area was rain-fed, having one crop per year. Farmers in upland areas with high to medium slopes were cultivating maize along the slope (up and down cultivation), triggering heavy soil erosion, as well as cash crops and rice on the lower lands for domestic use. The watershed faced severe soil erosion and crop productivity was declining year by year due to land degradation.

Several soil, water, nutrient and integrated crop management interventions were introduced in 2003. In consultation with the farmers, the Land Development Department constructed 17 farm ponds each of 1,260 m^3 storage capacity to facilitate supplemental irrigation to crops, fruit trees and vegetables, particularly in the post-rainy season. Field bunds were constructed along with vetiver grass largely in uplands. Sowing through hand dibbling was promoted on steep slopes; and cultivation using tractor-mounted implements was promoted in farms with moderate to mild slopes. About 70 per cent of the area was promoted under contour cultivation. Relay and sequential cropping systems were promoted to use green water efficiently and improved varieties of seeds were introduced. Fruit tree cultivation was promoted and improved plantation methods were introduced to enhance the land and water use efficiency.

Maize yields increased by 30-40 per cent compared to the conventional system due to the increased availability of green water resources. Surface run-off (60 per cent reduction) and soil loss (40 t ha^{-1} to 8 t ha^{-1}) were reduced drastically and crop productivity increased. Areas under fruit tree cultivation increased in and around Tad Fa watershed within three years of the project implementation. This has helped in controlling soil erosion and provided better and more sustainable income to farmers which significantly contributed to enhancing rural livelihood.

The way forward

Integrated watershed management is an important strategy for strengthening resilience to drought, especially in uplands which are hotspots of poverty, water scarcity and land degradation. Soil and water conservation practices have resulted in higher groundwater recharge which enables supplementary irrigation of the monsoon, bridging of dry spells and scope for irrigation of a second dry-season crop. Moreover, *in-situ* water harvesting has resulted in enhanced green water use efficiency in rain-fed agriculture. Productivity enhancement, crop intensification and diversification further helped farmers to utilize available resources effectively and earn more. Watershed interventions are also helpful in strengthening various ecosystem services such as reduced nutrient and soil loss, which is expected to have positive impacts on in-stream river ecology and run-off generation for other downstream water uses. Under the changing climatic scenario with reduced annual rainfall and higher rainfall intensities, watershed development programmes are increasingly important for securing agricultural yields in upland areas to achieve food security and improve the livelihoods of small and marginal farmers and, most importantly, for building the resilience of systems to the changing climate. Scaling-up of these initiatives is urgently needed to achieve the desired level of impacts and outcomes for food, nutrition and water security for the growing population through sustainable development.

The Uttarakhand Sustainable Land and Ecosystem Management project — applying integrated approaches

Mohamed Imam Bakarr, Jean-Marc Sinnassamy, Ulrich Apel, and Andrew Chilombo, The Global Environment Facility

The Global Environment Facility (GEF) funded Uttarakhand Sustainable Land and Ecosystem Management (SLEM) project was linked to a US$70 million World Bank aided decentralized watershed management (UDWDP) with an additional government contribution of almost US$17million.

The UDWDP was designed to improve the productive potential of natural resources and increase incomes of rural inhabitants in selected watersheds through socially inclusive, institutionally and environmentally sustainable practices. This foundation for integrated management of natural resources in the watersheds served as a basis for the Uttarakhand SLEM project.

The GEF project aimed at the comprehensive treatment of watersheds to restore and sustain ecosystem functions and biodiversity while simultaneously enhancing income and livelihoods. GEF resources were specifically targeted on 20 micro-watersheds, all of which were selected based on severity of erosion, extent of poverty, and lack of infrastructure facilities. The project generated valuable lessons learned on how the environment and natural resource issues can be effectively integrated across watersheds and how demonstrated success can be scaled up and mainstreamed at state and national levels.

The Uttarakhand SLEM project used various approaches and participatory processes toward building ownership at multiple levels — from development and management of

Image: © Patrizia Cocca/GEF

A resource map in Katna, India: community participation is knowledge-sharing and is key to SLEM project interventions

Image: © Patrizia Cocca/GEF

Village motivators like Tulsi Devi have been key in encouraging women's participation in the project design and decision-making in Uttarakhand

watershed plans, to creating options for enhancing livelihoods and institutional strengthening. The project was based on a participatory and community-driven approach for the planning, implementation and monitoring of activities. At the micro-watershed level, the Gram Panchayats (GP) were reinforced as local governance authorities and better armed to endorse their responsibility for administration, management and development of village resources. Building on economic activities that addressed individual needs, GEF resources helped to catalyse integration of the notion of ecosystem services at watershed scale to:

- mainstream sustainable watershed management approaches into GP watershed development plans
- enhance biodiversity richness at watershed level through domestication and cultivation of threatened medicinal and aromatic plants
- enhance the understanding of the impact of variability and climate change impacts on the mountain ecosystems and help devise adaptation and mitigation strategies.

The project approach also took into account the crucial link between ecosystem services and livelihoods of women and vulnerable groups in the fragile watersheds. As often, women play a significant role in social and economic aspects, notably around the use and management of forests and other natural resources. The project focused on inclusion of women in decision-making processes, using various tools and mechanisms: 'women motivating women' for awareness and social mobilization, empowerment of women in decision-making processes, improvement of participation of women in various committees and institutions, greater emphasis on women-led income-generating activities, and promoting drudgery-reducing interventions.

The village communities actively participated in the entire project activities from planning and implementation to monitoring and evaluation. Various participatory mechanisms and tools, such as focus groups, were used to select and implement interventions, covering the aspects of community-level development based on natural resources (such as water management, land management to increase fodder, livelihoods, agribusiness). The interventions financed by GEF were an opportunity to add specific activities related to the protection and management of ecosystem services (including surface water protection, underground recharge, mainstreaming biodiversity in forest restoration and management, and agrobiodiversity). Particular attention was given to equity and vulnerable groups through self-help activities that generate income and promote their empowerment.

The Uttarakhand SLEM project was designed to embody multidisciplinary perspectives covering ecological, social, economic and institutional priorities across multiple scales. This was essential to ensure flexibility in applying the wide range of interventions to treat the watersheds and restore ecosystem functions based on demand-driven needs of the communities. Interventions were defined through participatory processes with communities, and drawing on local

Image: Patrizia Cocca/GEF

Terraces in the Nainital district of the Himalayas are helping farmers to keep the topsoil and increase water penetration

knowledge of the resource base and tools for decision support (for example resource mapping). As a result, the priority interventions reflected strong links between livelihood needs and drivers of ecosystem degradation in the watersheds, which created opportunities for a GEF catalytic effect through the integrated ecosystem management (IEM) approach.

The priorities included interventions for controlling land degradation at watershed level; reducing pressure and dependence on the natural resource base through fostering markets for non-timber forest products; biodiversity conservation and management through watershed planning and community participation; and increasing adaptation to climate change in natural resource-based production systems. The interventions were based on good practices for integrated management of land, soil, water and forest vegetation to ensure improvements and maintenance of critical ecosystem services in the watersheds. For example, ponds and recharge pits on upper levels of slopes were used to reduce erosion, capture water for recharge, enhance rejuvenation of traditional water sources and increase moisture for plant regeneration in the watersheds, including high value perennial grasses for livestock feeding. Other best practices with regards to soil conservation include terrace repairs with the help of vegetative boundary, rainwater harvesting in village ponds, dry stone check-dams, irrigation channels and river bank protection.

The Uttarakhand SLEM project was a unique opportunity to implement the watershed guidelines of the Government of India approved a few times before the beginning of the project. The Watershed Management Directorate (WMD) serves as a state-level agency to manage all the watershed projects in the state. Multidisciplinary teams of four to six specialists seconded from line departments (horticulture, agriculture, animal husbandry, minor irrigation, forestry and community mobilization) played a key role in providing technical support across the watersheds. In addition to expertise from line departments, the WMD also mobilized a wide range of national institutions and civil society organizations (CSOs) to harness technical support for delivering interventions.

The institutions contributed training and capacity needs, demonstration of new technologies, microfinance, and development of market value chains for communities across the targeted watersheds. These efforts further increased the potential for communities to take advantage of improvements in land and water resources for income generation, such as through use of high-value crops (ginger and turmeric) and adaptive livestock breeds (goats and buffalo). These oppor-

Images: Patrizia Cocca/GEF

Pine briquetting reduces dependency on fuelwood collection by women as well as reducing deforestation and greenhouse gas emissions

tunities were further enhanced through support to Farmer Interest Groups (FIGs) as a means of increasing access to production and marketing services. The FIGs now operate as a federation, with technical support provided through a CSO known as the Central Himalayan Environment Association.

The project also engaged scientific institutions to address specific needs for knowledge-generation, monitoring and assessment of interventions, and quantification of environment and development benefits. A key example is the Energy and Resource Institute (TERI), which served as a partner for baseline and final impact assessment for the project. TERI was involved in developing a sampling framework, designing questionnaires, field testing, pilot surveys, refining questionnaires, field surveys, data cleaning and entry and, finally, data compilation and aggregation.

As part of internal monitoring, the progress of the annual works programme was monitored on a monthly basis through a Monthly Progress Report generated at the divisional level and consolidated at WMD level. Monitoring teams were constituted with members drawn from various technical wings of the directorate who regularly visited the project area. Random field visits, monthly meetings, checklists, brainstorming, amid all stakeholders at district level at monthly intervals and at regional level on a half-yearly basis, was an integral part of the internal monitoring. At the district level there was a District Level Governing Committee for monitoring and supervision of the project and at the state level there was a State Steering Committee with representatives from concerned line departments and non-governmental organizations (NGOs). The State Steering Committee reviewed the project progress at half-yearly and annual intervals, and periodic field visits were undertaken by senior government and project officers.

Participatory monitoring and evaluation with community members was introduced to ensure stakeholder participation, with full involvement of GP-level teams, which include representatives from all stakeholder groups at GP level. The project placed special emphasis on 'social auditing', which ensured transparency, accountability and openness with full involvement of the communities. In keeping with these principles there was widespread disclosure of information through wall writings, awareness-generation campaigns, radio programmes and publications. Finally, the use of information technology (IT) was an integral part of the project from formulation, planning and database management to monitoring of the project's physical and financial progress and impact assessments. Management information system software was developed as an endeavour to use IT for management of information.

The global environment benefits (GEBs) of SLEM in Uttarakhand are largely associated with the following interventions at watershed, sub-watershed and micro-watershed scale: improving soil and water conservation, reducing erosion and siltation, sustainable use of forest resources (non-timber forest products), and introducing alternative energy sources. The GEBs from the interventions include forest protection (contributing to biodiversity conservation and sustainable flow of water resources), improvements in soil carbon and reductions in greenhouse gas emissions from deforestation. The participatory approach for planning and implementation of interventions with communities ensures that GEBs are generated in the context of addressing drivers of degradation.

Image: Patrizia Cocca/GEF

Improvements in land and water resources provide opportunities for income generation through high-value crops such as turmeric

As a result, overall functioning of the watershed ecosystem is at the heart of the SLEM in Uttarakhand, which also ensures long-term sustainability of the project outcomes.

The project also demonstrates how GEBs are linked directly to interventions for improving livelihoods and creating options at local level. For example, pine briquetting reduces dependency on fuelwood collection by women, which in turn reduces deforestation and greenhouse gas emissions. Furthermore, the reduced felling of trees for fuelwood protects the fragile slopes, contributes to biodiversity conservation and helps to increase flow of water. Therefore, socially and economically empowering communities by putting them at the centre of soil conservation has also led to the creation of global environmental benefits. With respect to the monitoring of GEBs, the focus was mainly on silt loading in drainage lines in representative streams using a turbidity meter and discharge and durability of flow for water sources based on time series measures, and climate change mitigation (carbon benefits were also determined from estimating emissions avoided through alternative energy intervention such as biogas, water mill and pine briquetting). Biodiversity benefits were much less established and derived only from vegetation surveys in the watershed and areas of forest protected by communities.

Knowledge activities were implemented at different levels and reflect the importance of linking scientific and traditional sources. Traditional knowledge was taken into account during the planning phase and fully harnessed by the implementation team through consultations with communities and surveys. Knowledge-sharing also flowed from the implementing team and NGOs involved in the project to the beneficiaries, with the dissemination of information and knowledge about new techniques and methodologies to harness and preserve water resources, increase and diversify agricultural productivity and create alternative livelihoods. A Farmer Field School was also established with the cooperation of one of the farmers as a hub for training and knowledge-sharing.

Lessons learned and best practices applied within the project were shared with other government agencies, partners and donors as a means of facilitating up-scaling beyond the project areas. The manuals, methodologies, community resource maps, watershed work plans, video documentaries and documentation of lessons learned from the project will be invaluable for informing the design of other IEM projects and for informing policy transformations to support the integrated approach at state and national level.

By mobilizing technical experts from various line departments in the state, the project presented opportunities for the alignment of interventions and outcomes with the investment priorities of those departments. This will ensure that the project outcomes are integrated into future plans of the line ministries, and that links between environment and development needs in the watersheds are maintained in the long term. A state government order introduced at end of the project reinforced this convergence, in addition to oversight of the project assets created during implementation. At the level of individual micro-watersheds, the communities assumed full ownership of all assets created to improve ecosystem functions. The communities also signed memoranda of understanding with the WMD for operation and maintenance of the assets.

Ancient soils reborn

Noel Oettlé, Environmental Monitoring Group, South Africa

The Bokkeveld Plateau is a remarkable heritage site that for many millennia was home to the San peoples of southern Africa, who left their timeless art on the walls of caves in the sandstone cliffs of the area. At the meeting point of the Fynbos and Succulent Karoo biomes, the vegetation and the soils of the plateau are remarkably diverse, reflecting evolutionary processes that are still ongoing. Some of the soils are sands first deposited in a rift valley that existed here over 300 million years ago, transformed into monumental rock formations over time. Others are shales deposited in ancient seas and by Gondwanan ice sheets.

The diverse soils of the Bokkeveld support the equally diverse crops of the communities that live here today: wheat on the loam soils derived from the shales, and rye, oats and rooibos tea on the infertile sandy soils amidst the sandstone massifs. Retaining a tenacious grip on the land in the more marginal parts of the area, where average rainfall may be as low as 150 mm per annum, a community of small-scale farmers cultivates rooibos (*Aspalathus linearis*) and also harvests the wild-growing plant to produce a remarkable tea, exported to many parts of the world.

Rooibos was first used by the first people of South Africa, the KhoiSan. In the twentieth century its remarkable health-giving properties led to its becoming more widely known, both within and beyond the borders of South Africa. Equipped with a combination of strategies, rooibos is well adapted to the hot, dry summers of the area: its tap roots can reach groundwater metres deep in the sandy soils, nodules on the roots provide nitrogen and cluster roots use the water from far down in the soil profile to utilize plant nutrients in the topsoil. These abilities enable rooibos to thrive in conditions that do not favour any other commercial agricultural crop. While rooibos promised a way out of poverty for the small-scale farmers of the Bokkeveld, discrimination and isolation meant that they were not able to benefit from their knowledge of the plant.

Following the end of Apartheid in 1994, the small-scale farmers of the Bokkeveld were able to access global markets for organic and Fairtrade products and thereby improve their livelihoods. In 2001 they formed the Heiveld Cooperative to process and market their rooibos products. The Heiveld has been certified organic since 2001, and in 2004 became the first rooibos producer in the world to become Fairtrade certified, illustrating the determination of its members to create a more equitable society.

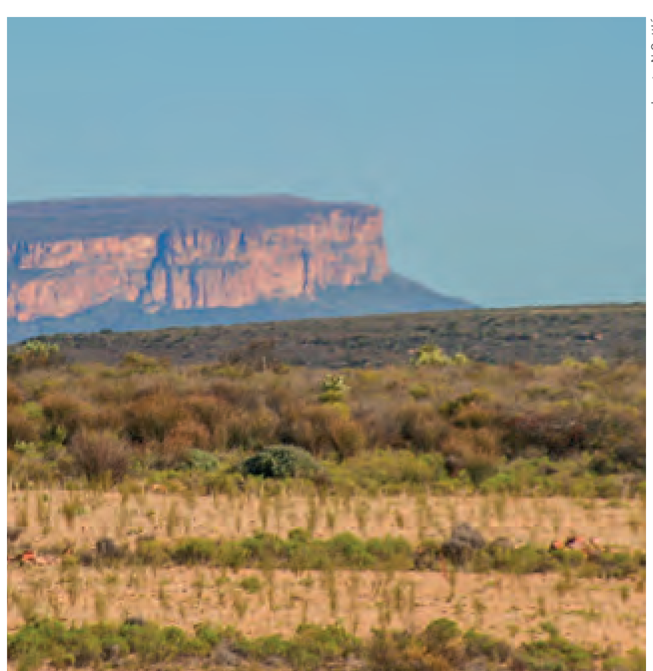


Image: N Oettlé

The Bokkeveld landscape, with cultivated rooibos tea in the foreground

Image: N Oettlé

Wild rooibos plants are only harvested every second year, and the biodiversity of the environment is maintained

Image: N Oettlé

Heiveld rooibos is available in markets on four continents

Certification and direct market access have enabled the members of the Heiveld Cooperative to improve their livelihoods on the basis of their unique agricultural products. However, on reflection they realized that much of the more fertile soil of the area had been washed and blown away in previous decades, and that the practice of clearing large lands was leaving them vulnerable to rapid erosion. Their vision of a sustainable future without poverty was under threat.

Inspired by their shared vision of a sustainable community using its resources wisely, farmers in the Suid Bokkeveld set their minds to using their knowledge effectively to prevent excessive soil erosion, and learning from others where appropriate. An inspiring visit to the degraded sands of the Kalahari Desert in 2004 contributed to the evolution of new techniques to combat erosion.

The farmers learned from one another, with the support of mentor farmers appointed by the cooperative. The most effective practices became incorporated in the Organic Management Plan of the cooperative, and have become standard practice among the farmers. These include retaining or establishing buffer strips of natural vegetation in the rooibos lands, contour ploughing, retaining all organic matter in the lands, not burning plant material, and making contour bunds to prevent soil erosion and promote infiltration of run-off water.

On the basis of the findings of participatory research, the members of the cooperative also follow strict guidelines for the sustainable harvesting of wild populations. This ensures not only the sustainable production, but also the conservation of the rich biodiversity of the Fynbos vegetation with which the wild rooibos cohabits. Soil carbon remains undisturbed.

The shale-derived soils of the Bokkeveld Plateau are highly vulnerable to water erosion, and because they are also the more fertile soils, large areas have been cleared of vegetation to sow wheat and other winter cereals and legumes. Since European settlement of the area in the mid-1700s, soils have been ploughed over, gradually reducing their organic matter, breaking down their structure and decimating populations of soil-dwelling organisms such as earthworms. In extensive areas denuded topsoil has been washed away, leaving only inhospitable, crusted subsoils exposed.

The wealth of all communities dwelling on the Bokkeveld Plateau has always depended on the soil. The nomadic Khoi communities who herded extensive flocks of sheep and herds of cattle did no harm to the soils, but after settlement European-style cultivation was introduced. As soils were exhausted, communities became impoverished. In the twentieth century the introduction of artificial fertilizers enabled farmers to produce crops on soils that were otherwise depleted, but the trend towards degradation continued. Soils once loose and friable became increasingly unyielding when dry, and treacherously unstable when wet.

The Avontuur farm in the wetter northern part of the Bokkeveld Plateau is a typical example of a piece of land that was overexploited for the production of dryland crops.

Image: N Oettlé

Hartwig Oktober demonstrates how a contour bund spreads the run-off water from rocky cliffs adjoining his rooibos lands

Injudicious ploughing of slopes and bottomlands in ways that contributed to excessive run-off and soil erosion removed thousands of tons of topsoil from relatively small areas. Once it had lost productivity, the land was abandoned and erosion carried on unchecked.

In 2008 the Avontuur property was purchased by the World Wide Fund for Nature to conserve its unique biodiversity. The property is home to more than 500 plant species, of which 34 are species of conservation concern and eight are not conserved anywhere else. Since 2009 the property has been leased to and managed by not-for-profit company Avontuur Sustainable Agriculture, which manages the property as a living landscape that is both productive yet conserved. The approach has been to restore the hydrological and ecological systems, particularly on the degraded lands; actively rehabilitate the most degraded areas; facilitate the gradual restoration of the indigenous flora on the old lands and enable the farm to produce sustainably.

Independent researchers identified the causes and extent of the degradation of the property, and recommended actions that could be taken to rectify the situation. On the basis of this a five-year programme of low-cost, replicable rehabilitation has been undertaken on the property.

More than 90 per cent of the land surface of the property is now stable and well conserved, and earthworm populations have rebounded on old plough lands. Nevertheless, some areas have been deeply scarred by injudicious land use, with erosion gullies up to 3 metres deep. The principles followed in restoring the land have been to keep as much rainwater as possible in the landscape (preferably in the soil), disperse and weaken the impact of raindrops and run-off water, establish or retain vegetative cover, create favourable conditions for earthworms and soil organisms, prevent the loss of topsoil by water and wind erosion and use ground cover to protect the soil and create favourable conditions for the germination of seed.

The approach has been to provide opportunities for vegetation to re-establish in degraded areas. Run-off water has been filtered so as to retain soil, seed and organic matter, and seed collected on the property has been reintroduced to bare areas.

The unique nature of the soil/climate/vegetation nexus on Avontuur is such that it was necessary to innovate and

Images: N Oettlé

The impact of gully rehabilitation over three years (left to right)

observe which approaches would prove to be most effective and economically feasible. Repeat photography has been used to visually record the impacts over time, and to enable comparison of the different interventions.

In practice the approach followed on Avontuur has been to first analyse the problem and differentiate between the causes and effects of disturbances and degradation. The focus is then on the causes: addressing the effects without remediating the causes will absorb resources without lasting impact. Wherever possible interventions are designed to start at the top of the affected catchment and work progressively downslope. We have sought to work with the forces of nature so that recovery becomes self-sustaining, and as far as possible to use only biodegradable materials. These have primarily been inexpensive local materials such as wood harvested from alien invasive trees, abundant shrubs (the toxic and invasive *Galenia africana* and the unpalatable *Elytropappus rhinocerotis*) and sawdust from local sawmills. In addition use has been made of jute geotextile. These materials have been used in various combinations for filtering run-off water in gullies, and for re-establishing cover on denuded soil surfaces.

A number of approaches have been tested to determine cost-effective ways of re-establishing vegetation on denuded surfaces. These have included trials in which the soil surface was broken and fertile topsoil, sawdust and manure were mixed in. In some cases seeds collected on the property were sown into the matrix. Geotextile was used to stabilize soil surfaces and hold moisture and wind-blown soil particles. Encouraging results have been achieved.

The work on Avontuur has generated much interest among the small-scale farming community from the southern part of the Bokkeveld Plateau, some of whom were employed in the off-season to undertake rehabilitation work on the property. A number of interactive workshops have been held, in the course of which participants were introduced to the approach followed on Avontuur, and then asked to apply the approach in practice in a small catchment that had not previously been rehabilitated. Working in small teams, the participants analysed the problem, identified the causes and designed and implemented measures to address these, using materials supplied to them. The results of these training interventions can be seen elsewhere on the Bokkeveld Plateau, where farmers have applied them in practice on degraded soils derived from shale.

Apart from the farming community, the results on Avontuur have been shared with scholars from the local school, and with staff of conservation agencies and non-governmental organizations. All have left their mark on the landscape, and are able to return and see how their efforts and the work of others have affected the landscape. In a rapidly changing world Avontuur offers the opportunity to witness the slower processes of regeneration and recreation of nature's self-sustaining ecosystems.

Image: N Oettlé

Succulent seedlings establish on previously bare surfaces covered with geotextile

Environmental education and awareness programmes in the United Arab Emirates

Habiba Al Marashi, Chairperson, Emirates Environmental Group

The United Arab Emirates (UAE) is situated in the arid west continent desert belt of the south-east region of the Arabian Peninsula in South-West Asia.[1] Its environmental conditions are highly sensitive due to the delicate balance between various factors of an arid ecosystem such as water, soil, climate, vegetation, natural resources and biodiversity.[2] To add to this, UAE has a population close to 9 million.[3] In order to sustain such a large population in a desert environment, large amounts of energy, water and land are required. Ever since the discovery of oil, UAE has invested in large-scale developments and has attracted many investors, which is one of the main reasons for its rising population. To satisfy the needs of the increasing resident population and tourists, millions of Dirhams have been invested in building houses, power plants, desalination plants, shopping malls, recreational facilities and so on. This has led to the release of large amounts of greenhouse gases, loss and degradation of land and an exponential increase in the amount of CO_2 emissions among others.

While there are many environmental challenges to overcome, some of the most important issues facing UAE today are desertification and land degradation and the basic lack of fresh natural water sources which is compensated for by desalinated water which comes at great costs. According to MICAD (2015), "Desertification includes land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities." The United Nations Environment Programme (UNEP)[4] states that about 6 million hectares are irretrievably lost or degraded by desertification each year and about 135 million people are severely affected by this process. This will invariably result in less productive land and in turn will lead to poverty and unsustainable development.

To further highlight the importance of this issue the United Nations started the United Nations Convention to Combat Desertification in 1994 and declared 17 June as the World day to Combat Desertification. While this has alerted the world's governments to the importance of combating desertification, it is essential to inform and involve the public and work at the grass-roots level. UAE has organized many events in trying to combat desertification, involving activities for the integrated development of land in the arid, semi-arid and sub-humid areas for sustainable development. The focus is to reduce further land degradation, rehabilitate the areas and reclaim these lands.

Images: EEG

For Our Emirates — We Plant is a unique campaign that combines waste recycling with tree planting initiatives

The total number of trees planted per year under 'For Our Emirates — We Plant'

Year	Number of trees planted per year	Total number of trees planted
2007	1,608,777	1,608,777
2008	5,444	1,614,221
2009	316	1,614,537
2010	476,703	2,091,240
2011	419	2,091,659
2012	468	2,092,127
2013	365	2,092,492
2014	685	2,093,177

Source: EEG

Annual CO_2 mitigation for the various campaigns under 'For Our Emirates — We Plant'

Year	Project	Participants	Trees	Million metric tons of carbon dioxide equivalent
2010	OROC	350	250	2,063,845
2011	NRP	28	29	7,370,875
	OROC	97	131	
2012	YCFT	69	15	14,682,783
	NRP	104	124	
	OROC	76	134	
2013	YCFT	43	27	13,031,707
	NRP	125	184	
	OROC	53	104	
2014	YCFT	49	18	17,789,314
	NRP	177	255	
	OROC	90	157	

Source: EEG

Many government and non-government organizations are working around the clock to combat the pressing environmental issues that face the nation. To achieve this, the best solutions are to create awareness and educate the public to manage their resource consumption and the resultant waste production, energy and water consumption. It is imperative to change the mind-set and attitude of the community towards the environment.

The Emirates Environmental Group (EEG) is a professional working group, dedicated to working towards the preservation of the environment. Its work primarily focuses on sustainability and mobilizing the masses in the country, region and beyond. EEG offers a wide range of programmes which are divided into broad sectors such as education, waste management and corporate activities.

As interest in preserving and protecting the environment becomes more apparent, the number of organizations and educational institutions willing to get involved is growing.

Images: EEG

Organizations, institutions and families collect aluminium cans to win an opportunity to plant an indigenous tree under their names

In line with EEG's core objectives, and to tackle the grave environmental issues of desertification and encourage community participation, EEG started various waste management initiatives which were cleverly combined with initiatives to plant indigenous trees across UAE and create sustainable green spaces. The idea of the projects is to provide a platform for the community to recycle their waste and reward their efforts by planting a tree under the entity's (company, academic institution or family) name in one of the Emirates, thus giving back to the environment.

Due to seamless methodology of outreach, collection and disposal, EEG hosts eight recycling campaigns which have been running for the last two decades. These include aluminium cans, glass, paper, plastic, toners and cartridges, batteries, mobiles, e-waste and beverage carton containers. EEG's waste management programme has been successful due to the combined support of the community, the Government and various recycling factories across UAE.

With its aim to achieve zero recyclable waste going to landfills, EEG reaches out to the community — public and private sectors, educational institutions and families — to encourage them and instil the culture of recycling in their daily lives. It is no easy task to educate, motivate and engage people in the act of recycling as a continuous and long-term practice, but since inception in 1991, EEG has made considerable progress towards that end.

EEG realizes that planting trees is key to protecting and preserving the fragile ecological balance. Under the aegis of UNEP's Billion Tree Campaign, EEG has planted over 2,093,177 trees across the Emirates with the active participation of public and private organizations, academic institutions and families. There follow some examples of EEG's prime waste management activities which were introduced with tree planting initiatives in mind.

For Our Emirates — We Plant is a unique, first-of-its-kind project that combines EEG's diverse waste management programmes with its simple, practical yet innovative tree planting initiatives. Under this banner, EEG planted 685 indigenous trees across UAE in 2014 with participation from public and private organizations, academic institutions and families. These trees on maturity (5-7 years) will save 2.57 metric tons of CO_2.

There are four innovative channels through which participants can plant trees in their names, the first three of which form part of EEG's waste management activities:

- Your Can for a Tree (YCFT) initiative (April-June)
- Neighbourhood Recycling Project (NRP) (June-September)
- One Root One Communi-Tree (OROC) initiative (July-November)
- Together We Plant (January-May and September-December).

The YCFT initiative has been hosted during April to June each year since 2012. Public and private organizations, academic institutions and families across UAE are encouraged to collect aluminium cans to win an opportunity to plant an indigenous tree under their names during EEG's Tree Planting Ceremony held in December each year. The initiative creates awareness among the adult population while emphasizing the importance of recycling aluminium cans. It also helps combat desertification and degradation of land by planting more trees and deviating waste from landfills.

Images: EEG

Under the Planting a Greener Future initiative, tree planting events were held in government schools across UAE

NRP is one of EEG's most sought-after summer programmes and is specifically targeted towards the student community. The programme runs from June to September and gives students an opportunity to involve the residents of their communities to start their own recycling initiative under EEG's guidance. Participants are required to involve 20 other families in the project. Through this activity, students collect one or all of the eight main recyclable materials within a span of two weeks.

Since its inception in 2011, NRP has attracted an increasing number of participants. From just 28 participants in 2011, the summer programme has steeply risen to 177 participants in 2014 with a total outreach of over 10,000 individuals. The increase in participants has also enabled EEG to collect more recyclables over the years. Since inception EEG has managed to mitigate 722 metric tonnes of CO_2 emissions, save 4,622 million BTU of energy and 815 m^3 of landfill space, and save 5,114 trees from being felled.

As well as reducing the amount of waste going into landfill, the collecting and recycling activities create awareness among the students and residential communities. Furthermore, recycling prevents unsustainable use of land by landfilling these otherwise useful items.

The OROC programme, which began in 2010, takes place in September, October and November each year and is another endeavour to increase sustainable green urban spaces through tree planting initiatives that are interlinked with waste management. Participating organizations are requested to send in recyclable items to EEG. Through this campaign EEG has planted trees across five Emirates over the course of five years and aims to plant in the remaining two Emirates in the years to come.

Since inception EEG has managed to mitigate 2,532 metric tons of CO_2 emissions, saved 18,472 million BTU of energy, saved 3,396 m^3 of landfill space and saved 12,724 trees from being felled. On accomplishing the goals, EEG has planted a total of 1,430 trees over five years. The trees act as a carbon sink and prevent land degradation, which in turn helps combat desertification.

EEG believes that corporations have a moral obligation and duty to protect and preserve the forests of the globe. The actions of a company have vast effects, whether positive or negative, on the environment. Education and action are the most proficient ways to achieve this. Towards that end, in 2008 EEG started the Together We Plant campaign.

Hosted under the umbrella of the For Our Emirates — We Plant initiative, Together We Plant targets two spokes: spreading awareness and acting on the gained knowledge. The campaign aims at hosting tree planting initiatives by corporations across schools in UAE. In that way, companies add to the sustainable green patch by planting trees in schools, helping to educate the youth about their importance and how a simple act can have a lasting impression on the environment.

2014 saw a number of tree planting initiatives under the Together We Plant campaign. With the cooperation of organizations and educational institutions across UAE, EEG planted a total of 245 indigenous trees which will help mitigate 1.45 metric tons of CO_2 upon maturity.

Such tree planting initiatives are of vital significance in educating the youth about the importance of trees and the various benefits which trees provide. The total number of trees planted to date through EEG's various waste management and

Participants at the Clean Up UAE event

tree planting initiatives is 2,093,177, which contributes to accumulative CO_2 mitigation of 17,789 metric tons.

For the corporations involved, these activities are an opportunity to move towards sustainability and set an example to the mass of organizations in this country. Bonds are made between generations of participants as they come together towards this goal. This activity not only promotes volunteerism, but it also promotes civic responsibility.

EEG's efforts have been aimed at helping the regional environment as a whole. The Arab region is one of the harshest terrains in the world and the injection of durable indigenous trees in the environment goes a long way in maintaining and sustaining an ecological balance. As a result of such initiatives, the quality of air improves and the planted trees contribute to creating healthier outdoor spaces and restoring urban habitats for wildlife, thus advancing global reforestation and intercultural awareness.

Believing that public-private partnerships shape the future of the country towards a more sustainable path, in 2014 EEG signed a contract with McDonald's UAE to host several tree planting events across UAE in various government schools. The initiative was named Planting a Greener Future and was planned to be hosted between April 2014 and April 2015. The initiative was created to develop three major areas — social growth, economic growth and environmental growth. It educates the youth on these three fronts and inspires them to work towards a means to achieve sustainable development.

Under this initiative seven government schools were selected across the Emirates and 50 indigenous trees were planted in each school. A total of 350 trees were plants by the end of this initiative in April 2015. The initiative created awareness among students and schools staff, contributed to mitigating UAE's carbon footprint and furthermore helped combat desertification in UAE.

The advantages and benefits of recycling are simply too many to ignore which is why EEG dedicates so much of its time and workforce in advocating the practice and asking the UAE community to join in this needful act. This programme keeps striding forward, expanding its outreach with every year and urging all members of society to join hands in making recycling a part of their cultural fabric, not something viewed as a luxury.

It is a well understood fact that the global community should take all the measures they can to prevent desertification and land degradation. Arid ecosystems within UAE are suffering serious desertification processes.[5] In order to combat these, more waste management and tree planting activities through community engagement need to be carried out.

Living Land

Disaster risk and two recent episodes in Japan

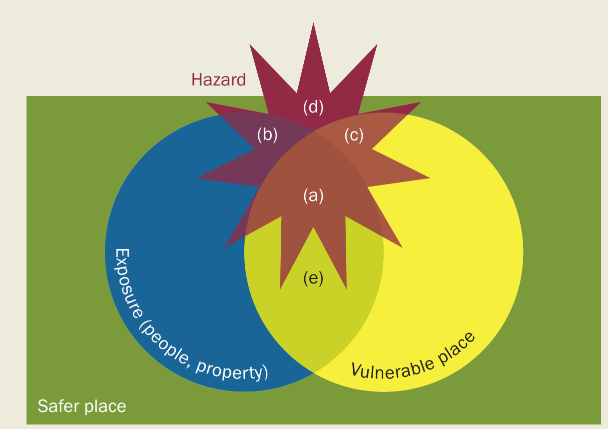
Kaoru Takara, Disaster Prevention Research Institute, Kyoto University, Japan

The following equation is often used to conceptually explain disaster risk: DR = H x E x V. In this equation DR stands for disaster risk, H is hazard, E is exposure and V is vulnerability. Hazard is a natural phenomenon such as earthquake, volcano eruption, landslide, storm, flood and heatwave. Exposure is defined as something to be affected by natural disasters, such as people and property. Vulnerability is defined as a condition resulting from physical, environmental, social or economic factors or processes, which increases the susceptibility of people or a community to the impact of a hazard.

Imagine a rock island in an ocean with a tsunami approaching it. If the rock island has no population and property, there will be no disaster risk, because exposure (people and property) is zero. In general, disaster risk is defined as an expectation value of losses (such as deaths, injuries and property) that would be caused by a hazard. Growing exposure and vulnerability increases the number of natural disasters and the levels of loss.

Living land is a place where people and properties are exposed to natural hazards. It should be protected from hazards by countermeasures such as infrastructures, specifically flood control facilities and anti-earthquake buildings. The countermeasures can reduce the vulnerability of the society or living land to natural hazards, or reduce exposure by adopting a policy of land use restriction.

Figure 1: A conceptual explanation of disaster risk, hazard, exposure and vulnerability



Source: Kaoru Takara

Figure 1 explains disaster risk in living land, in which the safer place is coloured green and the vulnerable place is indicated by a yellow portion. The blue portion indicates exposure; people and properties are located in both the safer and vulnerable places. When a hazard attacks this living land, there will be different disaster risk situations as indicated in the diagram:

(a) serious disaster damage is possible because people and properties are exposed by the hazard in the vulnerable place
(b) people and properties are affected by the hazard but there is no damage because they are located in the safer place
(c) the hazard hits the vulnerable place but there is no damage because there are no people or properties there
(d) no damage because there is no exposures in the safer place
(e) risky but no damage; exposures in the vulnerable place are about to be hit by the hazard, but it does not reach them.

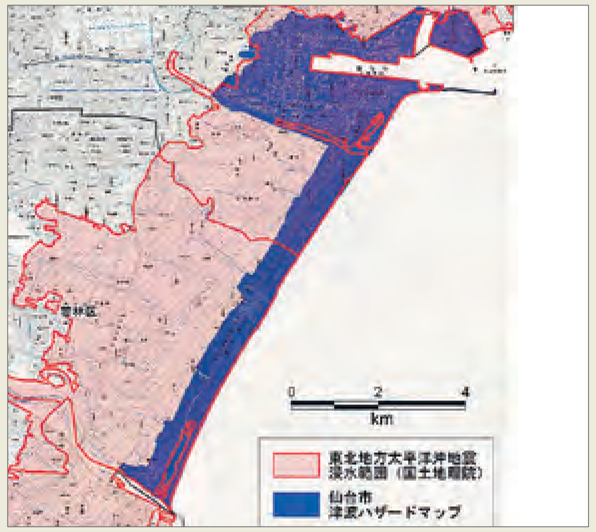
Readers may easily recognize that if vulnerability becomes bigger then disaster risk becomes bigger. Likewise, the more exposures, the more disaster risk. Countermeasures should make the area (a) smaller, namely reducing vulnerability by protecting the vulnerable place and decreasing exposures by relocating people and properties to the safer place.

Earthquake and tsunami in Sendai

Sendai is the largest city in the Tohoku region of Japan and the capital city of Miyagi Prefecture. A tsunami hazard map in the Sendai city area (786 km^2 with 1.04 million population), as seen in Figure 2, shows the areas where tsunami waves had been assumed to come up (the purple coloured portion). Caused by the Great East Japan Earthquake on 11 March 2011, the actual tsunami waves came up to the orange coloured portion and killed many people there. This suggests a danger of hazard maps. People who lived in the orange coloured areas may have misunderstood that there was no risk of tsunami. Usually hazard maps for floods and tsunamis are based on simulation results obtained from assumed 100-year events. In March 2011, however, the tsunami event was much larger than the envisioned tsunami. The tsunami hazard map was not useful for such a tremendous tsunami event.

Sendai city revised the tsunami hazard map (Figure 3), which shows the Level 1 tsunami area (orange portion) and Level 2 tsunami area (yellow portion). Two major roads have been reconstructed in order to protect against tsunamis: one is called the Shiogama-Watari Line (the 42.1 km long Prefectural Road

Figure 2: The tsunami hazard map for Sendai before 11 March 2011



Source: Geographical Survey Institute of Japan

No. 10, between Shiogama city and Watari town), managed by Miyagi Prefecture. The other is the Sendai-Tobu Road (the 24.8 km long highway, a part of National Road No. 6), managed by the Japanese central Government. It is interesting to know that these two roads are located on the borders of assumed tsunami events. The Shiogama-Watari Line (thick orange coloured solid line) forms a border between the Level 1 and Level 2 areas, on a 6 m bank, which can be a tsunami barrier for Level 2 areas. The Sendai-Tobu highway (thick blue coloured solid line) forms a part of the upper border of the Level 2 area. Combined with these two roads, Sendai city has newly revised its tsunami hazard map. These road banks can also be used for evacuation during tsunami events.

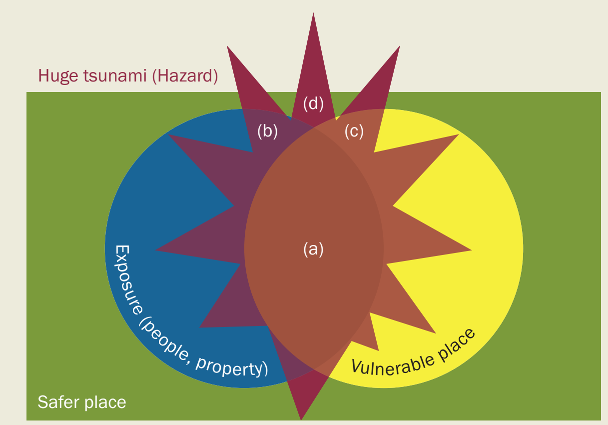
The conceptual diagram in Figure 1 can be recognized in Figure 4 for the 2011 tsunami hazard, which was too big for people to escape from it:

(a) almost all exposures (people and properties) in the vulnerable place were completely damaged
(b) exposures were assumed to be safe from the tsunami because they were in safer places
(c) vulnerable places were damaged by liquefaction or land subsidence, which affected agricultural lands (mainly rice paddy fields) through salt water from the sea
(d) safer places were also damaged because the tsunami run-up height at some locations in the middle and upstream of rivers was 40 m high.

Figure 3: The tsunami hazard map for Sendai after 11 March 2011

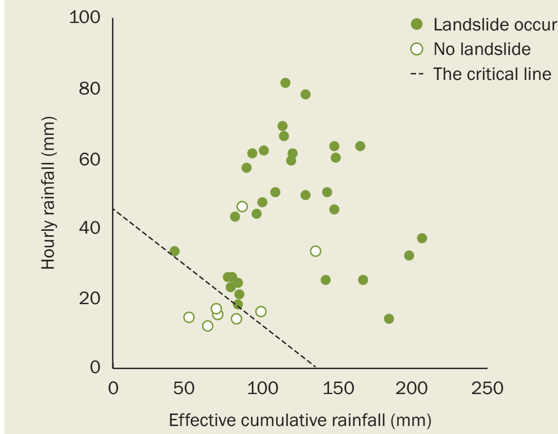
Source: Sendai City home page

Figure 4: A conceptual explanation of disaster risk, hazard, exposure and vulnerability (interpretation for a huge tsunami in Sendai)



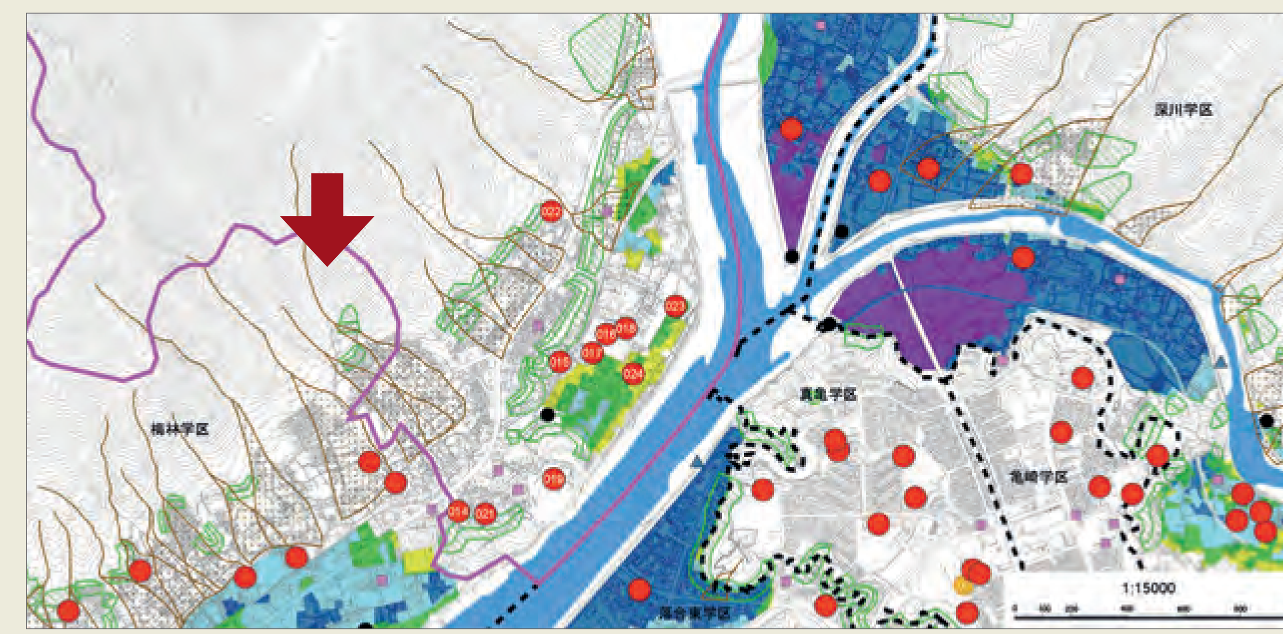
Source: Kaoru Takara

Figure 5: Landslide occurrence around Hiroshima city in June 1999



Source: Ushiyama, Ohido and Takara, 2001

Figure 6: Part of the flood hazard map of the Yagi District in Hiroshima



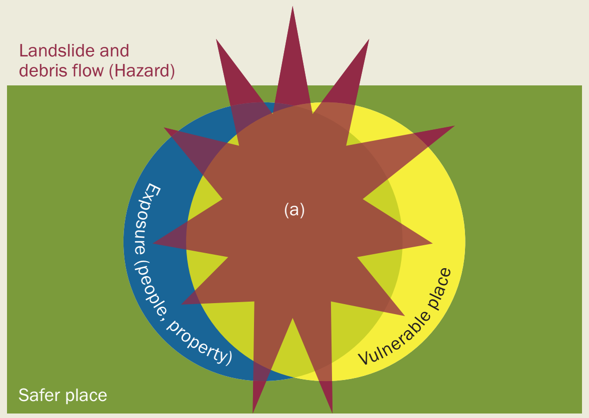
Source: Hiroshima City home page. Note: The red arrow indicates the location of the second photo overleaf

Landslide and debris flow in Hiroshima

Hiroshima city was damaged by two landslide and debris flow events in 1999 and 2014. On 29 June 1999, a severe storm event (50-200 mm during five days before the event) caused a landslide and debris flow disaster that killed 32 people and destroyed 101 houses mainly in Hiroshima Prefecture. At that time we investigated how landslide and debris flow events took place in terms of rainfall characteristics and estimated the critical line for the Hiroshima area, using effective cumulative rainfall and hourly rainfall that triggered landslides (Figure 5).

Immediately after this event, the Japanese central Government established the Act on Promotion of Sediment Disaster Countermeasures for Sediment Disaster Prone Areas, which encouraged local governments to disseminate information about possible sediment disasters caused by heavy rainfall-induced landslides and debris flows. Figure 6 is a part of the flood hazard map of the Yagi District in Hiroshima.

Figure 7: A conceptual explanation of disaster risk, hazard, exposure and vulnerability (interpretation for landslide and debris flow in Hiroshima)



Source: Kaoru Takara

Note that this flood hazard map also indicates sediment disaster prone areas delineated by brown coloured lines. Note also that the areas include many houses. Residential areas have been developed even in such vulnerable places.

Fifteen years later, on 19-20 August 2014, a similar event took place again in Hiroshima, killing 74 people and destroying 133 houses. Geological and meteorological conditions in this area are characterized as weathered granite that can easily become landslides and flow down as debris, and more than 200 mm rainfall during three hours. The photos are typical snapshots of sediment disasters in Asa-Minami-Ku, Hiroshima city. They show that residential areas were still in vulnerable places and many houses were seriously damaged. The flood hazard map in Figure 6 indicates the danger of sediment disaster. Readers can easily identify the location of the second photo (below), indicated by a red arrow.

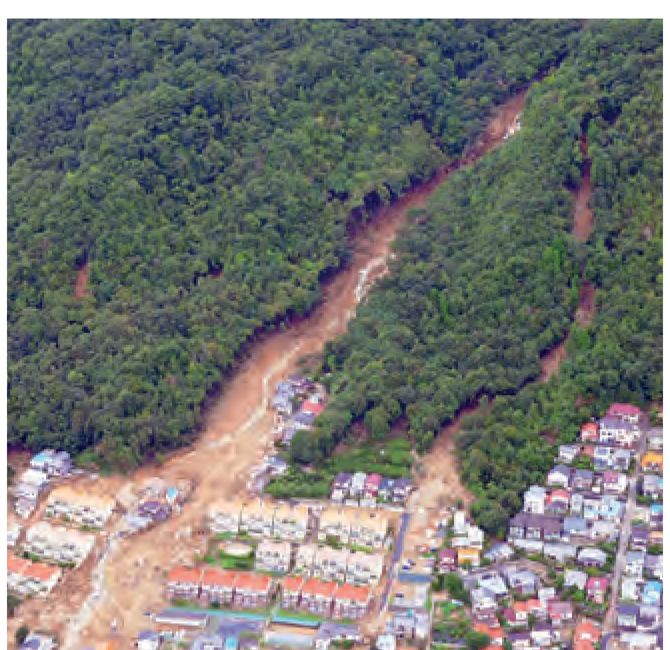
The conceptual diagram in Figure 1 can be recognized in Figure 7 for the 2015 landslide and debris flow hazard, which was caused by very localized intensive rainstorm. Almost all exposures (people and properties) were in vulnerable places. Thus, two circles (exposures and vulnerable place) are very much overlapped as shown in part (a) in Figure 7.

In addition to such a situation, it should be noted that rainstorms hit the area after midnight when all the people were sleeping. The timing of the event also makes the disaster more serious. Holidays (Saturdays and Sundays) are also weak points in terms of public services for emergency disaster management.

Lessons learned

Living land should be considered from the viewpoints of disaster prevention and mitigation. Hazard maps give us useful information about disaster risk in our society; but we should also be careful of the conditions in which hazard maps are made. Disaster risk, depending on hazard, exposure and vulnerability, also depends on physiographical conditions: location, geology, meteorology and hydrology, as well as the time of day or of the week and the season of the year.

In the discussion above, the author has denoted vulnerability mainly in terms of vulnerable place; however, vulnerability also can be applied to people and societies. People and societies who are well educated regarding hazards and disasters are less vulnerable and can adapt to emergency situations in their daily life.



Images: Masahiro Chigira, Professor, DPRI, Kyoto University

Sediment disasters in Hiroshima; residential areas were in vulnerable places and many houses were seriously damaged (NB. location of right hand picture can be identified by the red arrow within Figure 6)

Australia prepares for a cycle of extreme droughts

Professor Craig Simmons, Director, National Centre for Groundwater Research and Training, Australia

Climate change projections do not augur well for Australia, with forecasts of more severe droughts for a sun-baked nation where water is already a precious commodity.

The oldest continental landmass on Earth is also the driest after Antarctica. It is characterized by a cycle of droughts which parch the heavily weathered landscape eroded over millions of years. About a third of the continent has so little rain that it is effectively desert. Just over two-thirds of mainland Australia receives less than 500 millimetres of rain a year and is classified as arid or semi-arid. As the planet warms, weather records across Australia are tumbling, with hotter, drier conditions over much of central and southern Australia. Climate scientists are worried that even less rain will fall in future in the areas where it is needed most.

The so-called millennium drought which gripped south-west Western Australia, south-east South Australia, Victoria and northern Tasmania was described by the Bureau of Meteorology (BoM) as without historical precedent. Temperatures were about 1 degree Celsius hotter than previously recorded droughts and the duration — from 1995 until 2012 in some areas — was the longest ever known.

Image: istock.com/BenGoode

Various initiatives have been instigated to gauge Australia's current and future water use and inform sustainable planning and management

Drought in Australia coincides with the cyclical weather pattern El Niño when a band of warm ocean water rises off the coast of South America and expands westward across the Pacific Ocean to displace colder waters. This is associated with decreased rainfall for Australia, very hot daytime temperatures and earlier, more extreme fire seasons.

Nine of the ten driest winter-spring periods on record for eastern Australia have occurred during El Niño years. In the Murray-Darling basin — the so-called food bowl of Australia — winter-spring rainfall during El Niño events since 1900 averaged 28 per cent lower than the long-term average.

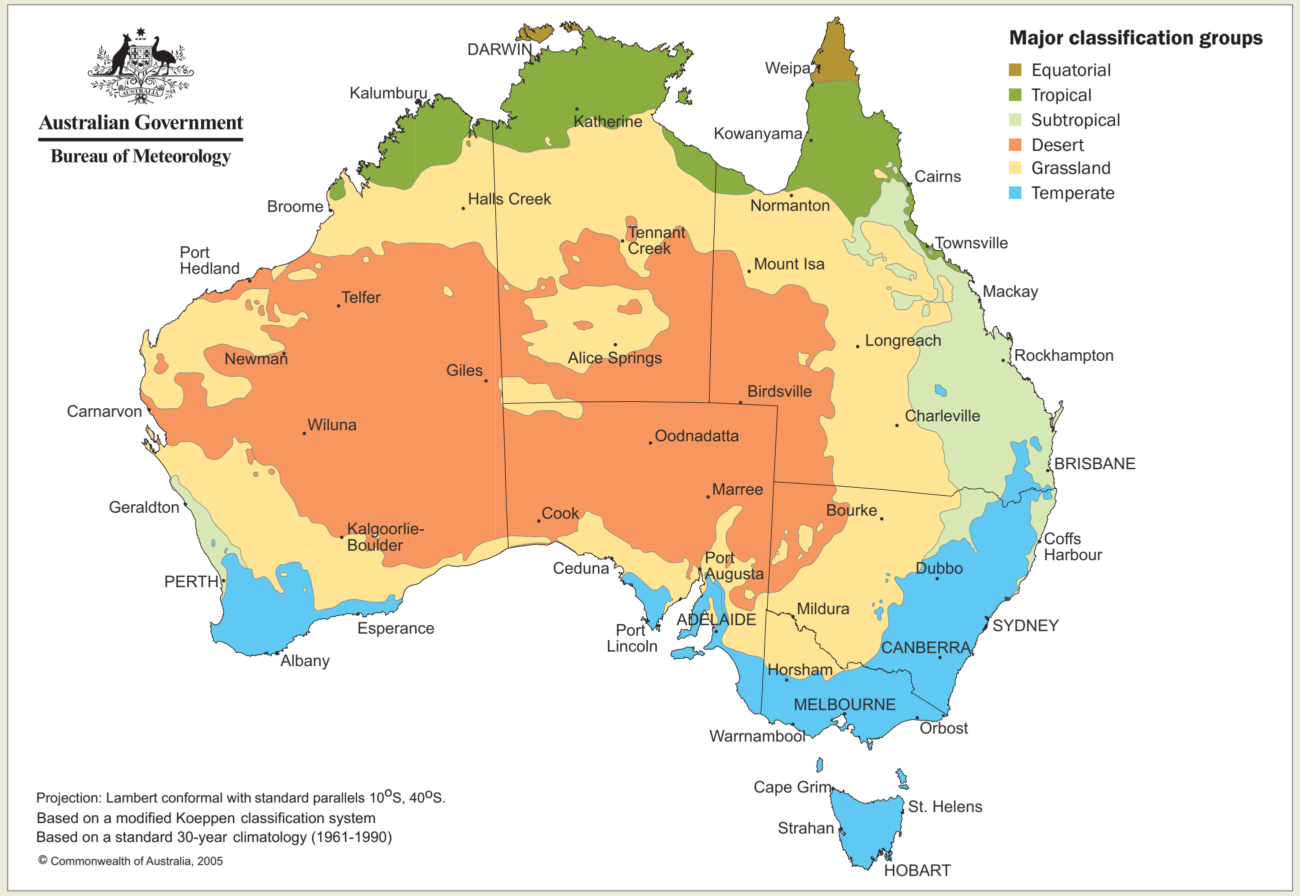
The opposite phase of El Niño is La Niña when Australia faces a higher risk of flooding, lower temperatures and more tropical cyclones. Successive La Niña events during 2010-12 were associated with record rainfall over much of Australia and some of the biggest floods in living memory.

As climate change takes hold, more extreme versions of the El Niño Southern Oscillation cyclical weather pattern are expected to result in more frequent flooding and drought. Modelling of weather data by scientists at BoM and the national science agency CSIRO shows that under projected global warming scenarios Australia can expect 'super' El Niños that are more intense, and that they are likely to occur twice as often.

Their fears are already being realized. Just three years after the official end of the millennium drought in 2012, BoM declared a major new El Niño event. By mid-2015 Queensland was in the grip of an unprecedented drought covering a record 80 per cent of the state. Rainfall was also lower across large tracts of southern Australia and western Tasmania.

Such extreme weather behaviour is in line with the latest dire predictions from the United Nations Intergovernmental Panel on Climate Change (IPCC). In its 2014 report, IPCC said Australia could expect more frequent flooding in some areas and severe drying in the Murray-Darling basin and in south-western and south-eastern Australia. These are key agricultural regions in arid and semi-arid areas and, if the worst-case scenario is realized, production could fall by a disturbing 40 per cent.

Australia's climate zones: just over two-thirds of mainland Australia is classified as arid or semi-arid



Source: BoM

As the land dries and these regions become vulnerable to increased desertification, salinity becomes an even greater issue. Since European settlement, native land clearance, farming and irrigation have created an imbalance in the hydrological cycle in many agricultural areas, with rising groundwater resulting in severe dryland salinity.

In 2000, the Australian Bureau of Statistics (ABS) estimated that 5.7 million hectares of Australia was at high risk of developing salinity. This could triple to about 17 million hectares by 2050, seriously impacting agriculture, ecosystems and infrastructure.

The vital role of groundwater in the Australian economy will become more critical as surface water becomes scarcer in arid and semi-arid regions. Its importance was highlighted in a 2014 report commissioned by the National Centre for Groundwater Research and Training (NCGRT) in the first attempt to quantify its value.

The report, by Deloitte Access Economics, found that groundwater helps earn the nation a conservatively estimated $A34 billion every year. It estimated annual groundwater extraction at approximately 3,500 gigalitres, with 58 per cent used to grow food, 12 per cent for mining and 17 per cent used in manufacturing. About 13 per cent is used for water supplies in regional and metropolitan communities.

Pressure on Australia's groundwater reserves is also intensifying as the population increases. Australia has the fastest population growth of any major developed country due to immigration — and it shows no signs of slowing. Currently standing at 24 million, ABS says Australia's population could double to 48 million people by 2061.

The key question that needs answering now is how such rapid growth, combined with the uncertainty of climate change, will impact on our water systems and the countless industrial, agricultural, community and environmental users that rely on them. There are no large water sources still to be found in Australia, yet water use is expected to at least double by the middle of this century.

Managing the cumulative environmental impact of multiple actions on the baseflow of rivers, springs, wetlands and other groundwater-dependent ecosystems is a huge challenge. The task becomes even more complex when a growing population and extreme weather patterns are added to the equation.

An estimate widely accepted by scientists and policymakers is that groundwater directly supplies more than

Managing the Murray-Darling basin

The Murray-Darling basin is the agricultural jewel in Australia's vast, mostly nutrient-poor land mass. Stretching over 1.06 million square kilometres — 14 per cent of Australia — it delivers 40 per cent of the nation's total agricultural value worth about $A15 billion a year.

While it covers a wide range of climatic and natural environments, most of the basin is classified as arid or semi-arid. Since the 1900s extraction and diversion of water has fuelled industrial growth, but at a cost. Considerable pressure has been placed on the natural environment resulting in a deterioration in the health of the river system. As such, it is extremely vulnerable to climate change.

As concern over its future mounted at the height of the millennium drought, CSIRO was commissioned to oversee the largest ever technical study of the basin. The 2007/08 Murray-Darling Basin Sustainable Yields Project found that total flow at the Murray mouth had been reduced by 61 per cent, causing it to cease flowing into the sea 40 per cent of the time, compared to just 1 per cent before water resource development. Heavy groundwater use in the basin was also found to be unsustainable in seven out of 20 irrigated areas.

The Murray-Darling Basin Authority set out to address these concerns in its historic national basin plan which was signed into law in 2012. The plan aims to return a minimum 2,750 gigalitres a year back to the river system and for the first time introduces a limit on groundwater use across the basin with consistent management arrangements for all groundwater resources.

Total groundwater sustainable diversion limits have been set at 3,334 gigalitres a year, which includes a potential 984-gigalitre increase in the annual extraction limit from areas with relatively low levels of development.


Image: istock.com/muchemistry

There is no room for complacency if Australia is to protect its water resources and resist further desertification

30 per cent of Australia's consumptive use — and more than double this in Western Australia. But as surface water supplies run critically low during drought, groundwater use increases significantly.

While groundwater has vast potential and is recognized as a major strategic asset, nobody has a clear idea of its exact size, how much recharge is occurring or how long it takes to recharge. The timescales involved in both recharge and groundwater flow can be extremely long, stretching over hundreds of years to hundreds of thousands of years.

For Australia's desert and arid regions, underground resources such as the Great Artesian Basin (GAB) provide the only reliable source of fresh water. GAB is one of the largest and deepest artesian basins in the world and stretches over 1.7 million square kilometres. But as the demand for water grows, the worry is that drawdowns on GAB and other essential water resources across Australia may be irreversible.

To help inform sustainable planning and management, the Australian Government directed CSIRO to undertake robust scientific estimates of current and future water use in most of the country's major water systems. Between 2007 and 2010 sustainable yields projects were conducted in four key regions: the Murray-Darling basin, northern Australia, Tasmania and south-west Western Australia.

CSIRO scientists examined the likely changes to surface and groundwater availability during climate change, including various drying and wetting climate scenarios. It was a comprehensive scientific assessment of water yields and provided an important analytical framework for national water policy decisions.

Various other important initiatives have been instigated over the past decade, including the national Groundwater Action Plan to help explore knowledge gaps through extensive hydrogeological investigations, and groundwater capacity-building through the establishment of the NCGRT. The development of national modelling guidelines was another key part of a coordinated effort to help better understand our groundwater systems.

It is no coincidence that all these initiatives were put into place during the brutal millennium drought. This was a time when floodplains dried and cracked and farmers watched their land transformed into dustbowls. The Murray-Darling basin dropped to just 25 per cent of capacity, placing huge stress on ecosystems and killing entire forests.

Major cities faced the unthinkable prospect of water supplies running out. This prompted massive capital investment in large-scale desalination plants around the nation — plants that were soon idle as the drought broke to be replaced by floods.

As the crisis eased so did the urgency for greater knowledge and more effective management systems for sustainable water use in future droughts. Policy imperatives and funding mirrored the peaks, ebbs and flows of our extreme weather.

The National Water Commission, established during the millennium drought, closed in December 2014. But that same summer more than 150 long-standing weather records were broken across Australia with new higher temperatures and longer dry spells. There is clearly no room for complacency in Australia if we are to protect our water resources and resist further desertification.

Research and achievements in combating land degradation and desertification for sustainable rural development

Satoshi Tobita, Takeshi Matsumoto, Yukio Okuda, Kenta Ikazaki and Akinori Oshibe,
Japan International Research Center for Agricultural Sciences

The Japan International Research Center for Agricultural Sciences (JIRCAS) is a national research and development agency of Japan which plays a role in international collaboration in the field of agriculture, forestry and fisheries research. One of its research directions is the development of agricultural technologies based on sustainable management of the environment and natural resources in developing regions.

Under this direction, several projects have been implemented to fight land degradation and desertification. There follow some examples of JIRCAS's achievements in Mongolia, Uzbekistan and Niger, which are the highest priority sites in the world in terms of land management.

Pasture-use planning in Mongolia

Nomadism thrives in Mongolia through the utilization of its vast natural grasslands, which account for approximately 72 per cent of its land area. Nomads usually graze their livestock while moving from pasture to pasture seasonally several times a year. It is said that Mongolia's transition from planned economy to market economy in the early 1990s has led unemployed people to become nomads and caused a rapid increase in livestock herd size due to the privatization and liberalization of livestock ownership. Furthermore, grasslands continue to experience extensive and localized overgrazing due to uneven distribution of usable wells and the concentration of nomads in nearby cities or around the main roads.

Image: T. Matsumoto

A vegetation survey on the pasture by nomads, to evaluate and estimate the degree of degradation and grazing capacity

Image: T. Matsumoto

A group of nomads discusses the plan for the pasture they use at BaroonBayn-Ulaan soum

These factors lead to the degradation of grassland vegetation, which is considered a major trigger for sandstorm occurrence. To solve these problems, it is necessary to realize comprehensive management and utilization of grasslands through planned pasture use suitable to their conditions. In this regard, JIRCAS conducted a case study aimed at creating pasture-use plans with the autonomous participation of local nomads residing in the Taragt and BaroonBayn-Ulaan soums (districts) in Ovorkhangai province in mid-south Mongolia.

In Taragt soum, the grasslands had been used by the native nomads in a traditional way. Recently, however, the frequency of nomadic movement on these grasslands had decreased, causing permanent use of these pastures throughout the year and progressive localized overgrazing. Degradation of the pastures used by nomads during winter had been particularly pronounced, and the necessity to reduce it was pointed out. In making the pasture-use plans, we first divided all the nomads into groups that use the same winter pasture and conducted vegetation surveys for pastures in collaboration with each group. Thereafter, we prepared the plans based on the reduction of local pasture load by widely dispersing grazing livestock through increased frequency of movement from winter to summer or autumn pastures.

On the other hand, BaroonBayn-Ulaan soum is located in the Gobi Steppe region where conditions for grass growth are more severe; thus, the amount of grasses produced there has been constantly insufficient, making it necessary to graze traditionally in the pasture of the adjacent soum. However, since there are no existing rules or plans regarding grazing in this pasture, pasture-related conflicts between nomads of these soums, as well as vegetation degradation, have occurred. To remedy the situation, we included in the pasture-use plans a rule for this pasture, indicating that no grazing throughout all seasons using the whole area is allowed. This plan was discussed and confirmed by nomads of both soums.

These plans cannot be expected to deliver the anticipated outcome unless the nomads adopt them. To ensure their implementation, necessary procedures to formalize them were taken at the People's Assembly of each soum and at the regional villages (Bag). In cases where a plan extended across an adjacent soum, an agreement between the governments of these soums would be concluded and the role of each soum would be clarified to allow smooth implementation of the plan.

The adoption of these pasture-use plans resulted in an increase in the movement of the nomad population from one pasture to another from winter to summer or autumn in Taragt soum, from 31 per cent in the year prior to the creation of plans to 52 per cent the following year, and 74 per cent the year after. Also, at BaroonBayn-Ulaan soum, with the conclusion of agreements between governments, which had not been done before, pasture utilization extending across neighbouring soums was carried out according to the plan.

The procedures for creating the pasture-use plans, consultations or agreements, monitoring and evaluation after implementation were summarized in the guideline[1] for drawing up the plans. We hope that this guideline will benefit not only our study site in the Ovorkhangai province but also other areas in Mongolia.

Image: JIRCAS

Accumulation of salt on a wheat field in Oq-oltin District, Syrdarya Province, Uzbekistan (December 2010)

Image: JIRCAS

High groundwater level (70 cm from surface) was observed in Oq-oltin District, Syrdarya Province, Uzbekistan, on 21 March 2010

Salinity mitigation in Uzbekistan

The river basins of Amu-darya and Syr-darya flowing into the Aral Sea in Central Asia have been developed through the large-scale irrigation projects implemented there since the middle of the twentieth century. Agricultural productivity has increased with those developments. In Central Asia, Uzbekistan has the largest irrigated land area, covering more than 4.2 million hectares. The expansion of irrigated agriculture, which was focused on cotton, wheat and paddy rice, required large amounts of water; and the dissolved salts in the irrigation water have accumulated on the ground surface. The development of farming systems has therefore unwittingly caused the advancement of salinization. Excessive irrigation, leakage from decrepit irrigation canals, and malfunctioning drainage systems have driven up the groundwater level over the past decades. This rising groundwater increases the probability of salts moving up towards the surface through capillary action.

In parallel with farming system development, the Uzbekistan Government has dedicated efforts and resources to improve irrigated land conditions. A number of salinity mitigation measures have been implemented, such as repairing irrigation canals, cleaning drainage and leading farmers in leaching activity to wash out the accumulated salts from the fields, but they have been less effective in some areas so that almost half of Uzbekistan's land area is still affected by salinization. In 2008, the Government

Image: Dr K. Ikazaki

Sandstorm, a cause of wind erosion

established the Irrigated Land Reclamation Fund and started a state programme to allocate funds for the construction or reconstruction of related facilities, repair works, purchase of machinery and equipment and water-saving technologies. While these activities work well in reducing salinization, the continued use of excessive amounts of irrigation water in actual farmlands expose them to greater risk of salinization and rising groundwater levels. This farming activity renders the desalinization measures ineffective. Therefore, JIRCAS started a research project which was supported by the Government and the Farmers' Council (FC) of Uzbekistan. It was focused on farmers' understanding of salinization and what countermeasures can be applied. Studies and experiments have been implemented to improve the technical aspects and to verify the effects of the measures on actual farmers' fields in Syr-darya province, where the salinity-affected area is large.

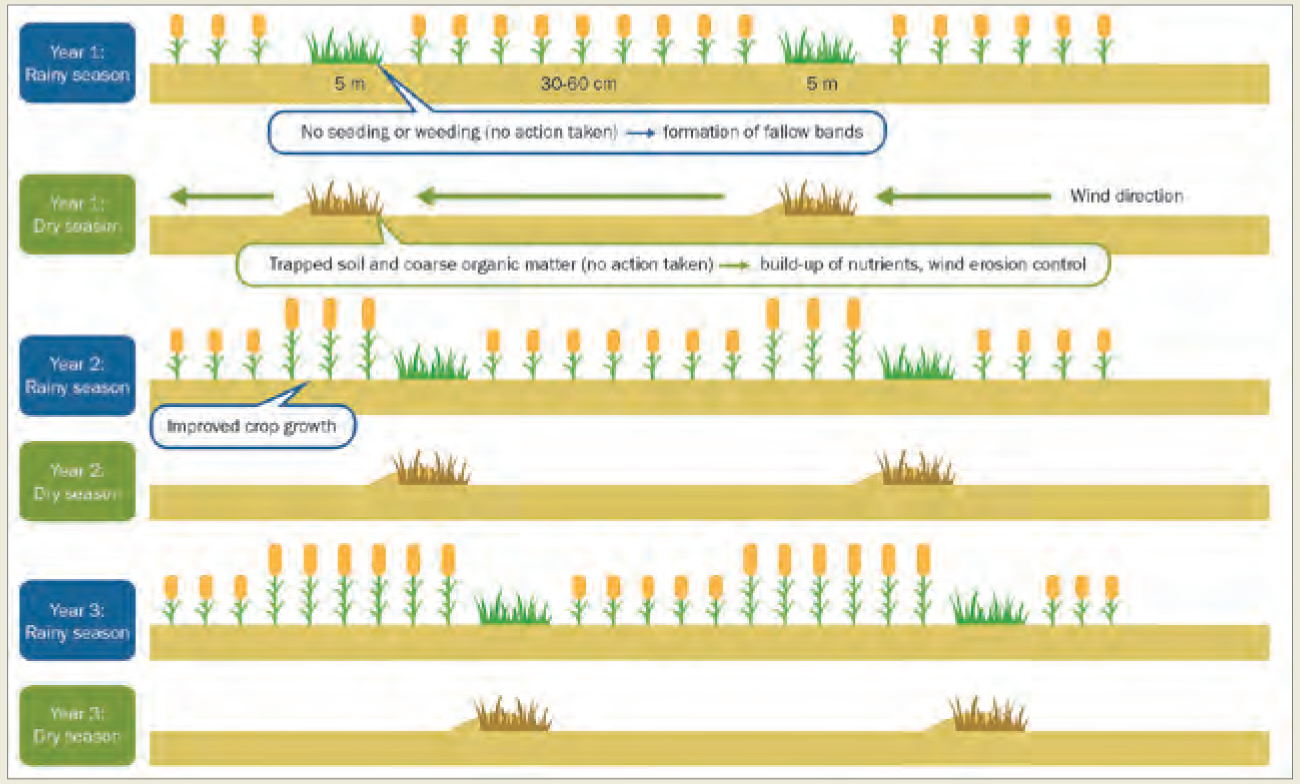
As a result of the project, a guideline[2] titled 'On-farm mitigation measures against salinization under high groundwater level conditions' was published in February 2013. The guideline was translated into Russian and Uzbek languages, with a simplified popular version in addition to the original one. It explains intelligibly to farmers the following topics: understanding salinization; monitoring salinization; water-saving irrigation; low-cost land levelling; drainage maintenance; crop rotation; and trial calculation of financial conditions. The first topic describes the mechanism and classification of salinization. The second discusses the necessity of monitoring groundwater, the farmers' monitoring method and the results of monitoring in the field. The third shows the modified furrow irrigation methods and their effects. The fourth explains the necessity of land levelling and the farmers' efforts in pre-levelling work. The fifth points out the importance of drainage maintenance and the farmers' role in the maintenance of drainage facilities. The sixth enumerates the summer crops to be cultivated to generate funds for the mitigation measures, as well as the green manure crops for soil fertility improvement. The last topic presents a trial calculation for the costs and benefits of introducing each measure. The guideline has been disseminated by the FC in relevant seminars in Uzbekistan.

Currently, JIRCAS is working on the establishment of methodologies for efficient groundwater control, such as improving of the management of surplus infiltration water and monitoring soil and groundwater levels to estimate the introduced methodology.

Improving soil fertility in the Sahel

The Sahel of West Africa, the southern periphery of the Sahara desert, is the most marginal land for agricultural production in the world. The soils are very sandy and infertile and the land is frequently afflicted by devastating droughts, pests and diseases. Indigenous systems, like corralling and fallowing, were for a long time sufficient

Outline and features of the Fallow Band System



Source: Courtesy of the Ministry of Agriculture, Forestry and Fisheries, Japan[4]

to maintain soil fertility for regional crop production. However, owing to the recent population increase (more than 3 per cent annually), together with failure of the corralling system and shortened fallow period, soil fertility cannot be well sustained by these local practices and the degradation of land productivity has resulted. Aiming at the improvement of soil fertility and expansion of crop production in the region, JIRCAS commenced a project based at Niamey, Niger, in collaboration with the International Crops Research Institute for the Semi-Arid Tropics and the National Agricultural Research Institute of Niger in 2003. The goal was to develop technology options through investigating more efficient use of plant resources, considering the biological and physical functions of fallow plants and lands, and incorporating well-adapted leguminous crops into the cropping systems. The developed technology options were evaluated for adoption by local farmers in on-farm participatory trials.

The project focused on wind-blown materials and their fates, as wind erosion is a major cause of the loss of relatively fertile surface soils/sediments in the Sahel. A new agricultural practice, called the Fallow Band System, was proposed and verified for the maintenance of soil fertility in the field.[3] Five-metre wide fallow bands were arranged at a right angle to the direction of erosive storms (east wind) in a cultivated field during the rainy season. Fallow bands can be easily created by skipping the usual seeding and weeding. Pearl millet plants, a staple food in the Sahel, were cultivated in other areas of the field in a conventional way. The fallow bands were also maintained in the next dry season, so they are expected to catch wind-blown materials containing a lot of nutrients. In the next rainy season, new fallow bands were made aside from the former bands towards the direction of the wind. Crops were cultivated on the previous fallow bands as well as in other areas of continuous cultivation. The pearl millet yield was estimated to be increased by 36 per cent to 81 per cent, compared with the area where the fallow band system was not applied. Also, wind erosion was reduced by about 70 per cent on a whole-field basis. This 'no labour, no cost' practice has been rapidly disseminated to farmers in the Sahel through local communities in follow-up activities by the Japan International Cooperation Agency.

We have also studied ways to improve the quality of the fallow band, by enhancing native fallow plants which can fix more nitrogen from the air through biological nitrogen fixation — for instance, a promising annual leguminous *Cassia mimosoides*.

JIRCAS is also currently conducting research activities in the savannah of West Africa (Ghana and Burkina Faso), on applicable technology options of conservation agriculture to minimize arable land degradation and to enhance soil fertility.

Earth Observation approaches to sustainable land management in drylands: experiences from the European Space Agency

Marc Paganini, Anna Burzykowska and Frank Martin Seifert, European Space Agency; Ute Gangkofner, GeoVille; and Thomas Häusler, GAF AG

The European Space Agency (ESA) has been collaborating with the United Nations Convention to Combat Desertification (UNCCD) since the World Summit on Sustainable Development in 2002, developing and delivering Earth Observation (EO) solutions that can be used, with little adaptation, by UNCCD parties to better combat desertification and land degradation and mitigate their effects for the benefit of local communities and in particular poor rural societies.

The approach taken by ESA responds to the strategic objectives of the convention with the provision of EO solutions that can improve both the living conditions of affected populations and the conditions of the ecosystems they depend on. Global approaches are needed to deliver consistent data to support national assessments and reporting, while local approaches are essential to respond to the specificities of rural communities who are facing different land degradation realities. The examples shown below address both global and local EO approaches to sustainable land management in drylands.

Global EO data sets and approaches for national assessment and reporting on land degradation

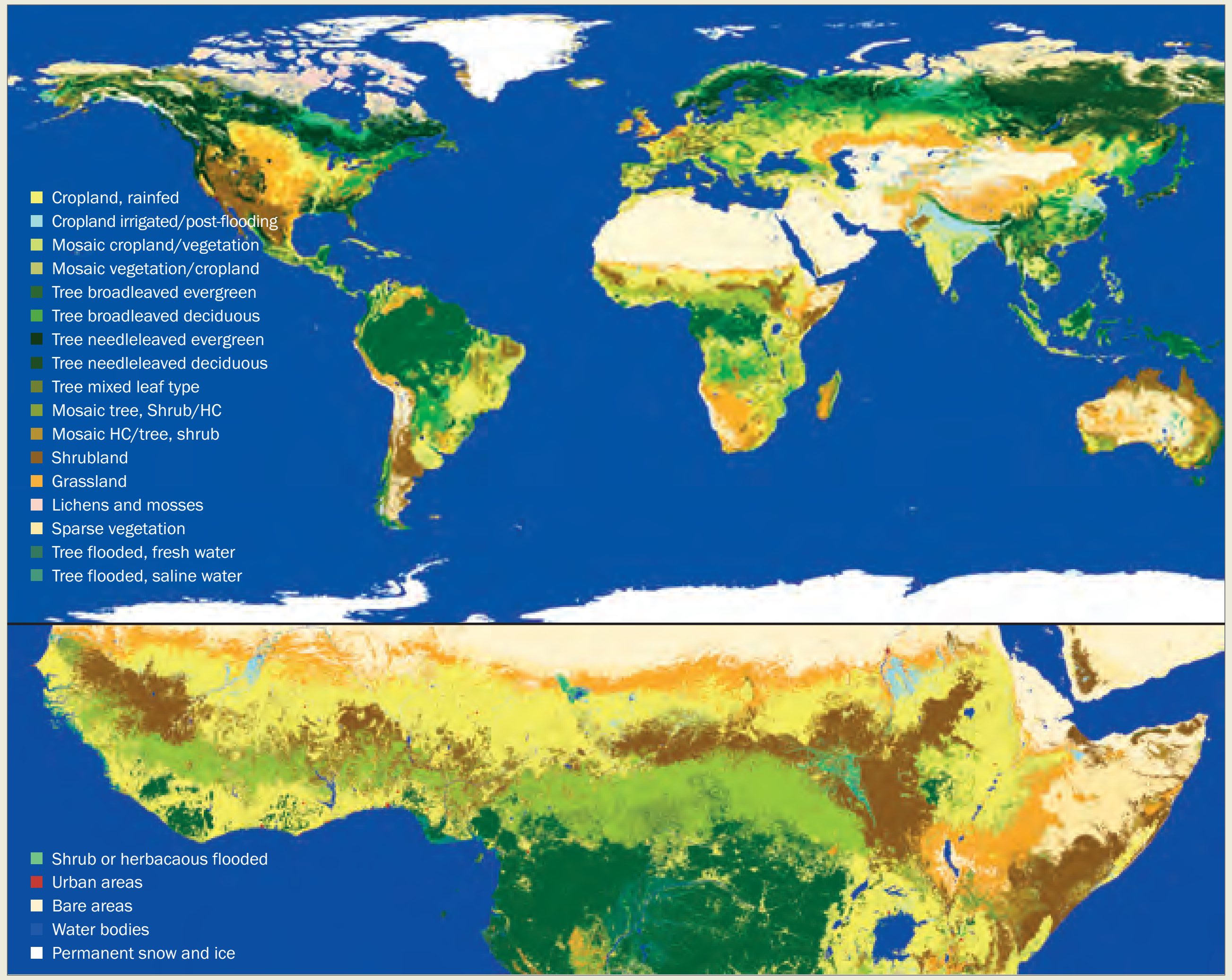
During its eighth session in Madrid in 2007, the UNCCD Conference of the Parties adopted a 10-year strategic plan elaborated around three strategic objectives that include, as the second objective, the goal to improve the conditions of affected ecosystems. A number of indicators were developed and refined along the years, resulting in 2013 with the adoption of six global indicators, comprehensively called progress indicators. The indicators adopted to monitor the conditions of ecosystems are the 'trends in land cover' and the 'trends in land productivity and functioning of the land'. These global indicators were accompanied by the necessity to develop mechanisms to encourage parties to develop their national indicators. This requires the development of cost-effective and scientifically sound global solutions that can be adapted to national specificities.

ESA has a long-standing experience in developing global and consistent data sets from EO missions. One of ESA's most recent and ambitious programmes is its Climate Change Initiative (CCI) that aims at producing long-term climate data records of key parameters of the Earth System. The objective is to provide long-term and accurate satellite-based measures of Essential Climate Variables (ECVs) that have been defined by the Global Climate Observing System to serve the data needs of the Intergovernmental Panel on Climate Change in its assessment of the state and evolution of the climate system. The ECVs include a number of terrestrial variables, such as land cover, which it is essential to monitor for the modelling of carbon and water cycles. The ESA CCI has produced a set of consistent global land cover maps at 300 m spatial resolution for the epochs 2000, 2005 and 2010 and is currently extending the temporal series to the years 1990 and 2015 (see case study). These global land cover data sets have been provided to UNCCD and constitute an excellent baseline for countries when measuring changes in land cover and stratifying their national assessment on land degradation.

Monitoring trends in land productivity is a necessity for countries that face the adverse conditions of living in drylands and is one of the UNCCD indicators to track progress in improving the conditions of ecosystems. EO approaches for measuring land productivity at global scale have been developed but have to deal with the complexity of phenomena. Best solutions are based on time series of proxies of Net Primary Productivity, a measure of the net flux of carbon from the atmosphere into organic matters and a fundamental ecological variable that indicates the conditions of healthy or degraded land.

The ESA Diversity II project has developed an innovative method based on the inter- and intra-annual fluctuations of Fraction of Absorbed Photosynthetically Active Radiation (fAPAR), a physical parameter that measures the ability of vegetation to absorb the energy of the solar radiation and generate green leaf biomass. fAPAR is one of the biophysical variables that can best monitor plant productive capacity in terrestrial ecosystems. Satellite-based fAPAR time series were analysed to extract a number of phenological parameters (such as the start and end of the vegetation year, growing and dry seasons) and to compute productivity parameters by integrating fAPAR values during the different vegetation periods. By analysing their fluctuations through the years, a set of indicators on the conditions of the ecosystems and on trends in productivity can be derived. These indicators can be used to analyse specific land degradation phenomena

Case study: Global land cover mapping



The 2010 Global Land Cover map

The ESA CCI has produced a three-epoch series of global land cover maps at 300 m resolution (2000, 2005 and 2010). The land cover maps follow a legend based on the United Nations Land Cover Classification System with 22 high-level classes for global use and 14 subclasses for regional adaptation.

Source: ESA CCI Land Cover project/Université Catholique de Louvain

such as bush encroachment, a major rangeland problem in south-west Africa (see case study).

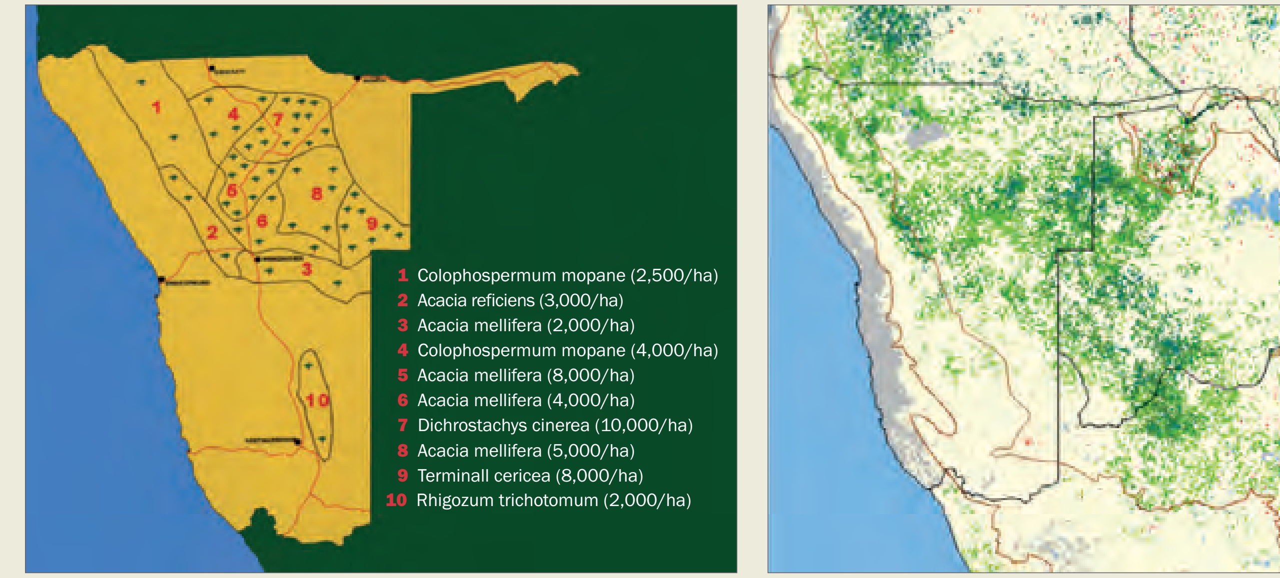
Partnering with international financing institutions for sustainable land practices in developing countries

Since 2008, ESA has taken important steps to showcase the potential of satellite observations to support sustainable development initiatives in developing countries by international financing institutions (IFIs) and multilateral development banks such as the World Bank, the United Nations International Fund for Agricultural Development (IFAD) and recently the Asian Development Bank and the Global Environment Facility.

EO methods have proven to be important tools for the sustainable management of lands in water-scarce environments: assessing land productivity, detecting decreased productivity due to diseases or reduction of water; mapping crop areas and types, estimating the conversion of natural resources into agricultural lands and assessing impact such as degradation of ecosystems; collecting statistics on crop production, providing yield estimations using agrometeorological modelling; estimating land suitability for optimum land use, reducing risks such as soil erosion; helping management of water resources, monitoring availability of surface waters and estimating water needs and use for irrigated crops; supporting climate resilience and adaptation strategies and assessing impact of climate change on natural resources.

A joint ESA-IFAD project developed a Land Erosion Risk indicator in Niger, which together with information on land use changes allowed the assessment of agricultural practices,

Case study: Bush encroachment in Namibia



Areas affected by bush encroachment in Namibia (left); Trends (2002-2013) of Dry Season fAPAR (right)

Image (left): Bester, F.V. (1998), *Major Problem — Bush species and densities in Namibia*. Ministry of Agriculture, Water and Rural Development, Namibia

The phenomenon of bush encroachment is a major threat for the livelihood of many people. Once densely established, bush species block grass growth and prevent the cattle from grazing. The image shows the major areas affected by bush encroachment in Namibia.

The ESA Diversity II project evidenced some gradients of increasing vegetation greenness during the dry seasons for the years 2002 to 2012 that matches well the areas known to be subject of bush encroachment.

The Dry Season fAPAR trends, together with land cover changes and rainfall trends, constitute a wealth of information for assessing bush encroachment in the region.

Source: ESA Diversity II project/GeoVille

analysis of environmental impacts of development projects, and supported the elaboration of irrigation and climate change adaptation scenarios (see case study).

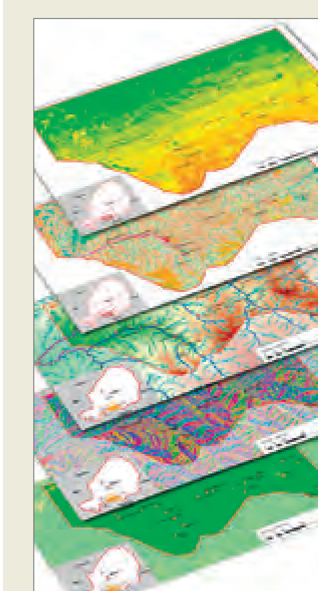
The importance of monitoring dry forests

ESA has been an accredited observer organization of the United Nations Framework Convention on Climate Change (UNFCCC) since 2001, providing EO solutions for systematic observations of the environment, long time series of essential climate variables and monitoring of forests to support climate mitigation activities like REDD+.

Reducing emissions from deforestation, forest degradation, conservation and enhancement of forest carbon stocks and sustainable management of forests (REDD+) has mainly concerned humid tropical forests due to their high carbon content, putting aside dry forests and woodlands despite their importance as carbon sinks. Recently more emphasis has been put on dry forests to develop dedicated forest monitoring, reporting and verification approaches relevant to REDD+. In Africa dry forests occur predominantly in sub-Saharan regions where they cover 2.4 million km^2. Population pressure for agricultural land, fuel wood and timber extraction leads to some of the highest deforestation rates, with negative impacts on biodiversity, soil fertility and water availability, as well as on the livelihoods of local people.

An ESA-funded project on dry forests developed a methodology to efficiently map dry forests in Southern Africa based on a

Case study: Erosion risk indicator for the Maradi region, Niger



From bottom: slope, slope aspect, drainage system, land use/land cover map and erosion risk indicator

The predominance of crop and livestock farming and poor diversification make Niger's economy very vulnerable to climate and market changes.

An erosion risk indicator was produced for the Maradi region, based on a combination of digital elevation model, land use/land cover maps and meteorological data.

The risk of erosion increases from north to south, due to fewer precipitations with less intensity in the north. Areas with high slopes increase the risk of erosion, as detected in several small Wadis.

Source: GAF AG, ESA and IFAD

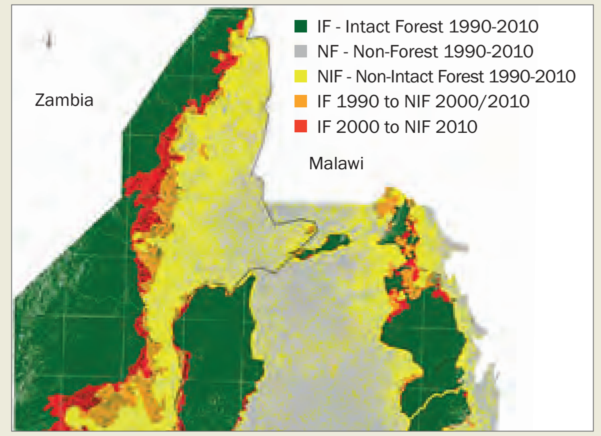
flexible monitoring system that analyses multitemporal data over the year (see case study).

Conclusions

The importance of global and sustained EO for monitoring dryland conditions has been stressed by all UNCCD stakeholders. The availability of long-term series of historical satellite observations allows us to measure trends of global indicators such as land cover and land productivity that are essential to assess land degradation and plan rehabilitation of degraded lands. The use of satellite information also provides opportunities for the development and verification of sustainable land practices in marginal rain-fed lands. As stated by an IFAD officer, “Poor rural people are on the front line of climate change impacts. The ecosystems on which they rely are increasingly degraded, their access to suitable agricultural land is declining, and their forest resources are increasingly restricted.” EOs provide accurate and consistent information that can support strategic planning and deliver quality solutions to these local rural communities.

ESA will continue to develop innovative EO solutions that support the collaborative efforts to achieve land degradation neutrality. This starts by empowering developing countries with knowledge and skills on how to use EOs for a sustainable management of their soil, water and biodiversity. Europe recently launched the first Sentinel satellites of its flagship Copernicus initiative, which will provide free and open access to satellite information to protect the environment, mitigate the effects of climate change and ensure a sustainable use of natural resources. ESA will pursue the collaboration with the Rio Conventions and the IFIs to mainstream the use of EOs within sustainable land practices.

Case study: Dry forest mapping in the Miombo woodlands



Status of the Miombo forests between Zambia and Malawi

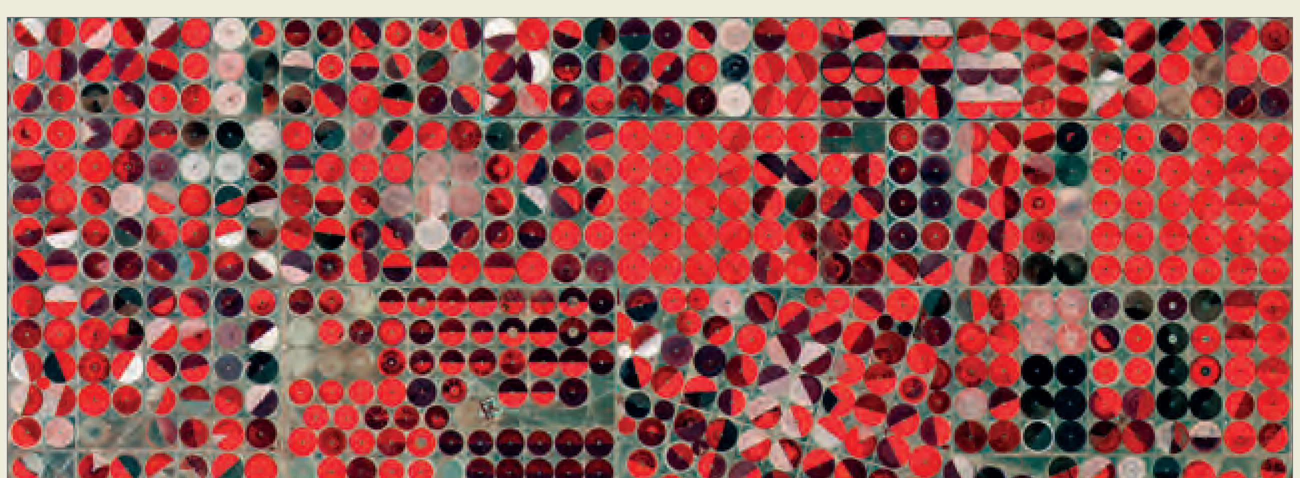
The Miombo woodlands with their varying phenology related to dry and rainy seasons have been identified as a priority ecozone because of their unique endemism.

The image shows the status of the Miombo forests between Zambia and Malawi, and the changes between three epochs (1990, 2000 and 2010).

The Miombo forests are widely harvested to provide fuelwood and to be converted in agricultural lands. The loss of dry forests are shown in orange (1990 to 2000) and red (2000 to 2010).

Source: ESA GSE Forest Monitoring project/GAF AG

Case study: Irrigated agriculture observed by Sentinel 2



A Sentinel 2 false-colour image showing agricultural structures near Tubarjal, Saudi Arabia, characterized by a central-pivot irrigation system

Despite the benefits that irrigated crops bring to local communities, some environmental issues exist such as depletion of water resources, soil erosion, run-off of chemicals, salinization of the soil and drainage of nutrients.

The Sentinel-2 mission, whose first satellite was launched in June 2015, will deliver high-resolution optical images of all land surfaces. The five-day revisiting together its 10 m resolution and its high spectral content make Sentinel 2 an essential tool for monitoring agricultural practices such as irrigated crops.

Source: Copernicus Sentinel data (2015)

Satellite laser altimetry: a powerful tool to enhance the capability of global forest inventory

Yoshiki Yamagata, Masato Hayashi and Habura Borjigin, National Institute for Environmental Studies, Center for Global Environmental Research, Japan

Global forest inventory is required for Reducing Emissions from Deforestation and Forest Degradation (REDD+) implementations. However, conventional methods depending on field measurements are extremely labour-intensive. Satellite laser altimetry can make it possible to efficiently collect enormous measurement data about forest carbon stocks without in-situ measurements. As a result of verification in Borneo, laser altimetry was shown to successfully and accurately measure canopy height and forest biomass. Furthermore, laser altimetry could be used to estimate the rate of forest loss, the distribution of forest biomass, and the total amount of biomass in Borneo.

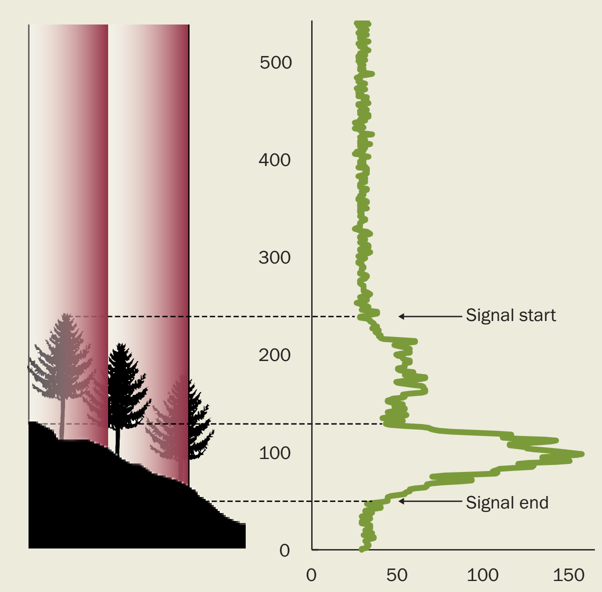
Among various ecosystem services of forests, the regulating services such as carbon storage have attracted public attention, because they could contribute to mitigating climate change. The REDD+ scheme has been developed in recent years to prevent global warming resulting from deforestation. Large-scale deforestation and forest degradation decreases the water-holding capacity of soil, and it is one of the principal causes of desertification. Therefore, REDD+ is also effective for combating desertification. The national report for REDD+ implementations requires the measurement of activity data (extent of deforestation activities) and the emission factor (greenhouse gas emissions per unit area). The emission factor is classified into three levels of complexity, from Intergovernmental Panel on Climate Change default values (Tier 1) to precise values based on a national forest inventory (Tier 3). A higher tier can result in a more accurate carbon budget estimation, but it may generally require labour-intensive field measurements. Therefore, if satellite remote-sensing can serve as a substitute or assistance for forest inventory, it will be extremely valuable to REDD+ implementations by reducing costs and labour.

For the estimation of forest carbon stocks using remote-sensing technology, estimating forest biomass is usually adopted as a substitute. Biomass represents the dry weight of trees and about half of it is carbon weight. Therefore, forest biomass can be easily converted into forest carbon stocks. However, measuring belowground (root) biomass is difficult for remote-sensing technology, so the aboveground biomass (AGB) is usually adopted as a measuring object.

In remote-sensing technology, various sensors are used on-board satellites. An optical imaging sensor is the most orthodox sensor and has a long history; however, an accurate estimation of forest biomass cannot be expected. Synthetic aperture radar is a sensor using radio waves (microwaves) and has an ability to measure forest biomass, but it has a weakness in that the sensitivity is saturated in high-biomass forests over 150 t/ha. Laser altimetry, which is also called light detection and ranging or LiDAR, is a sensor using laser beams, and it can accurately measure forest biomass without signal saturation. However, its weakness is that it cannot fully observe a large area because its observation points are discrete.

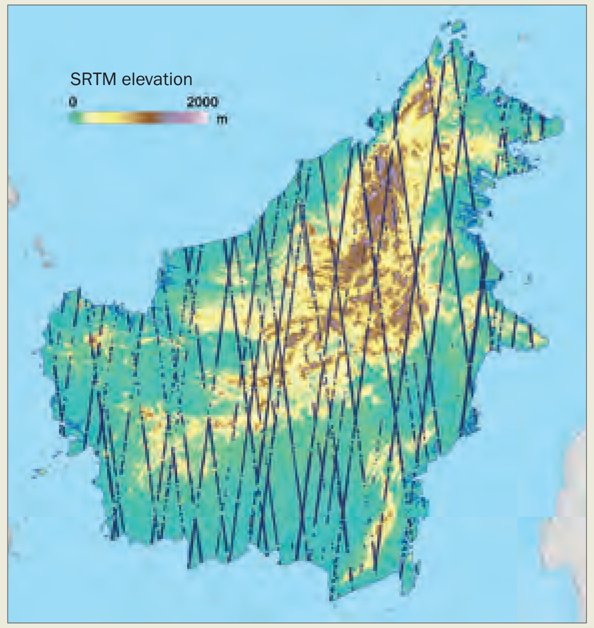
The only satellite laser altimetry so far has been the Ice Cloud and land Elevation Satellite (ICESat)/Geoscience Laser Altimeter System (GLAS), operated by NASA from 2003 to 2009. GLAS transmitted laser pulses with a frequency of 40 Hz, and its footprints were spaced at intervals of 172 m on the ground along ICESat’s orbital track. The footprint was elliptical with a 60 m nominal diameter, but the size varied according to the observation period. The GLAS observations

A schematic illustration of observations by satellite laser altimetry



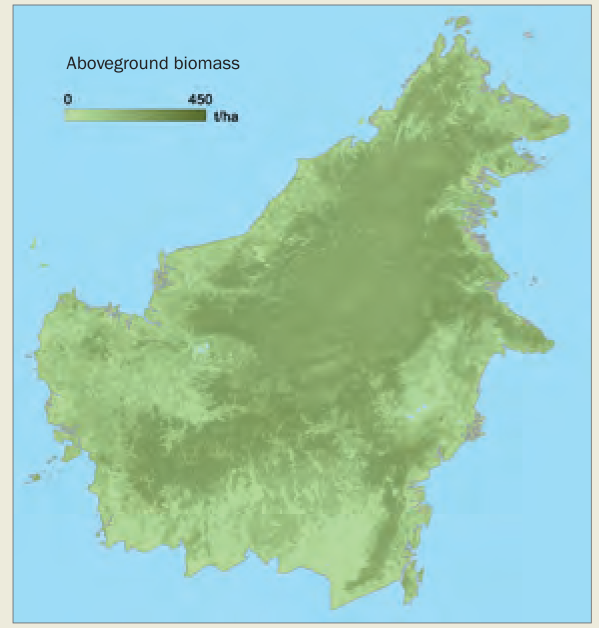
Source: CGER

The distribution of GLAS footprints in Borneo



Source: CGER

A forest biomass map of Borneo (500-m resolution)



Source: CGER

covered latitudes between 86°N and 86°S globally. The laser's return pulse was detected by a telescope on-board ICESat. GLAS recorded the changes in laser energy intensity as a waveform, and the waveform contained information on the vertical structure of forests. At flat areas, the height difference between signal start and signal end corresponded to the maximum canopy height within the footprint. If a waveform was bulky at high elevation, the observation was considered to have been made at a high-biomass forest because it meant a large reflectance from the canopy level. In this way, many studies have been conducted to analyse the GLAS waveform to estimate canopy height and AGB.

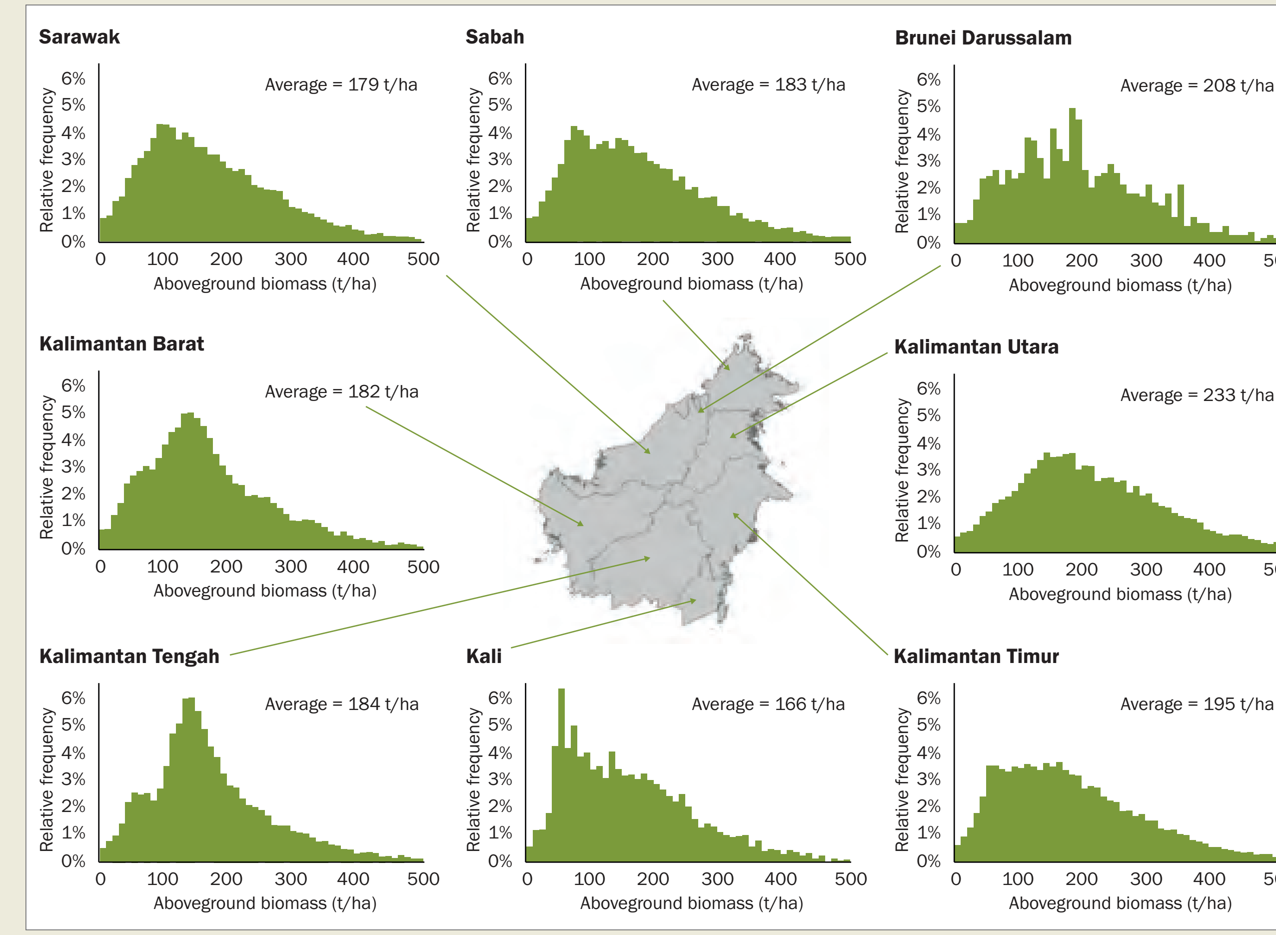
We developed a methodology to estimate canopy height and AGB using GLAS data, and evaluated its performance. A technology to accurately measure canopy height or AGB using satellite data will make it possible to acquire enormous amounts of data on forest resources without labour-intensive in-situ measurements. The study area was Borneo. The tropical forests in Borneo have a considerable canopy height and are rich in biomass even on a global scale, and also rich in biodiversity with many rare animals and plants. However, the area of forests in Borneo has been rapidly decreasing in recent years because of forest fires, oil palm plantation development and so on. Therefore, Borneo attracts attention from REDD+ implementations.

We collected field-measurement data of canopy height and AGB in 37 plots which coincided with the GLAS footprints. We used the data as reference data to examine the relationships between some parameters of GLAS waveform shape and canopy height or AGB. These relationships could be used to estimate canopy height and AGB from GLAS data. The estimation accuracies (root-mean-square errors) were 4 m for canopy height, and 38.7 t/ha for AGB. Among the field-measurement sites, there was a rich forest where tree height was 30 m and AGB was 300 t/ha. However, accuracy remained high even in such a forest.

We applied the estimation models of canopy height and AGB to the GLAS data in the whole of Borneo. After excluding data on cloud-covered measurements and non-forested areas, we obtained 127,862 data points that were valid for the analysis. Field measurements at 127,862 plots would require a great deal of labour, so using satellite data is an efficient method for collecting information on forest resources. The results of estimating canopy height and AGB from the GLAS data showed that the average canopy height was 17.3 m, and the average AGB was 191.8 t/ha over Borneo. Furthermore, we created AGB histograms for each province to compare the distribution of forest resources. In Brunei Darussalam, the forests were found to have high AGB because of the many forest reserves. The forests in Kalimantan Utara and Kalimantan Timur, in the eastern part of Borneo, also had a high AGB. By contrast, in Kalimantan Barat, Kalimantan Tengah and Kalimantan Selatan, in the southern part of Borneo, relatively low-AGB forests were found. Finally, in Sabah and Sarawak, in the Malaysian part of Borneo, forests with a wide range of AGB were distributed.

Next, we divided the GLAS data into two groups according to their observation period, and we estimated the rate of forest loss between the two periods by identifying GLAS data for non-forested areas (estimated canopy height < 2 m). As a result, the forest loss rate was 2.4 per cent per year during three years from 2004 to 2007. The rate in the Malaysian part of Borneo was 1.4 per cent per year and

Histograms of aboveground biomass for each province in Borneo



Source: CGER

that in the Indonesian part of Borneo was 2.9 per cent per year. These values are a little higher than those found in most previous studies. A possible reason is an increased frequency of fires caused by droughts related to El Niño, which occurred in 2006. The forest fire frequency in the Indonesian part of Borneo was much higher than in the Malaysian part, which might have increased the rate of forest loss in the Indonesian part.

Next, we estimated the total AGB in Borneo. To do so, we calculated the average GLAS-estimated AGB for each province and for each forest type, multiplied them by the area of each category (forest type and province) and summed them up. As a result, AGB in Borneo totalled 10.3 billion tons. This value corresponds to 2.1 per cent of the total AGB on the Earth, according to the Food and Agriculture Organization of the United Nations Global Forest Resources Assessment 2010. Borneo occupies only 0.5 per cent of the global land area, so we can understand that the Bornean forest stock has a high biomass.

GLAS observed only discrete points along the track, therefore it could not make a complete observation of large areas. However, GLAS data can be used as reference data for developing a wall-to-wall forest biomass map using optical satellite imagery. We combined GLAS data with Moderate Resolution Imaging Spectroradiometer (MODIS) imagery, which is an optical imagery sensor making high-frequency observations. High-biomass forests were found to be distributed along the backbone of the Bornean mountains. Such a map can make it possible to understand the detailed distribution of forest resources.

In this way, satellite laser altimetry can provide enormous amounts of data for the efficient and accurate estimation of canopy height and forest biomass without in-situ measurements. It will be able to bring about a revolution in global forest inventory. Since ICESat ceased operation in 2009, there has been no satellite laser altimetry system capable of observing land surfaces. However, ICESat-2 is scheduled to be launched in 2017, and there are plans to mount laser altimetry systems for forest observation on the International Space Station. These next-generation satellite laser altimetry systems will play an important role in global forest resources monitoring in the future.

Enabling investments in sustainable rangeland management

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Rangelands are places of important biodiversity and ecosystem services that occupy up to a half of the Earth's landmasses and up to three quarters of the world's drylands,[1] providing benefits to local communities, to national economies and to global society. Desertification and land degradation significantly affect rangelands, and in many countries measures to address rangeland degradation are weak or absent. Furthermore, integrated assessment of rangeland health status is absent in most countries and this is contributing to inappropriate investments and policies that in turn can lead to desertification and poverty.

Current projections establish that we need at least 70-100 per cent greater food production from existing land in order to feed the current population and future generations.[2] This is likely to place more pressure on existing resources, leading to conversion of forest and rangeland to cropland, and consequent risk of land degradation. Land use conversion and land cover change have been identified as the leading factors in land degradation and desertification.[3] Proximate causes of land degradation such as overexploitation for agriculture and extractive activities have a number of common roots. Fundamental social or biophysical processes underpin the proximate causes of land degradation and desertification, which are immediate human or biophysical actions with a direct impact on dryland cover.[4]

Despite weak evidence in many countries, there is widespread (though not universal) belief that overgrazing is a leading cause of land degradation. In practice overgrazing is poorly understood and frequently misrepresented, and in a number of cases under-grazing is an equally important issue. Many rangeland ecosystems depend on herbivore action to maintain specific plant communities and when this action is disrupted, degradation processes can be triggered. Grazing mismanagement practices are a common outcome when herd management and seasonal herd movements are restricted. Policies and strategies of sedenterization, the loss of transhumance corridors, or inappropriate location of water points contribute to this outcome. Such mismanagement can become common practice across a rangeland landscape when small but critical resource patches are rendered inaccessible (for example dry-season grazing areas converted to croplands, or forest patches fenced off to create protected areas).[5]

Images: Abu-Zanat

Left, Hima Bani Hashem, Zarqa Governorate and (right) a Bedouin herder in the Hima Iyra Range Reserve, Salt Governorate

Sustainable rangeland management

SRM should focus on enhancing the resilience of rangeland ecosystems in view of the high variability and unpredictability of precipitation, which is likely to be exacerbated by climate change. Much can be learned from local customary practices that have developed indigenous livestock breeds and management systems, which demonstrate remarkable adaptation and tolerance and are often critical to the efficiency of the system. Indeed, a frequent feature of indigenous SRM technologies is their orientation towards ensuring productivity in the worst years rather than maximizing on the good years. In lands where drought is the norm rather than the exception this is a logical adaptation and is central to resilient rangeland livelihoods. However, this age-old ecological insight can be easily jeopardized by a myopic focus on maximizing production in the short-term, and especially through use of unsuitable land use and cropping strategies.

Multiple benefits of sustainably managed rangelands

Source: Adapted from McGahey et al, 2014[12]

Sustainable land management (SLM) plays a vital role in halting land degradation and in rehabilitating degraded lands. Many countries face the challenge of maintaining long-term productivity of ecosystem functions while increasing productivity of food and other ecosystem services. This also applies to sustainable range management (SRM), a term we adopt to cater for the specific conditions of rangelands.

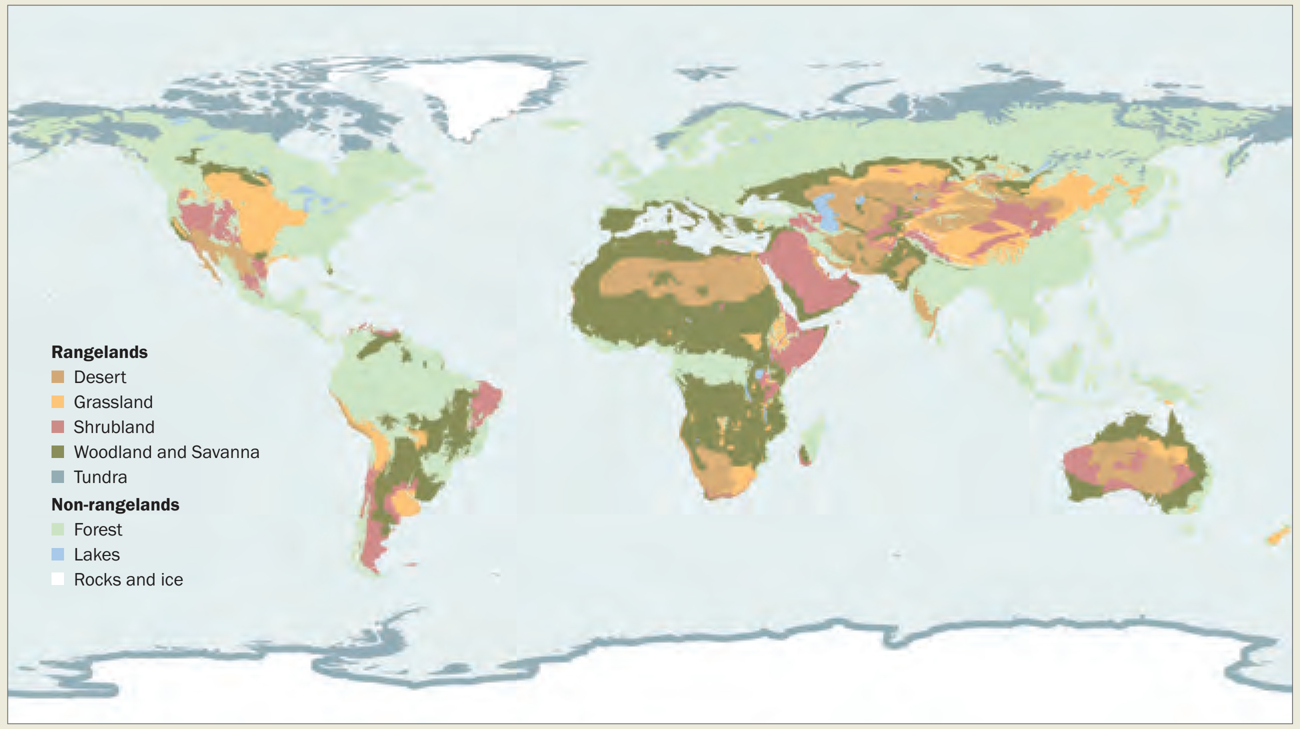
Sustainably managed rangelands can also deliver important benefits through ecosystem services — such as water cycling or climate regulation — which have knock-on effects on populations locally and externally. Improved rangeland hydrological cycles lead to better infiltration of water and reduced surface flow, which contribute to fewer floods and lower risk of drought. Indeed each action that takes place in the rangelands has an impact on surface and groundwater.[6] The hydrological cycle in rangelands can be characterized as providing irregular water inputs that are dependent on irregular rainfall patterns and, in general, regular water outputs in the form of regular flows of surface and groundwater. On the basis of these water outputs other ecosystem services can be provided as a function of the health of a rangeland ecosystem.[7] These can include higher biodiversity, soil fertility, carbon sequestration, quality of drinking water and its health benefits, and maintenance of rangeland products like fodder that are the basis of the pastoral economy.

Recent studies have suggested that soil carbon management presents the most cost-effective climate change mitigation option.[8] Rangelands (including grasslands, shrublands, deserts and tundra) contain more than a third of all the terrestrial above-ground and below-ground carbon reserves.[9] With improved rangeland management they could potentially sequester a further 1,300-2,000 MtCO2e by 2030.[10] This is confirmed by research estimating that 51 per cent of the global 2011 net carbon sink was attributed to the three Southern Hemisphere semi-arid regions. The higher turnover rates of carbon pools in semi-arid areas make rangeland ecosystem dynamics an increasingly important driver of global carbon cycle inter-annual variability.[11]

Good practices in rangeland management thus offer win-win situations for simultaneous economic, social and environmental benefits. Moreover, sustainable land management in rangelands has the potential to provide multiple benefits not only to communities that directly depend on rangelands but also to others: neighbouring rural communities, urban centres and global society. At the same time sustainable range management can be an important vehicle to contribute to land degradation neutrality (LDN).

In the many cases where pastoralism is practiced unsustainably, the common response is to intensify land use, notably by converting rangeland to croplands. However, land use intensification is driving investments away from the multiplicity of benefits from ecosystem services towards a narrower focus on single benefit streams. At the same time, such conversion bears the multiple costs of land degradation, degradation of watersheds, reduced biodiversity, increased poverty, social inequity and release of greenhouse gasses, as well as concomitant costs of land and biodiversity restoration or rehabilitation.

The world's rangelands



There is considerable disagreement over how rangelands should be defined which leads to divergent estimates of their extent. According to the World Resources Institute (1986) rangelands cover 51 per cent of the total land area of the world. This shows that rangelands are not confined only to drylands, but the majority of rangelands are in drylands and the majority of drylands are rangelands.

Source: Society for Range Management[13]

Sustainable management of rangelands requires innovative solutions to manage the high levels of climatic risk that are experienced over these landscapes and to address the many other unique features of dryland ecology. While such innovations are often found in customary management practices, these practices have often been undermined by inadequate development and policy interventions. Re-enabling customary practices and supporting them to adapt and flourish in a modern economy is central to SRM. Local institutions are vital for rangeland development and effective solutions tend to be grounded in improvements in local governance and communal resource rights.

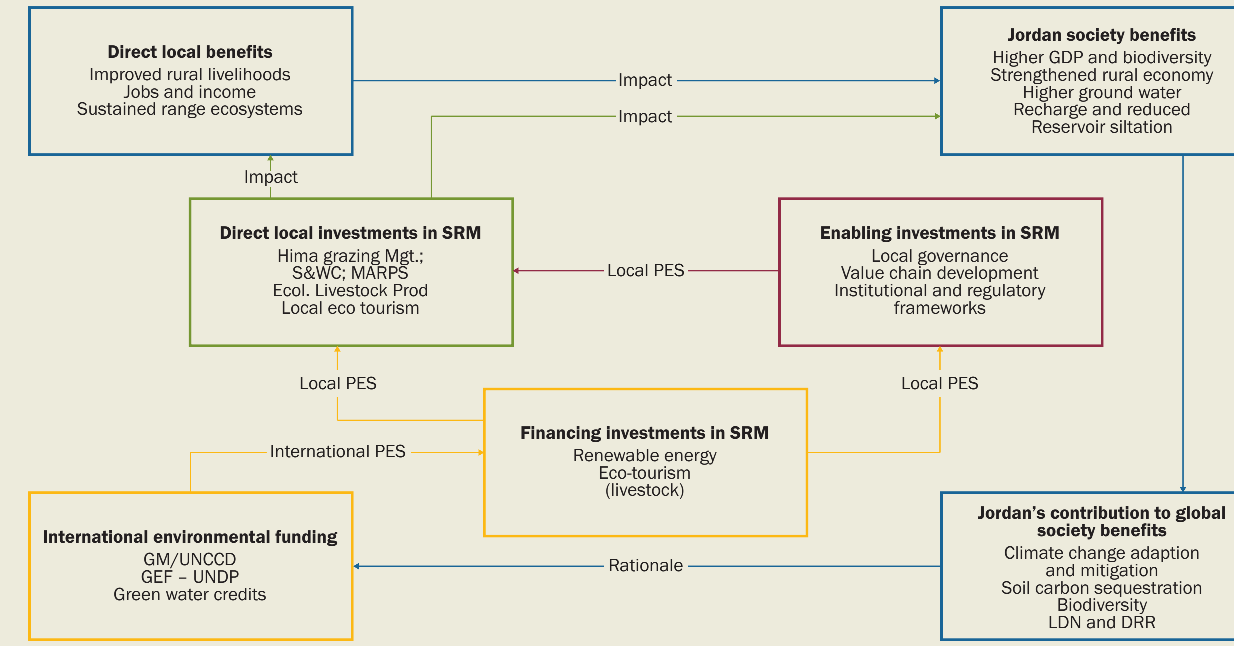
This approach to SRM requires a rethinking of orthodox investment paradigms and the role of the private sector. Local rangeland users already invest heavily in terms of labour and social capital to produce a wide array of environmental and economic benefits; new investments should be responsive to these existing investments and the risk management strategies of these local rangeland users. Innovation is needed in designing clever investment options and capturing the interest of investor groups to provide appropriate rangeland management solutions. Moreover, enabling investments may be required to establish conditions for improved asset investment and to put in place necessary safeguards.

An alternative approach is indeed needed that focuses on the optimization of investment returns in a variety of ecosystem services through greater capture of local benefits and reward for positive externalities. Advancing this investment approach requires improved local governance, stronger consultation with rangeland users, better informed decision-making and the facilitation of financial flows, possibly through payment for ecosystem services (PES) or other compensation for environmental benefits. Progress towards these targets requires greater motivation within government agencies in particular, to establish enabling investments for sustainable growth, and also within the private sector to strengthen value chains and to target appropriate asset investments.

Priorities for intervention include strengthening communal management of rangeland resources through the revival and strengthening of local institutions, adaptation of traditional governance practices according to the changing environmental and political context, and more secure communal resource management rights.

It is also important to improve local decision-making in the rangelands; better informed decision-making can be achieved through more inclusive, stronger participation of local rangeland users in public planning, improved

Linking local range governance to productive SRM investments and PES



In Jordan, the International Union for Conservation of Nature Regional Office for West Asia and the Ministry of Agriculture have engaged with key relevant stakeholders in more detailed studies on rangeland investment options. This has led to proposals for investments in SRM such as ecological livestock and medicinal plant production, 'Hima' grazing management and soil, carbon and water (SCW) conservation as well as in ecotourism and renewable energies.

In order to create long-term impact and sustainability, this study emphasizes close participation and management ownership of local range users. It is argued that this will require important investments in appropriate local governance structures. Where most of the above mentioned investments can be economically viable, others such as in SCW conservation and local governance may be more difficult to finance. Economic valuation studies have indicated that in Jordan, the value of rangeland restoration can amount to JD15 million (US$21.5 million) per year for roughly 30 per cent of the rangelands, if sustainably managed. This value does not yet consider other resulting ecosystem benefits such as increased biodiversity and carbon sequestration.

The proposed investment packages have high potential to create local and societal ecosystem benefits. By implementing them Jordan can also contribute to ecosystem benefits at the global society level, such as biodiversity conservation, climate change adaptation and mitigation and LDN. Such contributions need to be rewarded, and global PES could provide a platform for this. Engaging in promising investments such as in ecotourism and renewable energy could provide the vehicle, through taxation and licensing, for country-level PES modalities. Both PES modalities could provide the financing flows needed to invest in SCW conservation and in required local governance structures.

Source: Laban, 2015[14]

coordination between public sectors for more integrated, responsive and sustainable development, and through participatory technology development and innovation.

Better science-based evidence is needed in targeting policy and investment. Evidence of rangeland health and development opportunities for better targeting of policy and investment can be strengthened through the use of scalable assessment tools that are adapted to non-equilibrium dryland ecology. Evidence-based decision-making can be boosted with support for knowledge management, communications, capacity building and advocacy.

Advocacy is a priority to address sustainable development concerns in rangelands. Motivation for effective policy implementation within government agencies, and prioritization in rangeland investment, can be stimulated through greater, more informed engagement of local rangeland users in public consultations and involvement in political processes.

It is important to leverage appropriate investments in SRM. Greater investments can be generated through awareness-raising based on economic valuation of ecosystem services and communication of the multiple values of rangelands. In many countries enabling investments in appropriate public services and infrastructure are a priority. Investments in multiple ecosystem services are needed, as well as mobilizing innovative market-based options such as value chain development and PES.

Emphasis must be placed on policy implementation. Policy barriers may impede SRM and LDN in some cases, but in most countries supportive policies already exist and priority should be given to raising awareness and capacity and mobilizing resources to implement these policies.

Considering the importance of rangelands within the drylands, progress towards a land degradation neutral world will only be possible if major attention is now given to this globally important biome, and if investments and policies are oriented towards supporting locally generated solutions.

Combating desertification and land degradation in the drylands: research integration in practice

Mahmoud Solh, Director General and Lamia El-Fattal, Executive Assistant to the Director General, International Center for Agricultural Research in the Dry Areas

Desertification seriously impairs the ability of the land in some of the driest, and often the poorest, parts of the world to provide food and other resources. It is a major threat to food security and livelihoods at the global level with heavy economic, social and environmental costs. The drylands of the world are the most vulnerable to desertification.

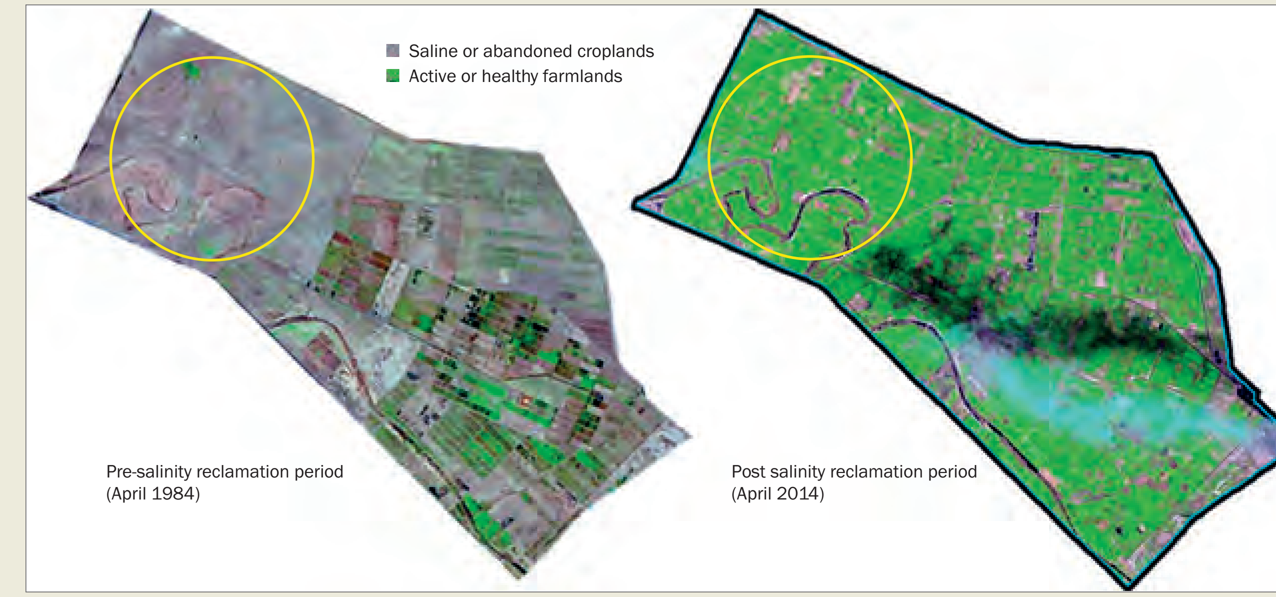
The drylands are home to over 2 billion people, or approximately one-third of the world's population. Poverty is concentrated in the drylands which are home to the poorest and most marginalized people in the world, with 16 per cent of the population living in chronic poverty. Women and children suffer the most. Characterized by water scarcity, the drylands — which cover more than 40 per cent of the land surface globally — have less than 8 per cent of the world's renewable water resources. They are challenged by frequent droughts, excessive use of groundwater resources, salinization of irrigated lands, land degradation and loss of biodiversity, all of which lead to desertification — the loss of fertile land. Climate change, which in the dry areas leads mostly to lower rainfall, greater rainfall variability, higher temperatures, shorter growing seasons and seawater intrusion in coastal areas, is compounding these challenges and further threatening livelihoods in the drylands. As a result, there is greater pressure on the already limited natural resources, leading to overexploitation and mismanagement of land and water resources, loss of valuable biodiversity, desertification, increased poverty, poorer nutrition, migration and increased political instability which together pose significant threats to national and international development efforts.

The experiences of the International Center for Agricultural Research in the Dry Areas (ICARDA), after more that 37 years of research for development in the drylands, confirm that research and science — along with indigenous knowledge — can offer technically viable and economically feasibe long-term solutions to combat desertification in the drylands while enhancing economic growth, alleviating poverty and using natural resources sustainably. Examples of such accomplishments abound.

Image: ICARDA

Salinity threatening irrigated land in Iraq; complementary approaches are helping to reduce the negative effects of salinity on Iraqi agriculture

Landsat satellite images of pre- and post-salinity reclamation in Dujaila, Iraq, showing significant improvement in agricultural productivity by 2014



Source: ICARDA/NASA

ICARDA's most successful 'science for impact' experiences have relied on using holistic integrated human and agrosystems approaches. Such integrated approaches produce robust bodies of new knowledge, technologies and practices synthesized from three main research and practice domains, namely natural resource management; crop and livestock genetic improvement; and socioeconomics, policy and institutions. Through their integration, ICARDA and its partners in national programmes are tackling the complexity of the challenges on the ground and achieving large-scale impact, particularly when this integrated agrosystems approach is tailored to the different agro-ecological zones in the drylands with different agricultral livelihood systems such as pastoral/agropastoral, rainfed, tree-based and irrigated production systems. Using integrated agrosystems approaches also requires the collaboration of various stakeholders including multidisciplinary teams of researchers, farming communities, pastoralists, policymakers, civil societies and private and public sector actors. Below, we have shared two examples where such an approach has been particularly successful at ICARDA.

Salt-affected soils in Iraq

In 2013/14, biophysical and social scientists from ICARDA, together with scientists from the Iraqi Ministry of Agriculture and the Ministry of Agriculture and Water Resources of the Iraqi Kurdistan Region Government, adopted an integrated approach to combat land and water degradation caused by salinity. The project, which aimed to improve agricultural productivity and livelihoods in Iraq, was funded by the Australian Centre for International Agricultural Research, AusAID and the Italian Government. It followed two complementary approaches for adaptation, namely managing salinity (such as leaching salts added with irrigation water by drainage and other means) and living with salinity (such as planting halophytes and salt-tolerant plants). The collaborative research focused on saline water management; salt-affected soil and water management; and plant management and adaptation of agricultural production systems to salinity. Multidisciplinary teams of scientists worked side-by-side with smallholder farmers to test the impact of soil salinity and water management as well as the management of crop adaptation to salinity. Through a combination of interventions such as regional irrigation and drainage management; reclamation; salt extraction; salinity prevention and shifting agriculture systems to grazing; biosaline agriculture and agroforestry at watershed; irrigation district and field scales, agricultural productivity in salt-affected soils had improved significantly by 2014, compared to 1984 before any salinity reclamation efforts were implemented.

Parallel to these efforts, the project also researched fodder species that thrive despite salinity and drought stresses and are palatable to the livestock. Various fodder species were tested by the local communities of Iraq's rangelands. A pitter seeder was developed by ICARDA scientists to make a series

Images: ICARDA

Greening the Badia: laser-guiding micro-catchment water harvesting technology on contours for forage shrubs

of semicircular long depressions in the ground to drop seeds of selected palatable forage species. Livestock scientists also conducted research into rams and ewes in an effort to improve sheep flock productivity. The project provided 265 drought-tolerant and rust-resistant wheat genotypes developed in collaboration with ICARDA, which were tested by the Iraqi Government under irrigated conditions. Finally, significant policy research and support were provided to the Government on the national seed law, wheat seed policy and policy modelling. This holistic agroecological integrated research approach was effective in understanding and addressing the complex realities of Iraq's drylands and received positive evaluations from the donors, the governments of Iraq and the Iraqi Kurdistan Region Government.

Thus, through this project a new body of evidence related to soil and water salinity management was developed that included rehabilitation of irrigation and drainage networks, introduction of new salt-tolerant crops, improving the quality and management of groundwater, and introducing best farming practices to enhance crop production. This can provide new options and solutions for reducing the negative effects of salinity on Iraqi agriculture.

Jordan's rain-fed Badia

ICARDA, in collaboration with Jordan's National Center for Agricultural Research and Extension, is working with the Jordanian Government to reverse and prevent land degradation and desertification across the Jordanian Badia. The Badia stretches across most of Jordan and receives less than 200 mm of rainfall per year. It is a highly fragile, marginal and threatened agroecosystem that has become severely degraded over the last few decades as a result of overgrazing of rangelands and monocropping, the agricultural practice of culitvating the same crop year after year on the same land.

An elaborate integrated research site selection process was carried out involving the collection and analysis of geographic information systems data, hydrological surveys and rapid rural appraisals conducted by crop, livestock and soil scientists as well as social scientists to interact with the local communities and to conduct socioeconomic and policy analysis. The final sites were selected to test various innovations which included water harvesting, natural resource management technology packages and drought tolerant crops — mainly barley.

Among the interventions tested and adopted is the micro-catchment water harvesting technique using the Vallerani plough which ICARDA's scientists have further upgraded with an inexpensive auto laser-guiding technology. This new system enhances water harvesting capacity for forage shrub growth and reduces the cost and time required to identify effective water harvesting contours. It has tripled the water harvesting capacity, improved efficiency and precision and substantially reduced the cost of creating micro-catchments. The impact of the large-scale application of the Vallerani water harvesting technology has effectively reduced soil erosion and enhanced the collection of scarce water resources to conserve the precious rainfall as well as boost crop production — a win-win situation for the people of the Badia.

The improved Vallerani technology has been implemented on over 1,800 hectares of rangeland so far and the adoption

Images: ICARDA

Water harvesting technology in the Jordanian Badia has reduced soil erosion, enhanced the collection of water and boosted vegetative cover

rate is quickly rising. The Jordanian Government has decided to adopt the water harvesting technique to enabling large-scale planting throughout the Badia, which is substantially improving fodder and forage productivity, crop yields and incomes for pastoralists and farmers. Planting the fodder shrubs in widely spaced roads has reduced the pressure on rangelands which have now recovered with much more vegetative growth/cover. This has initiated the recovery process of lands degraded due to overgrazing and desertification. Benefiting pastoralists and farmers are enjoying more than 1.6 times their previous forage shrub production and significantly higher rangeland productivity. Their yield for barley has more than doubled as compared to that grown without water harvesting and water application.

This intervention was coupled with research to promote drought-tolerant shrub species as a crucial means of assisting rangeland rehabilitation efforts, helping to conserve rapidly-depleting water resources and maintaining grazing at sustainable levels. One of the most commonly planted shrubs in the Mediterranean, *Atriplex halimus*, is known for its remediation of degraded rangelands and salt-affected areas. It is commonly used as a forage plant for sheep and goats and contributes significantly to the feed calendar when herbage availability is low. It is the only green, protein-rich forage available during late summer and early fall when it is needed for the nourishment of pregnant and early-lactating ewes. Disseminated as part of a participatory sustainable grazing strategy, which was developed in cooperation with landowners, pastoralists and other community members, the promotion of native perennial shrubs has been a successful response to continuous land degradation. Recent successes include a significant increase in barley production, up from 50 tons per hectare to 200 tons per hectare in one rural community, and a near total halt of sediment loss due to the construction of micro water harvesting structures.

These technologies implemented in Jordan's rain-fed Badia for improved water and land management have successfully increased the vegetative plant cover and improved soil productivity, leading the way for expansion and scale-up in similar agroecosystems.

These examples from Iraq and Jordan demonstate the power of the integrated agrosystems approach which has been the cornerstone of ICARDA's research philosophy to address the challenges facing dry areas including the serious effects of climate change. We earnestly believe that this approach holds the key to bringing out the underutilized potential of the drylands. But science and technology alone cannot succeed without continuous investments in agricultural research and development and the support of an enabling policy environment. New and strong partnerships also assist in combating desertification since it is obviously beyond the scope and capacity of any one institution or country to cope with this. Therefore, in the cases mentioned above, both the Jordanian and Iraqi governments were involved as full partners from the beginning of the research process where both the countries adopted the technologies to launch large development interventions to combat land degradation and desertification. It is through partnerships, alliances and collaborative efforts such as the United Nations Convention to Combat Desertification, the Consultative Group for International Agricultural Research, the Global Dry Land Alliance and others that governments in dry areas are supported in planning for and envisioning prosperous dryland communities with higher incomes, better access to food, improved nutrition and health and increased capacity to manage natural resources in equitable, sustainable and innovative ways.

Food insecurity, drought and climate change: the case of Karamoja, Uganda

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Karamoja region in Uganda is among the most underdeveloped, poor and food insecure regions in the world. Bordered by an unstable and violent southern Sudan to the north and arid western Kenya to the east, Karamoja is the driest and poorest region in Uganda.[1]

The World Food Programme, other United Nations organizations and many non-governmental organizations (NGOs) are involved in humanitarian aid and development programmes, yet the region remains extremely poor and food insecure. Recurrent droughts are blamed for its chronic food insecurity. A drought risk assessment was carried out, and analysis of the historical meteorological data does not point to a higher occurrence of dry periods. However, the importance of Karamoja's vulnerability to dry periods due to economic, social and environmental factors was highlighted.

Recurrent droughts, coupled with human and animal diseases, conflict, sociopolitical challenges and economic distortions, have resulted in famine and extreme poverty among the Karamojong. Historically, these factors have exacerbated the climate for increased internal and external conflicts.[2] Means of livelihood in Karamoja were never owned by an individual but by all people in the community. Traditional weapons and firearm possession was common to protect community assets from enemy raiders. Historical intra- and inter-clan conflict over cattle and access to pastoral land and resources like water also added to the adverse effects; as did cross-border incursions by clans from neighbouring South Sudan, and the Turkana and Pokot from Kenya.

The population in Karamoja has increased 3.5 fold since 2000 to just over 1.4 million today.[3] The increased pressure on natural resources contributes to the perception or experience of a rise in drought incidences in Karamoja. Most of Karamoja experiences chronic food insecurity with approximately 82 per cent of the population living in extreme poverty. Life expectancy of the Karamojong is only 47.7 years with infant mortality of 178 per 1,000. Approximately 50 per cent of the Karamoja people are younger than 18 years with just 115,985 children in the 245 primary schools and 7,158 children in the 20 secondary schools.[4] Socioeconomic infrastructure and services such as roads, health centres, clean potable drinking water, sanitation and schools, and infrastructure such as roads and markets are poorly developed. Only 46 per cent of people in Karamoja have access to safe drinking water and 8 per cent have access to sanitation.

Image: 2014 DigitalGlobe

A satellite view of a manyatta in Karamoja

Image: DiMTEC

Pastoralists in Karamoja, like these young herders, own mainly cattle, goats and sheep

Image: DiMTEC

Most of the primary cultivation and weeding is done manually, by women

The Karamojong stay in 'manyattas' (homesteads) — a secure environment in which more or less 20 households live together. These households share a common perimeter, fenced off with local materials such as wooden poles and thorns to form a manyatta. The families in a manyatta are often related and live in close proximity, appreciating the need for safety and interdependence. They engage in shared labour like herding, watering livestock and gardening, and provide social support to each other in times of need.

The climate in Karamoja varies from arid to semi-arid, with precipitation from 500 mm per annum in the east to 1,200 mm in the west. Precipitation varies widely from year to year and by region. Karamoja has a unimodal rainfall pattern with rainfall from the end of March to October, and a prolonged dry period from November to March. Maximum temperatures in the east are 35.6°C with a minimum of 5.5°C during the dry season. Dry periods and droughts are a natural occurrence in Karamoja and part of the climate regime. A number of recent reports blamed recurrent droughts on the effect of climate change.[5]

The Karamoja region consists mainly of three agricultural systems: pastoralist in the east, agro-pastoralist in the central part, and predominantly agriculturalist in the north-west, named the 'green belt' of Karamoja. Livelihoods and agricultural systems are mainly linked to climatic conditions.

Land tenure is one of the most important vulnerability and/or coping capacity indicators for drought risk. The four main tenure systems in Karamoja are freehold, leasehold, mailo and customary. Customary tenure consists of individualized and communal subtenures, each with distinct characteristics and resource rights for individuals, households and the community. The two subtenure types are distinguished on one hand by grazing lands and shrine areas within the communal subtenure system; and on the other by arable cultivated land and land used for homesteads on which the manyattas are constructed in the individualized customary subtenure,.

The pastoralists in Karamoja own mainly cattle, goats and sheep with a few camel owners close to the Kenya border. Though characterized by a nomadic grazing pattern, their livelihoods are sedentary with families remaining in the manyattas while herders migrate to available grazing areas with drinking water as determined by the season and dry conditions. The mobility of pastoralists in Karamoja is one of the main coping mechanisms against drought and the single largest factor contributing to resiliency against dry periods and drought. The relatively low population and animal numbers, combined with available land, currently favour

Image: DIMTEC

Typical granaries

Image: DIMTEC

Sufficient, high quality grazing is essential to the pastoralist system, but restocking could cause a return to overgrazing

the communal land tenure system and the nomadic grazing patterns of pastoralists.[6]

The security situation in Karamoja, however, has a negative impact on the mobility of pastoralists and the pastoralist system. Pastoralists are forced to kraal their animals every night in fear of raiders from neighbouring South Sudan and Kenya. This practice results in overgrazing around the kraals and underutilization of grazing far away from them.

Crop production in Karamoja is rain-fed with high potential yields in the western districts of Abim, Napak, Nakapiripirit and the green belt of Kaabong and Kotido. These areas are ideally suited for rain-fed crop production due to good quality soils and annual rainfall of more than 800 mm. The main crops produced are sorghum, maize, millet, beans, groundnuts, cowpeas, pigeon peas, sesame, sunflower and sweet potatoes. Cassava is a new crop recently successfully introduced into the region due to its drought tolerance. Intercropping with maize, sunflower, sorghum, beans and cowpeas is a common practice in the higher rainfall zones.

Cultivation of fields and gardens is done manually with hoes and only the more progressive farmers utilize oxen for cultivation. The absence of oxen as the main method of cultivation was evident in the eastern districts with more draught power utilization in the western districts. Women mainly do primary cultivation and weeding while generally men take the lead with harvesting.

Lack of water harvesting or soil conservation practices has resulted in poor plant growth. Cultivation only starts after the first rains. Seeding is done on poorly prepared seedbeds with resultant low germination and uneven plant densities. In addition, weeding is done too late and weeds compete with crops for available soil moisture. Cultivation and seedbed preparation is key in the successful production of crops, yet the way it is done in Karamoja makes agriculturalists highly vulnerable to dry periods.

The disaster risk assessment methodology as proposed by Wisner, Blaikie, Cannon and Davis[7] and adapted by Jordaan[8] was used as the framework for drought risk assessment. Phase 1 consists of the hazard analysis, Phase 2 the analysis of vulnerabilities and coping capacity, while Phase 3 entails the identification of adaptation and coping strategies.

The main determinant for hazard assessment in the case of drought is water deficit for normal production caused by too little precipitation and too high evapotranspiration. Assessment of these factors was based on historical meteorological data and contributions from focus groups and other stakeholders.

Dry conditions were analysed using satellite-based monthly rainfall estimates at 5 km^2 spatial resolution. The source of the rainfall data was 'CHIRPS', a blended rainfall dataset developed by the United States Geological Survey for the whole of Africa for agricultural productivity and long-term drought analysis. Macharia prepared the precipitation anomalies for the past 10 years.[9]

Analysis of the results clearly shows that below-average precipitation is the exception rather than the rule and the perception of droughts every second year is totally unfounded.[10]

Drought vulnerability was measured using indicators for each of the seven districts and these were grouped according to economic, social and environmental indicators. The main economic vulnerability indicators were extremely low crop yields as a result of poor agricultural practices; high post-harvest losses (40-60 per cent); market imperfections; and high animal mortalities mainly due to animal diseases.

The traditional social structure in Karamoja elevated the importance of social vulnerability. The main social vulnerability indicators were cultural beliefs and practices; gender discrimination and beliefs regarding gender responsibilities for food production; extremely low literature levels; lack of knowledge — which resulted in poor agricultural practices; and security, which limits the movements of pastoralists and agriculturalists.

Environmental vulnerability to drought in this case refers to natural resources such as grazing, soil and water. Important indicators were bush encroachment, overgrazing, water availability and soil quality.

Image: DIMTEC

Gold mining is a survival practice that has negative and unintentional consequences

Some people in Karamoja survive and cope during dry periods in spite of extreme poverty and vulnerability. Different survival practices with negative and unintentional consequences are utilized for survival. These include sand mining, gold mining and charcoal burning. The large number of NGOs and United Nations organizations involved in humanitarian support also assist livelihoods to survive but this is not sustainable due to the development of a dependency syndrome among the people in Karamoja.

The best and most sustainable example of coping with dry periods is the pastoralist system.[11] Pastoralists have sufficient land to follow the water and grazing. They move their animals from the dry regions to regions with sufficient grazing. The current land ownership system and relatively low animal numbers allows for such movement. However, the restocking programme from the Government is threatening this strategy. Animal numbers in Karamoja declined by about 50 per cent after the successful disarmament programme of the 'Karamoja warriors' in 2008. An unintentional consequence was that rebels and others from neighbouring south Sudan and Kenya then raided and stole large numbers of animals without resistance from the Karamoja pastoralists. Reduced animal numbers allow for the recovery of overgrazed land and therefore sufficient grazing for pastoralists. Restocking will increase pressure on available grazing and the pastoralist system will also be more vulnerable to dry periods.

Drought risk is a more complex problem than what is normally defined as a negative deficit in annual mean rainfall. Rainfall distribution is important, as is annual rainfall, but farmers, government and development partners cannot do anything about that. When farmers start to experience droughts every second year, clearly there is a problem with the agricultural system; it is not adapted to the current climatic conditions and requires adaptation, or farmers employ risk-seeking methodologies such as poor agricultural practices.

Most of the droughts experienced in in Karamoja since 2000 are in fact man-made and not the result of poor climatic conditions; that means that agriculturalists and pastoralists can do something about drought risk. They can reduce drought risk and build resiliency against drought simply by implementing good agricultural practices. In order to achieve that, they must have the necessary knowledge and institutional support. Limitations in terms of cultural beliefs, gender and security should also be addressed.

Development partners such as NGOs and United Nations organizations can reduce drought risk by implementing coordinated and specifically designed programmes with a focus on drought risk reduction. Government should develop and implement policies and create an environment for sustainable development according to a commonly agreed strategy in Karamoja.

Biosaline agriculture as an approach for combating desertification

Dr Abdullah Dakheel, Dr Rao Nanduri and Dr Richard Soppe, International Center for Biosaline Agriculture, Dubai

Desertification has several causes, including population pressure, changing climatic conditions, economic, political and social conditions, and lack of access to science and technology.

The Millennium Ecosystem Assessment lists overgrazing as one aspect of the desertification cycle, when land and water do not provide enough resources for sustainable grazing. Salinization of soils is another chain in the process towards desertification. Desertification usually results in more poverty which in turn strengthens the conditions leading to desertification. Rehabilitation of desert systems requires the adoption of multiple strategies including the rehabilitation of natural degraded ecosystems and the use of the limited water resources in agriculture production, afforestation and aquaculture systems in certain cases. However, water resources in deserts are in most cases limited to groundwater of ancient origin or shallow aquifers that mostly have became salinized due to overutilization and depletion. In coastal and subcoastal deserts seawater and highly salinized groundwater resources exist in large quantities; however their use in rehabilitation requires the use of special agroecosystems that can tolerate such high levels of salinity.

An approach to break this cycle is through the application of biosaline agriculture at different locations in the landscape. More salt-tolerant and drought-tolerant plants can be introduced, allowing the use of marginal water resources to increase plant production for foraging or fodder, thus reducing the risk of overgrazing. Higher-value salt-tolerant plants and trees can be introduced to provide a source of income to local populations. In addition to introducing landscape management, socioeconomic and (implementation of) policy decisions are needed. The introduction of managed forage land under saline conditions, for example, should not result in an increase of the grazing population larger than the carrying capacity of the managed lands.

Several aspects need to be considered when biosaline agriculture is introduced. Introducing new genetic resources (new genotypes or more salt-tolerant species) requires access to seeds, or introducing nurseries, as well as an assessment of crop diversity and management to maintain the local diversity (prevent invasive species to compete out the local genotypes and varieties, for example as is the case with wild melon in Australia). Maintaining the local biodiversity ensures an ecosystem that is adaptable to changing environmental conditions.

Image: ICBA

Rehabilitation of desert areas with salt-tolerant grasses (Oman)

Image: ICBA

Salicornia is produced on a large scale and irrigated with seawater in coastal areas

The economics of the introduced biosaline agricultural system are important. Since desertification is related to the poverty cycle and marginal agricultural ecosystems, it is important that the new landscape management system has a positive contribution to the local economy. Two examples are the introduction of more salt-tolerant date palms, a cash crop with an already existing market system in many desert-prone areas, and quinoa, a high market value crop which produces seeds and biomass well under marginal conditions (salinity, high temperatures and drought).

Providing forage and grazing genotypes and varieties that are adapted to marginal conditions (such as drought and salinity) also requires an analysis of the nutritional value, and the palatability of the introduced crops. A crop can be growing well under the marginal conditions, but if it does not have a nutritional addition, or if the small ruminants are not willing to consume it as part of their diet, the value of the crop is limited for the region.

In some areas, only seawater is available. Some plants growing under hot, coastal conditions, halophytic plants, can provide an economic value, for example plants from the Salicornia genotype. In the Netherlands, a market chain was developed and supported, including the development of customer demand through the introduction of cooking classes and recipes, for Salicornia imported from the coastal and desert areas in Mexico.

Land and water management needs special attention when managing agroecosystems under dry and saline conditions. Water resources are often non-renewable (fossil groundwater) and application of saline water on soils without considering the potential accumulation of salts can lead to non-sustainable, short-term solutions. Although in some cases, short-term solutions can be applied to overcome crises periods, the long-term aim of land and water management in fragile and marginal environments is to develop sustainable solutions.

When saline water is used for crops, forestry or any type of biomass growth, evaporation and transpiration will result in an increase of concentration of salts. These salts, previously stored in the water source (groundwater, seawater or other surface water sources) are increasing in concentration due to evapotranspiration, but also due to the spatial accumulation at the locations where plants are grown and irrigated. Consideration of where the accumulated salts are stored is a necessity under biosaline agriculture. Options are to store salts in the soil below the active root zone (through leaching of salts, that is the application of excess water to move the accumulated salts away from the plant roots), leach salts into the groundwater (less preferable), or concentrate salts in evaporation ponds where they can be collected in solid form and taken out of the agro-production system).

Six different groups of biosaline systems have been piloted in the Arabian Peninsula, providing opportunities to break the poverty cycle, green the desert and reclaim salinized lands. These groups can be classified as conventional forage production systems; non-conventional forage production for subcoastal and coastal deserts; high-value crops and date palms; medicinal crops production systems; seawater-based systems including aquaculture; and production systems based on treated wastewater.

Forage production systems

Water scarcity and salinity are two of the biggest constraints to agricultural production in several counties in the Middle East and North Africa region. In the United Arab Emirates (UAE), over the years, more than 70 per cent of the farms were dedicated to forage production, mainly with Rhodes grass (*Chloris gayana*) — a high water consuming crop. The large-scale cultivation of this fodder grass species to meet the increased demand for forages in the emirate, has had a profound impact on the usage of water resources for agriculture and contributed to the depletion of the groundwater reserves faster than the aquifer recharge that depends on the scanty rainfall and as well as in increased aquifer salinization due to intrusion of seawater, especially in the coastal areas with close to 4,800 farms facing the risk of abandonment. In a pilot project on three farms in the UAE, four halophytic perennial grass species were planted: *Distichlis spicata*, *Sporobolus virginicus*, *S. arabicus* and *Paspalum vaginatum*. The new grasses, with the mean green biomass yields ranging between 122 t/ha and 141 t/ha per year and dry matter yields between 24 t/ha and 42 t/ha per year, proved to be excellent and viable alternatives to Rhodes grass for sustainable forage production in salt-affected/degraded farms. In terms of water productivity, the forage yields obtained per cubic metre of highly saline water (15-18 dS/m) were 66 per cent more than the yields reported for Rhodes grass with low salinity water (2 dS/m). In terms of water saving, it means saving 44 per cent of water to produce the same amount of forage as Rhodes grass.

Potential high-value crops

Several neglected and underutilized species, because of their resilience and natural adaptation to harsh growing conditions, can provide alternatives to the staple crops to sustain farm productivity in desert environments constrained by water scarcity, poor soil fertility and other such yield-limiting factors. Among the species native to or naturalized in the Middle East, Christ's thorn jujube (*Ziziphus spina-christi*), purslane

Image: ICBA

Salt-tolerant and drought-tolerant plants allow the use of marginal water resources to increase plant production and reduce overgrazing

(*Portulaca oleracea*), jute mallow (*Corchorus olitorius*), rocket (*Eruca sativa* and *Diplotaxis tenuifolia*), safflower (*Carthamus tinctorius*) and wild drumstick tree (*Moringa peregrina*) have considerable value in terms of their tolerance to salinity and harsh climatic conditions. Many such species have the potential for more widespread use and their promotion could contribute to food security, agricultural diversification and income generation, particularly in areas where cultivation of major crops is constrained or economically unviable. Similarly, salt- and drought-tolerant non-native species such as leaf mustard (*Brassica juncea*), quinoa (*Chenopodium quinoa*), salicornia (*Salicornia bigelovii*), guar (*Cyamposis tetragonoloba*) and amaranth (*Amaranthus cruentus*) which showed good adaptation in field trials under harsh conditions in the UAE, are likely to be of value in providing cost-effective and long-term solutions to problems of water shortage and increasing salinity of soil and water resources in the region. Besides their tolerance to abiotic stresses, all these species are nutritionally rich and can thus play a crucial role in combating vitamin and micronutrient deficiencies frequently experienced by inhabitants of marginal environments. Research to improve the productivity and value of these crops, and to encourage them to be more widely cultivated, would contribute to food, income and nutritional security for smallholder farmers in marginal environments.

Medicinal crop production systems

In combating desertification, integration of biodiversity conservation into economic development — accomplished through sustainable production and commercialization of natural products derived from native plants — is beginning to emerge as a major strategy in several countries. Deserts harbour a variety of flora adapted to the dry conditions and surviving for several years without water. The medicinal value of these plants is well known, for example, nearly 20 per cent of the 750 native plant species documented in the UAE are known to have medicinal properties. Two good example are *Aloe vera* (sabar), a shrubby xerophytic, succulent plant used for centuries for its health, beauty, medicinal and skincare properties, and *Cynomorium coccineum* (tarthuth) a parasitic plant considered as a 'treasure of drugs' because of its numerous traditional therapeutic uses in treating colic and stomach ulcers, piles, nosebleeds, dysfunctional uterine bleeding and as a contraceptive. Most medicinal plants are still being collected from the wild population and many are being seriously threatened by overgrazing and habitat degradation. According to the UAE Red Data plant list, of the 132 species of medicinal plants, six species fell under the threatened category. Thus, it is important to integrate commercial exploitation with action plans for sustainable conservation and use.

Seawater and brine-based systems

To provide additional income and reduce the poverty cycle, improving water supply for human consumption and irrigation purposes requires the desalination of groundwater. Approximately 15 per cent of farmers in the Arabian Peninsula have installed small-scale reverse osmosis (RO) plants to desalinate the groundwater for field crop irrigation. These RO plants produce highly concentrated brine which can be used as a resource under best management practices. A project to showcase the potential of a farming system using seawater-level brine was developed in the UAE. The desalinated water is used to irrigate a large variety of high-value vegetable crops (such as asparagus, eggplant and radish). The produced brine is used for aquaculture, followed by irrigation of salt-tolerant forages and halophytic plants. The mariculture system contains fish, sedimentation and seaweed tanks. Two fish species (sobaity seabream and tilapia) showed adaptability to the fish tank conditions in the Emirati climate. One of the halophytic species irrigated with brine is *Salicornia bigelovii*, a multipurpose species that can be used as a vegetable, biofuel or fodder. Previous research found that cultivating the proper salicornia varieties, combined with suitable agronomic practices, could be economically viable and successful in marginal land.

Production systems based on treated wastewater

Arab countries are expected to face severe water scarcity as early as 2015, when the annual per capita water share in the region will fall to less than 500 m^3. Give that agriculture uses 70-80 per cent of all water, the reuse of reclaimed (treated) wastewater for irrigation could contribute considerably to the reduction of water scarcity for domestic use. In many countries of the Arabian Peninsula, due to the problem of social acceptance and the perception of health risks, municipal wastewater, even after tertiary-level treatment, is not used for growing food and feed crops. In the UAE, of the 600 MCM of tertiary-treated wastewater produced per year, 58 per cent (352 MCM) is used mainly for landscaping and the rest is discharged into the sea. In fact, reclaimed wastewater can be a valuable resource to grow bioenergy crops for the specific purpose of producing liquid fuels, with considerable economic and environmental benefits, when social barriers prevent its use for growing edible crops. If bioenergy crops can be cultivated on a commercial scale, they can reduce pressure on fossil fuels while simultaneously improving environmental quality and reducing desertification/soil erosion which is also a matter of serious concern in the region.

Restoring the soil to feed people and fight desertification

Claire Péhi-Verny, President, Association Pour un autre monde

The association 'Pour un autre monde' (For another world) was founded by seven people from the academic community in Alsace, with the goal of educating for sustainable development. Pour un autre monde chose to target school pupils because, being educators, we believe that what is learned at school can imprint something in a pupil's mind and make a more responsible adult. Living in Alsace, a French province with water pollution problems and a lively 'organic network', we focused on agroecology for our contribution to stop desertification. We also taught French and nearby German pupils a form of active solidarity and reflection on their own energy-consuming behaviour.

The association first worked in Sri Lanka after the 2004 tsunami. Coming to Burkina Faso in 2006 was pure chance: a Burkinabè (resident of Burkina Faso) had seen our website and requested to partner with us. We have remained in the country to work in depth in order to address real local needs.

Our first president discovered Africa when he flew to Burkina Faso. He started the first project in Bobomundi with the help of the Centre écologique Albert Schweitzer in Ouagadougou, and signed an agreement with the Government. I discovered Africa when I was 12 years old. I went to school and university in Dakar and Abidjan and married in the Ivory Coast, so taking part in a Pour un autre monde adventure in Burkina Faso was only natural.

Soon, contacts with local teachers brought us to the Loroum Province in the North region. We began training teachers, pupils and volunteer parents of the first four partner schools in Sahelian compost making, growing organic vegetables, mulching, limited watering, water harvesting, shrubbery and tree planting. Through these endeavours we improve the daily food rations of both the children and their families. We restore the degraded soil, sterilized by 40 years of drought, by producing humus and we plant local trees to combat desert growth, using seeds from the National Forestry Seeds Centre in Ouagadougou.

The four school gardens of Hargo, Salla, Siguinonguin and Rimassa attracted the attention of colleagues coming for meetings at the education offices. We now work with 26 primary school partners, two secondary schools in Loroum and one 700 km away in Sebba, in the Yagha province of the Sahel region. Two coordinators, Appolinaire Bazié in Titao, Loroum province and Souleymane Diabate in Sebba, follow the projects year-round on a voluntary basis.

Images: Association Pour un autre monde

Pupils collect material such as cow dung, ash and poultry bones to help create natural compost, and enjoy stamping the damp clay during watering of the trenches dug by the parents

Images: Association Pour un autre monde

Trenches are layered using the natural fertilizer material and water, then dried grass is added to the top and weighed down to secure

Pour un autre monde works with small investments for big profits. We are a small non-governmental organization (NGO) with a €30,000 yearly budget, but we help feed 15,000 pupils for eight months of the year. Those pupils are able to study better and are in better health. Girls can remain in school longer instead of pounding sorghum.

As volunteers we pay for our own plane tickets and food, only declaring these costs to the tax office to get a one-third rebate on annual income taxes. The NGO rents a house in Titao and bought its own vehicle — a three-wheeler motorbike — to visit the schools, meet partners and carry materials, covering distances of approximately 5,000 km in 12 weeks. Transferring know-how is free.

The projects include fostering 40 pupils or students and providing materials and books, photovoltaic plates (we have already installed 18, 10 of which were co-financed by Sol Solidari), 40 pedal sewing machines for girls leaving school, five mesh roll hand machines for out-of-work youth (creating 10 self-sustained jobs with profits going to the schools), and five fuel grain mills controlled and managed by mothers. We plan to open the first solar powered mill in November 2015.

A project begins with somebody contacting the coordinator (kindly loaned by the Directeur Provincial de l'Education Nationale et de l'Alphabétisation (DPENA) in Titao) or any Pour un autre monde representative — phone numbers, cards and flyers are easily passed from hand to hand. Before making a decision about the request, we meet three or four times with teachers (and pupils' heads in secondary schools), parents' and mothers' associations (APE/AME), the Education Inspector, local authorities such as chiefs, elders and mayors, and environment and agriculture directors. We report twice yearly to the DPENA.

The first group of partners wrote a 'guide for sustainable projects' in 2012, which was completed in 2014. The guide describes activities during the five years of the project, the role of the NGO and what the teachers, pupils and parents will do (including a 20 per cent contribution in money or work). It lists the people responsible and the materials in the school's inventory, and explains how controls are established with the school garden copy book (written by different pupils) and with the APE/AME bank book (as schools soon gain money selling surplus vegetables or grain, iron mesh rolls, charging telephones or grinding flour).

If everybody agrees, after hours of friendly discussion, news, translations and thanks, the plan is signed and a copy is given to the DPENA. We set up a Comité de suivi et de gestion (monitoring and management committee) which consists of parents and teachers working together with the NGO as a non-voting member. Once that is in place, the practical work begins.

Here is a typical account of how we work to make a garden out of a 'zipelle' (a sterile ground haunted by djinns). Before the first practice visit, parents have dug the first of four trenches (3 m x 0.75 m x 0.4 m). Pupils have collected 'rumbs bindu' (dried cow dung) for azote, dried vegetal refuse for carbon, little bags of ashes from the kitchen fire for potash, and dried small poultry or fish bones for calcium and phosphorus. The cow dung and vegetal refuse, including sorghum chaff, are watered two days beforehand to revive the good bacteria and prevent people from inhaling cow dung dust when breaking it into small pieces (this causes pneumonia, as I found out).

To check soil permeability we throw water from five watering cans into the bottom of the trench: if it disappears quickly we need clay, of which there is plenty in Loroum. We then ask volunteers to stamp the damp clay — the pupils enjoy this chance to have their feet in water and mud with their parents' and teachers' approval. If water remains we start some damming using the pupils' feet as well. Then we make a gigantic sandwich consisting of 17 wheelbarrows full of damped dried plants, six to seven wheelbarrows full of humid cow dung in small pieces, two handfuls of ashes and two handfuls of pounded bones, with five or six cans of water for each layer. This fills the trench up to knee-level. To finish, we add plenty of dried grass in a layer 10 cm thick. If it

Image: Association Pour un autre monde

A mix of vegetables and plants in the hewn and watered beds

Image: Association Pour un autre monde

Young trees are protected by woven baskets

is very windy we put broken, spikey branches from the Balanites aegyptica tree on top to make sure the materials will not fly away.

Two weeks later, parents have planted the posts for the iron mesh protection and dug the rest of the trenches. I put my hand into the mixture, take a handful of the already fermenting compost and sniff it. This shocks the children and parents at first, but they don't see the different components anymore, only the black compost, and once everybody has sniffed it they agree that it does not smell bad. In fact, there is always a child who says that it "smells like the rainy season", like earth after the first rainfall — and that is a delicious smell to all Sahelian noses.

I then start putting aside the straw layer with the help of Appolinaire Bazié or Souleymane Diabaté. We ask pupils to bring water and we pour five watering cans full in the second trench. We start throwing the contents of the first trench into the second, and after three minutes the picks and shovels are taken from our hands and parents, teachers and pupils take turns (temperatures are 35-45 degrees Celsius depending on the season). For the first turnover you need only the first five watering cans of water at the bottom and five on the top layer before you put the straw cover on it. Then we fill the first trench again, as we did before.

We bring a dozen young trees for this visit, and we give a tree planting course: dig a hole 60 cm deep and 40 cm in diameter, throw in about five litres of water to make a water reserve, mix one third of young compost with sand or small gravel and red earth. Undo the recycled plastic bag with care, free the roots, place seedling in the half-filled hole, fill and harden the soil with your fist to make a small basin and complete with mulching and protection — this can be a nicely woven basket or a makeshift job with branches. The rest of the trees will be planted by the teachers.

Six weeks after the first practice we return to find three trenches underway, and two- and four-week-old compost. Pupils have hewn and watered the future vegetables beds. This time we bring more young trees, seeds and vegetable seedlings that are 20-30 days old. Pupils plant a mix of vegetables of different families (it is a challenge to explain that tomatoes, aubergines and potatoes are of the same family and so 'eat' the same nutrients in the ground) and then mulch with a mixture of chaff, dried leaves and grass, watering every evening the first week and three times a week — or even twice weekly — during the next weeks. This is judged by digging a forefinger in the soil: if the soil is 'cool', don't water. In two to four weeks cooks will have something to use, pupils will have seen different stages of vegetable development and learned that some will perhaps not give anything, in spite of loving care. Semi-ripe compost can be used with different vegetables. Pierre Rabhi, the inventor of that technique, kindly allowed us to copy the drawings in his book and leave them in the schools.

Finally, in week eight the compost is ripe: it can be used for cereals or dried in the shade and put in sacks for further use, especially during the rainy season when too much water would make it rot and smell. In the meantime the 'compost wheel' continues to turn. There is always something underway and the schools produce 500 kg of compost every two weeks after the first two months. This amount can improve a half-hectare in cereals or vegetables, so we ask the schools to share it with the parents who help out.

That's how schools in several villages have each planted a garden and trees, and how every year four or five parents in each village have tried for themselves. It is the way many women's groups have learned how to grow vegetables without buying fertilizers and how to protect against predators with azadirachta indica oil or tea, tomato leaves or dangling broken CDs against the birds, how to make paper balls for the stove instead of burning it away, and how to use old plastic bottles for insect traps or slow-drip watering.

Each successive DPENA has facilitated our work, understanding the long-term issues. Our dream is to make it part of the primary schools curriculum in Burkina Faso so that in every dry yard, even in town, on every dry patch of land, everyone will have the know-how to grow vegetables, beans, cereals and trees, with three times more than the average chemically fertilized production, with little water, less hard work, no chemical pesticides, little expense and a nice profit. Sahel will be green again, forests and rains will come back, and hunger will be a ghost of the past.[1]

Long-term drought in southern Australia

David Jones and Alex Evans, Australian Bureau of Meteorology

Australia is the driest inhabited continent with strong rainfall variability from year to year. Annual mean rainfall averaged across the continent is 465 mm, but this has varied between a low of 314 mm during 1902 (an El Niño event) to 760 mm during 1974 (a La Niña event). While rainfall is not strongly correlated from year to year, a number of multi-year drought events have occurred of varying spatial and temporal duration and intensity including the federation drought (1896-1902), Second World War drought (1937-1945) and more recently the millennium drought (1997-2010).

Each of the multi-year drought episodes resulted in severe societal and economic impacts, with the loss of life through wildfires and heatwaves. The first two of these multi-year droughts were widespread in impact affecting the bulk of continental Australia, whereas the millennium drought mostly impacted southern Australia. While an estimate of the full cost of the millennium drought is not available, extremely low rainfall during 2006 saw the loss of an estimated $A7 billion in agricultural production alone. Devastating wildfires occurred during the summer of 2002/03, 2006/07 and 2009 in forests which were tinder dry due to drought and heat. The Black Saturday bushfires of 7 February 2009 resulted in 173 deaths and at least $A4.4billion in property damage across south-east Australia, being one of the costliest disasters in the country's history.

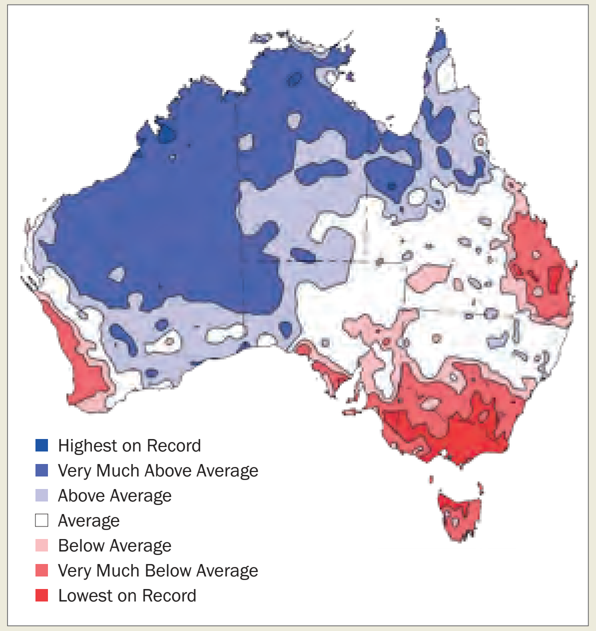
While drought is an episodic feature of the Australian climate, the most recent drought highlights a confluence of climate variability (drought) and climate change (changing aridity) and raises the question of how to define and manage drought in a changing climate.

The millennium drought affected most of southern Australia with particularly severe conditions experienced in the more densely populated and cultivated south-east and south-west regions. A feature of the millennium drought was the especially marked decline of cool season rainfall in the south with little reduction in the warm season rainfall in the south and excessive summer rainfall in the tropical north. The cool season is the main agricultural period across southern Australia. This meant that irrigated agriculture reliant on winter inflows into dams was badly affected across the south, as was winter grain production in the southern cropping regions of Australia (annual grain production is near 40 million tons). Impacts on ecosystems and urban water supplies dependent on cool season replenishment were also significant. In striking contrast northern Australia, a region of low population density and lower intensity agriculture, saw above-average to record-high rainfall during the summer half of the year.

The effect of below-average rainfall during the cool season was accumulative in southern Australia, leading to increasing hydrological impacts which compounded over the years. This saw a long-term drying of vegetation and a drawdown of surface and ground water resources. For example, in Melbourne (a city of more than 4 million people) urban water storages dropped from almost full in October 1996 (97.5 per cent) to only one-third full by June 2010 (33 per cent). Water supplies for this city would have been emptied at the peak of the drought were it not for water restrictions and price increases applied to water use in response to the drought which curtailed consumption.

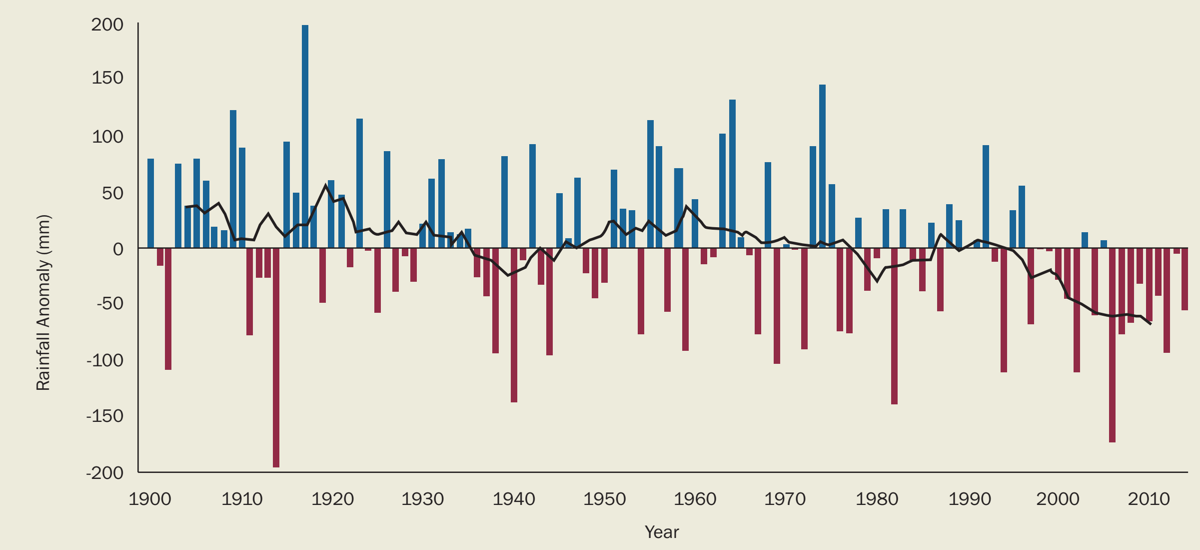
With the millennium drought affecting all major capital cities across southern Australia, large-scale urban water projects were commissioned, including the construction of desalination plants in Perth, Adelaide, Melbourne, Sydney and Brisbane with a total cost of more than $A10 billion. The trigger for supplemental water supplies was a lack of confidence in the past as a

Rainfall deciles for the peak of the millennium drought, calculated from national rainfall data from 1900 to the present



Source: Australian Bureau of Meteorology

Cool season rainfall in south coastal Australia: the solid line shows the 10-year running anomaly



Source: Australian Bureau of Meteorology

guide to the future, and the very real fears for water supplies in the event that the drought continued.

The distinctive feature of abnormally heavy warm season rainfall in the north and cool season rainfall deficits in the south has no obvious parallel in the historical record, and is not easily understood in terms of the dominant natural variability tied to the El Niño Southern Oscillation. Past droughts tended to extend across most of Australia and have a particular focus across the eastern third of the country, where rainfall is reduced during El Niño events. The millennium drought, however, manifests out of strong seasonal rainfall across Australia, which also provides insight into the proximate ('local') cause of the drought.

Rainfall in northern Australia is dominated by the summer monsoon, with rain coming from storms, monsoonal lows and the occasional tropical cyclone between November and April. The cool season is virtually rain-free with high rates of evaporation, low humidity and clear skies.

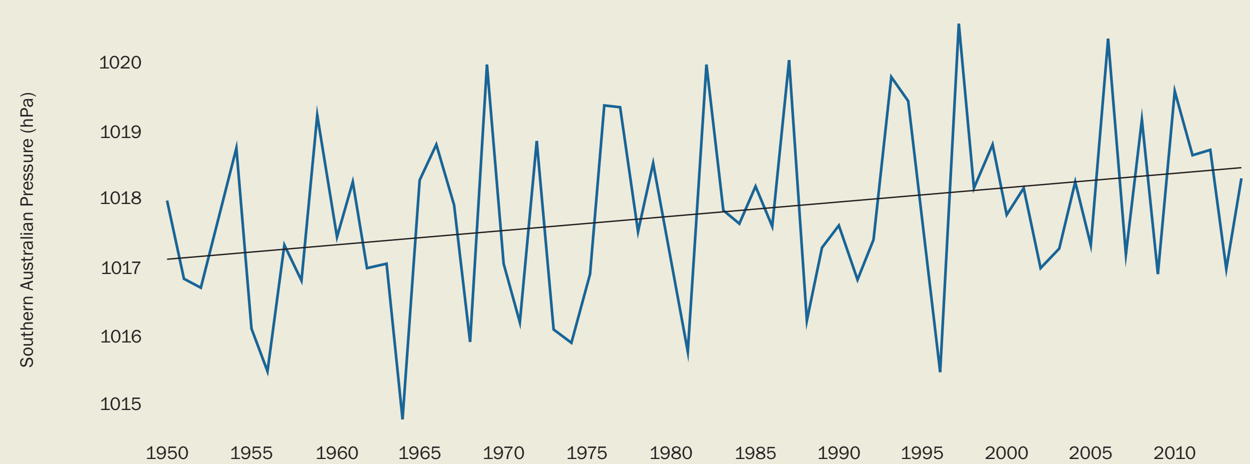
In southern Australian (south of about 35°S), most of the annual total rainfall comes as a result of cold fronts and mid-latitude (baroclinic) low pressure systems. These systems peak between April and October (the cool season) when the lows in the Southern Ocean tend to move closer to Australia as the dominant belt of high pressure moves further north to be placed over the Australian landmass. While summer rainfall does occur, surface water balance is such that during the warm months it contributes very little to water supplies for urban use, and has very limited use for agricultural production.

Southern Australia sits on the northern limit of the mid-latitude westerlies and is particularly susceptible to shifts in the intensity and latitude of fronts, low and highs. Of particular importance is the dominant high pressure belt, known as the Subtropical Ridge, which extends across central Australia during the cool season. This high pressure belt is the cause of the semi-arid and arid dry zones that occupy the subtropics in both the northern and southern hemispheres. A poleward shift in the high pressure belt and increases in its intensity means dry zones expand further into the mid latitudes (and vice versa). El Niño events are one factor that can drive an expansion and intensification of the high pressure belt over Australia, which is part of the reason for the droughts that Australia commonly experiences during these events.

The April to October cool season rainfall across southern Australia shows a systematic decline in recent decades that is broadly consistent with climate change projections for the region. The recent multi-year drought appears as a continuation of lower rainfall which commenced in the 1970s. The initial decline appears as a loss of very wet years and more recently the near-complete dominance of below-average rainfall conditions year after year. During the past decade the mean rainfall in this region is more than 15 per cent below average, meaning the loss of more than 1.5 years of cool season rainfall in total during the millennium drought. This anomaly is more than twice as large as for any previous like period and up to four times as large in some high rainfall catchments relevant to urban water harvesting in southern Australia.

The recent decline in rainfall has coincided with increasing atmospheric pressures between the months of April to October and a subsequent decline in the penetration of fronts and lows across southern Australia. The intensifying pressure means an increasing dominance of dry weather as the subtropical ridge has become more dominant. Atmospheric pressure across Australia shows remarkably strong correlations with rainfall and explains some 60 per cent of the year-to-year variability (variance). The accumulated impact of the trend in pressure implies a mean rainfall reduction of nearly 50 mm over the past 50 years. This figure is close to the anomalies which have been observed during the millennium drought in southern Australia. In other words, the proximate cause of the recent cool season

Cool season (April-October) mean sea level pressure near southern Australia showing an increase since 1950



Source: Pressure observations taken from National Centers for Environmental Prediction/National Center for Atmospheric Research reanalyses

rainfall deficits during the millennium drought is the dominance of high pressure. This suggests that the drought should be considered, at least partly, as a shift to a more arid climate rather than just an episodic drought event following which conditions will return to the historical norm.

Even though the millennium drought is popularly considered to have ended during the 2010-2012 La Niña sequence, there has been little recovery of cool season rainfall across southern Australia. The period from late 2010 to early 2012 saw nearly continuous La Niña conditions in the Pacific resulting in the wettest two-year period on record for Australia. However, the heavy rainfall was confined to the summer half of the year, reinforcing the multi-decadal pattern of increasing tropical (summer) rainfall in northern parts and poor cool season rainfall in the south. With the return to near El Niño conditions in 2014 and a subsequent El Niño in 2015, rainfall patterns in southern areas and parts of eastern Australia have returned to a situation similar to that which occurred during the millennium drought. Preliminary data suggests that pressure over southern Australia is likely to be above average in 2015, indicative that the background trend continues.

It remains to be seen whether the emerging impacts become as severe as those felt during the millennium drought. Detailed climate change projections for Australia show that continued rainfall declines are likely in the cool season in southern Australia, and it is very unlikely that these will be offset by summer rainfall increases. These changes will interact with natural drought cycles and may be expected to give rise to conditions beyond earlier experience.

Climate science and continued weather observations highlight that recent dry periods across southern Australia are more accurately characterized as a shift to an increasingly dry climate (increasing aridity), rather than simply episodic drought events. The poleward extension of the subtropical dry zones and contraction of the westerlies is one anticipated impact of a warming climate under the enhanced greenhouse

Image: Australian Bureau of Meteorology

A dry lake bed (Tchum Lake) in the Mallee region of Victoria at the peak of the hydrological drought

effect with ozone depletion enhancing this shift. These anthropogenic drivers provide a causal mechanism for the changes in pressure and rainfall in Australia's south which continue.

While natural rainfall variability in Australia remains large, and rainfall continues to be strongly influenced by the El Niño Southern Oscillation, it is likely that the drying across southern Australia in recent decades cannot be explained by natural variability alone. When combined with increasing temperatures and heightened demands for water, it is imperative that managing for drought must look beyond the past as a guide, and towards understanding the interaction between climate variability and change to better inform decisions for the future.

Recovering life in the desert: successful experience with indigenous communities in Mendoza, Argentina

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In contrast to the widespread image of Argentina as the 'the world's breadbasket', reality shows a vast territory (around 70 per cent) of dry, arid, semi-arid and dry sub-humid lands affected by different degrees of desertification. The Monte Phytogeographic Province makes up an arid diagonal that crosses the country with all gradations of aridity. This ecoregion, devoted to raising cattle and livestock, is the driest of cattle lands in Argentina. Agriculture is confined to areas under intensive irrigation, the winemaking 'oases'. Both types of land use are responsible for a great part of the degradation, evidenced not only by biodiversity loss and deforestation of native woodland, but fundamentally by the poverty of the people, most of them subsistence goat herders who still remain in non-irrigated drylands in extremely critical survival conditions.[1]

Mendoza, with a surface area of 150,839 km^2 and a population of 1,741,610 people, is located on the central strip of Argentina's drylands and 100 per cent of its territory is desertified.[2] This territory is organized on the basis of a great contradiction; the confrontation between irrigated lands (oases) and the non-irrigated lands of the desert. Competition for the use of water arises as one of the major environmental conflicts in interaction between oasis and desert: the latter no longer receives surface water inflows because river flows are fully used for irrigating the cultivated area and for consumption in urban settlements. Hence, non-irrigated drylands, which represent 96.5 per cent of the territory, are characterized by very sparse population — 1.5 per cent of the total population — with a subsistence economy based on goat production, and by their dependence for equipment on distant urban centres. The desert has lost its natural and social capital, which was used for building wealth in the oasis. Over time, it has offered valuable resources such as mesquite woodland and grasslands, which have been overexploited. The problems of land tenure, isolation and marginalization of desert inhabitants have produced strong exodus and migration movements. This involves abandonment of productive lands and increased suburbanization processes in the urban fringe.

The ultimate environmental problem affecting drylands is desertification, triggered by climate variability and human activities.[3] Despite the extent of Mendoza's drylands, it is essentially difficult to simplify the analysis of desertification because of the high diversity of socioeconomic, political, ethnic and ecological situations taking place throughout the area. Combating desertification is essential to ensure long-term productivity of these drylands. Many efforts have failed for using partial approaches, disregard-

The DPU experience involves active participation from communities in the 'El Junquillal' locality of Argentina

Source: IADIZA

Images: IADIZA

Members of the DPU community make brooms from rattan, one of the Lavalle desert's natural resources

ing the complexity and multiple cause-effect relationships and, above all, for not considering that dryland people are the major resource in these lands. They know the problems and potentials of drylands and have developed knowledge, technologies and skills to produce under restrictive conditions. However, they have been not only ignored, but also blamed for generating desertification. Traditional land use methods were often abandoned and replaced by foreign solutions which in many cases only managed to exacerbate poverty. Nevertheless, especially in recent times, successful experiences have been achieved by organizations that were able to listen to the local people, learn about their problems and priorities and rescue their knowledge in order to find shared solutions, putting into practice the concepts of participation, bottom-up planning, gender sensitization, reinforcement of identity processes and fighting against exclusion. In this context, the Demonstrative Production Unit (DPU) experience is presented, with active participation of local communities in the Lavalle desert.

The DPU initiative emerged in 2002 as the result of international cooperation. The Argentine Dryland Research Institute (IADIZA), Spallanzani Institute and the Desertification Research Centre (University of Sassari) conducted a feasibility study and started working on raising awareness and empowering local communities. With the support of the United Nations Convention to Combat Desertification Global Mechanism, a research-action programme was designed to generate strategies for local development and production diversification to combat desertification and poverty. The proposal leans on three pillars (natural, economic and sociocultural components) and, through local development, aims at achieving a better land use, improving and diversifying goat production, reducing livestock pressure and increasing producers' income. It combines innovative aspects of desertification assessment and monitoring, recovery and management of degraded lands for forage production, adaptation to global change, optimization of water resources, revegetation, establishment of nurseries, herd sanitation, design of DPUs directed towards production diversification (healthy goat milk and by-products), capacity-building in the local population and government, halting of migration through business opportunities and youth employment, training of specialized technicians, promotion of producers' associations and technical assistance for product trading. The work combines diverse methodologies: participatory assessment procedures, thematic mapping, participant observation, remote sensing, field control and establishment of measurement plots.

The DPU experience is set in the El Junquillal locality (Lavalle, Mendoza), located in the non-irrigated area: the desert. The territory exceeds 1 million hectares with indigenous communities, with a population reduced by migration and poverty to only 3,500 people (0.5 inhabitant/km^2), grouped in small settlements (hamlets built with adobe bricks). More than 31 per cent of their basic needs are unsatisfied and they have an illiteracy rate of 8.2 per cent. They are entirely devoted to subsistence goat production. The population self-identifies as being of Huarpe ancestry, and the productive activities they

Image: IADIZA

The community manufactures 'green' (unfired) bricks with local materials for the construction of the DPU

perform are related to a subsistence economy destined for self-consumption. These activities mostly include raising small livestock for the production of meat and manure. The climate is arid and precipitation ranges from 80-100 mm per year, which strongly affects productive activities. The experience is focused on a small Huarpe community called Pinkanta, of around 40 families. Eleven families in this community formed the Kanay Ken cooperative with the aim of participating with IADIZA and the Municipality of Lavalle as beneficiaries of the project. The people expect that the project will enable them to improve their quality of life through productive diversification and improvement of their fields, and to earn higher income and be able to rise above the poverty line, taking on the challenge that the desert can be productive and sustainable.

The proposal includes innovative traits in comparison with the strategies implemented thus far in an area whose natural resources have been devastated. It is based on acknowledging the rural environment potential from a surmounting perspective of the assistance and compensatory approach. It is framed within a conception of rural territory development that aims at competitive and sustainable agriculture, articulating the rural territory with dynamic markets. Its goals are to generate development strategies for the sustainable development of rural indigenous communities in the desert, improve the status of the ecosystem through an integral management of natural and cultural resources, and promote improvement of the socioeconomic conditions of dryland inhabitants. It takes into account compatibilizing ecosystem regeneration with investment in infrastructure and services, transformation and diversification of productive activities, generation of employment and increase in revenue.

An interdisciplinary group of technicians and researchers took part in the design of the proposal and the integrated desertification assessment in the fields. The beneficiary community participates in fieldwork and construction, through their work and contribution of their knowledge, land and livestock. This cooperative and the demonstrative experience is a pilot case that can be replicated throughout the territory, nucleating other scattered communities. In this action the Municipality of Lavalle supports the development of infrastructure, equipment and services such as roads, water supply and materials.

A significant change would be encouraged by moving the people above the poverty line, and reducing the pressure of stocking rates would also promote improvement and

Images: IADIZA

Construction of the water supply system for the DPU in the desert of Lavalle, Mendoza

recovery of the fields. The experience involves a profound change in the traditional extensive livestock management system: with only 28 goats coming into the system of the DPU, the profit obtained is equal to that generated by 200 goats under the current method of livestock use. The system would need only 56 goats to double the monthly income of the family group, versus more than 400 goats with the current model. Other activities related to the utilization of the area's natural resources include production of brooms from collecting rattan (junquillo), manufacturing ecological bricks with local materials for the construction of the DPU, genetic improvement of goats to keep them rustic and to produce better milk in larger quantities, and nurseries of native species with low water requirement for the revegetation of degraded areas. Training, community empowerment and local government interest are the factors that ensure that the enterprise keeps running when IADIZA withdraws the project. The community has learned and, without intermediaries, has established links with national and local agencies to access projects that keep this line.

The DPU experience shows that it is possible to promote an integral development so that communities at risk become able to support themselves with dignity, in health and prosperity. At the same time, those communities are considering basic principles such as recovery of cultural guidelines; identity; knowledge of traditional lifestyles; and the creativity to associate those guidelines with new possibilities derived from the knowledge of ecosystem structure, functioning and production capacity. It is an approach that highlights dryland environments and their sociocultural aspects of food production and consumption, and innovation in the production alternatives for a healthy diet and a decent life, by applying technological advances adapted to the needs and requirements of the community.

The initiative is an integrated one and involves environmental, social and economic dimensions, so during these years the results have increased impact in and outside the community. The case was a Land Degradation Assessment in Drylands pilot site and is currently a pilot site of the National Observatory of Land Degradation and Desertification, which ensures high visibility and potential for replication in areas with similar problems.

Current results indicate that dialogue and joint work among populations, local governments, research institutes and international financing agencies are of great importance for the coherence, depth and continuity of actions to combat desertification. It is necessary to work in interdisciplinary teams, which go beyond the fragmentary visions of scientific specialities. Experience indicates this as the best way to work on mitigating the adverse consequences of desertification and reach its invisible causes, transcending isolated cases to tackle complex and dynamic problems at territory scale. Dialogues with local populations must exceed consultation levels, generating active processes of empowerment and equality in terms of decision-making. Systematic work with populations affected in their rights denotes the importance of attending, in the short term, to the possibilities of social reproduction of the groups, solving their unmet basic needs. Only thus will environmental, social and economic balance be possible.

Wasteland rehabilitation for sustainable agriculture in the Indian Himalayan region

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Land degradation is a global problem caused by a variety of factors and processes including soil erosion by water/wind and deterioration in the physical, chemical and biological properties of soil. These lead to long-term loss of the productive capacity of land, biodiversity and associated ecosystem goods and services. In India, land degradation estimates vary, ranging from 53-188 million hectares.[1]

In the Indian Himalayan region (IHR), which extends over 2,500 km in length and 240 km in width, wastelands account for about 34 per cent, and the area under wasteland varies from one state to another. This is mainly because about 22 per cent of land in the IHR is either under snow or barren, and does not support any biological growth. Out of 59 million hectares total geographical area of IHR, 7.3 million hectares are degraded community land, 13.5 million hectares are degraded government forests, and 1.2 million hectares are abandoned agricultural land. Of the 23 wasteland categories,[2] those such as land with open and dense scrub, current and abandoned shifting cultivation area, underutilized/degraded forest scrub, agriculture land inside notified forest land, and degraded pastures/grazing land comprise a total of 32 per cent of the IHR area, and these can be rehabilitated for biomass production and to reduce the pace of soil erosion. This region is thus faced with increasing land degradation and wasteland generation and reduced livelihood opportunities. For example, during 2005/06 and 2008/09 remarkable increases in land with dense scrub (3 per cent), open scrub (18 per cent), degraded pasture (15 per cent) and mining wasteland (6.8 per cent) have been recorded in the region. However, decreases ranging from 0.4 per cent to 33 per cent in all other categories of wasteland have also been recorded during this period.[3]

Subsistence agriculture is the mainstay of rural people in the IHR. The majority of holdings are marginal (<2 ha), and agriculture is heavily dependent on the surrounding forests and pastures for a variety of ecosystem services such as fodder for livestock; forest floor litter for livestock bedding and fertilizing the crop fields; wood for fuel; agricultural implements and other minor timber needs. Furthermore, people derive a variety of wild edibles and raw materials for cottage industries from the forests that generate income and employment and contribute to livelihoods. Thus continuing biotic pressure on various categories of land year-round

Image: GBPIHED

A community pasture land taken up for silvi-pasture development: note the trenches dug along contours for soil and rainwater conservation

Image: GBPIHED

Silvi-pasture developed on a community wasteland

Image: GBPIHED

Plantation activities through women's participation in a degraded community forest in Champawat

for subsistence living has left the degraded mountain slopes devoid of vegetation and prone to soil erosion, landslides, nutrient washout and invasion of weeds. This region is faced with a vicious cycle between land degradation, scarcity of natural resources, loss of biodiversity, food insecurity, poverty and outward migration. Under these circumstances land degradation is deepening and wasteland is increasing. These issues need to be tackled to restore biodiversity and ecosystem services for the revival of dwindling agriculture and threatened livelihoods.

It is evident from the foregoing that a reconciliation of the livelihood interests (immediate tangible benefits) of local communities with concern for ecology and biodiversity (long-term intangible benefits) is of the utmost importance for sustainable rehabilitation of degraded wastelands. Since its inception in 1988, the GB Pant Institute of Himalayan Environment and Development (GBPIHED) has followed several approaches/methods across the IHR for rehabilitation of degraded watersheds and forests, pastures/non-arable land and abandoned agricultural land. Mobilization of stakeholder communities for micro-planning, selection of suitable multipurpose tree species (MPTs) based on ecological suitability and the indigenous knowledge of the community, application of soil and water conservation (SWC) measures such as contour trenches (5-6 m long, 30-45 cm feet wide at 5 m intervals), filling pits dug out for plants with fine soil along with farmyard manure (20:80 ratio) and biocompost, participatory plantation and aftercare were followed across all the wasteland rehabilitation models, and are briefly summarized below.

Eco-restoration of degraded watersheds: A package of practices named 'sloping watershed environmental engineering technology' was devised for treating five degraded watersheds. This approach integrates SWC measures, plantation of suitable MPTs for provisioning fodder and fuelwood, biofencing and aftercare of plants along with the introduction of low-cost, environment-friendly and income-generating activities to boost the livelihood of local people and thereby reduce their dependence on the forests. Measures such as rooftop rainwater harvesting for household needs and increasing the water retention capacity of watersheds were also areas of prime concern. This approach was used in 55 hectares of degraded land in the Bhimtal lake catchment area (Nainital district, Uttarakhand). A total of 38,322 saplings of more than 20 MPTs were planted on barren hill slopes, where they registered a 16-47 per cent survival rate after five years. The highest growth was recorded by *Alnus nepalensis* (211 cm height; 5.6 cm

Important MPTs suitable for wasteland plantation in the Central Himalayan region

Species	Main use	Minor use	Crude protein (%)	Season of major use
Bauhinia variegata (D)	FD, FR	AG, F	18.1	Winter
Celtis australis (D)	FD, FR	AG	8.2	Summer
Grewia optiva (D)	FD, FR	F	26.1	Winter
Melia azedarach (D)	MT, FR	FD	18.4	Rainy
Prunus cerasoides (D)	SC, S	FR, FD	19.2	Year-round
Quercus leucotrichophora (E)	FD, FR, SC	AG	18.1	Year-round
Albizia stipulata (D)	FR	FD	15.0	Summer
Alnus nepalensis (D)	SC	FR, FD	12.6	Year-round
Dalbergia sissoo (D)	T	FD	9.1	Summer
Ougeinia dalbergioides (D)	FD, AG	MT, M	18.2	Summer

FD= fodder, FR = firewood, MT = minor timber, SC = soil and water conservation, S = sacred, T = timber, AG = agricultural implements, F = fibre, M = medicine, D= deciduous, E= evergreen

Source: Negi & Dhyani, 2014 [7]

collar diameter). In Arah village in Garur Ganga watershed (Uttarakhand), after treatment of 9 hectares of degraded land the soil fertility, ground grass cover and plant canopy improved and soil loss was reduced by 60 per cent after 12 years. Fodder production increased from 2.7 tons per year (Rs4,050) in 1993 to 16.4 tons per year (Rs75,020) in 2006, thus gradually reducing the women's workload and improving income from the degraded land.

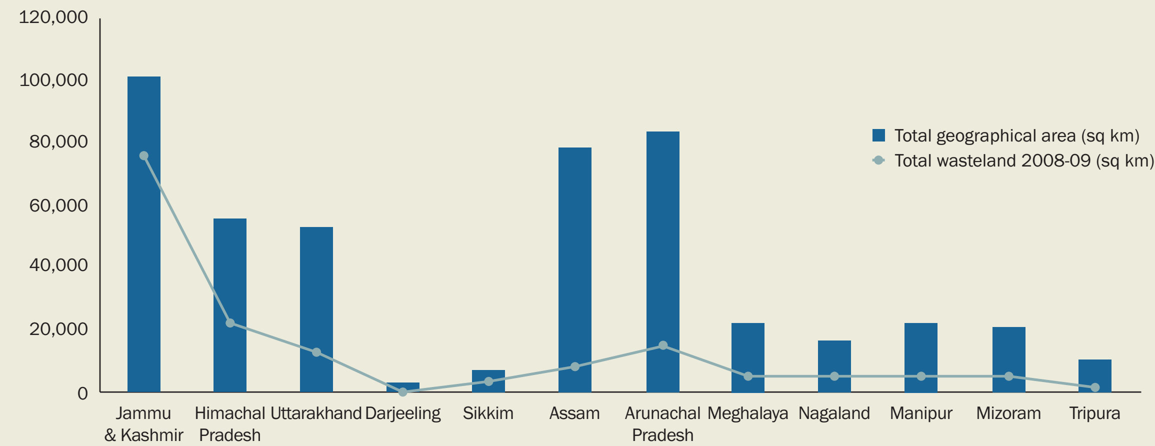
Image: GBPIHED

Oak forest converted to open scrub due to lopping for fodder and fuelwood

Rehabilitation of pasture/non-arable land: This category of land, suffering from high grazing pressure, soil erosion and gully formation and the invasion of non-palatable grass/weeds, was treated with a silvi-pasture development approach by planting fodder trees and grass of high fodder value and placing a ban on grazing. A nursery of suitable plants was raised using healthy seed/root stock from the nearby areas. This model followed five community grazing lands across IHR (area 60 hectares). Improvements were achieved in fodder productivity (from 0.5 to 4 t/ha^{-1}/yr^{-1}) and soil fertility (soil carbon increased from 0.44 per cent to 0.96 per cent), organic matter (from 0.75 per cent to 1.66 per cent) and soil moisture (from 13.2 per cent to 20 per cent). In a fodder bank development method on 6 hectares of degraded grazing land in Maikhanda village (Rudraprayag district, Uttarakhand) a combination of MPTs, indigenous and exotic fodder grasses were planted with the participation of women's groups. Improved fodder quality and an eightfold increase in fodder yield not only saved about a week in terms of the time needed to collect fodder from forests, but also improved the milk yield of the animals from 0.5 litres to 1.5 litres per day due to feeding nutritive grasses, particularly Napier.[4]

Rehabilitation of abandoned agricultural land: In this category of land, abandoned due to low soil fertility and crop yield, an agroforestry model was developed. Selection of MPTs for plantation was based on agroforestry traits such as straight bole, deep roots and a low canopy shade, so that the food crops grown underneath (local cereals and vegetables) do not face much competition for sunlight, soil moisture and soil nutrients. This approach was demonstrated in 6 hectares of abandoned agricultural land at Bansbara village in Garhwal Himalaya where, after 20 years, height growth (5-17 metres per tree), biomass (20-160 t/ha), C sequestra-

Total geographical area of different IHR states and their respective total wasteland area (for West Bengal only, Darjeeling district is considered)



Source: Wasteland Atlas of India, 2011

tion (0.95-2.09 t C/ha^{-1}/year^{-1}), and fodder harvest (14.4 t/ha^{-1}) was recorded. Vegetables grown in this demonstration site were consumed and sold by the stakeholder families.[5] Similarly, in Dharaunj (14 ha) and Gumod (6.5 ha) villages of Champawat district (Uttarakhand) cash crops of medicinal and aromatic plants (MAPs) were planted and capacity-building of farmers on cultivation, harvesting, value addition, packaging and marketing of MAPs was undertaken. Income generated from *Ocimum basillium* (Rs98,500 per hectare) encouraged 120 farmers to adopt MAPs for income generation and a benefit-sharing mechanism was devised by forming a MAPs growers group.

In the shifting cultivation (jhum) affected area in the north-eastern IHR, extreme soil erosion and loss of soil fertility has accelerated the pace of land degradation and reduced crop yield. In such areas contour hedgerow intercropping was practiced, which involved the planting of local leguminous nitrogen fixing shrubs at 1.5 m to 2 m distances (the alleys) along contours. Crops were grown in the alleys by applying a mulch of these hedgerow species to improve soil fertility (nitrogen from 0.165 per cent to 0.173 per cent) and yield of vegetables (20 per cent to 100 per cent). Soil erosion was reduced to 50 per cent after three years.[6]

Eco-restoration of degraded forest land: Mobilizing people for plantation of degraded forest lands in the high altitudes is rather a tough task as this land is owned by the Government and people often do not consider themselves to be the real stakeholders. In such land, the creation of sacred forests and integration of science with religion was adopted as an innovative approach for inviting the participation of the people. After eco-physiological scrutiny, plants acclimatized for high altitude were distributed as 'Briksha Prasada' by the local religious authority to pilgrims and local people, and were planted as an act of devotion. The plantation is dedicated to the local deity, and cutting of trees is banned through religious sentiments. This approach was demonstrated in the restoration of Badrivan in Badrinath — a famous Hindu shrine at high altitude in Uttarakhand,[7] and Raksha Van (a defence forest) established by army people in 10 hectares of land at Bantoli (Badrinath). Also, at Kolidhaik village (Champawat district, Uttarakhand) 5.6 hectares of degraded land was brought under plantation of 6,200 saplings of 20 MPTs which have attained over 3-4 metres in height. This approach was included by the International Union for Conservation of Nature in its guidelines for planning and managing mountain protected areas.[8]

It can be inferred from the above mentioned case studies that owing to the great biophysical diversity of the IHR a range of approaches would be required to address wasteland rehabilitation/restoration and stop further degradation of land. Some of the major recommendations drawn from our studies are to:

- strengthen village institutions as they comprise crucial traditional knowledge on natural resource management; the best practices must be scaled up
- promote participatory consultation with communities to share knowledge, beliefs and resources for rehabilitation of degraded land
- emphasize ecological, agroecological, and socioeconomic considerations
- develop strong linkages among technical institutions, village institutions, practitioners and policy planners
- strengthen formal and technical information networks on land rehabilitation engineering, erosion control measures and productivity enhancing techniques
- include religions and cultural/economic/livelihood concerns in rehabilitation activities and incentives for participation
- facilitate community skill development and training on key sectors of ecological rehabilitation of wastelands.

Soil and the living land — threats and responses

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Soil constitutes the infrastructure for all terrestrial life on Earth. Jointly, soil and the life it supports make the living land, whose fertility caters for plant productivity, which generates food for all other terrestrial organisms, mankind included.

Soil provides mechanical anchorage and nourishment to the land's plant cover, which injects to the atmosphere the oxygen we breathe, and absorbs atmospheric carbon dioxide thus regulating the climate. Jointly with its underlying soil, the land's plant cover is engaged in water filtration and regulation locally, and in driving the water cycle globally. The soil functions as a bioreactor for recycling nutrients, as moisture and water storage, and as a repository for organic matter that facilitates water-holding capacity, and its sequestration contributes to climate protection. All these life-support benefits to mankind travel across scales, from current to future generations, from local to global land. But when the land user inadvertently harms the soil of his land, the repercussions of the resulting local fertility loss travel far, in time and space.

Loss of soil fertility is detrimental to the local land user, hence local responses to prevent it are required. Direct users of land productivity are often unaware of the losses or they lack tools and resources for proper responses. The global indirect users of soil fertility often possess the knowledge, technologies and financial resources required by the local, direct land users. Therefore, cooperation between the local direct and the global indirect users of soil fertility would benefit both — it would outweigh the short-term costs of using the soil prudently borne by the local direct user, and the cost of international development aid borne by the global indirect land user.

The major threat to soil fertility is when its exploitation, directed at increasing land productivity that is of economic value, leads to soil erosion, losses of organic and mineral compounds, and salinization at rates faster than natural. Rather than the aspired increase in economic land productivity, the land use practices bring about a persistent and often irreversible productivity decrease relative to the soil's potential fertility. This persistent reduction in the land's biological productivity comes under the heading of 'land degrada-

Images: Uriel Safriel

A Bedouin village in the Negev dryland of Israel: its degraded land due to ploughing (left) is a candidate for restoration; ongoing degrading land use (right) can be offset when the degraded land has been restored tion' which, when occurring in drylands, is labelled 'desertification'. These are driven by land use practices that turn exploitation into overexploitation, sustainable into non-sustainable land uses, and result in reducing rather than increasing land productivity.

Though the knowledge required for sustainable land use exists through millennia of accumulated traditional knowledge and centuries of scientific research, three interlinked socioeconomic policy drivers currently combine to invoke the drivers of land degradation — increasing global human population size, increasing per capita calories consumption, and increasing socioeconomic inequity.[1] These reflect on increasing demands from, and pressure on, soil fertility and point at a paucity of resources for averting the mounting threats of land degradation by transporting knowledge and technologies to, and effectively implementing them in, the developing world.

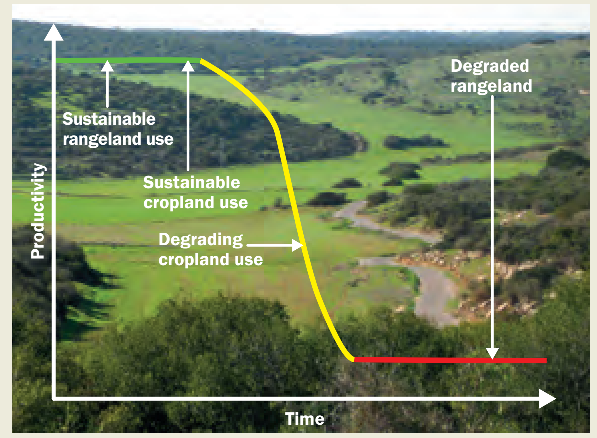
Though much knowledge for preventing land degradation is available, means to detect and quantify it are controversial. A quarter of the global land may be degraded[2] and the socioeconomic and policy drivers of land degradation are intensifying; hence the rest of the global land is at a risk of land degradation.[3] Furthermore, local soil erosion, a major driver of the land's productivity loss and the loss of vegetation cover, is also the driver of off-site, transboundary detrimental impacts on non-degraded lands — covering agricultural plots, blocking water reservoirs, generating floods and dust storms and increasing water and air pollution. Other social off-site impacts of local land degradation — local poverty in degradation-affected areas causing migrations and refugees — may trigger foreign interventions.[4] Finally, the spatial spread of land productivity loss, associated with the impaired soil function of carbon sequestration, would undermine global food security and global climate change mitigation, respectively.

Long before land degradation had become widely recognized, many countries promulgated legislations and adopted policies each addressing a specific driver of land degradation. In some cases these increased rather than reduced land degradation,[5] and in most cases they have not explicitly targeted land degradation.[6] Furthermore, the United Nations Convention to Combat Desertification (UNCCD) text obliges the parties to more effectively implement and enforce the already existing policies and states that only when these tools "do not exist", "enacting new laws and establishing long term policies" would be required.[7] Thus, in order to address land degradation holistically, land degradation needs to be recognized as an interlinked syndrome of global dimensions that requires global policy responses.

The opportunity for this came when the family of nations under the auspices of the United Nations agreed upon interlinked development-environment targets — reducing biodiversity losses, mitigating climate change and alleviating poverty. These cannot be acheived by setting targets that only address each of these processes, since the state of soil and its backdrop of biodiversity loss, climate change and poverty need to be addressed through setting a land degradation target, ambitious and realistically attainable within a plausible time frame. This target, conceived at the United Nations Conference on Sustainable Development (Rio+20), is the land degradation neutrality (LDN) target.

LDN is based on three observations. First, even though the precise spatial dimension of degradation is not yet consensual,[8] it is undisputable that degradation already prevails in many areas.[9] Second, there is sufficient evidence derived from

Identifying states of land use for a local LDN project in a semi-arid watershed in Israel



Source: Uriel Safriel

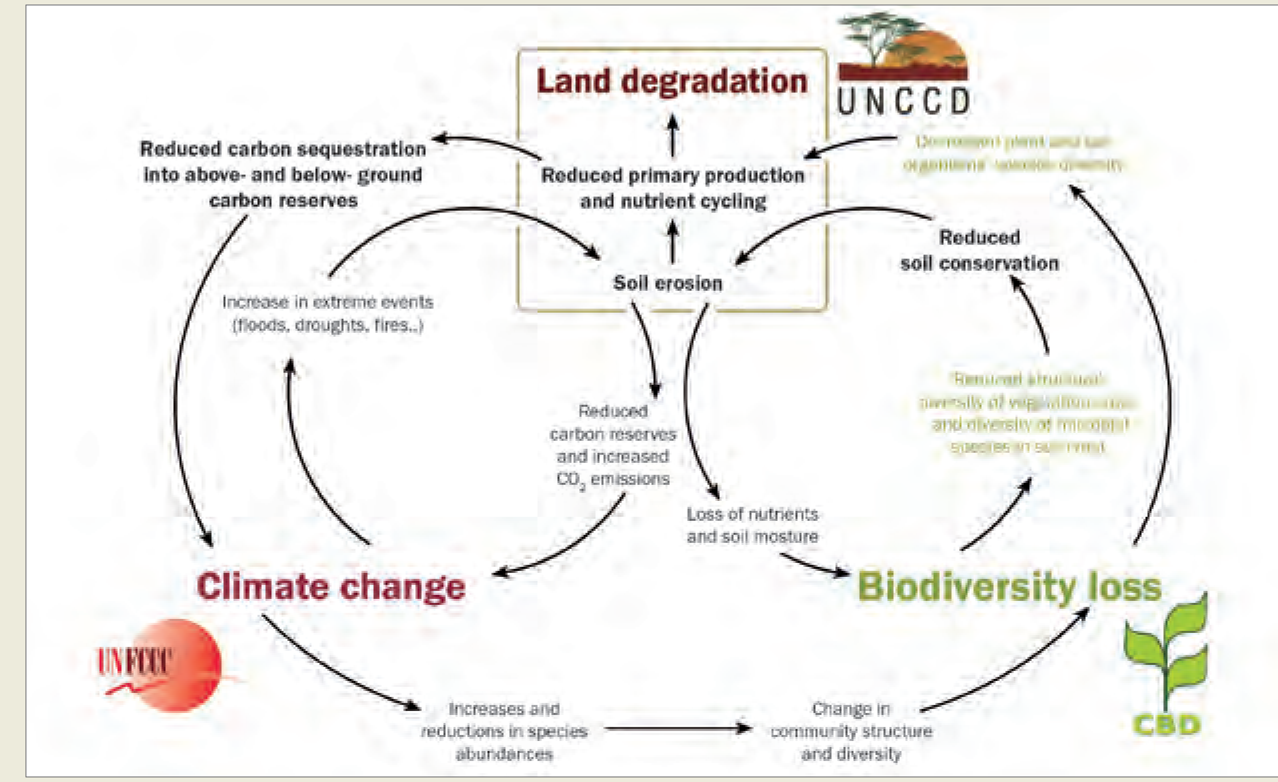
time-series satellite images that degraded land continuously accumulates,[10] a phenomenon projected to continue.[11] Third, degraded soil can be rehabilitated such that land productivity can be restored, as has been demonstrated by a number of well-studied cases in non-drylands[12] and drylands.[13]

LDN is achieved when, within the time period in which an amount of non-degraded productive land becomes degraded, an identical amount of already degraded land of the same productivity potential is restored to its non-degraded state. In other words, LDN can be achieved by offsetting the amount of land being degraded each year through reclaiming land of equivalent area and productivity potential from already degraded land. This implies that when LDN is achieved, land degradation has not been totally arrested, but the amount of the domain's productive land stabilized.

The direct quantifiable indicators of this target are conceptually (but not yet technically) straightforward: one is the area of newly-degraded land and the other is the area of degraded land newly restored, nominally and as proportions of the domain under consideration. These values need to be compared for determining the distance from the LDN target set for the LDN project's domain. Thus, attaining the LDN target depends not only on successful restoration, but also on the protection and management for sustainability of the used land — both the restored land, and the land not yet degraded but coming under use. Most important is that attaining LDN is a cumulative process — when each region within a country achieves LDN, the country as a whole becomes land degradation neutral; furthermore, all countries combined can strive to achieve a land degradation neutral world.

An LDN project requires an identification of the state of land with respect to its productivity, a tool kit for applying the appropriate land use practices for each state of land, and a reliable system for monitoring the changes in these states. These require the support of a global mechanism that assesses the available science and technology, identifies knowledge gaps and sets out to bridge them, and then interfaces them to policymakers, to be eventually extended to the land users.

Land degradation, climate change and biodiversity loss are mutually reinforcing nested feedback loops



Source: Millennium Ecosystem Assessment. Adapted from Adeel, Z. et al, 2005[20]

The UNCCD's 11th Conference of Parties in 2013 took the first step in this direction by deciding to establish its Science-Policy Interface, which started functioning as of June 2014. This included motivating and assisting the Intergovernmental Platform of Biodiversity and Ecosystem Services to set and to carry out a thematic assessment of land degradation and restoration, whose findings would assist in guiding responses to land degradation, including attainment of LDN at all scales.

One stumbling block for applying effective responses to land degradation is that the UNCCD is directly relevant to only 34.5 per cent of global land since its mandate is restricted to drylands only.[14] But loss of biological or economic productivity resulting from processes spelled out by UNCCD text also occurs in most of the other 64.5 per cent of global land, regardless of whether it is exposed to risk of land degradation or desertification. For example, land degradation in China depends more on land use than on whether it is dryland or not. Other evidence of severe land degradation in non-drylands is being increasingly detected.[15] In addition, non-drylands also abound in most 'dryland countries': only 43 per cent of these countries have drylands covering more than 95 per cent of their territory, and in about third of the dryland countries, drylands take up less than 50 per cent of their territories.[16] Desertification national action plans compiled by dryland countries, pursuant to their commitments as parties to the UNCCD, address land degradation while ignoring the delineation of drylands within their territories.

Furthermore, the climatic boundary of the drylands was set at an aridity index value of 0.65,[17] that is to say areas where the ratio of precipitation to potential evapotranspiration is higher than 0.65 do not qualify as drylands. The aridity index used for mapping the global drylands[18] was based on the rainfall and temperature means for the period 1951-1980. However, the directional anthropogenic climate change undermines the stability of the aridity index and changes the spatial expase of the drylands. Most of Africa, for example, has become drier: the hyper-arid and arid drylands increased by 51 and 3 million hectares respectively, and the non-drylands of 1931-1960, 'lost' 25 million hectares. Finally, rainfall decreases and evapotranspiration increases are projected to intensify this trend in many drylands by mid-century.[19] Thus, lands identified as non-drylands due to their climatic conditions during 1950-1980 already qualify, and many more will qualify as drylands in the future, making the current distinction between the UNCCD drylands and non-drylands redundant.

Finally, recalling that land degradation impacts biodiversity and exacerbates global climate change, expanding the focus of UNCCD to cover all lands and their soils would also enable the addressing of land and soil issues at the global scale. Jointly with the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change, addressing the land-biodiversity-climate interlinkages would comprise an effective framework for holistically securing the living land's life-support system of the planet.

Returning agricultural productivity to former tin mining land in Peninsular Malaysia

Dato Dr Sharif Haron, Dr Mohamad Roff Mohd Noor, Dr Wan Abdullah Wan Yusoff and Rohani Md. Yon, Malaysian Agricultural Research and Development Institute

For more than a century, tin ore was one of the main pillars of Malaysia's economy which was based on primary commodities. The prominence of tin in the economy lasted until the world tin industry collapsed in the mid 1980s. Following this event, the country's tin industry greatly reduced its activities. With the collapse of the tin mining industry large tracts of land, which have been used for depositing tin tailings, are left vacant. 'Tin tailings' refers to the materials other than the tin minerals coming out of the mining process that were deposited on the mined or unmined land adjacent to the mining sites. Three types of tin tailings are usually found in the tin mines: gravel (>2 mm), sand (coarse sand, 2.0-0.2 mm and fine sand, 0.2-0.02 mm), and slime (silt, 0.02-0.002 mm and clay, <0.002 mm).

It is estimated that the total area of ex-mining land in the whole of Malaysia is about 127,550 hectares. About 60 per cent of the ex-mining land has been rehabilitated or reused for other puprposes. Present uses of the ex-mining land include housing and settlement areas, industrial estates, agriculture, aquaculture and animal husbandry, tourism and recreation facilities and public institutions and facilities.

Presently, about 50,000 hectares of ex-mining land remain unused. These areas are found quite near the urban areas. Most of these areas are tin tailings which have been deposited with sand, therefore they are known as sand tailings. Like other marginal soils, sand tailing is a problem soil because of its poor physical and chemical properties making it unsuitable for crop growth. The sand tailing contains coarse sand grains with less than 5 per cent clay content. The sandy texture of sand tailing leads to excessive internal drainage and low water holding properties. Sand tailing also has a high surface temperature.

Sand tailing has a pH of about 5 or less and is characterized by a very low level of bases, phosphorus and nitrogen. Organic

Images: MARDI

Margenta groundnut planted on sand tailings, producing a yield of 300 g/clump

Effects of organic and inorganic fertilizer inputs on yields of sweet potato, chilli and tomato on sand tailings

Crop	Yield (t/ha)			
	No inputs	Organic inputs only	Inorganic inputs only	Organic + Inorganic inputs
Sweet potato Organic: 60 t/ha POME Inorganic: 1.4 t/ha NPK	-	11.2	-	25.0
Chilli Organic: 30 t/ha poultry dung Inorganic: 3 t/ha NPK	0	-	1.4	6.1
Chilli Organic: 30 t/ha POME Inorganic: 3 t/ha NPK	0	1.1	1.4	3.1
Chilli Organic: 100 t/ha EFB Inorganic: 3 t/ha NPK	0	0.5	1.4	4.1
Tomato Organic: 30 t/ha poultry dung Inorganic: 1.5 t/ha NPK	0	12.5	3.0	40.0
Tomato Organic: 30 t/ha POME Inorganic: 1.5 t/ha NPK	0	7.5	3.0	31.3
Tomato Organic: 100 t/ha EFB Inorganic: 1.5 t/ha NPK	0	5.5	3.0	21.0

NPK = 12 N: 12 P205: 17 K20: 2 MgO+trace elements

Source: Vimala and Sukra (2010)[1]

matter content and cation exchange capacity are extremely low, leading to high nutrient leaching rates. All these properties make the sand tailing uncondusive to crop growth.

The Malaysian Agricultural Research and Development Institute (MARDI) took on the challenge and undertook research to overcome these problems so that the sand tailing areas can be utilized for crop production. The close proximity of these areas to the urban areas makes them attractive for crop growing since there is a ready market in the urban areas for fresh food crops. Such proximity to the urban areas would reduce transportation and marketing costs.

The above constraints to crop production can be overcome with the use of appropriate agrobiomass and inorganic fertilizers. Application of both organic and inorganic nutrient inputs is important for obtaining good yields of crops grown on sand tailings such as sweet potato, chilli, cabbage and tomato.

MARDI has successfully cultivated a range of food crops and herbs at the Tin Tailing Research Station in Kundang, Selangor. The crops cultivated include vegetables (leaf, fruit and root vegetables), field crops (sweet potato and sweetcorn), herbs (lemon grass, turmeric, ginger, noni and aloe vera) and fruit crops (papaya, ciku and starfruit).

Organic ameliorants used were mainly agrobiomass such as oil palm empty fruit bunch (EFB), palm oil mill effluent (POME), animal manures and various composts which were either made on site from crop residues or purchased. The organic amendments are mainly agrowastes available abundantly in the country and generally inexpensive.

The key to transforming barren sand tailings to productive cropland is the use of agrobiomass which provides organic matter and nutrients. The provision of organic matter is the more vital role of agrobiomass as the nutrient content in organic matter is limited. Nutrients can be supplemented from chemical fertilizers. Agrobiomass also serves as mulching material. The agrobiomass needed for crop production can come from either plant or animal sources.

The largest source of agrobiomass in the country comes from the oil palm industry which provides about 50 million tons of agrobiomass comprising of fronds, trunks, EFB, POME, nut shell and pressed fibre. Of these, EFB and POME have been extensively evaluated as sources of organic matter and nutrients on sandy soils.

Empty fruit bunches are available from the oil palm factories after the oil containing fruits are removed by steaming, leaving behind the empty bunches. These bunches are

Yields of leafy vegetables on sand tailings compared to mean yields on normal soils

Common name		Yield (t/ha)	
English	**Local**	**Sand tailings**	**Normal soils**
Chinese mustard	Sawi bunga	12-20	12.8
Chinese spinach	Bayam	12-25	14.3
Water convolvulus	Kangkong	10-20	10.0
Lettuce	Daun salad	8-15	17.9
Chinese chives	Kucai	10-15	11.5

Source: Abd. Shukor et al.[2]

Yields of fruit vegetables on sand tailings compared to farmers' mean yield

Common name		Yield (t/ha)	
English	**Local**	**Sand tailings**	**Farmers' mean**
Chilli	Cili	6-19	11.8
Brinjal/egg plant	Terung	25-30	16.0
Okra/lady's finger	Kacang bendi	~20	13.4
Cucumber	Timun	38	19.1
Tomato	Tomato	21-40	28.4

Source: Abd. Shukor et al.[3]

Herb yields on sand tailings compared to farmers' mean on normal soils

Common name		Yield (t/ha)	
English	**Local**	**Sand tailings**	**Farmers' mean**
Lemon grass	Serai makan	17.8-24.7	12.1
Ginger	Halia	16.0-24.9	6.0
Turmeric	Kunyit	6.2-10.9	12.6
Noni	Mengkudu	3.7, 14.8, 12.9	1.2, 16.0, 18.0*
Aloe vera (gel yield)	-	14.5	-

*Yields in first, second and third years

Source: Abd. Shukor et al.[4]

sterilized during the oil extraction process and can be considered as pathogen-free and therefore relatively safe to use directly without composting in the planting hole especially for the cultivation of fruit crops. EFB can also be applied in furrows for the cultivation of long-term vegetables such as sweet shoots. The EFB becomes the source of slow-release organic matter and some nutrients to the infertile sand tailings. It also aids in retaining nutrients and water, and can be used as a mulch to prevent the surface soil temperature from rising too high.

The POME is collected in ponds near the palm oil mills. Here the effluent undergoes a series of anaerobic and


Images: MARDI

Sweet potatoes planted on sand tailings to produce a crop of VitAto (red) and gendut (white) varieties

aerobic fermentation. Solid particles of the effluent settle to the bottom of the pond and as the water evaporates the POME is produced. POME is rich in nutrients and has a low carbon-nitrogen ratio indicating that the material has undergone extensive degradation during the fermentation process. The nutrients present in POME are readily available to the growing plants. Studies have shown that POME is a good nutrient source for vegetables and sweetcorn in sand tailings.

Animal manures have also been reported to improve yields and soil properties of sand tailings. Poultry, sheep, goat and cattle manure are good sources of slow-release nutrients for crops on sand tailings such as chilli.

In addition to using agrobiomass directly, plant and animal materials can be composted and used as nutrient sources. The nutrient content of compost can vary widely depending on the nutrient content of the source materials as well as the proportion of the different materials used.

Legume species, with their ability to fix atmospheric nitrogen, can be used as a soil ameliorant on sandy soil. These legumes can be ploughed in at flowering, as a means to maintain or improve soil organic matter and fertility. Legumes such as *Calopogonium mucunoides*, *Centrosema pubescens*, *Indigofera tinctoria*, *Mucuna cochinchinensis*, *Vigna radiata*, *Glycine max*, *Arachis pintoi* and *Pueraria javanica* have been found to establish well on sandy soils. The legume species must be inoculated with appropriate inoculants and mixed with a little phosphorus before sowing to get effective nodulation and nitrogen fixation to occur. Incorporation of the green manure must be done three weeks before seed sowing.

For the rehabilitation of sand tailings, the organic sources of biomass can either be broadcast on the surface of the plot and then incorporated into the soil or applied in furrows and mixed with the sand in the furrows. However, furrow application of POME or poultry manure was superior to broadcast application for a number of vegetable crops in sand tailings such as French bean, okra, cucumber and tomato.

In both methods, it is important that the organic source is thoroughly mixed into the soil and then left for about three to five days before sowing or transplanting, especially if animal manure is used. This is to ensure that the seeds or

Image: MARDI

Newly planted sweet potato on sand-tailing for the production of cuttings with a sprinkler watering system

Images: MARDI

Irrigation for agriculture: (left) a lake on ex-mining land provides a water source and (right) mangoes are planted on slime tailings with an irrigation trench

transplants are not scorched by any ammonia gas that may still be emanating from the organic sources.

Spot application of organic manure is recomemmended for crops such as lemongrass, watermelon and fruit trees and also for those crops with spacing at 1 m x 1 m or greater. Spot application will save the total amount of organic sources required per hectare. The organic source is applied in planting holes and then thoroughly mixed with the sand before planting.

The rates of application of the organic inputs depend on the crops to be planted. For tomatoes the yield increased significantly with application of 70 t/ha of POME while leaf mustard yield increased linearly when poultry manure was applied at 10-40 t/ha. Okra and cucumber yield increased when 40-50 t/ha of poultry manure was applied. Chilli increased significantly when 80 t/ha POME was applied. For leafy vegetables an application of 30-60 t/ha of poultry manure significantly increased the yield. For short-term leafy vegetables a basal application of about 40 t/ha of poultry manure is sufficient.

Organic fertilizer significantly affects the yields of crops. Applying organic matter greatly increased the yield of crops such as sweetcorn, chlli and tomato. A combination of organic and inorganic fertilizers greatly boosted the yields of all the crops. Yields of leafy vegetables such as Chinese mustard, Chinese spinach, water convolvulus, lettuce and Chinese chives, grown on sand tailings with appropriate amounts of organic and inorganic sources of nutrient can match or exceed the mean yields achieved by farmers on normal soils. Several fruit vegetables also perform well on sand tailings compared to the mean yield of farmers working on normal soils. This clearly shows that organic inputs supplemented by inorganic fertilizers are crucial to high productivity. Planting herbs on sand tailings also produced good yields. Herbs such as lemongrass, ginger, turmeric, noni and aloe vera produced yields that exceed farmers' means when planted on sand tailings.

These results indicate that problem soils such as sand tailings can become productive farms when given proper treatment with organic inputs. Crops such as vegetables, fruits, sweet potato, sweetcorn and herbs can be successfully produced by application of the technologies developed by MARDI. With these technologies sustainable agriculture production on sand tailings is equal that obtained from normal soils. Thus soil improvement in sand tailings has not only produced fresh fruits, vegetables and herbs for the nation but also helped to improve farmers' incomes.

Image: MARDI

Sand tailing areas are close to urban areas with a ready market for fresh food crops

Innovative agricultural intensification of sandy desert soils using organic and inorganic amendments

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Earth's total land mass is about 148,939,063 km^2 which is about 29.2 per cent of its total surface. Water covers approximately 70.8 per cent of the Earth's surface, mostly in the form of oceans and ice formations. Earth is the only planet known to have an atmosphere containing free oxygen, oceans of water on its surface, and life. Thus, if it provides sustainable ecosystem services we can call it a living land. If, however, its capacity is diminishing due to diversified threats then we have to think of its sustainable management for long-term services for human beings, maintaining biodiversity and environmental services.

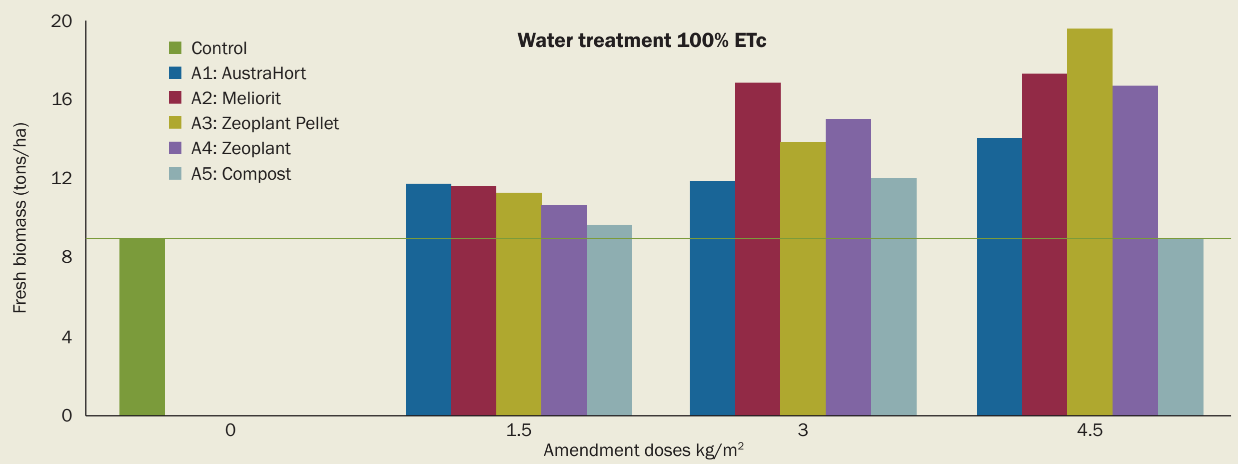
'Land' is a broad term, which includes diversified features, mountains, rivers, forests, agricultural farms, buildings and so on. However, 'soil' is narrower in meaning and exclusively means a medium for plant growth. Overexploitation of soil resources, for quick benefits without appreciating soil health, has shrunk soil resources to an unprecedented level and there is growing concern that over years it may not be able to provide sufficient food to meet human demand. Therefore it is essential to maintain soil health for long-term benefits; this is only possible when we manage the soil through scientific diagnostics and innovative ways including diversified organic and inorganic soil amendments.

Trials on soil amendments for forage production at the International Center for Biosaline Agriculture (ICBA) have revealed a general increase, and in some cases a doubling, of fresh biomass over the control treatment where amendments were not added. Results from greenhouse and field

Image: ICBA

Land degradation is a serious environmental problem, especially in the drylands that occupy one-third of the Earth's surface

Sandy soil amended for agriculture intensification



A field trial was conducted on sandy soil (*Typic torripsamment*) at an ICBA station for barley forage production. Sandy soil is dominant in the United Arab Emirates (UAE) and other Gulf Cooperation Council countries and is used for agricultural and landscaping activities. The sandy soil was amended with four inorganic amendments (AustraHort: A1, Meliorit: A2, Zeoplant pellet: A3 and Zeoplant: A4) and one organic amendment (Compost: A5) applied at the rates of 0, 1.5, 3 and 4.5 kg/m^2. Standard fertilizer rates were used to offset nutrient requirements of barley crop. Treatments were triplicated in Randomized Complete Block Design. The plot size was 2.25 m^2 (1.5m x 1.5m).

Soil amendments can boost soil resource capacity, improving the cost-effectiveness of agricultural production.

The standard agronomic parameters were recorded and biomass determined. The trial was irrigated at two irrigation levels (75 per cent ETc and 100 per cent ETc). The results have shown positive effects of amendments addition to soil on biomass production. At both irrigation levels the addition of amendments has shown promising results in terms of fresh biomass increase (more than double) over control treatment. At 75 per cent ETc and 100 per cent ETc (control) biomass was recorded as 6.5 and 9 tons/ha, whereas with the addition of amendments variable increase of biomass was recorded, the maximum being 15.5 tons/ha with the application of 4.5kg/m^2 meliorit at 75 per cent ETc (138 per cent increase) and 19.5 tons/ha with the application of 4.5 kg/m^2 zeoplant pellet at 100 per cent ETc (117 per cent increase). This preliminary investigation provides hope for the intensification of agriculture in sandy soils which are inherently low in crop productivity.

Source: ICBA

trials give us hope for the intensification of agriculture in desert sandy soils through organic and inorganic amendments and boosting forage production.

Soil is made up of sand, silt and clay and has many thousands of soil taxa, depending upon where you are on the world soil globe. Plants and crops depend on soil for the supply of water and nutrients, anchorage of plants and as a medium in which to grow. Soil is a fundamental component for food production and in providing other soil functions such as climate regulation, nutrient cycling, habitat for organisms, flood regulation, a source of pharmaceuticals and genetic resources, foundations for human infrastructure, provision of construction materials, cultural heritage, provision of food, fibre and fuel, carbon sequestration and water purification and soil contamination reduction. Thus we are justified in saying that soils deliver ecosystem services that enable life on Earth.

Over many years humans have used soils to gain great economic rewards. However, many of the methods used to gain those benefits are now seen as unsustainable, because in many cases they lead to degraded land. Hence land degradation (loss or reduction of land functions or land uses) becomes a serious worldwide environmental problem, especially in the drylands that occupy one-third of the Earth's land surface. Land degradation is induced through natural and human activities, and accelerated due to persistent droughts in many developing arid countries.

Irrational use of soil resources has been carried out by powerful competing economic and social forces that have little knowledge about the potential of soil resources and little or no regard for the long-term care of soils. Therefore, there is a lot riding on our capacity to understand, conserve and manage soil resources efficiently and sustainably. The unsustainable use of soil resource is ultimately diminishing its capacity for long-term services especially producing food. Sustainable soil management could produce up to 58 per cent more food through agricultural intensification, so that 95 per cent of our food is directly or indirectly produced on our soils.[1] This provides hope for meeting the future food demand of an increasing population.

Global data shows that 33 per cent of soils are degraded due to diverse ailments. Among the natural forces of land degradation, under desert conditions wind has a major role in soil erosion. Globally over 24 billion tons of fertile soil was lost due to erosion in 2011, that is 3.4 tons per person per year, costing US$70 per inhabitant, or US$419 billion worldwide. Without fertile soils, food security, poverty alleviation and climate change mitigation and adaptation will not be achieved. In addition to affecting agricultural farms through nutrient mining, drifting soil also causes environmental issues.

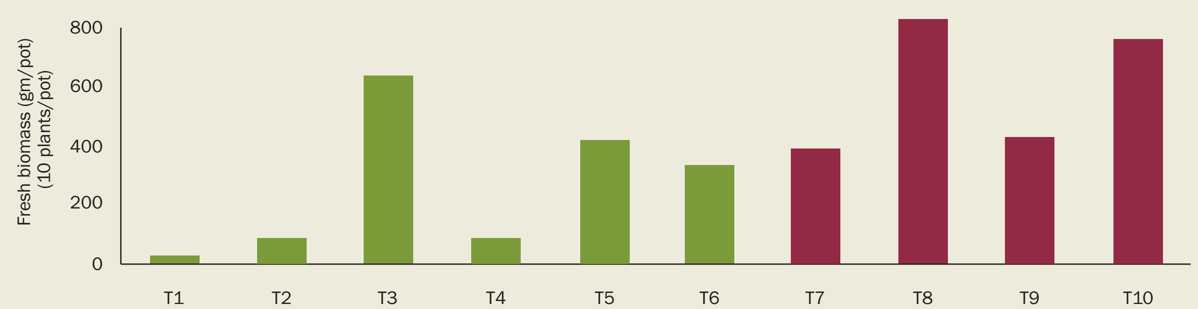
Image: ICBA

ICBA has experience in managing marginal lands with sandy, salt-affected soils through scientific and site-specific diagnostics

Due to increasing population growth and unsustainable land uses, arable lands are shrinking. Currently, each human has only 0.22 hectares at their disposal; in 1960, that figure was 0.5 hectares. The other major constraint to food production is the development of soil salinity in irrigated agricultural farms which is great concern as 40 per cent of world food is produced from irrigated agriculture and 60 per cent from rain-fed agriculture. Currently, an estimated 20 per cent of irrigated lands is salinized to various degrees and the global annual cost of salt-induced land degradation in irrigated areas could be US$27.3 billion because of lost crop production.[2] Globally about 1.6 million hectares are lost annually due to salinization. With this pace of loss, the irrigated area that is now contributing to agricultural foods will be out of production in nearly 140 years — an alarming situation since by 2050 we have to produce 70 per cent more food to feed 2 billion extra mouths in addition to current 7.3 billion. The impact of climate change is another constraint to achieve sustainability in food security. An Intergovernmental Panel on Climate Change (IPCC) synthesis report[3] has recognized the major impacts of climate change as food and water shortages, increased displacement of people, increased poverty and coastal flooding.

Overexploitation has shrunk arable lands for food production and it may not be able to provide sufficient food to meet human demand. Globally there are 1,500 million ha cropland including 250 million ha (17 per cent) irrigated producing 40 per cent of world food, and 1,250 million ha (83 per cent) rain-fed agriculture contributing 60 per cent of world food production.[4] Under a business-as-usual scenario, by 2050 agricultural production must increase by 60 per cent globally — and almost 100 per cent in developing countries — to meet food demand alone for 9 billion.[1] To achieve such targets it is essential to understand soil health constraints and develop problem-solving, innovative ways which have long-term effects. This requires the development and implementation of new agricultural and food policies, and water, environmental and soil protection plans. The concept of climate-Smart Agriculture (CSA) could be a step in the right direction. The CSA being promoted by FAO[5] is not a single specific agricultural technology or practice that can be universally applied. It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices. With this understanding, using innovative ways to improve soil health, intensification in both irrigated and rain-fed agriculture may be possible. However, increasing agriculture lands may not be a viable option in many countries due to various factors including unfavourable terrains, such as in African countries.

Integrated plant nutrient management for sandy soil



One of the best ways to improve soil properties and prevent nutrient losses is to improve soil health through innovative ways using organic amendments and minimizing the use of fertilizers. In order to achieve this we have conducted a greenhouse experiment to test the integrated effects of chemical fertilizer (CF), compost (C), biofertilizer (BF) and biochar (BC) on maize crop productivity and improvements in nutrient availability.

A pot experiment was conducted in the greenhouse using the following treatments with three replication:

T1 — Control
T2 — Compost @ 5 tons/ha
T3 — Compost @ 5 tons/ha + 100 per cent conventional fertilizer
T4 — Compost @ 5 tons/ha + 5.5 L/ha biofertilizer
T5 — Compost @ 5 tons/ha + 50 per cent fertilizer + 5.5 L/ha biofertilizer
T6 — Compost @ 5 tons/ha + 25 per cent fertilizer + 5.5 L/ha biofertilizer
T7 — Compost @ 5 tons/ha + 5 tons biochar/ha
T8 — Compost @ 5 tons/ha + 100 per cent conventional fertilizer + 5 tons biochar/ha
T9 — Compost @ 5 tons/ha + 5.5 L/ha biofertilizer + 5 tons Biochar/ha
T10 — Compost @ 5 tons/ha + 50 per cent fertilizer + 5.5 L/ha biofertilizer + 5 tons biochar/ha.

The results are presented as grams per pot (each pot contains 10 plants). They show that agricultural intensification in desert sandy soils can be achieved through appropriate combinations of organic and inorganic soil amendments

General observations revealed the maximum biomass production was found when biochar was applied in combination with 100 per cent conventional fertilizer (T8), which is 29 per cent more compared to where chemical fertilizer was applied alone (T3). All treatment combinations increased fresh biomass over the control treatment (T1) in various ranges. It was also found that when half of the chemical fertilizer was applied in combination with biofertilizer and biochar (T10), an increase of 19.7 per cent fresh biomass was recorded compared to where 100 per cent conventional fertilizer was applied (T3). The application of various amendments has increased cation-exchange-capacity (9-15 per cent) and organic carbon (48-52 per cent) compared to T3.

Source: ICBA

ICBA has vast experience in managing marginal lands (sandy, salt-affected soils) through scientific and site-specific diagnostics. The marginality has been mainly in two forms: desert sandy soils and salt-affected lands. The former is confined to desert environments where loose sand forms the major landscape and basis for agricultural farms.[6] The salt-affected lands can be found both on sandy deserts and other arid region soils of various soil textures. ICBA scientists believe that it may be possible to keep the soils healthy and productive for a long time when a soil health programme goes simultaneously with agricultural activities.

Sandy desert soils (hot arid climate) are plagued with very low water and nutrient holding capacities, which results in frequent irrigation and nutrient application, high leaching and nutrient losses. Such harsh conditions call for new ways to conserve water, improve soil properties and prevent nutrient losses. One of the best ways is to modify sandy soils with organic and inorganic amendments to improve soil tilth and ultimately improve moisture and nutrient retention, leading to efficient use of water resources and preventing groundwater pollution. At ICBA we have proved through greenhouse and field trials that the addition of suitable quantities of organic and inorganic amendments improved soil qualities, leading to significant water saving and doubling fresh biomass production.

Image: ICBA

Desert soils are loose and fragile — a view of degraded land in UAE deserts

Reclaiming degraded lands and building resilience to climate change in Maharashtra, India

Dr Marcella D'souza, Executive Director and Karan Misquitta, Researcher, Watershed Organisation Trust

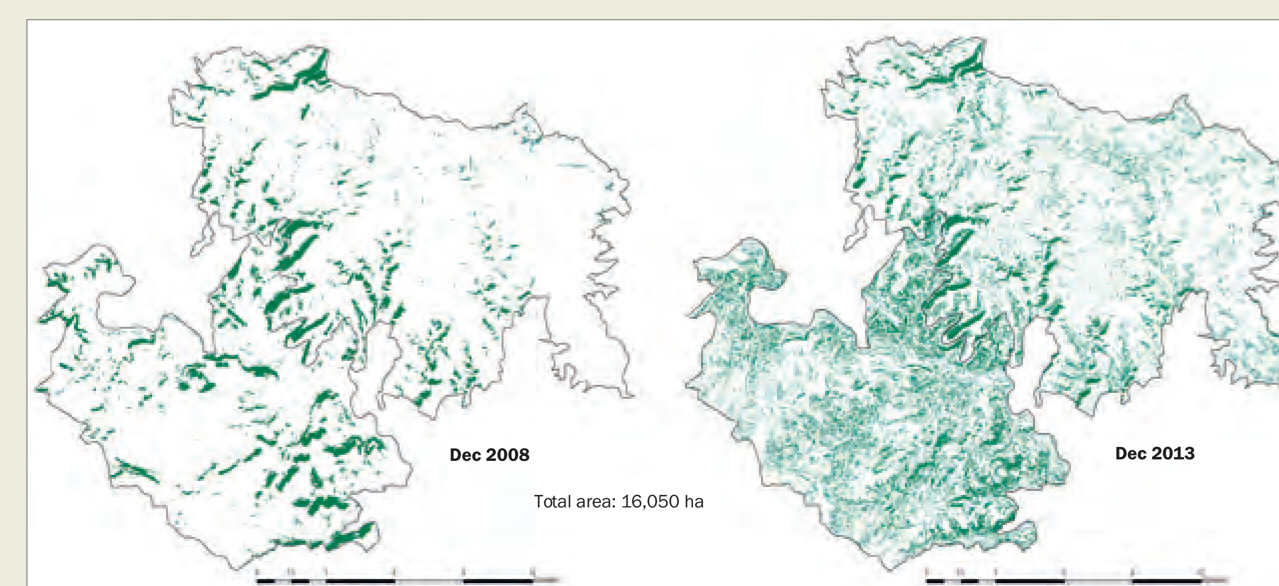
Drylands constitute 69 per cent of India's total area. These are heavily populated regions where the livelihoods of the inhabitants are vulnerable as they depend on a natural resource base that is degraded and deforested. According to the National Bureau of Soil Survey and Land Use Planning, an area of 146.82 million hectares is reported to be suffering from various kinds of land degradation, with erosion caused by water alone contributing to about 61.7 per cent and wind erosion contributing to 10.24 per cent. Much of this is reversible or can be arrested, as dryland regions and degraded ecosystems can be significantly improved by participatory and integrated management of water and natural resources. However, management of dryland resources must be viewed from the broader climatic and socioeconomic context.

The Watershed Organization Trust (WOTR) has played an important role in developing techno-participatory approaches to watershed development that have proven to significantly conserve soil and water and improve land productivity. Importantly, WOTR has always focused on developing scalable and replicable interventions and has directly and indirectly implemented and supported successful watershed development across 83,857 km^2 in 1,422 villages in seven states of India, benefiting over 1.2 million people.

However, it has been observed that unless climate change adaptation is factored into project design, weather variations will continue to obstruct progress and development. Hence, in 2009 WOTR included weather uncertainties into project design. There follows below an account of the impact in 16 villages, in the Sangamner Block of Ahmednagar, of a climate change adaptation (CCA) project implemented by WOTR and supported by the Swiss Agency for Development and Cooperation (SDC) and the National Bank for Agriculture and Rural Development (NABARD). The findings described are the results obtained from various studies, impact assessments and reports.

Ahmednagar district, Maharashtra, lies in the dry semi-arid rain shadow of the Western Ghats. The land has little biomass

Satellite image analysis of the Sangamner cluster project villages shows an increase in the area under vegetation cover



Source: WOTR

cover and rainwater run-off is high. It receives an average of 450 mm of annual rainfall. The temperature ranges between 19.2ºC and 32.9ºC in Sangamner. When the Community Driven Vulnerability Evaluation tool, developed by WOTR, was applied in representative villages, people highlighted delayed monsoons, prolonged dry spells, droughts, unseasonal heavy rainfall, increasing temperatures and prolonged summers as climate risks. They also stated that market demands pushed crops that were new to the region. In 2009 the majority of agriculture was rain-fed and 54 per cent of households were smallholder producers, dependent on agriculture for income. In times of climate stress, people coped by turning to seasonal distress migration for survival. Food security was met from the public distribution system, with a little from their farms and purchases when possible. During summers and in times of drought, wells ran dry and water had to be supplied in tankers for domestic purposes between February-March and June.

Leveraging WOTR's expertise in participatory watershed development, the 16 villages were organized into two clusters for better management. In each village the Village Development Committee and women's self-help groups were capacitated and worked in close cooperation as the primary stakeholders. WOTR moved to ecosystems-based adaptation to help vulnerable communities build the resilience of their livelihoods resource base, now threatened by climate change. WOTR introduced a bottom-up, holistic and integrated approach with appropriate interventions, towards adaptation and resilience-building.

Farmers in the region are mostly dependent on seasonal rains which are highly variable in time and space. Weather events such as drought, storms and heatwaves have severe effects on agricultural production. The impact of these events on farmers' livelihoods can be reduced if:

- farmers are able to align their agriculture with climate-smart, sustainable agronomic practices
- they are able to access advance information about the probable occurrence of these events, as well as the possible contingency measures for their geographical locations.

Responding to this WOTR has developed and promoted a locale-specific comprehensive package of agricultural practices. Through the CCA project more than 6,000 farmers in the 16 villages were trained in the use of these techniques. Applying these techniques improved yields, particularly of traditional dryland crops like sorghum and groundnut, which increased by 10-30 per cent, while reducing the costs of cultivation and promoting sustainable agriculture.

In response to the second need, WOTR installed automated weather stations in project villages. Locals were trained to read the meteorological data displayed on blackboards in the village. Information is provided in the local language to the villages through mobile telephone based Short Message Service (SMS) texts, together with crop-specific advisories. Weekly forecasts and advisories for the common crops are also printed on wall posters. Agro-advisories are prepared by in-house agricultural experts based on local soil conditions, crops currently grown in the villages and forecasts provided by the India Meteorological Department. The advisories place emphasis on organic and sustainable farming methods and contain marketing advice where appropriate. The objective of these locale-customized advisories is to help farmers take informed decisions, which in turn helps increase productivity, mitigate risks and reduce losses. The SMS-based delivery system for the agro-advisories allows WOTR to take advantage of the high degree of mobile telephony penetration in the Indian countryside. To date WOTR has sent approximately 300,000 SMS-based advisories to 6,612 farmers in Sangmaner and the adjoining block of Akole. The intervention helped create awareness among the farmers in the project and nearby villages about climate variability and means to reduce the negative impacts on their livelihoods. Further it serves as a platform to promote WOTR's package of climate-smart agriculture techniques. Increased usage of organic manure and pesticides has been observed by the villagers who received information from the Agro-SMS services provided to them, while decreasing the application of inorganic pesticides and fertilizers. All these efforts have helped farmers ensure income even during low rainfall years and improve overall crop productivity.

Under the CCA project in Sangamner at total of 4,180 hectares was treated. Besides this in the previous decade, 4,506 hectares in six villages had watershed development

Ecosystems-based adaptation: key features

Community-led: people-centric. Local Institutions are strengthened to be inclusive and to ensure that benefits reach all stakeholders. Attention is directed to building the capacity of local communities to participate in and lead interventions.

Ecosystems-based watershed development as a means to reduce risks, stabilize and enhance nature-based livelihoods, reduce the impact of extreme meteorological events, increase productivity, conserve biodiversity and improve quality of life.

Adaptive sustainable agriculture promotes Low External Input Sustainable Agriculture methods, use of indigenous seeds and the system of crop intensification to increase crop and land productivity and reduce costs of cultivation. This is combined with agrometeorology and water budgeting to make agriculture sustainable, efficient and adaptive keeping in mind food and nutrition security, markets and income.

Automated weather stations and SMS-based agro-advisories provide timely, locale-specific crop-weather advisories to farmers so that agricultural activities are planned accordingly. Evidence from around the world shows that texts-based advisories and reminders have a positive effect on the adoption of new technologies and techniques.

Water budgeting helps communities visualize and plan their crops based on water availability, their water needs and requirements, ensuring optimum and efficient use of water, equitable sharing of excess water, and informed decisions on groundwater withdrawals.

Biodiversity. WOTR integrates biodiversity concerns and builds awareness in the community about the importance of promoting, conserving and protecting the local biodiversity; helps them keep a record of it through participatory mapping; identifies and sustainably promotes biodiversity-based economic activities; and sensitizes local bodies to the likely adverse biodiversity-related impacts of decisions taken by them.

Source: WOTR

Image: WOTR

Community members in Wankute collect data from an agrimet station

works implemented with the support of WOTR. Satellite image analysis shows that the area under vegetation cover in project villages increased by more than 500 hectares, or almost 30 per cent, between 2009 and 2013. This can be attributed to plantation and grazing regulation and monitoring activities done under watershed development projects by WOTR and other government project implementing agencies.

Besides the impact on land restoration and arresting degradation, the interventions under the project have had tangible impacts on the livelihoods and well-being of local communities. While the pre-project intervention was characterized by widespread reliance on daily wages, the end-line assessment of the project found that the average number of days where people are engaged in primary occupation (agriculture) has increased by 16.8 per cent (from 184 days to 215 days) post-project implementation. Further, due to poor land conditions within the village, in the pre-project period 22.7 per cent of the individuals reported temporarily migrating in search of labour. Post-project data indicates a 29 per cent reduction in the number of individuals reporting temporary migration.

As part of a more holistic approach to rural well-being, WOTR monitored the nutritional status of children of the 16 villages using the weight-for-age measure. There was a 25.9 per cent decrease in 'Grade III' malnutrition and during the same period an increase of 37.1 per cent in 'normal' grade children was noted.

Concerning the aggregate benefits of watershed interventions, the World Resources Institute calculates that the net present value of a project implemented by WOTR in Kumbharwadi village in Sangamner ranged from US$5,573 to US$8,172 per hectare treated or US$29,650 to US$43,479 per household, with a benefit-cost ratio that ranged from 2.28 to 3.76.

To move to scale, WOTR has developed a suite of tools, methodologies and implementation processes. The Community Driven Vulnerability Evaluation — Programme Designer (CoDriVE-PD) for adaptation planning identifies key vulnerabilities early on in the project design and integrates these variables within the project framework so as to minimize adverse impacts and ensure that the project is able to achieve the desired outcomes.

Given the complexity of the challenge presented by land degradation and climate change, it is apparent that any effort to respond to these problems would require collaboration among various stakeholders, both state and non-state. This project brought together experts from complementary fields — NABARD, SDC, the Central Research Institute for Dryland Agriculture, local agriculture universities, the International Centre for Research in Agroforestry, and the support of the Government of Maharashtra. WOTR's work demonstrates that with appropriate support, communities are able to co-create a sustainable natural resource base and leverage the possibilities presented by innovations in information technology to develop inclusive governance of shared resources and increased access to benefits for all.

Rehabilitation of degraded tropical forests in Malaysia

Ismail Harun, Raja Barizan, Raja Sulaiman and Samsudin Musa, Forest Research Institute of Malaysia

Malaysia has been blessed with relatively large tracts of natural tropical forests amounting to 18.01 million hectares and covering about 55 per cent of its total land area. The forestry sector is an important economic sector and has continued to contribute to the socioeconomic development of the nation. Consequently, Malaysia has accorded the sustainable management of its forests a high priority. While focusing on economic growth and development, Malaysia will continue to give equal attention to promoting the conservation and protection of its natural environment.

An important strategy in the sustainable management of forests is to ensure that the forest is able to recover and regenerate within the cutting cycle. This will ensure that the forest will not continue to be degraded with each cutting cycle and end up completely devoid of forest vegetation.

An important step in the sustainable management of the forests is their gazettement as permanent reserved forests (PRF), national parks and wildlife reserves. There is a total of 14.52 million hectares of PRF in Malaysia, of which 11.2 million hectares is categorized as production forest while the remaining 3.32 million hectares is categorized as protection forest.

Production forests are managed under a selective management system (SMS) where large trees are selected to be felled based on a cutting regime. The regime addresses the sustainability of the residual stand for a future cut by retaining sufficient healthy advanced regeneration that will make the next crop, while minimizing damage and encouraging optimal utilization of resources.

Inland forests

The application of the SMS has significantly reduced forest degradation. An important management strategy is to undertake a post-felling assessment of the forest and carry out suitable silvicultural treatments to assist in the rehabilitation of the stand. Some silvicultural treatments include planting of all skid trails and large gaps. Where the residual stand is poorly stocked, enrichment planting will be undertaken. An enrichment planting scheme promotes both the horizontal and vertical structures of the forest for biological conservation while sustaining a desired level of marketable high quality timber species.

Image: FRIM

Eroded coastal mangroves at the beach of the D' Muara Marine Park Resort, Selangor

Image: FRIM

Growth monitoring of *Avicennia alba* planted using Comp-Pillow planting techniques, 36 months after planting

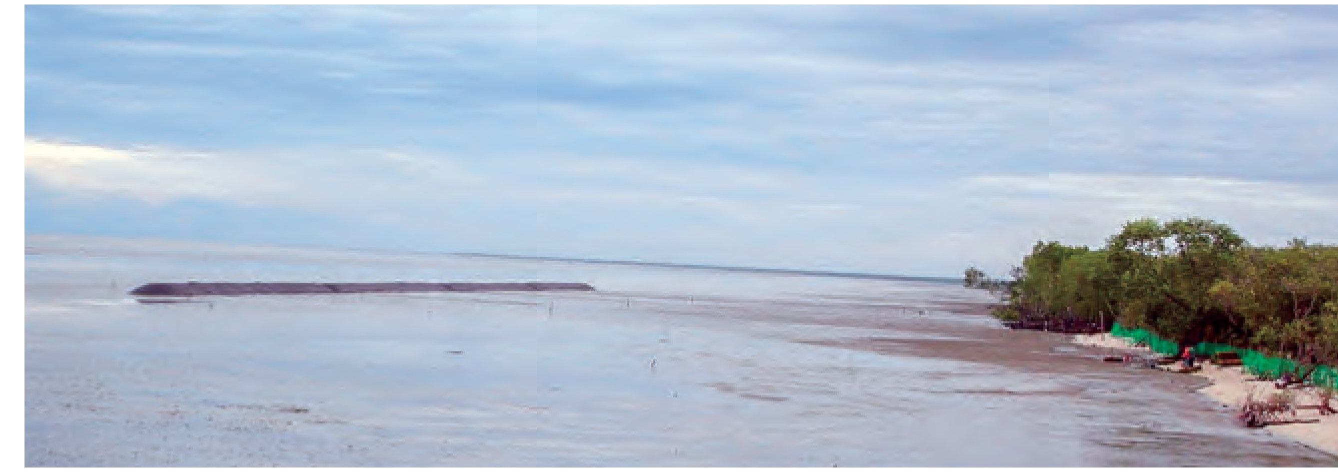


Image: FRIM

The geotube breakwaters constructed at the beach of D' Muara Marine Park Resort (before planting)

Logging decks, where the soil is more compact, are areas where rehabilitation is often difficult. Based on research findings, using larger sized plants, bigger planting holes and slow release fertilizers has enhanced the rehabilitation of such areas.

Outside the forest reserves, open areas are also being rehabilitated. A good example of badly degraded areas that have been rehabilitated can be seen in the forests within the Forest Research Institute of Malaysia (FRIM) campus. Planting on the campus, which was originally a tin mining and agricultural area, began in the 1920s. Today the area has fully regenerated into a healthy and highly stocked forest with rich biodiversity. The mean volume of timber is estimated to be close to 400 m^3/ha which is twice that of a rich natural forest. Biomass has been estimated to be in excess of 450 tons/ha.

Rehabilitation of degraded coastal mangroves

Mangrove forests are one of the most productive and biodiverse wetlands on Earth. They grow in unique conditions and are frequently found along sheltered coastlines in subtropical and tropical areas. The coastal forests play a vital role in coastal protection, especially in reducing coastal erosion and the impacts of storm surge (tsunami). Mangrove forests represent an important ecosystem and have been accorded high priority in maintaining protective and productive functions along the coastline. These forests also play a vital role in carbon sequestration and mitigating climate change. They are an important ecosystem for carbon reservoirs known as carbon sinks, and an integral part of the global biological system. As such, the implementation of coastal forest conservation and rehabilitation to reduce forest degradation and deforestation and enhance the carbon stock is a commitment under the United Nations Framework Convention on Climate Change.

The total mangrove area in Malaysia is currently 575,000 hectares. The area was reduced from 695,000 in the 1970s to about 575,000 in 2005 due to land conversion or reclamation for agriculture, aquaculture, urbanization, infrastructure development and natural causes, mainly coastal erosion. After the 2004 Indian Ocean tsunami caused a catastrophic disaster in the coastal areas facing the sea, the Government of Malaysia realized the critical need to stabilize the country's shoreline areas that could potentially be affected by tsunamis in the future. This could be achieved through conserving the existing mangrove forests and rehabilitating the degraded coastal mangroves. To undertake this, a National Task Force Committee on Planting Mangroves and Other Suitable Species on Shorelines of the Country was formed on 7 February 2005 by the Ministry of Natural Resources and Environment. The main objective of the task force was to monitor the progress and implementation of planting programmes throughout the country's coastal regions. The national task force was supported by two technical committees: Planning and Implementation (PPTC) and Research and Development (RDTC). These two committees are working in parallel to ensure the success of the planting programmes. The PPTC, which is headed by the Forestry Department of Peninsular Malaysia, aims to conduct coastal stabilization through planting in sheltered areas that have a low risk of coastal erosion. The RDTC, which is headed by FRIM, was given the task to carry out research and development related to mangrove forest conservation and rehabilitation. One of the activities under the RDTC was focused on ensuring a high rate of survival of mangrove seedlings planted in coastal mudflats which are classified as highly eroded with strong wave actions.

The mudflats of mangroves are still unstable environments for natural succession to take place due to active erosion and accretion occurring within the areas. To facilitate the stabilization of coastal mudflats prior to innovative techniques of mangrove planting, 'soft engineering' techniques were applied whereby partially submerged woven geo-textile tube (geotube) sand-filled breakwaters were constructed. Four geotubes, each 1.8 m high, 3.7 m wide and 50 m long were successfully constructed in July 2007 at the beach of D' Muara Marine Park Resort in Sungai Haji Dorani, Sungai Besar, Selangor. The design and placement of the geotubes as breakwaters took into account the height of the incident waves, depth, tidal range and site conditions (soil profiles).

Images: FRIM

Rhizophora apiculata planted using Comp-Mat planting techniques (clockwise, from top left) six months, 18 months, 27 months and 36 months after planting

The geotubes create a calmer wave environment in their lee as larger waves break upon them. The calmer state behind the geotubes induces substrate build-up allowing the setting of semi-stable mudflats between the geotubes and shoreline. This provides space for mangrove planting trials. However, the mudflat is still in semi-liquid form. Thus, it provides poor anchorage for mangrove seedlings to grow and cannot withstand the strong wave and current actions. Therefore, innovative planting techniques have been introduced as alternative means for rehabilitating the site.

The rehabilitation project commenced in December 2007. Three innovative mangrove planting techniques were developed and tested (Comp-Mat, Comp-Pillow and Bamboo Encasement methods) against the current standard planting practice or conventional planting techniques with the establishment of geotubes as breakwaters at the project site. Three species of mangrove seedlings were used to investigate the suitable planting techniques. These were *Rhizophora apiculate, Rhizophora mucronata* and *Avicennia alba*. Assessment of survival and growth performance of the planted mangroves has shown that only Comp-Mat and Comp-Pillow planting techniques were successful in rehabilitating the degraded mangroves at high-risk sites.

The project has proven that the breakwater geotubes induced substrate build-up on the landward side and that the semi-liquid mudflats changed to structured mudflats, thus allowing a setting for the regeneration of mangroves either through replanting using innovative techniques or through natural regeneration of mangrove wildings. New information and records on rehabilitating eroded coastal mangroves were generated from the successfully established seaward demonstration plot at the beach of D' Muara Marine Park Resort with mixed mangrove species (*Rhizophora apiculata, R. mucronata, Avicennia alba* and *A. officinalis*). From the output of the project it was concluded that the design of geotubes established at the project site can be used as a benchmark for establishing breakwaters in other places.

Awarding innovation to combat desertification and drought

Abdulmalek A. Al Alshaikh, General Secretary, Prince Sultan Bin Abdulaziz International Prize for Water

The Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) is a leading scientific award, offered every two years, that focuses on innovation. Since its establishment in 2002 by HRH Prince Sultan Bin Abdulaziz (1930-2011), PSIPW has given recognition to scientists, researchers and inventors around the world for pioneering work that addresses the problem of water scarcity in creative and effective ways.

To this end, PSIPW offers a suite of five prizes, covering the entire water research landscape. First, there is the Creativity Prize, worth US$266,000, which is awarded for cutting-edge interdisciplinary work that can rightly be considered a breakthrough in any water-related field. Then there are four specialized prizes, each worth US$133,000: the Surface Water Prize, the Groundwater Prize, the Alternative Water Resources Prize, and the Water Management and Protection Prize.

Nominations are evaluated by an international panel of distinguished scientists who serve on various committees for each of the five prizes. Nominations undergo a rigorous three-tiered evaluation process, starting with a preliminary evaluation committee, followed by a referee committee, and ending with a final selection committee.

As a prize focusing on water, a number of our winners have been awarded for work that is directly relevant to the problem of desertification and water management in arid lands. Their innovative research has made substantial contributions to our understanding of desertification and potential ways to combat it.

Predicting drought

In our Sixth Award, given in December of 2014, the Creativity Prize was awarded to Dr Eric F. Wood and Dr Justin Sheffield of Princeton University for developing a state-of-the-art system to accurately monitor, model and forecast drought on regional, continental and global scales. Today, virtually every drought monitoring system in the world uses Wood's and Sheffield's approach. Their efforts have culminated in the recent development of a drought

Image: PSIPW

Eric Wood and Justin Sheffield with the African Flood and Drought Monitor

Image: PSIPW

The PSIPW Sixth Award ceremony, December 2014

monitoring and forecasting system with the United Nations Educational, Scientific and Cultural Organization (UNESCO) for sub-Saharan Africa. Another very important outcome is the unique Princeton Global Meteorological Forcing Dataset that is now widely used by scientific and drought forecasting communities worldwide.

Wood's and Sheffield's system utilizes modern remote sensing and ground monitoring capabilities to help fuse state-of-the-art hydrologic science, much of which they helped develop, with seasonal climate and shorter-term weather studies in a way that enhances, fundamentally and significantly, our understanding of land-atmosphere coupling and the ability to monitor as well as quantify the space-time variability of droughts, past and future. An important component of this fusion is the bridging of scales between relatively low-resolution climate models and hydrologic models having much finer spatial and temporal scales of resolution. Consequently, terrestrial hydrology can be simulated at fine temporal (hourly) and spatial (12 km) scales over continental domains for the long periods (50 years) necessary to create the historical record required to fit probabilistic models.

Previous assessments of historic changes in drought over the late twentieth and early twenty-first centuries expected climate change to cause an increase in drought frequency and severity due to a corresponding decrease in regional precipitation and increase in evaporation. In a 2012 letter to *Nature*, the team effectively overturned this expectation by demonstrating that it is based on an oversimplified potential evaporation model. By contrast, their more comprehensive approach indicates that there has been little change in drought over the past 60 years. This explains why tree-ring drought reconstructions diverge from earlier drought records, and it alters our perspective on how global warming impacts hydrological phenomena and extremes.

Climate change and the world's water

There has been considerable work in previous awards that relates to the problem of desertification. In 2012, Dr Kevin Trenberth and Dr Aiguo Dai from the National Centre for Atmospheric Research in the United States won our Surface Water Prize for their ground-breaking work that provides a powerful estimate of the effects of climate change on the global hydrological cycle, with a clear explanation of the global water budget. If we are going to tackle desertification in the twenty-first century, one of the overwhelming challenges is to understand hydrologic variability and the impact that climate change is certain to have on global water resources.

Trenberth and his team made a unique contribution through the investigation of climate variability and trends in the past, and through the use of models and other creative efforts to reconstruct river discharge into the oceans across the planet for almost 1,000 river basins. They used climate models to understand likely changes in the future and the uncertainty associated with those predictions, and explained their findings using such popular indicates as the Palmer drought index. As a result, they have provided an exemplary account of the global water budget that is now being used in textbooks and encyclopedias.

They have made pioneering contributions to understanding the past with real data, and evaluating the future prospects within the context of what we know of the global climate and hydrology. They have provided a much better understanding of hydrologic responses to climate change, which in turn will provide tremendous guidance for anti-desertification and land reclamation initiatives.

Ecohydrology

In 2010, Dr Ignacio Rodriguez-Iturbe of Princeton University and Dr Andrea Rinaldo of the École Polytechnique Fédérale de Lausan in Switzerland won the Creativity Prize for their invention and development of the new field of ecohydrology which bridges the gap between the physical and life sciences. Ecohydrology is a multidisciplinary research field borrowing from a number of 'classic' disciplines (physical sciences, life sciences) yet aiming at a unified picture of water-supported biological dispersion. In practical terms, the new research field presents itself as a comprehensive blend of theory (mathematical modelling), interpretation of past and present biological records, and field experimentation. Ecohydrology is a powerful tool in combating desertification, since human activities alter the linkages between climate, ecosystem functioning and water availability in arid lands. Dryland ecohydrology directly tackles the crucial question: do human beings cause deserts?

Managing human water needs in the desert

In 2008, Dr Patricia Gober won the Water Management and Protection Prize as co-director of the Decision Center for a Desert City (DCDC) at Arizona State University, for work at the forefront of integrating physical and social science into a decision support system for enhanced water planning in an urban, desert region, with proven results. DCDC successfully engages with the daunting challenge of managing water in the face of climate change by introducing a new kind of scientific enterprise — one that includes social and policy scientists along with climate scientists, hydrologists and engineers; one that embodies a holistic, system-wide perspective and considers the dynamic interactions between energy and water use; one that facilitates collaboration between decision makers and scientists, and one that is firmly focused on the future. As a 'decision centre' the organization asks the 'what if' questions, it explores the kinds of decisions that must be made today to avoid future disasters, and it provides strategies that are robust enough to work over a wide range of future climate conditions.

Water resources management in arid areas

Dr Howard S. Wheater of Imperial College, London, won the Water Management and Protection Prize in 2006 for his work in improving our understanding of the hydrology of arid areas, developing suitable modelling tools for the management of those areas, applying them in practice and disseminating state-of-the-art information to students and practitioners. He carried out some of his winning work as a co-chair of the UNESCO initiative, G-WADI (Global network for Water and Development Information in arid lands), a network which promotes international and regional cooperation in the arid and semi-arid areas.

Other PSIPW initiatives

Besides awarding its suite of prizes every two years, PSIPW is active in numerous water-related projects, some of which focus on combating desertification, community development and sustainable agriculture through the restoration and rehabilitation of degraded land. One of these initiatives is the Prince Sultan Project for the Rehabilitation of Villages and Hamlets in Saudi Arabia, which engages in rainwater harvesting and groundwater recharge to provide sufficient water for sustainable agriculture in the country's rural areas. PSIPW also supports a research chair at King Saud University with a focus on rainwater and run-off water harvesting and storage.

PSIPW Sixth Award winners

Image: PSIPW

Winners of the PSIPW Sixth Award. Top: Kristine Larson, Eric Wood and Justin Sheffield, and Larry Mays. Bottom: Jesús Carrera Ramirez, Polycarpos Falaras and William Yeh

The Sixth Award ceremony for the Prince Sultan Bin Abdulaziz International Prize for Water was held in Riyadh, Saudi Arabia on 15 December 2014. The winners were:

Creativity Prize: the GPS Reflections Group led by Dr Kristine M. Larson (University of Colorado, Boulder) for discovering how GPS instruments, which exist all over the world, can be used to provide critical information to hydrologists, like soil moisture, snow depth and vegetation water content, at minimal cost.

Creativity Prize: Dr Eric F. Wood and Dr Justin Sheffield (Princeton University) for developing a state-of-the-art system for accurately monitoring, modelling and forecasting drought on regional, continental and global scales, which is used for drought prediction throughout the world.

Surface Water Prize: Dr Larry Mays (Arizona State University) for demonstrating how ancient water technologies can be adapted to address the urgent needs of people living in water-scarce regions today.

Groundwater Prize: Dr Jesús Carrera Ramirez (Institute for Environmental Assessment and Water Research, CSIC, Barcelona, Spain) for contributing decisively to the development of mathematical hydrogeology and transport modelling in groundwater systems.

Alternative Water Resources Prize: Dr Polycarpos Falaras (National Center for Scientific Research 'Demokritos', Athens, Greece), coordinator of the European Union's CLEANWATER Project, for developing a novel detoxification system that destroys toxins through solar photocatalysis during the water filtration process.

Water Management and Protection Prize: Dr William W-G Yeh (University of California, Los Angeles, USA) for pioneering the development of optimization models to plan, manage and operate large-scale water resources systems throughout the world. His methodology, and the algorithms he developed for the real-time operation of complex, multiple-purpose, multiple-reservoir systems, have been adopted in a large number of countries including the United States, Brazil, Korea, Taiwan and the People's Republic of China.

Land use and the restoration of degraded land towards sustainable development in Malaysia

Omar Osman, Kamarulazizi Ibrahim, Kanayathu Koshy, Fauziah Ahmad and Ahmad Shukri Yahaya, Universiti Sains Malaysia, Penang

With a rising population and increasing destruction of fertile soil and agricultural land, the need to promote prudent land management has become an integral part of sustainable development. Although land degradation leading to desertification is not a serious issue in Malaysia, there is increasing concern about landslide and slope-land stability in the context of development activities linked to construction and cultivation.

Taking those negatives and developing a positive approach that looks at rainfall variability, climate change, risk assessment, slope monitoring and computer-aided slope stability scenario generation are key priorities. Within the new vision of Universiti Sains Malaysia (USM) to transform higher education for a sustainable tomorrow, a risk-reduced development pathway that integrates sustainability challenges in natural sectors with cross-sectoral areas such as climate change, population and production has been gaining ground.

Developed as a result of the United Nations Conference on Environment and Development 1992,[1] the United Nations Convention to Combat Desertification (UNCCD)[2] is a unique instrument that has brought attention to the land degradation affecting some of the most vulnerable people and ecosystems in the world. The UNCCD benefits from the largest membership of the three Rio conventions and is increasingly recognized as an agreement that can make an important contribution to the achievement of sustainable development and poverty reduction.[3] In order to attract more attention to climate-compatible development, the United Nations launched the Decade on Deserts and the Fight against Desertification (UNDDD).[4] During the launch of the decade, the United Nations Secretary General Ban Ki-moon said: "Continued land degradation — whether from climate change, unsustainable agriculture or poor management of water resources — is a threat to food security, leading to starvation among the most acutely affected communities and robbing the world of productive land." This summarises the issues and connects CCD to other development goals such as the Millennium Development Goals and by extension the Sustainable Development Goals to be finalized at the United Nations in September 2015.[5]

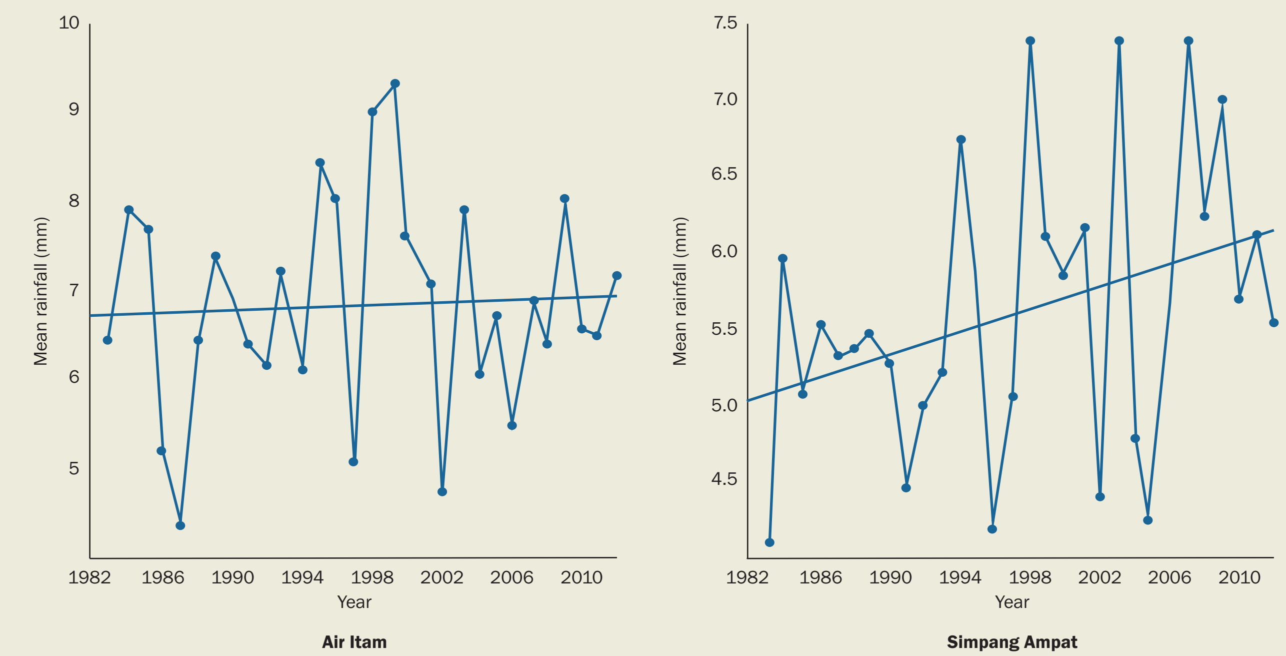
Image: USM 2015

Professor Dato' Omar Osman, USM Vice-Chancellor and Professor Kamarulazizi Ibrahim, Director of the CGSS discuss USM's Five-Year Plan for sustainability implementation

Based on the evapotranspiration to rainfall ratio of 0.005-0.65, most of Malaysia does not fall under the definition of deserts. However, Malaysia is not devoid of land degradation problems, associated mostly with forest harvesting, hill and agricultural development, and mineral exploitation. In order to manage challenges in these areas, the mitigation measures taken mainly involve policies, legislation, guidelines, soil conservation practices and awareness campaigns.

The following is based on Malaysia's reports to UNCCD in 2006 and 2014. Three major policies worth mentioning in this regard are the National Forest Policy (NFP),[6] National Agricultural Policy (NAP)[7] and National Urbanization Policy (NUP).[8] The implementation of NAP involves measures such as: not opening new lands, using underutilized and marginal lands, mixed farming, integration of livestock into plantation forests (rubber and oil palm), and soil mapping. Under NFP the measures taken include setting aside 4.84 million hectares as permanent reserved forest, sustainable management of forest through classification into protection and production forest, forest for timber, soil protection, flood control, water catchment, sanctuary for wildlife, virgin jungle, amenity, and research purposes. As part of NUP, the Department of Town and Country Planning in collaboration with various other departments and agencies has developed a multisectoral sustainable land use master plan for the whole country. National development follows these plans and practices.[9]

Mean rainfall for Air Itam and Simpang Ampat, 1983-2012



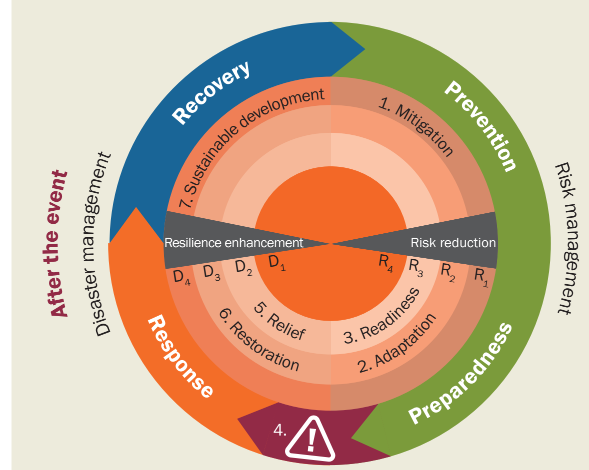
Source: USM

Although a special national programme to combat desertification, land degradation and drought (DLDD), as promoted by the United Nations, is not drawn up in Malaysia mainly because land issues are addressed sectorally, about 41 per cent of the national population is informed about DLDD and/or DLDD synergies with climate change and biodiversity.[10]

Within the new vision of USM to 'transform higher education for a sustainable tomorrow', the university has embraced a whole-institution sustainability transition. The university's Sustainability Policy 2014 uses such an integrated approach with a sustainability priority represented by WEHAB+3.[11] This is an expanded version of the WEHAB — water, energy, health, agriculture and biodiversity — the sectoral challenges popularized by Kofi Annan during the World Summit on Sustainable Development[12] and '+3' stands for three overarching cross-sectoral issues — climate change/disaster risk management, production/consumption and population/poverty.[13] Within the accelerated implementation of the sustainability policy, the USM Vice-Chancellor is currently engaged in active discussion with various sections of the university.

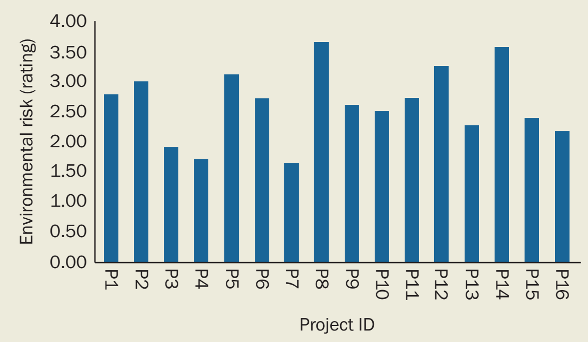
One of the practical innovations USM is proposing is a risk-reduced development approach that builds resilience and eventually leads to sustainable development. For example, each land use problem may be visualized in terms of the result of the impact of a 'hazard' (whether 'natural', like heavy rain or 'unnatural', the direct result of human activity) on vulnerable exposure units. When a hazard meets vulnerability, a risk is generated. This risk is later realized as

The DRM-SD model for risk reduction



It is assumed that the radius of the right hemisphere represents the full risk and that on the left, the full disaster. The key to the successful implementation of the model is the ability to progressively reduce risk through mitigation (R_1), adaptation (R_2) and readiness (R_3) measures carried out 'before the event' under 'prevention' and 'preparedness'. The residual risk is shown by R_4 which when realized as disaster (D_1) is presumably small and manageable. The post-disaster activities relief (D_2), restoration (D_3) and sustainable development (D_4) will enhance resilience (reduced disaster) under the response and recovery phases.[19]

Source: CGSS-USM



The graph shows the results applying the authors' methodology to 16 selected project sites, P1-P16, which are also landslide-prone hillside development sites in Penang. The results show that 12 per cent of project sites were at high environmental risk, 44 per cent at medium risk and others at low risk.[20] The results are used to develop the guidelines for slope land use and sustainable management by the Penang State Government.

Source: USM

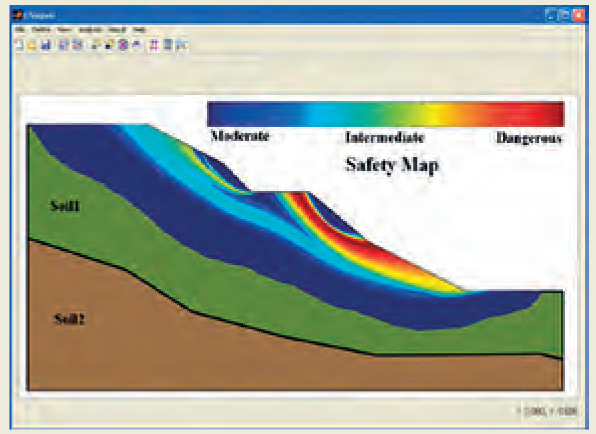
disaster. Such considerations, and the UNDDD, have helped USM to refocus attention on land use and land degradation under sustainable development. Malaysia and its universities are an active part of national efforts to manage land and land resources sustainably.[14] The disaster risk management for sustainable development (DRM-SD) model, developed by USM and the Centre for Global Sustainability Studies (CGSS), shows such an approach.

There follows a description of USM's research efforts towards risk-reduced land use by addressing potential negatives and turning them into positives that promote sustainability. In order to address land degradation and risk management within the context of this article, we have identified four specific areas: rainfall and land erosion; risk assessment; slope monitoring; and slope stability software where the authors (Fauziah Ahmad and Ahmad Shukri Yahaya) have played lead roles. Although these projects have focused on land management issues of Penang state in Malaysia, the methodologies used and the results obtained have much wider applications.

Rainfall erosivity — the ability of rainfall to cause erosion due to its physical characteristic — is increasingly used for soil erosion risk assessment for current and future, especially under a changing climate. Land management models use rainfall amount and intensity as key factors.[15]

The effect of rainfall erosivity in Penang was considered for two stations, Air Itam and Simpang Ampat. Monthly as well as annual rainfall data, obtained from the Department of Drainage and Irrigation, Malaysia for 30 years (1983-2012) was used to calculate the mean and standard deviation per decade.

The coefficient of variation is less than 0.3 for all stations, showing that the mean rainfall has very small variability although the regression line shows a slightly



Typical output of Safety Map Analysis using USlopeM™ software

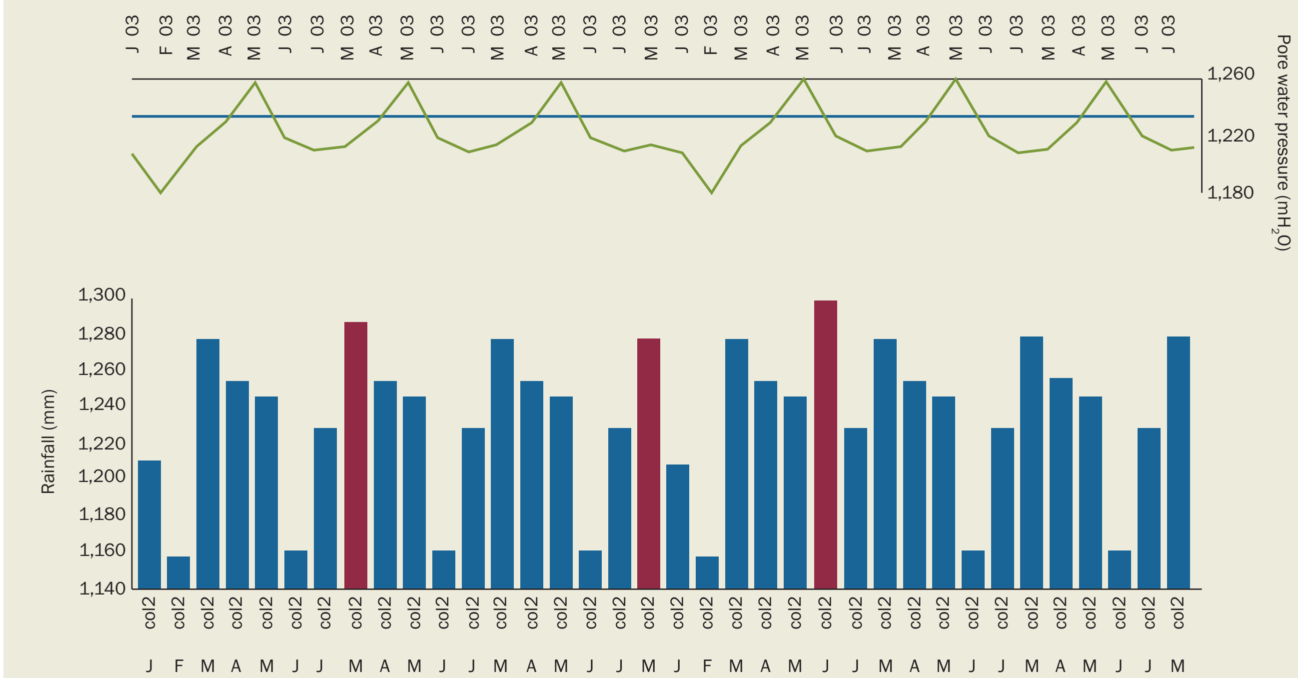
Source: USM

moderate positive trend. Mann-Kendall trend analysis and Sen's slope tests were carried out to establish the decadal mean monthly rainfall variability. The Fournier indexes were used to determine the effect of extreme rainfall events towards soil erosivity. Air Itam recorded 10 per cent cases of very severe impact using the Fournier index and 3.33 per cent cases of very high impact using the modified Fournier index. This shows that while Air Itam is susceptible to soil erosion due to rainfall events, Simpang Ampat is more prone to landslide.[16]

Penang has a corrugated and hilly topography. Construction activities in these areas are increasing primarily for residential and commercial purposes. Assessing the extent of the corresponding development risk is critical to the life and property of local inhabitants. Using 13 variables such as slope gradient, soil profile, rock quality designation, plastic index, shear strength of coarse and fine grained soil, groundwater monitoring, land-use suitability, slope stabilization measures, slope stability analysis, rock fall analysis, retaining and foundation system, soil erosion and sedimentation control and maintenance monitoring, the authors have modified existing rating systems to arrive at a methodology to assess the overall risk thresholds for landslides.

USM's main campus in Penang has an aesthetically beautiful and hilly terrain. As part of its commitment to be a sustainability-led university, a pilot slope-monitoring study was conducted by a group led by the authors to monitor and mitigate USM's hillside hostels. The Well-Inform Landslides Monitoring System (WILMS), a real-time web monitoring system, was developed which integrates the use of Short Messaging Services and Multimedia Messaging Services technology to disseminate results.[17]

Based on the on-site data collected without needing constant manual intervention, WILMS forecasts when land instability is more likely to occur. Such data eventually form the basis on which WILMS outputs are computed. WILMS' capacity to establish secure communication with users while preserving proper data transfer between data



Source: USM

acquisition tools, servers, computers and mobile devices via wired and wireless is one of its unique properties. It also has an alarm system that is triggered when changes are detected in the geotechnical parameters of the slope that exceed the safety limit.

Although developed for the USM Kampus Sejahtera (Healthy Campus) Programme (2000), WILMS is a handy tool to alert slope stability managers when remedial measures are deemed necessary.

Evaluating the stability of slopes is a big challenge for geotechnical engineers. It involves locating the slip surface with the minimum factor of safety (FS). An in-depth study revealed that most of the current commercial slope stability software suffers from poor search algorithms, resulting in over-estimation of stability. Considering this limitation, USlopeM™ was developed which employs state-of-the-art metaheuristic search algorithms to locate critical slip surfaces to determine the minimum FS that indicates probable slope failures. USlopeM™ addresses the possible existence of multiple, rather than single failure modes. Currently, engineers have to run commercial software several times using different initial parameters to locate all important slip surfaces. USlopeM™ finds all global and local minima of FS in a single run without significant reliance on engineering experience. The software is released with a CAD-like graphical user interface for creating slope models and viewing results. It also uses parallel computing to exploit the full performance of multi-core central processing units. The major end product of the analysis is a Factor of Safety Map which will indicate the region of critical area in just less than a minute.[18]

The software has obtained copyright and trademark and has also won gold medals at the 25th International Invention, Innovation & Technology Exhibition in Kuala Lumpur; at the Belgian International Trade Fair for Technological Innovation in Brussels; and at the Korea International Women's Invention Exposition in Seoul.

USM is at the forefront of research and capacity-building within its renewed vision for an all-institution mainstreaming of sustainability. This finds expression in campus sustainability promotion on the one hand and integrating global sustainability principles and practices, as articulated through the Rio process, on the other. Within this priority we have focused this discussion on land use issues relating to slope land erosion and slope failures. Considering the impact of rainfall, new development and other emerging issues that increase the vulnerability of slope lands, we have highlighted risk assessment as a way to monitor slope strength. A new slope stability software, USlopeM™, has been developed at USM to generate slope stability scenarios for risk-reduced land use. Through research, training and community based initiatives, USM will continue its UNCCD focus. After all, desertification represents the acute convergence of a wide range of challenges that must be faced globally — poverty reduction, economic growth, food security, climate change, land use, water management, good governance and the achievement of Sustainable Development Goals.

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Enhancing water resources management in irrigated agriculture to cope with water scarcity in arid regions
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Sustainable smallholder agriculture, food security, agricultural policy and the role of smallholder farmers
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Rethinking the sustainability of Israel's irrigation practices in the drylands

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Restoring lands and livelihoods in rain-fed areas through community watershed management

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