भारतीय मानक
Indian Standard

IS/ISO/TR 14055-2 : 2022

पर्यावरणीय प्रबंधन — भूमि क्षरण और मरुस्थलीकरण का मुकाबला करने के लिए अच्छी प्रथाओं को स्थापित करने के लिए दिशा-निर्देश

भाग 2 क्षेत्रीय मामले के अध्ययन

Environmental Management — Guidelines for Establishing Good Practices for Combatting Land Degradation and Desertification

Part 2 Regional Case Studies

ICS 13.020.01

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Environmental Management Sectional Committee, CHD 34

NATIONAL FOREWORD

The Indian Standard which is identical with ISO/TR 14055-2 : 2022 'Environmental management — Guidelines for establishing good practices for combatting land degradation and desertification — Part 2: Regional case studies' issued by the International Organization for Standardization was adopted by the Bureau of Indian Standards on the recommendation of the Environmental Management Sectional Committee and approval of the Chemical Division Council.

Land degradation and desertification are fundamental and persistent problems. They are caused by climate variability (for example, drought and floods), other natural factors and unsustainable human activities, such as over-cultivation, overgrazing, deforestation, over-extraction of water, impacts of construction activities and unsustainable irrigation practices. These activities can lead to loss of vegetation and biodiversity, declining water supply and poor water quality, soil erosion and the loss of soil fertility and structure. The consequences in the medium to long term are loss of agricultural and economic productivity, loss of soil quality and function and loss of ecosystem services, including biodiversity loss and adverse social impacts. This document provides regional case studies of good practices in land management to prevent or minimize land degradation and desertification.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

The technical committee responsible for the preparation of this standard has reviewed the provisions of the below mentioned ISO standard and has decided that it is acceptable for use in conjunction with this standard.

International Standard	*Title*
ISO 14055-1 : 2017	Environmental management — Guidelines for establishing good practices for combatting land degradation and desertification — Part 1 : Good practices framework

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Introduction

Land degradation and desertification are fundamental and persistent problems that have long been recognized. They are caused by climate variability (e.g. drought and floods), other natural factors and unsustainable human activities, such as over-cultivation, overgrazing, deforestation, over-extraction of water, impacts of construction activities and unsustainable irrigation practices. These activities can lead to loss of vegetation and biodiversity, declining water supply and poor water quality, soil erosion and the loss of soil fertility and structure. The consequences in the medium to long term are loss of agricultural and economic productivity, loss of soil quality and function and loss of ecosystem services, including biodiversity loss and adverse social impacts.

The IPCC Special Report on Climate Change and Land, Summary for Policymakers, noted that “human use directly affects more than 70 % of the global, ice-free land surface” and that “about a quarter of the Earth’s ice-free land area is subject to human-induced degradation”[3]. Le et al.[4] estimated that at least 3,2 billion people were affected [by land degradation], while Barbier and Hochard[1][2] estimated that 1,33 billion people were affected, of which 95 % were living in developing countries[5].

Land degradation is a driver of climate change through loss of carbon stocks in vegetation and soil, albedo changes and reduced capacity to sequester carbon as soil fertility declines. Furthermore, land degradation is exacerbated by climate change; for example, through reduction in ground cover caused by increased incidence of drought, and enhanced erosion caused by increased frequency and intensity of storms.

Recognizing the significance of land degradation leading to desertification in dryland areas, the United Nations Convention to Combat Desertification (UNCCD)[6] was developed to combat desertification and mitigate the effects of drought in dryland regions, particularly in sub-Saharan Africa. The UNCCD recognizes desertification as a social and economic issue as much as an environmental concern. Therefore, it has a major focus on fighting poverty and promoting sustainable development in areas at risk of desertification. Parties to the UNCCD agreed to implement national, regional and subregional action programmes, and to seek to address causes of land degradation, such as unsustainable land management. This document is intended to complement and support the activities of the UNCCD by providing guidance to land managers on the establishment of good management practices that, when implemented, will reduce the risk of land degradation and desertification and assist in rehabilitation of lands affected by degradation. Land managers expected to benefit from the document include land users, technical experts, private and public organizations, and policymakers involved in the management of land resources for ecological, productivity, economic or social objectives.

The purpose of this document is to provide case studies, in support of ISO 14055-1, on the management of land degradation from all hemispheres of the globe and across tropical, sub-tropical and temperate climates, and from a variety of topographical areas, including deserts, wetlands and marginal landscapes. Participating communities include those with poor economic profiles and limited resources, and those evidencing some wealth and access to technology and the benefits of research.

This document aims to make ISO 14055-1 more relevant and understood, and to promote its use through an illustration of regional case studies and examples that support the Sustainable Development Agenda 2030[7] of SDG 15 (life on land) and SDG 13 (climate action). This document engages a broad range of stakeholders and countries to benefit from their initiatives in combatting environmental degradation and desertification.

Indian Standard

ENVIRONMENTAL MANAGEMENT — GUIDELINES FOR ESTABLISHING GOOD PRACTICES FOR COMBATTING LAND DEGRADATION AND DESERTIFICATION

PART 2 REGIONAL CASE STUDIES

1 Scope

This document provides regional case studies of good practices in land management to prevent or minimize land degradation and desertification in support of ISO 14055-1:2017.

The case studies are presented to facilitate the application of ISO 14055-1 across a wide of range of geographical and local conditions.

NOTE The cases studies are presented as different ways of applying good practice and do not preclude alternative ways of applying good practices in accordance with ISO 14055-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14055-1:2017, *Environmental management — Guidelines for establishing good practices for combatting land degradation and desertification — Part 1: Good practices framework*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14055-1:2017 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Abbreviated terms

AVCF	agricultural value chain finance
BAMB	Botswana Agricultural Marketing Board
C-BP	clearing and brush packing (in brush packing restoration method)
CBO	community-based organization
CEDA	Citizen Entrepreneurial Development Agency, Botswana
CLDS	composite land development sites

CNFR	Comisión Nacional de Fomento Rural (National Rural Development Commission), Uruguay
CO	clearing only (in brush packing restoration method)
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas (National Scientific and Technical Research Council), Argentina
CRILAR	Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (Regional Center for Scientific Investigation and Technology Transfer of La Rioja), Argentina
CRS	clearing and re-seeding (in brush packing restoration method)
CRS-BP	clearing, re-seeding and brush packing (in brush packing restoration method)
CSA	climate smart agriculture
CSRS-BP	clearing, soil disturbance, re-seeding and brush packing (in brush packing restoration method)
DPAP	Drought Prone Area Programme, India
DPSIR	drivers/pressure/state/impact/response
EU	European Union
FAO	Food and Agriculture Organization
GIS	geographic information system
HDI	human development index
ICAR	Indian Council of Agricultural Research
IFD	intervenciones físicas demostrativas (demonstrative physical interventions), ECONORMAS programme
IICA	Inter-American Institute for Cooperation on Agriculture
IMSD	Integrated Mission for Sustainable Development, India
IPM	integrated pest management
ISPAAD	Integrated Support Programme for Arable Agriculture Development, Botswana
KAZA TFCA	Kavango–Zambezi Transfrontier Conservation Area, Bostwana
LADA	Land Degradation Assessment in Drylands, Argentina
LDN	land degradation neutrality
LULC	land use/land cover
NDB	National Development Bank, Botswana
NDVI	normalized difference vegetation index
NGO	non-governmental organization

ONDTyD	Observatorio Nacional de Degradación de Tierras y Desertificación (National Observatory of Land Degradation and Desertification), Argentina
PBE	Proyecto Básico y Ejecutivo (basic and executive project), ECONORMAS programme
RS	remote sensing
SDG	Sustainable Development Goal
SEZ	special economic zone
SFR	Sociedad De Fomento Rural (Rural Development Society), Uruguay
SLM	sustainable land management
UC	no clearing (control plot) (in brush packing restoration method)
UNCCD	United Nations Convention to Combat Desertification
UNSDF	United Nations Sustainable Development Framework
USD	United States dollar
WAWD	Water Access and Wasteland Development, Pragya project, India
WMP	Watershed Management Programme, India

5 Presentation of case study examples

This document provides examples of measures undertaken to reduce the impact of land degradation. Wherever possible, the examples were selected to demonstrate challenges in different climatic zones – temperate, sub-tropical, tropical – as well as different geographical regions (see Figure 1). The studies have been compiled according to a template so that the logic of each study is properly described, and the relevant good practice emphasized. The relationship between the template and the relevant guidance is shown in Figure 2.

The case studies provide examples of the application of technology, the development of restoration and conservation techniques, stakeholder engagement and innovation, and the alignment of socio-cultural practices. Some projects have been undertaken with international co-operation and support and the participants are described in the study.

The vernacular is used in many case studies and the description of some terms can be found from other sources.

The actions, results, proposals and conclusions described or made within each case study are solely with respect to the particular case study conditions and not intended as a general requirement, recommendation or permission in relation to the use or application of ISO 14055-1:2017.

Key

Symbol	Location	Clause	Case study	Focus
1	Costa Riojana	6	A	Community education and sustainable livelihoods
2	Madhya Pradesh	7	B	Use of GIS and RS
3	western Rajasthan	8	C	Sand dune stabilization
4	Ladakh-Kinnaur	9	D	Water supply for irrigation and household use
5	Pandamatenga	10	E	Food security and value chain analysis
6	D'Nyala Nature Reserve	11	F	Restoration after woody clearing
7	Valles Calchaquíes	12	G	Regional cooperation to combat desertification and drought
8	Irauçuba			
9	Chaco Paraguayo			
10	Tala			

NOTE Source: Base map: http://equal-earth.com.

Figure 1 — Location of case study examples

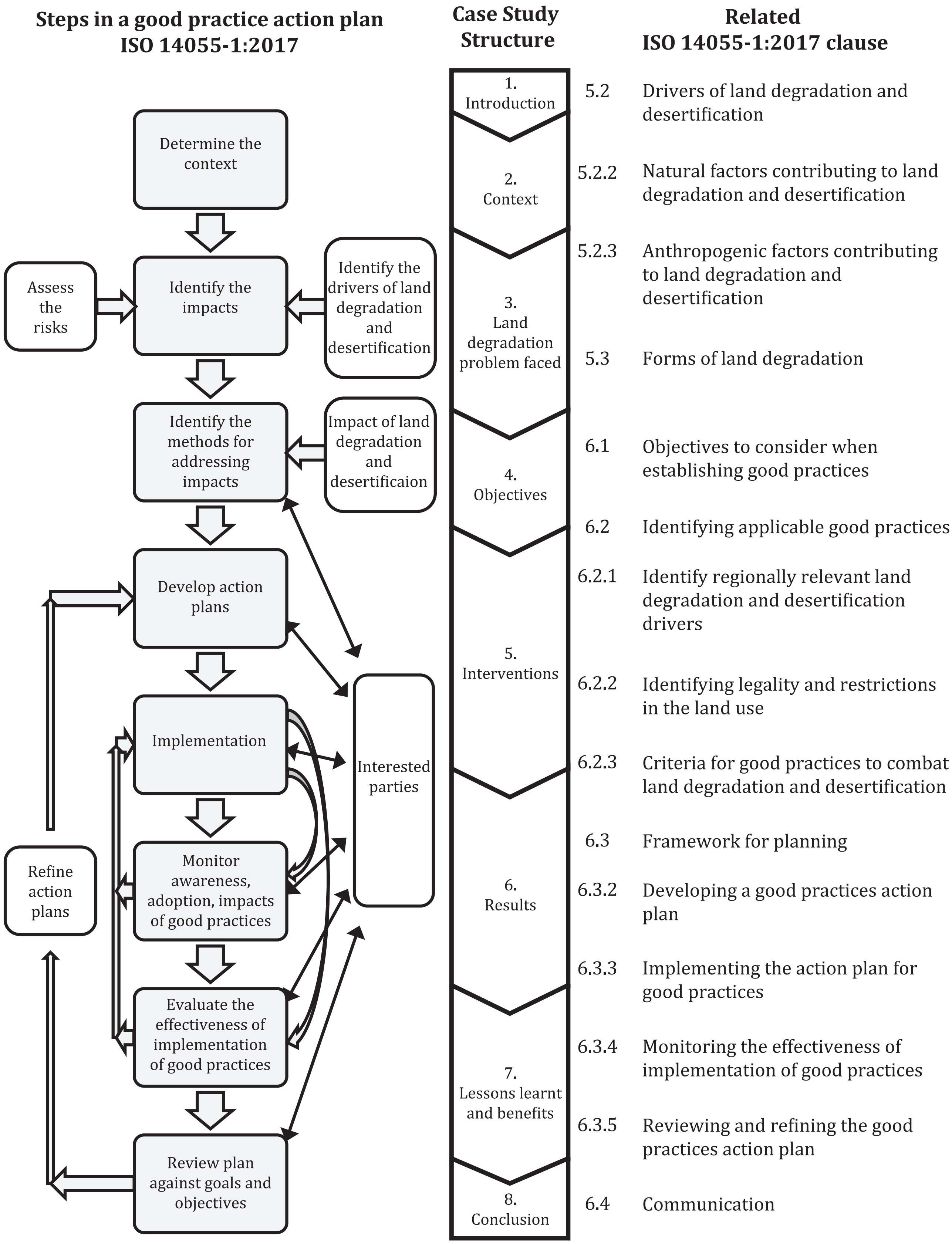


Figure 2 — Case study structure and related ISO 14055-1:2017 clause

6 Case study A — Community education and sustainable livelihoods for land degradation management in the sub-montane La Rioja province, Argentina

6.1 General

In 2011, Argentina formed the National Observatory of Land Degradation and Desertification (ONDTyD) as a network of institutions and researchers. This was an outcome of the report on evaluation of desertification in Argentina, under the Food and Agriculture Organization (FAO) Land Degradation Assessment in Drylands (LADA) project[9]. In 2013, the Regional Center for Scientific Investigation and Technology Transfer of La Rioja (CRILAR), under the National Scientific and Technical Research Council (CONICET), located in Anillaco, La Rioja province, became a member of the ONDTyD. The province of La Rioja is located in the northwestern sub-montane region of Argentina and is a semi-arid area which faces severe droughts and desertification.

The Costa Riojana, La Rioja, was selected as a pilot site for an ONDTyD project to collect information about the state, trends and risks of soil degradation and desertification in the area. The purpose was to develop recommendations for the prevention, control and mitigation of damages to the land, so as to assist the decision-making process in relation to environmental management by both the private and public sectors. The members of the ONDTyD project team are from the CRILAR-CONICET.

First, the people of the pilot site, including the representatives of the community, were invited to a workshop that had been organized. After analysing the answers, it was concluded that one of the main causes of desertification during the previous years was the indiscriminate cutting down of mesquite trees (*Prosopis* sp.).

Next, an alternative was proposed: to incorporate the mesquite fruit into the human diet. This would not only promote a healthy diet, but would also promote a sustainable process that would use each and every available resource without damaging or negatively impacting the environment.

One challenge was weather conditions that restrict the use of large portions of the land for agricultural activity. This also resulted in a growing desire to generate work opportunities and productive projects to improve the quality of life for the residents of the area. It was concluded that the most viable solution was the use and care of the mesquite tree. After years of evolution in the area, the native mesquite tree, or “algarrobo” in Spanish, is able to survive the lack of water and climatic variations. The trees survive plagues, their production costs are low and they do not involve much care.

There are different mesquite species, e.g. white mesquite (*Prosopis chilensis*) and black or sweet mesquite (*Prosopis flexuosa*), which are frequent in the Costa Riojana and have multiple applications. Unfortunately, the main demand is for the wood, which is used for firewood due to its high heat capacity, causing deforestation, soil erosion and loss of the vegetation cover.

There are multiple advantages in focusing on the mesquite fruit that would improve the quality of the life of the residents of the area. First, they are excellent sources of protein and good carbohydrates. Second, they can either be consumed fresh or processed. Third, they would help to control nutrition problems in rural areas. Finally, their industrialization would generate new job opportunities.

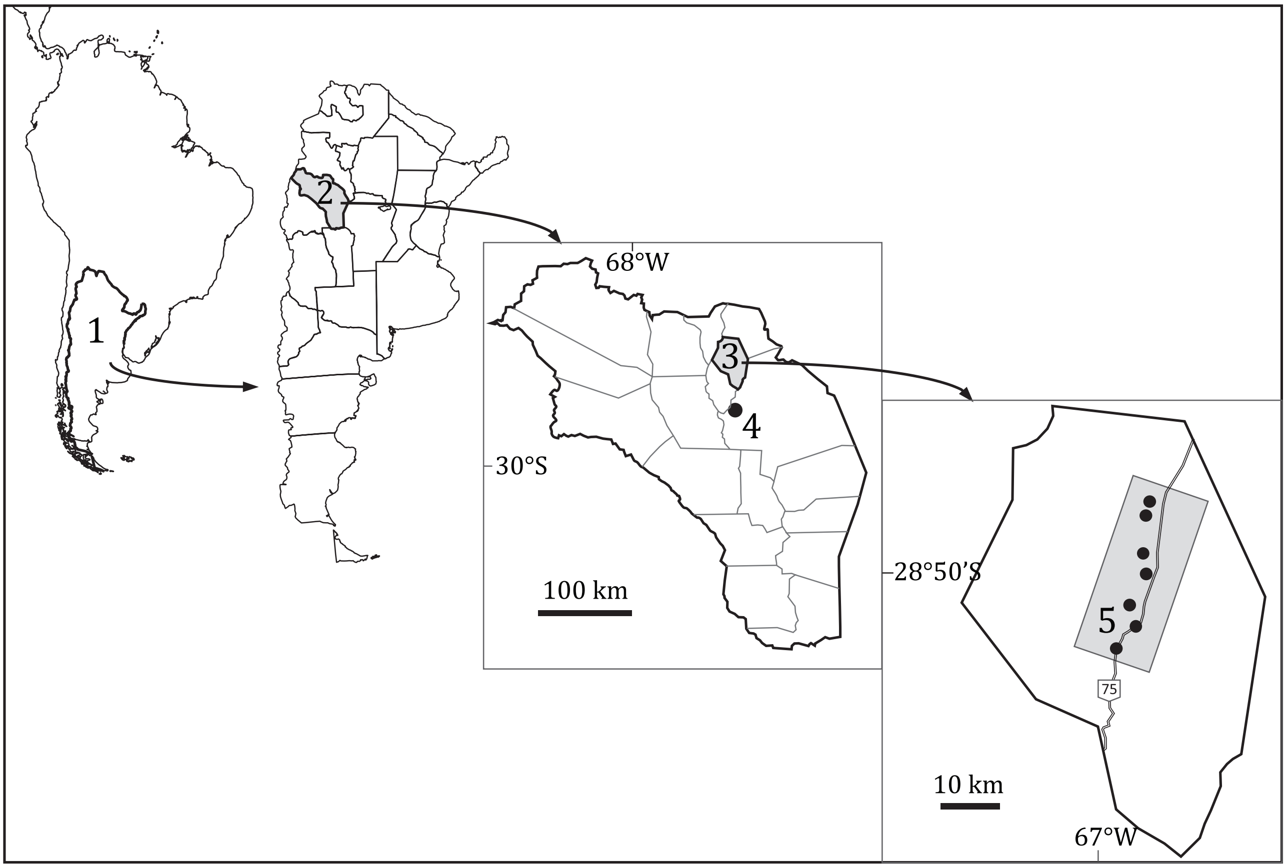
The mesquite fruit is a pod with pulp (smaller in the white mesquite tree and larger in the black one) that contains many seeds that can be used to feed animals. Unfortunately, only a few do so. The pulp corresponds to the mesocarp, it is sugary, very sweet, sticky, visibly developed, with an approximate thickness of 1,5 mm to 2,0 mm. The natives used it in pre-Hispanic times. This was verified in archaeological remains.

The use of the mesquite fruit is the solution for many problems of the pilot site Costa Riojana. It would improve a healthy diet, would help nutrition and would generate jobs opportunities, while avoiding soil degradation and desertification.

6.2 Context

6.2.1 Location

The ONDTyD pilot site of Costa Riojana, is located in La Rioja province, northwestern Argentina (see Figure 3). The area under study is bounded by a polygon with the following coordinates: northeast corner at 28° 45′ 16,90″ S 66° 48′ 28,17″ W; northwest corner at 28° 42′ 10,73″ S 66° 57′ 10,51″ W; southwest corner at 28° 57′ 56,41″ S 67° 3′ 31,91″ W; and southeast corner at 29° 0′ 44,40″ S 66° 56′ 46,81″ W.



Key

1 Argentina
2 Costa Riojana (La Rioja Province) in Argentina
3 Castro Barros Department in the La Rioja Province
4 La Rioja city
5 study area and sites along Highway 75 in Castros Barros Department

NOTE Source: http://equal-earth.com; https://commons.wikimedia.org/wiki/File:Argentina_-_mapa_de_las_provincias.svg.

Figure 3 — Location of the ONDTyD pilot site at Costa Riojana

6.2.2 Physical features

6.2.2.1 Climate

The climate is semi-arid, with rainfall that does not exceed 180 mm per year. The minimum winter absolute temperature can reach –12 °C and the maximum absolute summer temperature is 38 °C. The average annual temperature is 16,8 °C (2000 to 2008 period). Frost occurs between the months of June and September. There is a large daily thermal amplitude, which can reach up to 21,3 °C. During July and August, the Zonda (a warm and dry wind) is characteristic.

6.2.2.2 Topography

The pilot site covers an area of 43 200 ha, limited by the northeastern flank of the Sierra de Velasco to the west and the mountains of Punta and Mazán to the east. The populations settle in the foot hills of the eastern slope of the Velasco, at an average altitude of 1 400 m above sea level.

6.2.2.3 Soil

The soil can be divided into that of the valley, the flood zone, the piedmont and the mountains.

The valley is characterized by low slopes (between 1 % and 2 %) and moderate to high bare ground cover. The soil in the valley has the characteristics of that of the Aridisols type. This soil is typical of desert areas, and has low organic matter content, light colours, little development or direct absence of horizon A, high porosity and low abundance of roots. The texture is predominantly sandy and silty and has no effective depth limitation.

The flood zone is located adjacent to the channel of the transitory river that acts as a collector of the mountain slopes to the west. Its name comes from its sporadic flood during the rainy season. These characteristics determine a low coverage of bare soil due to the presence of algarrobo trees (*Prosopis* spp.). The soil is predominantly clayey, with a more developed horizon A, a higher content of organic matter compared to the valley and a high abundance of roots.

In the piedmont, the slopes follow the altitudinal gradient, with values of 2 % at the base and up to 30 % at higher altitudes. The coverage of bare soil is low to moderate due to an increase in vegetation cover with increasing altitude. The soil is predominantly open, with a variable A horizon, that can range from absent to moderately developed. It presents greater limitation to effective depth relative to the valley, and it is mostly porous but also with the presence of lumps in lands with agricultural use.

The Sierras, with the highest altitudes, have the highest slopes, exceeding 30 %. The soil has similar characteristics of that of the piedmont, but with a higher content of organic matter and dark brown colour.

6.2.2.4 Natural vegetation

The vegetation in the valley region corresponds to the northern portion of the Monte[8]. It is an open shrub steppe dominated by *Larrea cuneifolia* “jarilla”, and accompanied by *Bulnesia retama* “retamos”, fabaceas shrubs and cactaceas. Herbs and grasses are scarce and their abundance depends on the seasonal pulses of rainfall. The forests are open and marginal to transient rivers, with *Prosopis chilensis* and *Prosopis flexuosa* “algarrobo” (known as mesquite in the United States of America and Mexico) as the dominant tree species. The piedmont vegetation becomes more abundant due to the increase in the humidity that follows the altitudinal gradient. Here, as characteristic species of the Monte vegetation appear *Flourensia fiebrigii,* and *Trichocereus terscheckii* “cardón” in the alluvial fans. Following the permanent rivers, in the riparian forests thrive the trees *Acacia visco* “visco”, *Lithrea molleoides* “molle” and *Schinus fasciculata* “moradillo”.

6.2.3 Socio-economic features

6.2.3.1 Land use and governance (tenure, customary access arrangements)

The predominant land use in the pilot site is a small-scale agricultural production of fruit trees (mainly vine, olive and walnut) and extensive livestock. The farmlands are arranged as small farms of up to 1 ha within the boundaries of the villages. Both irrigation water and water for human consumption come from the permanent rivers of the Sierra. There are two intensive wine productions located in the valley, which use drilling water, drip irrigation and agro-chemicals.

In the pilot site, the following conditions and processes currently impact on land degradation: extraction of firewood in the valley (mainly algarrobos and retamos), lack of territorial planning, water scarcity and conflicts associated with its use, loss of productivity and economic profitability of small holder farms, ignorance of agricultural good practices and alternative forms of sustainable production, lack of association activism, dependence on state employment, absence of protected areas, and poor awareness of the ecosystem services that provide for the native flora and fauna.

6.2.3.2 Population/demographic/socio-cultural setting

The pilot site has a population between 300 and 2 000 residents distributed in small villages. Their main activities are the harvest of vineyards, walnuts, olives and fruits, as well livestock (mainly goats and cows).

6.2.4 Interested parties

The main goal of ONDTyD project is to provide information about the state, tendencies and the risk of land degradation and desertification, in order to:

a) develop ideas and proposals;

b) promote the prevention, control and mitigation of land degradation and desertification.

This information can be used by both public and private organizations in charge of decision-making in relation to this issue. To make this possible, potential interested parties are identified, including among the general population, government, universities and research institutions.

6.3 Land degradation problems faced

6.3.1 Types of land degradation observed

The types of land degradation observed were degradation of the ecosystem structure and biodiversity, and biomass decrease:

— after clear cutting, there is natural replacement of the forest with secondary forests of reduced productivity, which results in a reduction in biomass and a decrease in species diversity, as well as a reduction in carbon stocks;

— great areas of woodlands were cleared and transformed to open space for agriculture purposes that later were abandoned [see Figure 4 a)];

— there is natural wind and water erosion, frequently aggravated by human activities (anthropic erosion), such as agriculture and over-catching.

One of the main problems of the ONDT y D Costa Riojana pilot site is that people cut down the native tree “white algarrobo” *Prosopis chilensis* and “black algarrobo” *Prospis flexuosa* to obtain firewood, ignoring provincial laws that penalize this practice [see Figures 4 b) and 4 c)].

a) Dismantling of the native vegetation

b) Cutting down of algarrobo

c) Trucks transporting firewood from *Prosopis* sp.

NOTE Photo credit: ONDTyD project group.

Figure 4 — Land disturbances

6.3.2 Drivers of land degradation

The drivers of land degradation identified were:

— unsustainable agricultural practices, such as:

  — dismantling of native mountain vegetation without previous planning;

  — historical overgrazing;

  — biomass extraction for non-sustainable energy;

  — indiscriminate cutting of algarrobo trees to obtain firewood and wood;

— anthropogenic disturbance involving agriculture and their associated industries generates agro-industrial wastes that produce habitat loss and fragmentation of the wildlife as well as the loss of biodiversity;

— the use of firewood and crop residues as energy sources reduces the content of organic matter, vegetation and forest cover and can also affect rain fall patterns, as well as the hydrology of watersheds.

6.3.3 Risk of future land degradation — Resilience

Some of the risks for land degradation are the indiscriminate use of firewood and wood, as well as the clearing of land for agriculture that is then abandoned due to very high economic costs and lack of profitability. All these practices can be avoided.

Other problems include the lack of education about alternative practices for sustainable land management (SLM), historical overgrazing and dismantling of native mountain vegetation without previous planning.

The lack of information and knowledge of the native flora and fauna is aggravated by the water deficit.

Anthropogenic disturbance involving agriculture and their associated industries generates agro-industrial wastes. As a consequence, it produces habitat loss and fragmentation of the wildlife and loss of biodiversity (see Figure 5).

NOTE Photo credit: ONDTyD project group.

Figure 5 — Olive pomace being loaded into a truck for application on the fields

6.4 Objectives

Among the principal goals of the project are the following:

— recovery of degraded areas with algarrobo (*Prosopis* sp.) through the planting of seeds, and practices that use the minimum amount of water;

— avoidance of the indiscriminate cutting of algarrobo trees to obtain firewood and wood, and promote the valuable of the fruits for human consumption;

— creation of added value to the fruits by selling them (processed) as flour or pudding;

— production of edible fungi on agro-industrial waste and use of any of the remainder for feeding of the local cattle.

6.5 Interventions

Since the beginning of the project in 2013, surveys and evaluations have been made of the pilot site. Researchers from CRILAR-CONICET discovered numerous archaeological sites that indicate the use of algarrobo by native people as their food source. The presence of mortars, conanas and seeds demonstrated the elaboration of algarrobo flour (see Figure 6).

a) Rock mortars

b) Close-up of a mortar

NOTE Photo credit: ONDTyD project group.

Figure 6 — Presence of pre-Hispanic mortars

The following observations were made:

— the land degradation was due to the indiscriminate cutting of algarrobo trees to obtain firewood and wood;

— ancestral practices used since pre-Hispanic times, such as the use of algarrobo fruit for human consumption, had been abandoned.

Several intervention activities were carried out at the pilot site, as follows:

— Members of the pilot site study began to give workshops to develop understanding of these matters in the schools of the area. General meetings were also conducted to raise awareness of these problems. Posters were distributed to explain degradation and desertification in 10 schools of Costa La Rioja.

— The first mechanical mill (see Figure 7) was acquired for an agrarian school, which incorporated the milling of algarrobo flour. In each grinding, 10 % of the production is given to the school.

— An edible fungi was produced on agro-industrial residues (pomace from the elaboration of olive oil, grape pomace, walnut shell and remnant of the milling process of algarrobo tree).

Finally, trials of reforestation with *Prosopis flexuosa* and *Prosopis chilensis* with irrigation only in the initial stage are being carried out. These trials have been successful so far (see Figure 8).

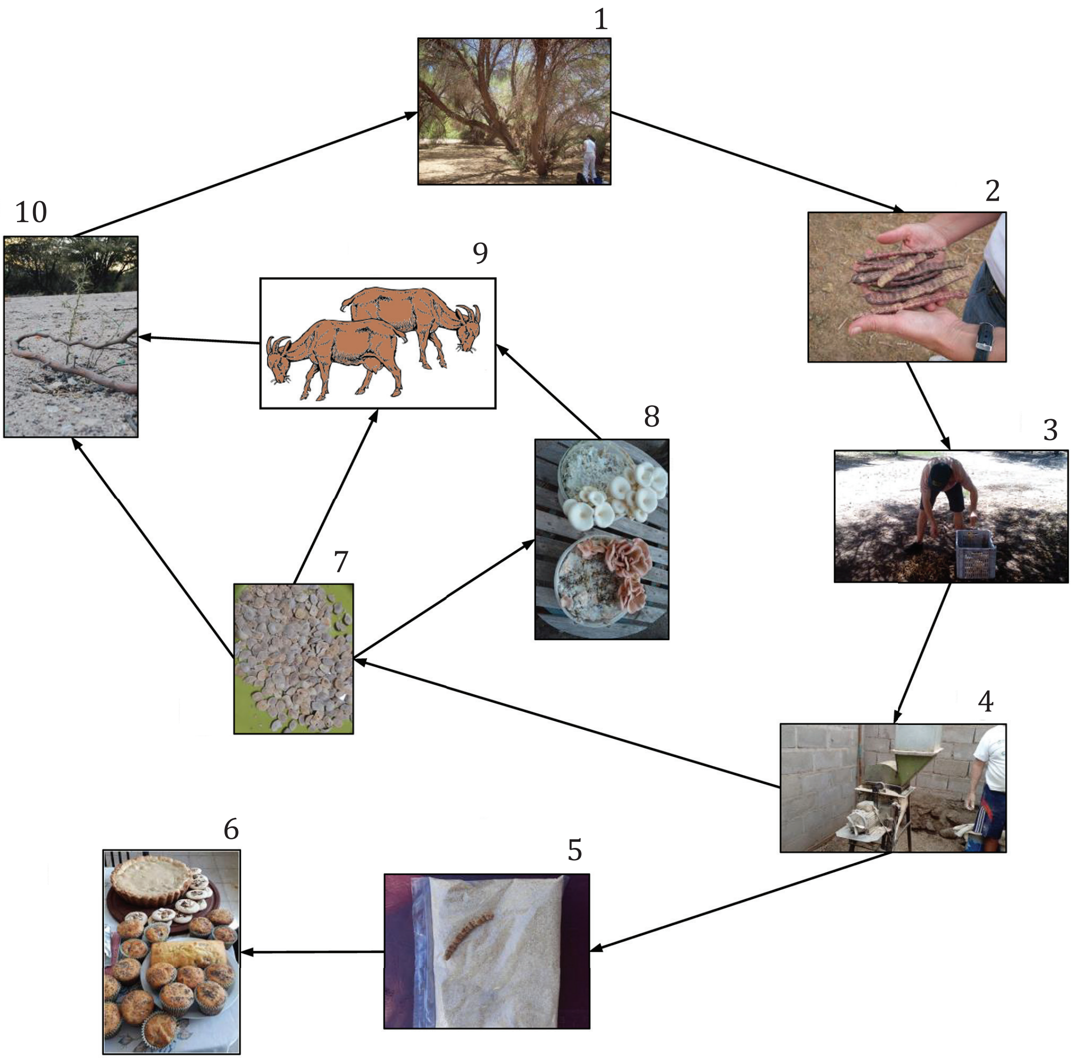
NOTE Photo credit: ONDTyD project group.

Figure 7 — First algarroba mill installed in an agro-technical school within the pilot site

NOTE Photo credit: ONDTyD project group.

Figure 8 — Afforestation with only an initial irrigation using hydrogel

The project applied a circular economy approach (see Figure 9), whereby it can be made sustainable with minimal environmental impact. The algarrobo fruits are used to make flour. The flour is used to elaborate human food. Then, the residue of the flour is reused to obtain seeds and then the seeds are used for reforestation. In addition, with other agro-industrial wastes (olive oil, wine, walnut shells) as soil compost, edible fungi is grown and produced. Their fructifications are used for human consumption (girgolas), while the rest of the residue, together with the mycelium of the fungus, is recovered for feeding goats.



Key

1 algarrobo mezquite tree
2 fructification
3 harvesting of the fruits
4 flour mill machine for grinding the algarrobo seeds
5 flour produced from algarrobo
6 breads and puddings from algarrobo flour
7 agro-industrial waste from the processing activities
8 girgolas (mushrooms) are grown using the agro-industrial waste residue
9 goats feed on the organic waste residue and contribute to natural fertilisation
10 seedlings grow on hydrogel from agro-industrial wastes and organic fertilisers

NOTE Photo credit: ONDTyD project group.

Figure 9 — Circular economy based on the algarrobo

6.6 Results

The interventions were found to have resulted in the following achievements:

— reduction of the indiscriminate use of firewood and wood, thus avoiding logging as the main cause of land degradation;

— reduction of the impact of land degradation through forestation;

— provided availability of mills for the whole community and for the possibility of continuity with the acquisition and use of more mills in other towns or localities;

— rescue of an ancestral cultural food such as the algarroba, adapting it to the current consumer demands (food security), given its high nutritional value and suitability for celiacs (incorporated to Argentine Food Code in 2014);

— rescue of lignocellulolytic edible fungi (*Pleurotus* sp.) growing on agro-industrial substrates (see Figure 10);

— better quality cattle feed and sustainable feeding practices.

NOTE Photo credit: ONDTyD project group.

Figure 10 — Girgolas (*Pleurotus sp.)* growing on agro-industrial substrates

6.7 Lessons learnt and benefits

The interventions resulted in benefits for the community and there were lessons learnt in implementation of the interventions:

— The workshops and lectures in schools have allowed children to stimulate their thinking and to reconfigure their actions by disseminating good practices in their families.

— The planning of ideas was well accepted, but the stage of implementation is slower. In one of the agro-technical schools, the mill has been used but the algarroba flour was not used as food. The consumption of algarroba flour is a challenge, and several certifications that would give added value to the product (as a product suitable for celiacs, an organic product and conformity with International Standards, since the pods are currently extracted from the field).

— It is important to evaluate the advantages and disadvantages of different types of mills according to where they would be located, e.g. in a populated town. It would be easier to place a mill in a permanent place. However, if houses are scattered, then a portable mill would be more convenient for the inhabitants.

— The native algarrobos tree grows well in the soil conditions of the desert. In this context, reforestation is not necessary. Nevertheless, care and protection of the algarrobo trees is critical to allow them to grow to a mature age.

6.8 Conclusion

Based on the experience at the pilot site, the following actions were proposed by the ONDTyD:

— identify the drivers of land degradation including the impact of past/current practices;

— raise awareness among the population about the problems generated by the use of unsustainable management practices;

— diminish land degradation by locally improving sustainable environmental practices;

— recover ancestral feeding practices, adapting to the new demands of the current consumer;

— mitigate the environmental impact by preventing the algarrobo felling and giving value to the flour obtained from their fruits;

— achieve the use of each stage of algarrobo flour production, mitigating environmental impacts;

— encourage the production of new foods with high nutritional value;

— improve the quality of life of the local population by generating new jobs through a circular economy approach (see Figure 9).

The activities can be aligned with SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

7 Case study B — Use of GIS and RS to support spatial planning for drought resistance in continental marginal lands in India

7.1 General

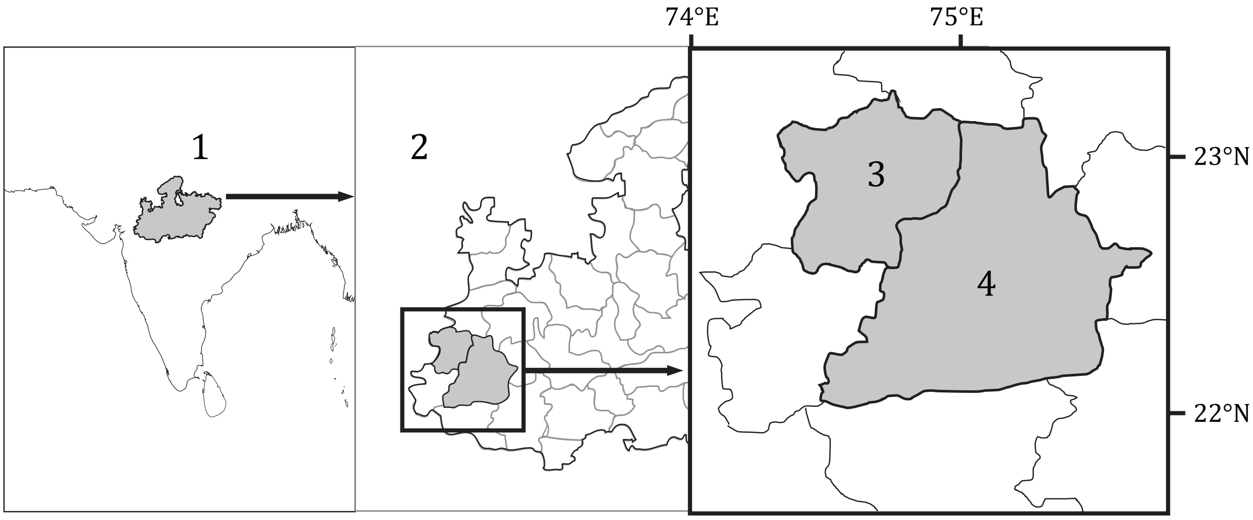
Nearly 228,3 mha (69 %) of India’s total geographical area is under dry lands and 105,8 mha (25 %) areas of the country have been affected by desertification. In 1994, the Ministry of Rural Development, Government of India, launched a Watershed Management Programme (WMP) under the Drought Prone Area Programme (DPAP). The main purpose of this programme was to use a scientific approach for conserving the soil and water resources and optimizing their utilization for increased/sustainable agricultural productivity, regeneration of natural vegetation, and better livelihood opportunities for the people living in the arid regions of the country.

In this clause, the use of the spatial analysis strategy of using remote sensing (RS) and geographic information tools for planning the resulting interventions for combatting soil erosion is presented. The case study area is in the DPAP areas of Jhabua and Dhar districts of Madhya Pradesh, India. A composite land development sites (CLDS) approach was applied with the aid of RS satellite data, other ancillary information and geographic information system (GIS) environment for implementing various watershed management plans in the selected region.

7.2 Context

7.2.1 Location

The Jhabua and Dhar districts of Madhya Pradesh, India, were selected for study under the DPAP. The Jhabua and Dhar Districts are located in the southwestern corner of Madhya Pradesh state, India. The total area of these two districts extends from about 23° 55′ N to 23° 14′ N latitude and from 74° E to 74° 42′ E longitude (see Figure 11).



Key

1 the state of Madhya Pradesh in India

2 districts in the state of Madhya Pradesh

3 Jhadpur District, Madhya Pradesh

4 Dhar District, Madhya Pradesh

NOTE Source: adapted from https://commons.wikimedia.org/wiki/File:Ecozone-Biocountry-Indomalaya.svg; https://commons.wikimedia.org/wiki/File:India_Madhya_Pradesh_location_map.svg; Arunima et al.[13].

Figure 11 — Study area districts of Jhabua and Dhar, Madhya Pradesh, India

7.2.2 Physical features

7.2.2.1 Climate

The area falls in the semi-arid tropics of India and is highly drought-prone with degraded wastelands. The whole study area falls in the hot, moist semi-arid agro-ecological subregion and is characterized by dry summers and mild winters. Natural vegetation in the area comprises tropical dry and mixed deciduous forest. Dryland farming is a common traditional practice. The normal annual mean maximum temperature is 32,8 °C and the normal annual mean minimum temperature is 19,1 °C. In Jhabua District, the highest day temperature in the summer is between 32 °C to 44 °C. The average rainfall in the district is about 600 mm to 800 mm.

7.2.2.2 Topography

The average elevation of the plateau is 365 m above the mean sea level. The terrain is hilly and highly undulating[12]. The geomorphic surface in the terrain is formed by Vindhyan hills and the Malwa plateau. The terrain is hilly and undulating due to differential erosion of hard rock especially weathering of basalt. The general trends of the hills are in the east-west direction. The erosional characteristic of a plateau in the area of basaltic terrain comprises a dissected plateau.

7.2.2.3 Soil

The soil constitutes gravel and sand. The terrain is flat to undulating. There is moderate to good silt or clay-sized unconsolidated grains of varying lithology. The dominant soil of this area is represented by the Sarol series and the Kamliakheri series, which are moderately deep, moderately well-drained and moderately permeable black soil. The valley soil is medium to deep, pale to dark greyish brown, almost black in places, clay to clay loams (40 % to 60 %) from alluvium of basaltic origin, giving a reaction of neutral to slightly alkaline. In the plateau area, the soil is deep to very deep, with dark, black cotton clay soil on elevated plateaus in the northeast of the district. In the piedmont and undulating uplands, the soil is shallow to medium depth, sandy to sandy loams, yellowish brown to reddish brown, and slightly acidic.

7.2.2.4 Natural vegetation

The natural vegetation comprises tropical dry and mixed deciduous forest. Dryland farming is a common traditional practice in highly undulating topography in Jhabua, with slopes of cultivated lands.

The main crop is maize, which occupies the largest area, followed by Jowar (sorghum). Rice is also cultivated in small areas.

7.2.3 Socio-economic features

This area has been identified as one of the most backward areas of the country. There is considerable rural poverty and large-scale unemployment among the casual farm and non-farm workers, as a result of inadequate work opportunities. The livelihood of rural people in these areas has always been under constant threat.

Rural poverty and extensive unemployment among the casual farm and non-farm workers indicate inadequate work opportunities in the hot, moist semi-arid agro-ecological subregion. Frequent droughts play havoc with agriculture. As a consequence, the livelihood of rural people in agricultural areas is under constant threat, resulting in extreme poverty.

Several medicinal plants grow naturally in this region that can be utilized for curing physical ailments and diseases through the Indian System of Medicine. These are used for the preparation of herbal drugs by the tribal community for the preparation of herbal drugs. The women make ethnic items including bamboo products, dolls, bead jewellery and other items that have for long a time decorated living rooms all over the country.

About 91 % of the population lives in rural areas. Tribal people form 85,60 % of the population and nearly 3 % of the population belong to scheduled castes. The density of the population is nearly 206 persons per km^2.

7.2.4 Interested parties

The interested parties for the geospatial analysis were the planners, scientists and technicians participating in the WMP in the area.

7.3 Land degradation problems faced

Dry land tribal farming is undertaken on highly undulating topography. In the absence of water resources and periodic droughts, agriculture production is very low. In order to supplement their income, people engage in pastoralism and overgrazing, which results in land degradation due to lack of vegetation cover.

Other causes of land degradation are lack of rains, periodic droughts and lack of water resources, and lack of vegetable cover further aggravates the soil erosion. Without the watershed management interventions and lack of vegetable cover, soil erosion conditions will further worsen the land degradation.

7.4 Objectives

The three main objectives of the WMP for the study area were:

— reducing the vulnerability to droughts, improving the income and livelihood of people, and providing short-term employment opportunities;

— providing various water harvesting measures to increase agriculture through an increase in surface and subsurface water;

NOTE An increase in agricultural production with proper soil and water management practices increases the carrying capacity of the land leading to sustainable development.

— creating employment opportunities to reduce poverty and improve livelihoods among casual farm and non- farm workers who are impacted by frequent droughts in the moist semi-arid agro ecological subregion.

A spatial analysis strategy was developed to support the implementation of the WMP. The goal was to develop a RS and GIS system which can collect and maintain the data and information in order to support the WMP objectives. In particular, the system would be able to assist in the monitoring of any land-use changes that were expected to be realized due to the proposed interventions, i.e. in relation to improvements in the water and soil resources.

7.5 Interventions

A WMP is one of the most appropriate and scientific approaches for conserving the soil and water resources using check dams, ground water recharge structures, farm ponds and water harvesting Bundhis (minor irrigation ponds) to counter the impact of droughts. These interventions optimize the storage and utilization of water and can result in increased/sustainable agricultural productivity, regeneration of natural vegetation and better livelihood opportunities.

Evaluation of the implementation of soil conservation, efficient management and utilization of rainwater, and management of the non-arable lands for fodder, fruit and fuelwood production in the watershed perspective are the core strategies of natural resource management in the semi-arid tropics of India.

All these water conservation measures are aimed at increasing soil moisture, reducing surface runoff and erosion, recharging groundwater in the discharge zone, and utilizing groundwater as well as rainwater for crop growth more effectively.

RS and GIS techniques have been employed to assess the resource status for the purpose of generating action plans. To monitor the positive impacts of desertification-combatting methods of the WMP, an evaluation can be made of the changes in surface water bodies, areal extent in irrigated agriculture and changes in vegetation of the agricultural lands in the selected districts. The RS-GIS methodology to study the impact of the WMP in the semi-arid districts of Dhar and Jhabua is described by Arunima et al.[13] and is shown in Figure 12.

Parameters used for evaluation and monitoring purposes included:

— land use/land cover (LULC) parameters;

— the extent of the irrigated area;

— vegetation index through the normalized difference vegetation index (NDVI) values;

— fluctuation in the depth of groundwater table;

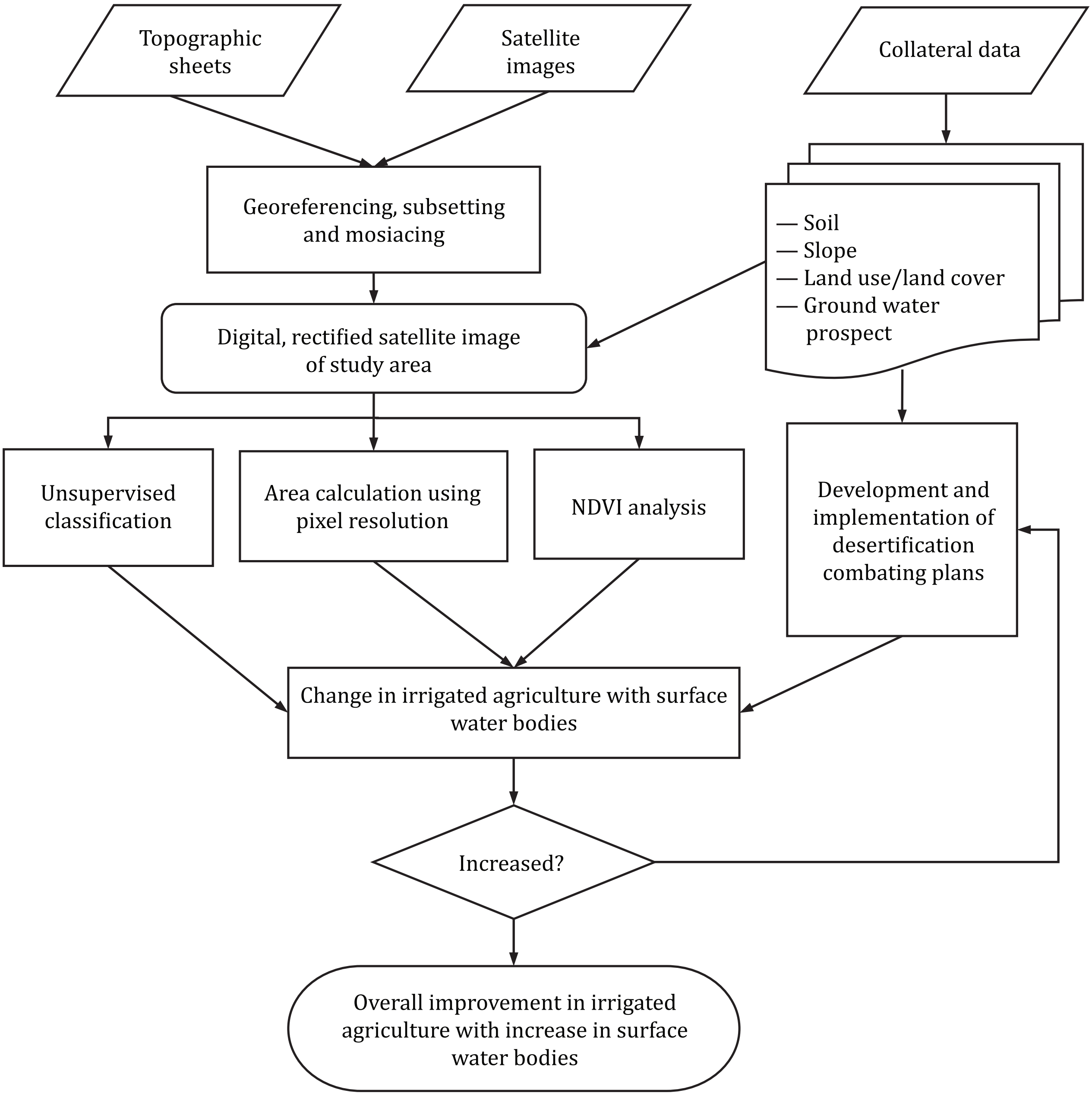
— well density and yield;

— cropping pattern and yield;

— the occurrence of hazards;

— related socio-economic indicators using the Integrated Mission for Sustainable Development (IMSD) guidelines[16][18].

The CLDS method was evolved and applied for the project. CLDS is an integrated method incorporating three major steps. First, four thematic maps were generated, namely soil, slope, LULC and ground water potential (derived from hydro-geomorphology map), representing individual classes of these parameters for any given problem area. Then this information was combined both spatially and aspatially, using GIS techniques for obtaining unique CLDS.



NOTE Source: Arunima et al.[13].

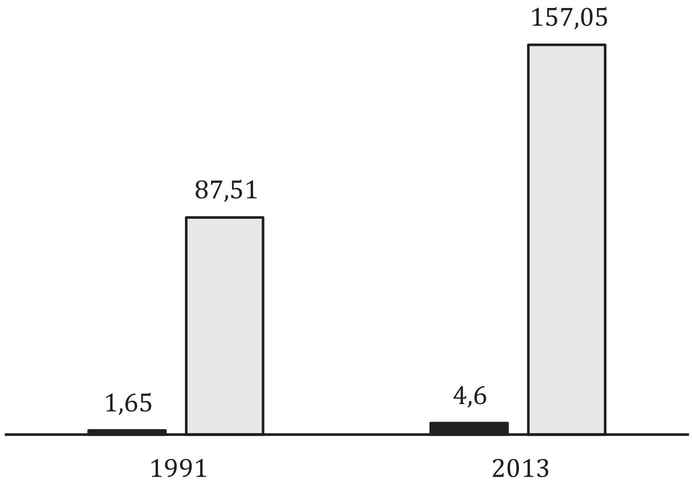
Figure 12 — Flowchart of the overall methodology used for the study

7.6 Results

Based on the RS-GIS evaluation and collateral data, several plans were proposed for the implementation of the intervention actions. In order to prevent soil erosion and increase the soil capacity to retain water, various measures such as contour bunding, growing grasses, afforestation, an agro-forestry and horticulture programme for fuel-fodder, and fruit plantation were undertaken.

For reducing runoff and erosion, increasing soil moisture, recharging of groundwater, promoting proper ground water exploitation and increasing surface water storage, water resource management and augmentation programmes such as check dams, nallah bunds, culvert-cum-stop dams and surface dukes were undertaken.

Comparison of the satellite images of the project area between 1991 and 2013 indicated the positive effects of the intervention practices[13]. The area of the water bodies increased by 80 times and the agricultural area increased by 34 times between 1991 and 2013. The latter was indicated by the NDVI values of the agricultural lands which were successfully estimated over the period of 12 years (see Figure 13). The WMP and intervention actions have brought socio-economic benefits for the people of the target area and improved the quality of life.



Key

water body area (km²)

agriculture area (km²)

NOTE Source: Arunima et al.[13].

Figure 13 — Changes in the area of water bodies and irrigated agricultural land in the project area before and after intervention measures (1991 and 2013)

7.7 Lessons learnt and benefits

GIS spatial analysis tools were used for the formulation of the action plan and for monitoring the changes brought by implementation of the action plan in real time. The results show that these tools are extremely useful for supporting the formulation of implementation programmes and evaluating the effectiveness of the desertification countermeasures for socio-economic development of the region.

As a result of the geospatial analysis, the results showed an increase in the area of water bodies and of irrigated agricultural lands (see Figure 13). It can be considered that the interventions to augment and manage water resources were successful measures to fight soil erosion and for the rehabilitation of eroded soil, thereby increasing agriculture productivity and improving the socio-economic condition of the population in the semi-arid areas. The storage of water in water bodies and increasing the water table in wells and soil are extremely vital measures for fighting the periodic cycles of droughts.

7.8 Conclusion

Combatting land degradation and desertification can involve meticulous planning in terms of evaluating the existing terrestrial bio-productive system for assessing the true level of resources and extent of degradation. This includes land productivity, vegetation cover, water resources, topography and quality of land. Only ground observations, which are time-consuming and costly, are not suitable for macro-scale area planning. It is also important that the tools used for monitoring are objective and unbiased. RS and GIS techniques have emerged as extremely useful tools for assessing the resource status to formulate action plans and for monitoring the impact of implementation of the plan over the scale of the period. The positive impacts of strategies used for combatting desertification through watershed management techniques can be quantified in terms of the positive changes in the area of the surface water bodies, areal increase in irrigated agriculture and changes in the quality of vegetation cover.

The experience has shown that GIS spatial analysis is a very appropriate approach for contributing to planning, monitoring and evaluating the desertification combatting strategies in the districts. The WMP developed has been suitable for the selected area.

It can be concluded that RS-GIS techniques are very useful for planning and monitoring the measures to combat desertification at macro scale. Use of these techniques in this study supported the collection of information for planning the interventions and allowed for real-time monitoring of the results of implementation of anti-desertification measures through the WMP.

8 Case study C — Sand dune stabilization in continental desert region of western Rajasthan, India

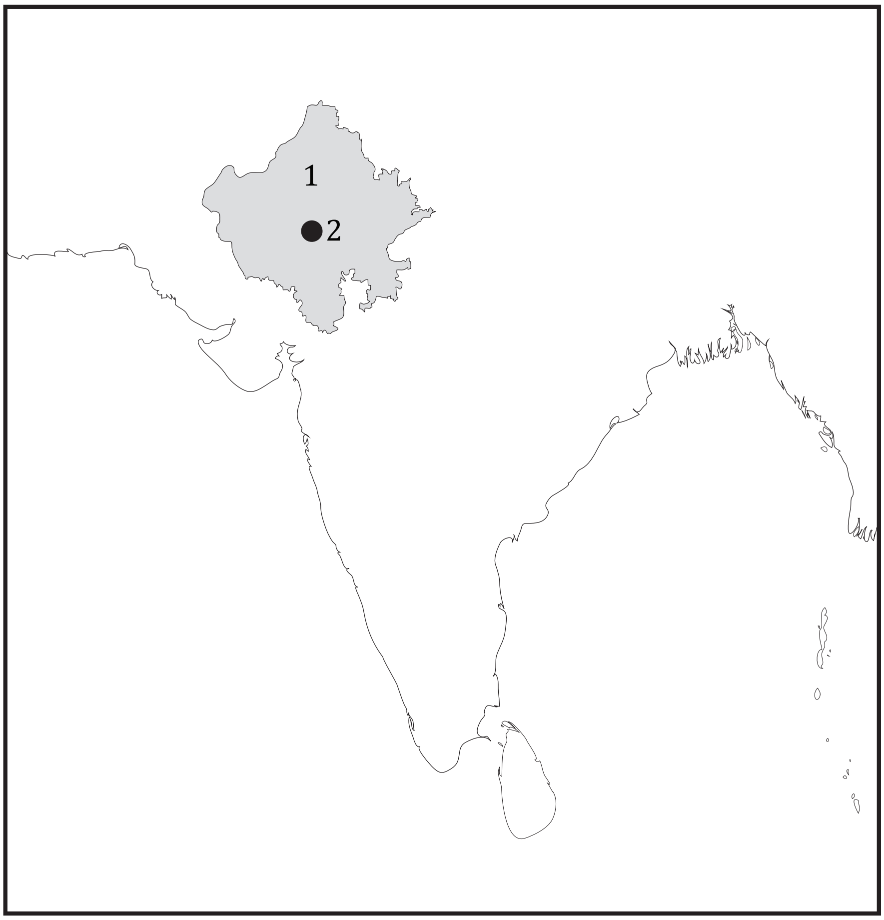
8.1 General

Soil erosion and desertification cause progressively reduced productivity and biological quality of the land. Water availability is also adversely affected. Periodic droughts further aid the desertification process. Shifting sand dunes were a major problem in the arid regions of the western Rajasthan. An operational research project was launched by the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, India, with a major focus on sand dune stabilization, grass and forage development, afforestation, shelterbelt plantation, demonstration of improved technologies in the cultivation of important vegetables and fruits for higher productivity, and watershed management. This was a foundational project to transform deserts in India. One of the salient features of this project was to involve beneficiaries in the project and give them knowledge for a multiplier effect. This project resulted in improving the socio-economic conditions of the population in the project area. Subsequently, a new project was undertaken by the villagers on their own without government intervention.

8.2 Context

8.2.1 Location

The area of arid western Rajasthan extends from 24° 37′ 00″ N to 30° 10′ 48″ N and from 69° 29′ 00″ E to 76° 05′ 33″ E (see Figure 14). Five contiguous villages of Mandore Panchayat Samiti, located north of Jodhpur, in the western part of Rajasthan state, India, were selected for the project. They were: Daijar (2 284 ha) in 1974, Basani Karwar (526 ha) in 1975, Palri Khicbayan (1 440 ha), Basani Lachha (650 ha) and Manaklao (2 912 ha).



Key

1 the state of Rajasthan in India

2 project area located north of Jodhpur

NOTE Base maps: adapted from https://commons.wikimedia.org/wiki/File:Ecozone-Biocountry-Indomalaya.svg; https://commons.wikimedia.org/wiki/File:IN-RJ.svg.

Figure 14 — Location of the project area in Rajasthan, India

8.2.2 Physical features

8.2.2.1 Climate

Western Rajasthan is a desert which is dominated by a sandy landscape with scorching sun, and a hot and dry strong wind. Large areas of the region are subjected to very strong wind during the hot summer months, which causes wind erosion. As a result, sand and other fine particles get blown from parts of the landscape and deposited at other locations. Average rainfall in this region is between 100 mm to 400 mm. Sometimes, temperatures exceed 54 °C in summer months and drop below freezing point in winter. High evapotranspiration (1 500 mm/year to 2 000 mm/year) takes place during the summer period.

8.2.2.2 Topography

The landforms are very heterogeneous. They comprise shifting sand dunes, sandy plains, saline flats, dead streams, alluvial flats, barren gravelly stretches, undulating topography and barren rocky areas (see Figure 15).

NOTE Photo credit: https://commons.wikimedia.org/wiki/File:Thar_desert_Rajasthan_India.jpg.

Figure 15 — Shifting sand dunes in the Thar Desert, Rajasthan

8.2.2.3 Soil

The sand-dune infested area in western Rajasthan alone accounts for about three-fifths of the total area and is mainly formed due to wind erosion. Its main feature is arid soil ranging from red to yellow in colour. It is generally sandy and saline. Humus and moisture content are very low, due to the dry climate and high evaporation rate. The lower portion of the area on the catchment side is also represented by a gravelly and undulating land surface, which is largely found in these villages.

8.2.2.4 Natural vegetation

Thorny bushes and *Prosopis cineraria* trees are found in this region.

8.2.3 Socio-economic features

Out of the total area of 7 812 ha in these villages, about 55 ha is under sand dunes. Nearly 1 383 ha is gravely waste area. About 50 ha area comprises saline and other wasted lands. An occupational distribution analysis of the population in these villages revealed that 64,4 % of the workers had agriculture as their main occupation, 19,9 % were agricultural labours and 1,2 % were engaged in animal husbandry. Approximately 14,5 % were engaged in other occupations. The average size of agricultural holding was 6,6 ha. Only 7,5 % of the land had irrigation facilities. Landholdings of the five contiguous villages of Mandore Panchayat Samiti, Daijar (2 284 ha) in 1974, Basani Karwar (526 ha) in 1975 and Palri Khicbayan (1 440 ha), Basani Lachha (650 ha) and Manaklao (2 912 ha) are shown in parentheses.

The cumulative landholding of these villages amounted to 7 812 ha (78,12 km^2) and these were inhabited by 548 households. The total population was 3 356 (made of up 1 806 males and 1 550 females). 976 were workers and 2 380 were non-workers. The population density was 45 persons/km^2. The size of holding per household was 6,59 ha, out of which 0,52 ha was irrigated and 6,07 ha was unirrigated. There were 105 active irrigated wells, out of which 38 were electrified.

8.2.4 Interested parties

The interested parties in this project were the residents of the five contiguous villages in the project area. Technical support was provided by the experts from Central Arid Zone Research Institute, Jodhpur, India. Financial support was provided by ICAR.

8.3 Land degradation problems faced

In the areas where wind erosion is predominant and continues over a long period, topsoil with its nutrients is usually blown away and leaves behind coarser substrata which are poor in nutrients. It adversely affects the production potentials of the land. The problem gets aggravated in the agricultural fields, which are ploughed before or during the high summer wind and remain without any protection, mulch or plant cover. At the sites where deposition takes place, the medium- to coarse-grained sand veneers the surface, and buries the productive soil. In both of these places, near-surface sediments become relatively less productive. Another major threat to agriculture from wind erosion is the injury to crops through sandblasting of the tender stems and leaves during the sandstorms. Exposure of the shallow root system by the erosion of the sediments eventually causes the death of the crop plants. In the areas of sand deposition, the smaller crop plants get buried under the sand. There is an urgent desire to break this continual cycle of sand dune movement by reclaiming the sand dunes, saving the good land from erosion and stopping the expansion of the desert. There is also a desire to put into use wasteland that has never been used by the farmers for growing crops, fruit trees and grass using watershed management techniques, instead of relying on good land only.

8.4 Objectives

The main objectives are:

— sand dune stabilization and control of wind erosion;

— putting barren land into productive use by raising tree plantations and grasses, which in turn would meet the fuel and fodder requirements of the farmers;

— saving the adjoining farm holdings from being engulfed by the moving sand particles due to erosion;

— using the land down the slope for producing food crops after reclamation.

8.5 Interventions

In order to achieve the objectives, the following interventions were made:

— afforestation and shelter-belt plantation;

— pasture, grasses and forage development;

— demonstration of improved technology in the cultivation of important vegetables and fruits for higher productivity and value addition;

— demonstration of improved technology in the cultivation of winter and summer crops for higher productivity;

— demonstration of effective rodent control methods.

Before the start of monsoon, the area with the dunes was fenced. After a few good showers, one-year-old seedlings of *Acacia tortilis* (Israeli babool) and *Prosopis juliflora* (Vilayati babool) were planted in pits of 60 cm × 60 cm × 60 cm. In between the rows of trees, grass seeds of *Cenchrus ciliaris* (dbaman) and *Cenchrus setigerus* (sewan) species were sown. Tree seedlings were planted 5 m × 5 m apart, with a nearly 100 % success rate. Simultaneously, micro-wind breakers were erected against the wind direction by using the locally available brush weeds. It has been estimated that the plantations on the dune will make it possible for the farmer to obtain 5 tons of fuelwood per year after 10 years and 1 ton of grass per ha per year, as well as providing a significant reduction of sand movement. Both winter and summer crops can be grown with watershed management techniques.

8.6 Results

A total number of 12 694 plants of *Acacia tortilis*, 6 210 of *Prosopis juliflora*, 165 of *Acacia senegal* (kumat), 112 of *Acacia nilotica*, 14 of *Dalbargia sissoo* (shishum) and 8 of *Azadirachta indica* (neem) were planted. Tree plantation was done in strips of 10 rows for plantation of the Cenchrus species of grass. A more than 90 % survival rate of the tree seedlings planted was recorded along with a fairly good establishment of the grass. The project gave good returns over the 10-year rotational falling schedule of timber and income from various varieties of fruits. Farmers especially liked the gola and Seb ber (*Zizyphus manritiana*) due to higher commercial value of the fruits. About 5 000 seedlings were planted in the fields of different farmers in five villages. The plantations were raised under unirrigated as well as irrigated conditions using sweet and brackish water. These were also raised on sloping, unlevelled and rocky areas.

On the farmer's own initiative, another sand dune of 2,7 ha area was selected for plantation of the above tree species on top-side and budded ber on the down-slope side. Improved grass species were sown in between the plant rows. Along the periphery, a wind strip was planted adjoining the boundaries of the field. Here, 300 new budded ber plants (*Zizyphus nummularia*) were planted and 400 local rootstocks were budded. There was a good demand for these fruits in the commercial market.

A water harvesting technique was used in crop production with the proper use of simple terracing, contour furrowing and bunding techniques. This permitted higher water retention by arresting the speed of the rainwater flow. A harvest of a seasonable crop of coarse grain in the catchment area below and pulses on the flat sandy area above was made possible as well as reducing sand erosion. With proper use of reclamation techniques and water harvesting, the eroded land can be put to productive use.

In summary, the main interventions undertaken were:

— fencing off the area;

— establishment of micro-wind breaks on the windward side (5 m chessboard or in 5 m parallel strips);

— sowing of grasses and transplanting of trees and shrubs with the onset of monsoon:

  — use of local shrubs/bushwood materials: Khimp (*Leptadenia pyrotechnica*), Pala (*Ziziphus numularia*), Sania (*Crotalaria burhia*) and Murah (*Panicum turgidum*);

  — tree species such as *Acacia tortilis*, *Prosopis juliflora*, *Acacia senegal* (kumat), *Acacia nilotica*, *Dalbargia sissoo* (shishum) and *Azadirachta indica* (neem) were also suitable;

  — subsequent studies show that the tree varieties such as *Acacia senegal*, *Tamarix articulate*, the grasses *Lasirus sindicus*, *Cenchurus ciliaris*, and the creepers *Citrullus colocynthis* are also suitable.

8.7 Lessons learnt and benefits

About 58 % of the area in western Rajasthan is under sand dunes. Techniques for the stabilization of such sandy areas and growing grasses, shrubs and trees on these dunes, which were previously unproductive, have been adopted by the farmers. The success of the programme can be measured by the fact there was accelerated demand for seedlings, seeds, etc. The majority of the farmers have gained full knowledge about the reclamation techniques. More than 50 000 seedlings of different species of plants were planted in one season alone. The biggest impediment was the lack of availability of saplings. Thus, a proper nursery for the growth of plant saplings can be established beforehand. Most of these plants were planted in strip formation and also served a purpose of acting as windbreakers and shelter belts. *Prosopis Cineraria* has also been highly recommended in later studies.

On marginal and sub-marginal lands, where crop yields are low and soil conservation hazards high, farmers were motivated to use such lands as pastures and rangelands for animal rearing. Grass species such as *Cenchrus ciliaris* and *Cenchrus setigerus* were found to perform very well on these lands. Farmers also realized the importance of growing improved grasses on a small portion of the land of their farms, as well as on all community grazing lands for the pasture development programme.

8.8 Conclusion

Sand dune stabilization can include watershed management, shelterbelts and rodent control. Such a programme can be an integrated programme and can include components such as growing tree and grass species to stabilize the sand dune, and the management of crop lands to collect and recycle the run-off from the rocky and sand dune catchments.

With these measures, the mortality of trees will be low and grass growth will be good. Wheat and coarse grain can be grown on cropland with supplemental irrigation. Growing fruit trees by using traditional rootstock will bring great economic benefits to the farmers, as these will make plants hardier.

Sand dune stabilization can involve considerable investment for fencing, seedlings, grass and irrigation facilities, and mechanized implements, which are beyond the means of poor farmers with very small landholdings. It benefits from government support, considering the overall advantages of saving cultivable land and other infrastructures from being engulfed by sand and stopping the forward march of desertification to other areas with good land. The Government of India has started a composite national programme on the stabilization of sand dunes in the arid regions of the country, which is considered one of the largest successful programmes in the world.

9 Case study D — Water supply for irrigation and household use in cold deserts, northwest Himalayas, India

9.1 General

Cold deserts in India are located in the remote northwest Himalayas in India, in the state of Himachal Pradesh and Union Territory of Ladakh (see Figure 16), located at an elevation between 2 700 m to 5 000 m. There is an extreme seasonal variation in weather in the cold deserts, ranging from a short, dry, cloudless, arid summer with the temperature reaching 36 °C to a long, windy, freezing winter reaching −32 °C. These areas exhibit highly arid conditions with an average annual rain/snowfall of nearly 50 mm to 100 mm. As a result, more than 77 % of the total area in these cold deserts is wasteland. Water is the lifeline of the population living in cold deserts for survival, food and livelihood in the cold deserts. However, the availability of water is very deficient for agriculture, silviculture and household use. It is also a cause of drudgery for women, who bring water from far-off springs for household purposes. The use of innovative technologies such as artificial stupas/glaciers, snow reservoirs, snow pits and snow fences have successfully tried to augment the water supply during lean months.

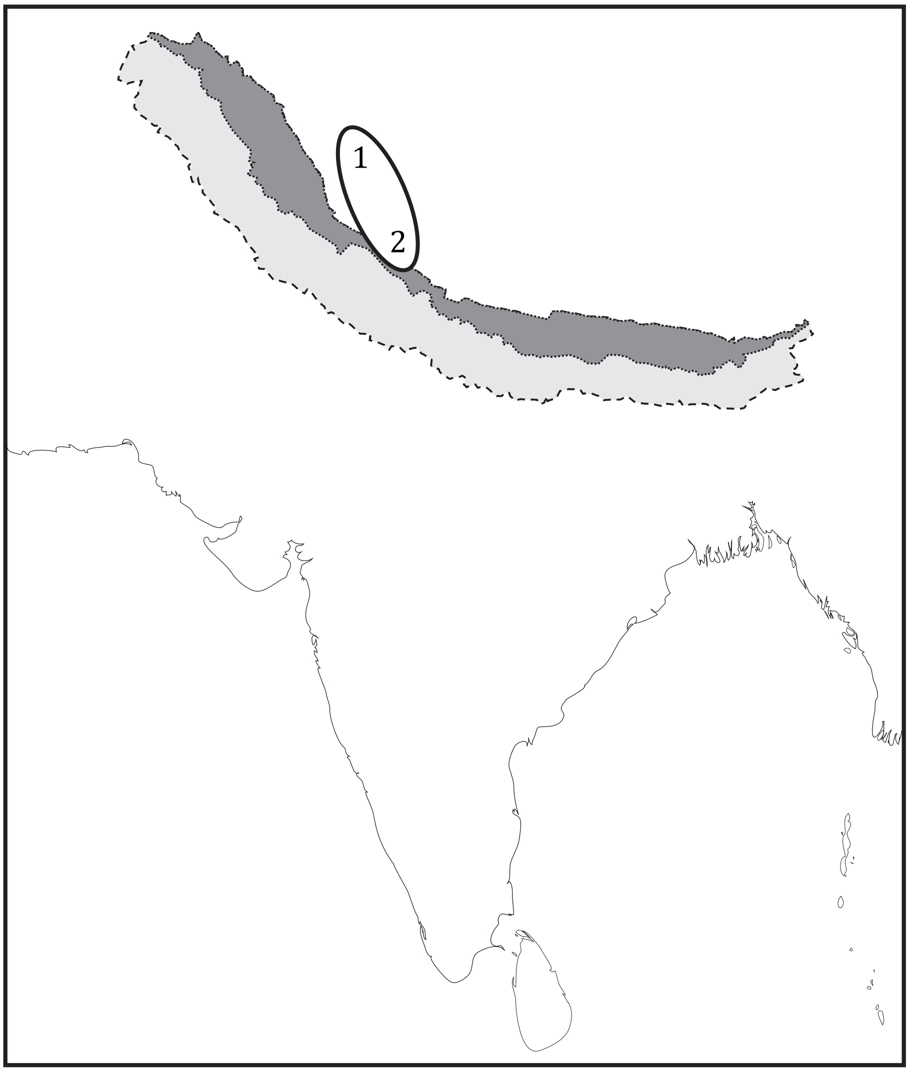
NOTE Photo credit: https://commons.wikimedia.org/wiki/File:Nubra_Valley_2.jpg.

Figure 16 — Cold desert topography seen in the Nubra valley, Ladakh

9.2 Context

9.2.1 Location

Cold deserts in India are located at the remote northern end of Himalayan ranges which lie between Kinnaur district in the south to Ladakh district in the northwest (see Figure 17).



Key

(light grey)	Himalayas	1	Ladakh
(dark grey)	Himalayan main range	2	Kinnaur

NOTE Base maps: https://commons.wikimedia.org/wiki/File:Ecozone-Biocountry-Indomalaya.svg; Nie et al.[32].

Figure 17 — Location of cold deserts in the Himalayan ranges

9.2.2 Physical features

9.2.2.1 Climate

These areas experience a large seasonal variation in weather ranging from a short, dry, cloudless, arid summer with temperature reaching 36 °C to a long, windy, freezing winter reaching −32 °C.

The region is not affected by the Indian monsoons as they lie in the rain shadow of the Himalayas. This results in highly arid conditions and an average annual rain/snowfall of only nearly 50 mm to 100 mm. The area experiences freezing winds and burning sunlight. Consequently, in some places, if a person sits in the sun with their hands in the shade, they will experience sunstroke as well as frostbite at the same time.

9.2.2.2 Topography

Ladakh is one of the highest cold desert plateaus in the world. The natural features mainly consist of high mountains and deep valleys. The inhabited areas in these cold deserts are located at an elevation between 2 700 and 5 000 m.

9.2.2.3 Soil

The soil is shallow to very shallow in depth. There is a very large variation in texture, colour, permeability and structure, depending on topography and vegetation. This soil is called “skeletal soil”, having an admixture of rock fragments due to withering of rocks and colluvial material (loose, unconsolidated sediments that have been deposited at the hillslopes) and permeability is very large.

Nearly 77,4 % of the total area of these cold deserts is wasteland. The net cultivable area is nearly 0,16 %. Only 20 % of the cultivated is irrigated and rest is the fallow land. There is little vegetation cover in cold deserts, which is getting depleted due to overgrazing and harvesting. This results in desertification and creation of more wasteland and increased soil erosion. By mid-June, there is excess of water and even floods due to the fast melting of snow and glaciers in the mountains. All farming operations end by mid-September.

9.2.2.4 Natural vegetation

There is a prevalence of xerophytes in cold deserts. The frozen soil of the cold desert results in shallow roots and lowly plants. At lower elevations, much of the area is covered by desert and semi-desert plants. Steppe vegetation is found at middle elevations from 5 000 m to 5 400 m. Alpine grasslands form a narrow belt above the steppe vegetation and extend as narrow strips near glaciers.

Herbaceous species were most common in all elevation bands (84 % to 100 %), followed by shrubs (3 % to 10 %), and trees (3 % to 12 %). The proportion of herbs and shrubs reached a maximum at altitudes from 3 401 m to 3 700 m, whereas the maximum tree species was between 3 100 m to 3 400 m.

Vegetation changes gradually from alpine meadows (Kobresia, Cares, Potentilla, Nepeta, etc.) to steppe vegetation (Caragana, Artemisia, Stachys, Ephedra, Stipa, etc.) with shrub land (Hippophae, Myricaria, Salix) along river courses. Even the diversity of woody plant species is fairly high, and more than 75 species of trees and shrubs have been reported from the region.

Other typical cold desert plants are *Leontopodium brachyactis*, *Saussurea bracteata*, *Draba lasiophylla*, *Corydalis govaniana*, *Nepeta longibracteata* and *Saxifraga flagellaris*.

Human settlements are always located around glacial streams, which help them grow crops such wheat, barley and vegetables, and fruit trees such as apricots and apples. Trees such as poplars and willows also grow around these settlements, which provide them with timber and firewood for cooking.

9.2.3 Socio-economic features

The socio-economic conditions of the population in the cold desert regions are not good. About 63,8 % of the population comprise marginal households with an average land holding of 0,25 ha to 0,75 ha of land. The net cultivable area is nearly 0,16 %. Only 20 % of the cultivated land is irrigated and rest is fallow land. Thus, farmers are compelled to do subsistence farming. The per capita income of target group is on average 47 % lower than the national average. Agriculture and animal husbandry are the main source of income. Cultivation is only possible in the summer months.

Soil and climatic condition allow only irrigation-aided agriculture. The majority of land holdings of small farmers is fallow in the absence of irrigation and lack of resources to develop this land. As a result, they have to engage in pastoralism to supplement agricultural income. This further aggravates the condition of the land due to overgrazing. Almost 70 % of pastures are facing degradation. There is hardly any Income from small agriculture land as most of the produce use for the personal use. For cash income people work as seasonal labourers for construction/maintenance of roads. Due to poverty and scattered nature of habitat, the small farmer and marginal farmers remain marginalised, as well as illiterate, and suffer malnutrition. By mid-June there is excess of water and even floods due to fast melting of snow and gracious in the mountains. All farming operations end by the mid- September.

There is little vegetation cover in cold deserts, which is getting depleted due to overgrazing and harvesting. This results in desertification and the creation of more wasteland and increased soil erosion.

9.2.4 Interested parties

The key interested parties are the village communities and women-led water and sanitation committees in the villages of Ladakh, Lahaul and Spiti in the northwest Himalayas in India. Other interested parties comprise non-governmental organisations, specifically the non-profit organization Pragya office in Gurgaon, India, and their Water Access and Wasteland Development (WAWD) pilot project in the Western Indian Himalayas, and the Whitley Fund for Nature[30].

Important innovation leaders are Mr Sonam Wangchuk, the Ice Stupa inventor, and founding director of the Student Educational and Cultural Movement of Ladakh, India, which implements the Ice Stupa projects[36]; and Mr Chewang Norphel (Ice Man), the artificial glacier engineer and designer, Ladakh, India[33].

9.3 Land degradation problems faced

Glacial flood streams are the main source of water. Water channels get filled with clay in summer and are damaged by avalanches in winter. However, due to climate change, the situation is becoming precarious. Streams and springs are drying up and evaporation losses are high. As a result of arid and water-less summers, water resources are depleting, crop yields are decreasing and arid conditions are becoming accentuated. Due to the low water retention capacity of soil, percolation ponds are not successful.

In order to improve the socio-economic conditions in these very harsh and fragile ecosystems, there can be activities for improving the supply of water for irrigation as well as for human consumption. Women have to travel 2 km to 3 km to collect water for their daily household requirements.

9.4 Objectives

The main objective of the projects was to improve water supply for irrigation and household use, especially during the summer months. There is no rain and temperatures are as high as 36 °C. There is a critical use for water for the newly planted agriculture crops as well as fir trees, especially in the areas which do not have perennial glacier melt water streams.

9.5 Interventions

Several multi-pronged strategies[29][30][33][36][37] have been used to improve the water supply in these areas for irrigation in the dry summer months, both for agriculture and household uses. These include:

— planting native trees, shrubs and herbs above the outlets of springs and the construction of trenches, snow pits, bunds on higher up slopes and construction of infiltration trenches at still higher slopes, in order to increase the accumulation of snow and reduce the run-off of snow melts, and also to help in recharging of aquifers, which are the main sources of water supply to the springs;

— construction of snow reservoirs for the accumulation of snow during the winter season for the production of water during the summer season;

- creation of an artificial snow glacier or snow pagoda during winter for a supply of water during the summer months;
- installation of snow fences for the accumulation of snow during high velocity wind in the winter season;
- use of solar energy for pumping water from the aquifers for irrigation.

9.6 Results

9.6.1 Augmentation of water supply to water spring

The village of Sakling is situated at a height of 3 755 m in the district of Lahul and Spiti. The only source of drinking water is the spring which is situated nearly 2 km above the village. Due to progressive desertification of the area, the spring flow was reducing. In order to increase the flow of water, an augmentation of water supply to the water spring in the village of Sakling was carried out, whereby nearly 20 snow pits of size 1,2 m × 0,9 m × 0,9 m were dug just above this spring. Vegetation and shrubs were also planted above the water spring to arrest the runoff. As a result, water availability increased during the summer season due to the melting of snow in the pits and recharging of the aquifer which feeds the spring.

9.6.2 Creation of snow reservoir

Daman village in the district Lahul and Spiti is located at a height of 4 269 m atop a ridge. In winter, temperatures go down to −23 °C. The topography is undulating and vegetation cover is sparse. A total of 65 houses in the village are engaged in subsistence agriculture and pastoralism. Snowmelt is the only source of irrigation for the fields through mud channels. About 40 % of the village land was wasteland due to the non-availability of irrigation water. In order to increase the irrigation water supply, a snow reservoir was constructed by the village community to harvest abundant snowfall in the winter and harness the melted snow water in summer for irrigation and drinking purposes. A reservoir was constructed 2 km from the village at an elevation of 4 389 m. The bed of the snow reservoir was constructed with a gentle slope towards the village. A wall was constructed on the sloping end of the reservoir. The wall was 59 m long, 2,5 m wide and 2,5 m high. This reservoir can irrigate 1 km^2 of agriculture land area to benefit the population of the village. Water scarcity was reduced to the extent of 70 %. In addition, it helped the recharging of the aquifer.

9.6.3 Creation of artificial snow glacier or ice stupa

In order to meet the requirements of water in the crucial months of April and May, an artificial snow glaciers/pagoda was created in a Ladakh village in the winter season[36]. This was done by directing the water from a perennial upstream water stream with the help of pipes to a place where the artificial glacier was to be created, using a natural gradient in the winter season. A sprinkler was used to spray water on a scaffolding to create a conical shape glacier, as a result of the low surrounding temperature (−20 °C to −30 °C). Due to the conical shape of the glacier, the melt rate of snow was approximately five times slower than that of naturally formed ground ice. The reason for this was the smaller surface area of the pagoda facing the sun. An artificial ice stupa/artificial glacier, 6 m high, was created by freezing 150 000 l of water. It was found that this ice stupa did not melt till 18 May that year, even when the temperature of the surroundings was above 20 °C. In view of the success of the project, the target for the year 2020 was fixed for constructing 25 such ice stupas.

An economic evaluation of the action was carried out. Poplar and willow trees in Ladakh use 10 l of water per day in the summer months. These trees reach a maximum height in 5 to 6 years. A full-grown tree can be sold at a price of USD 120. One ice stupa can sustain up to 200 000 trees through the dry months of April to June. Even with 50 % mortality, this will be 100 000 trees. Income from these tress will be USD 12 million. This amount will be equal to 100 times the return on investment in five years. The cost of water through ice stupa will be 1/20 of the cost of water from the cheapest reservoir built by the government. This technique has been appreciated all over the world[37].

9.6.4 Snow fences

In Kardang village in Lahaul Valley, extremely high velocity winds do not allow the snow to accumulate on ground, even in a large depression above the village. A fence 2,6 m high was installed along the side of the depression above the village to a length of 30,5 m with the gabion wall at the bottom. As a result, blowing snow was accumulated, and settled snow became compacted with the mass. This resulted in the prolonging of the melting period and provided water for irrigation as well as charging of the aquifer during summer months.

9.6.5 Use of solar energy for pumping water from aquifers

Solar pumps were installed in Chuchut and Umla villages in Ladakh for pumping subsurface water for the irrigation of a vast tract of barren land. A solar panel array of 1,2 kW was used to run a multi-stage pump with a dynamic head of 51,8 m. It had a capacity to pump 7 000 l of water from subsoil for irrigating 1,06 ha land in the village of Chuhut. It also supplied drinking water to 72 households, even during the winter season.

Similarly, a 900 W solar pump was successfully installed at Umra village to pump 3 000 l of water per day for providing water for irrigation and drinking water supply.

Installation of these solar pumps to pump water from the aquifers managed to increase the productivity of the land, and increased the agricultural output and income of households in these villages. They also provided drinking water to the households. As a result, the daily drudgery of the women in the villages was significantly reduced. Otherwise, they would have to travel many kilometres daily to fetch water for household use.

9.7 Lessons learnt and benefits

Several benefits resulted from the different interventions as described above. These techniques and lessons learnt can be replicated in similar agro-climatic regions in different parts of the world. Some observations are as follows:

— Water is the lifeline of populations living in cold deserts for survival, food and livelihood. These areas have one of the harshest climatic conditions in the world. Climatic conditions oscillate between extremely a severe winter and a very dry and harsh summer.

— Due to extreme arid conditions, the major part of the land is fallow.

— Fallow land can be made productive and productivity can be increased by using innovative technologies for the generation of water from natural snow in the critical dry summer months for irrigation and drinking purposes. This can be done by storing snow in winter and using the melt water in summer. Artificial glaciers/ice pagodas and snow reservoir technologies have been successfully tried in cold deserts.

— The water output of natural springs can be increased/made sustainable by using technologies such as snow pits and snow trenches.

— Solar pumps can be used where water is available in deep aquifers.

9.8 Conclusion

The conclusions are as follows:

— The rejuvenation of fallow lands and an increase in agriculture and horticultural productivity are vital for populations living in cold deserts, which have one of the harshest climates. This can be accomplished by technologies such as artificial glaciers, snow reservoirs and snow fences.

— Increased production of grain and horticulture produce will increase the income of the households. This will result in improved socio-economic conditions of the most deprived section of the society living in these inhospitable regions. It will also stop the seasonal migration for road-making and repair work.

— A continuous water supply throughout the year for household use is extremely important for survival as well as for reducing the drudgery of women, who otherwise have to travel long distances to fetch water for daily use. This can be accomplished by the use of snow pits and trenches to rejuvenate water springs and the use of solar pumps.

— Commercial activities such as timber growth and horticulture can be successfully undertaken by using artificial glacier technology.

Global warming is adversely affecting the ecosystem of cold deserts, and, as a result, the already fragile ecosystem is fast deteriorating and creating more hardship for the people as well as livestock. There is an urgent desire for adaptation interventions.

10 Case study E — Food security and value chain analysis for critical coexistence landscapes: The case of Pandamatenga Farms, Botswana

10.1 General

Land degradation is a global problem for the twenty-first century because of its adverse impact on agronomic productivity, the environment, on food security (and food waste) and the quality of life. It is largely related to agricultural use, deforestation and climate change. The strategy for slashing poverty and hunger on the African continent accelerated the rapid growth in the agricultural sector. This occurred in an unprecedented demographic context, as a direct consequence of this exponential population growth due to more mouths to feed. As an intervention measure in Botswana, the Pandamatenga commercial farm cluster was established as a commitment of the private and public sector actors in 1984.

The case study area in Pandamatenga is located in the northeast of Botswana and covers over 20 000 km^2 of land allocated to 54 commercial farmers. The Pandamatenga region occupies 280 380 ha, while the farms cover 45 074 ha of the total area in the plains. The farms here produce sorghum, maize, sunflower, cotton, cowpeas/beans, millet and wheat crop which contribute to the food security of the country.

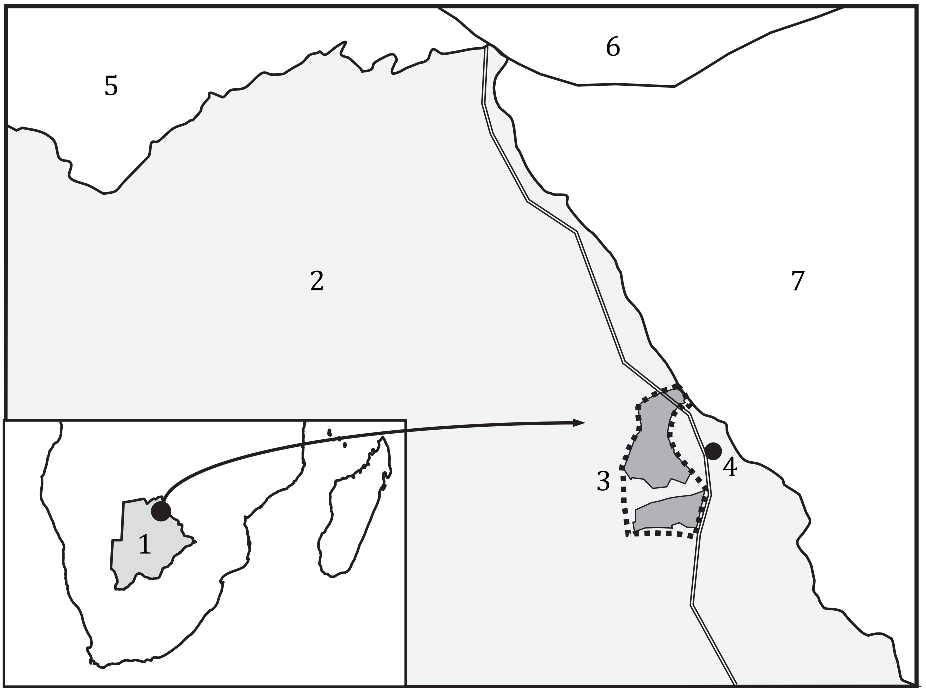
The Pandamatenga Farms in Botswana promote the use of agro-chemicals, technology and infrastructure to maximize yields to answer challenges of increasing population and greater food demand. The declining soil fertility is a key land degradation challenge. The use of agro-chemicals can increase the land productivity in the short and medium term, but it is not an appropriate long-term treatment. In a 2008 appraisal report[38], potential negative impacts included potential pollution of soil and water from the use of agrochemicals, occupational health and safety issues for farm workers, non-targeted impacts of pesticides on wildlife, potential transboundary impacts from return drainage waters, health impacts from the influx of seasonal workers, increased pressure on the community infrastructures. These are posing serious challenges on future food security. The objective of the interventions was to decrease vulnerabilities to food security and climate change to strengthen rural livelihoods as well as establish co-existence with wildlife. This is consistent with aspirations of land degradation neutrality (LDN) to improve ecosystem services and human well-being.

A value chain approach was used to enhance livelihood benefits for the rural poor and create integrated market opportunities. In an agricultural value chain, the range of activities and the actors involved from production to final consumption of the agricultural product is identified, and the relationships described through the flow of products and information along the supply chain by capturing the value added in each stage. The approach involves the stakeholders linked to markets to potentially overcome market failures and government deficiencies that affect competitiveness and quality standards. The analysis helps to identify change agents and leverage points for interventions.

10.2 Context

10.2.1 Location

Pandamatenga Farms lie within the Kavango–Zambezi Transfrontier Conservation Area (KAZA TFCA), which offers more than 519 000 km^2 wildlife and natural resources. The resources are a diversity of ecosystems and landscapes. KAZA TFCA is situated in a region of southern Africa where the international borders of five countries converge. The farms are located in the northeastern part of Botswana in the Chobe district (see Figure 18).



Key

1 Botswana
2 Chobe district, Bostwana
3 Pandamatenga Farm area with electric fence surrounding farm plots
4 Pandamatenga village
5 Angola
6 Zambia
7 Zimbabwe

NOTE Base maps: http://equal-earth.com; African Development Bank[38]; B.B. Mathangwane, Ministry of Agriculture, Botswana.

Figure 18 — Location of Pandamatenga Farms, Botswana

10.2.2 Physical features

The regional weather is associated with periodic droughts, extreme events such as flood, frost and high susceptibility to fire. The area has a relatively higher average rainfall (of at least 27 % chance) during the growing season, which significantly increases productivity. The summers are hot and moist with mild dry winters. Rainfall is variable with an average of 600 mm.

The Pandamatenga region is formed by flat plains, with gentle slopes.

The soil is dominated by vertisols (clay soil) which is a potentially good farming soil. Its physical and chemical properties make the soil very difficult to work with during dry seasons when it can become hard, cracking clays. In the wet seasons, the clays become sticky and swell, providing poor drainage, and on a gentle slope become prone to flooding. The poor soil drainage and high water retention on a gentle/flat slope make the area prone to flooding.

All the above characteristics give the area potential for rain-fed arable farming or dry-land farming of cereals (such as Sorghum) product, which is a crop of marginal and vulnerable areas that are highly susceptible to the changing climate. Generally, in contrast, its weather is associated with frequent droughts and other extreme events, such as flood, frost and natural disasters, such as fire.

The Pandamatenga Farms also lie within the KAZA TFCA, which comprises more than 519 000 km^2 of wildlife and natural resources. The resources are a diversity of ecosystems and landscapes. KAZA TFCA is situated in a region of southern Africa where the international borders of five countries converge.

10.2.3 Socio-economic features

The population of Botswana has been estimated to have increased almost twenty-fold between 1901 (120 000 persons) to 2016 (2 250 260 persons), i.e. in just over a century. The rapid population increase has rendered the traditional systems of agriculture inadequate to cope with the high demand for crop land.

Pandamatenga village has a population of about 1 750 residents, made up of a multi-ethnic group, mainly BaSubiya, and also BaTawana, BaMbukushu and BaYeyi, BaKalanga, Ndebele, and white Afrikaans. The lands around Pandamatenga are under an existing legislation governing the administration and management of tribal lands in which both commercial and communal farming takes place. This farming is practised by families, companies and individual farmers, in both large and smallholdings. The economic activities in the area are dominated by crop production, livestock production and wage employment; big and small holding farms; and adequate access to farm inputs.

The area has experienced the intensification of food production and would benefit from better and more sustainable farming methods. A government initiative to commercialize farming was the conversion of cattle posts and wildlife management areas into Pandamatenga agro-based cluster farms. Its establishment emphasized the agricultural value chain finance (AVCF) approach, which is a financial approach/instrument for agricultural and agribusiness financing.

This approach promoted flows of funds to and within a value chain to meet the desires of chain actors for finance and sales, and to improve efficiency. These linkages allow for financing to flow through the value chain, enhancing financial access with reduced agricultural costs and financial risks through insurance, grants, subsidies and loans. The development of value chains, in turn, led to outcomes such as poverty alleviation, meeting national cereals demands and reduced the food importation bill. Additionally, this created jobs in the tourism and agriculture related sectors.

Both commercial and communal farming takes place in the lands around Pandamatenga under existing legislation governing the administration and management of tribal land. These farms are leased through tendering process by the Ministry of Agricultural Development and Food Security on behalf of the Chobe Land Board, which then directly allocate land to individuals. The lease payments status for the commercial farms is done to the Ministry of Lands. Other key stakeholders, in addition to the government, are the private sector, communication, NGOs/CBOs, banking/financial sector, and energy and water sectors. The area has diversified economic activities, mainly in three domains: crop production, livestock production and wage employment.

The main market for the sorghum and maize produced is the Botswana Agricultural Marketing Board (BAMB)[43]. The BAMB functions as a market for locally grown scheduled crops and to ensure that adequate supplies exist for sale to customers. It also provides agriculture inputs such as fertilisers, including bio-fertilisers, seeds and stock feed.

10.2.4 Interested parties

Stakeholders can be divided into internal and external interested parties. Internal stakeholders can be employees, contractors, clients, customers, suppliers, unions and worker representatives. External stakeholders can be regulators, shareholders, neighbours, communities, local authorities and government agencies. The stakeholders can be placed within a value chain model to enhance/optimize sustainable production and benefits to all. Aside from the farmers themselves, the stakeholders are:

local authorities, government ministries, communities, suppliers, employees, contractors, clients, customers and financiers.

The different roles that stakeholders play, as influencer, provider, governance authority and user, at the various stages of the agricultural and food production value chain were categorised (see Figure 19). Examples of key stakeholders are the private sector, such as agro-chemical suppliers, parastatals such as the BAMB, financial sector, and the energy and water sectors (see Table 1).

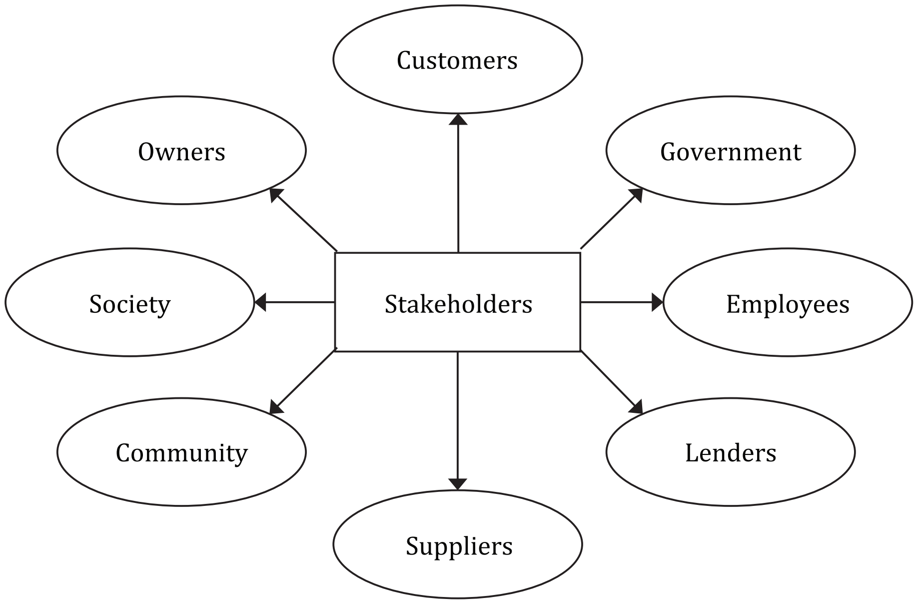


Figure 19 — Types of stakeholders in the AVCF instrument

Table 1 — Examples of internal and external stakeholders in the AVCF instrument

Internal stakeholders	External stakeholders
— clients and customers — employees and contractors — unions and worker representatives — legislative and regulatory bodies — owners (partners/investors) — customers/end user — suppliers	— suppliers — creditors — local authorities and government stakeholders — certification bodies — public groups — neighbours and communities — agricultural input companies (such as seed and fertilizer companies) — agricultural retailers — farmers and ranchers — agricultural credit institutions — crop consultants and advisors — aggregators — processors — distributors — transportation and refrigeration companies — ingredient manufacturers

10.3 Land degradation problems faced

10.3.1 Types of land degradation observed

Land degradation and desertification are fundamental and persistent problems that have long been recognized in the Pandamatenga Farms. The land degradation issues have varied processes, as follows:

— The poorly drained soil and flat terrain often result in water-logging and severe floods during heavy rains. The dominance of vertisols results in problems with soil alkalinity, salinization and plant injury.

— Soil fertility mismanagement during production and pesticides/herbicides use. The degradation of soil fertility affects the soil health; an appropriate chemical application is key.

— Decline in land productivity due to poor land management, which reduces its capacity to carry out basic services such as food production, its economic value, and biological and cultural diversity. These pose a threat to productivity growth and food security which is fundamentally influenced by economic, environmental and institutional factors. Hence the implementation of climate smart agriculture (CSA) practices.

— Biodiversity loss due to the demand for more space to cultivate to deal with the increased demand for food, which is always accompanied by an increase in soil pollution, leading to stunted growth and poor development, and later plants wither and die, and automatically incomes reduce. Hence, the introduction of agriculture insurance and relief/emergency costs programmes and adaptation of conservation agriculture.

— There are frequent hazards of droughts and wildfires, requiring disaster risk reduction measures.

Other agriculture-related problems are as follows:

— Poor crop productivity due to low levels of warning systems about climatic hazards (flood, uncontrolled fire, droughts) to provide added value information to decision-makers giving technical advice. Hence, useful actions can promote information sharing and improve access to skills and knowledge through capacity building and networking with outsiders within the region. These actions can be classified as disaster risk reduction measures.

— Agricultural yield losses and post-harvest losses, due to both biotic and abiotic factors, which reduce the quality and quantity of the harvest during harvesting, system of processing, storage, handling and marketing. In addition, crop damage by pests, such as animals, birds, insects and worms. This decreases profit from investment, which creates an importation deficit and has a bearing on the food security of the people in the affected area through losses on the storage grains caused by biotic (insects bacteria, rodents, fungi, mites) and abiotic (inappropriate moisture, temperature, lack of sunlight) factors.

— Poor market development due to unreliable climatic conditions, leading to low productivity, poor systems for disseminating improved varieties and lack of a functioning marketing system to link smallholders' producers with domestic and international markets. Hence, building the capacity of small-scale producers and other partners in the chain to support growth towards maturity in the value chain. Good governance developed markets (i.e. BAMB) and enough capital, making it easy for enterprise to fulfil their contract with farmers.

— Poor value chain development due to food loss and waste along the food chain stages. This has led to poor monitoring weakness in the chain that can increase financing risk at all levels. There were insufficient agricultural safety nets for rural people livelihoods (diversification). Hence, there can be a useful focus on targeting and monitoring of returns on investment.

— Lack of quality recognition of markets, in particular, related to phyto-sanitary norms and standards.

10.3.2 Drivers of land degradation

Important underlying drivers of land degradation in the farms include land tenure, poverty, population density, and weak policy and regulatory environment in the agricultural and environmental sectors.

The drivers of the land degradation are identified as:

— demographic changes and consumption patterns arising from health requirements, food access and price;

— poor management and planning due to lack of skills;

— poor communications network due to poor infrastructure (impassable roads, no electricity and telecoms connections);

— poor access to capital, financial assistance, research/information and markets;

— old policies that lead to mismatches in meeting current requirements and limiting transformative initiatives.

In addition, there were limited public–private partnerships for enhancing any value chain benefits.

10.3.3 Risk of future land degradation — Resilience

10.3.3.1 Land degradation

The results of these issues on the land and the environmental degradation include loss of soil fertility, soil erosion, changes in the soil structure, plant cover being lost and water loss that leads to an area becoming less supportive, such as:

— reduction in productivity, and therefore a decline in the productive resource base of the economy;

— environmental effects such as ground water and surface water contamination, air pollution and global warming are of growing concern owing to increasing consumption levels;

— land degradation also has serious knock-on effects for humans, such as malnutrition, disease, forced migration, cultural damage, resources conflicts and even war;

— rapid population growth leads to environmental changes, and creates unemployment for men and women.

10.3.3.2 Challenges/constraints

The key challenges were related to environmental issues (see Table 2):

— flooded fields due to flat terrain and poor drainage, which suffocates crops and hence reduce yields;

— dusty roads, which hamper transport logistics and are difficult to use during the wet season;

— crop damage by birds: Pandamatenga is situated adjacent to a forest reserve which is a breeding area for wild birds, mainly quelea birds, which can reduce crop yields;

— human/wildlife conflicts: damage to crops and infrastructure by pests and wildlife roaming onto the farm (mitigated by structures such as electric fences).

Table 2 — Factors affecting ecosystem functions/structure

Natural factors		Anthropologic factors	
Weather/climate	— Drought — Extreme events, e.g. floods, frost	Land use change	— Deforestation — Conversion of grassland to cropping
Topography	— Slope/terrain — Ground cover — Forest cover	Unsustainable forest practices	— Thinning — Harvest regimes — Inappropriate afforestation — Illegal logging
Soil properties	— Physical — Chemical — Biological	Unsustainable agricultural practices	— Overgrazing — Over cultivation — Excessive fertilizing — Irrigation use — Over-intensification, fire
Natural disaster	— Fire	Mining	— Contaminated water and land
		Demographic pressure	— Population increase — Increased urbanization — Waste pollution — Infrastructure development

10.4 Objectives

The project objectives were to:

— improve food security through improved land management;

— enhance supporting rural livelihoods to enhance livelihood benefits for the rural poor;

— create viable market opportunities for agricultural produce through the AVCF approach;

— elicit stakeholder participation and collaboration for effective farming clusters;

— establish co-existence with wildlife in the surrounding forest and nature reserves.

The specific objectives are to maintain/improve productivity, decrease vulnerability to climate variability, and maintain or improve ecosystem services. Thus, the project objectives are consistent with LDN targets on food security, human well-being and healthy ecosystems through increasing gains from the land.

The project success was measured through reduced crop damage through erection of electric perimeter fence and bird scaring technologies. Improved accessibility within the farming area and to the market through improved infrastructure.

10.5 Interventions

10.5.1 Approaches

The interventions covered both soft and hard measures with stakeholder consultations, capacity development and infrastructural improvements.

A multi-stakeholder cluster approach was adopted through the value chain approach for enhanced sustainable agriculture benefits. Stakeholder participation and collaboration is important in this approach for formulating effective clusters.

The efforts for improving food security when in co-existence with wildlife systems can address sustainability and key risks such as:

— weather/climate, e.g. droughts and floods;

— high reliance on risky rain fed agriculture;

— an economy heavily dependent on exhaustible diamonds.

Thus, SLM approaches such as diversification of livelihood support systems, more targeted agricultural research and innovation, investments in agriculture support services, value chains and market infrastructure, are useful in support of the United Nations Sustainable Development Framework (UNSDF).

In an endeavour to promote and support commercial agriculture in Botswana, the government took deliberate moves to re-direct extension services from being scattered and disorganized subsistence farmers towards organized commercial farmers.

10.5.2 Challenges and constraints

There were many challenges and constraints identified, especially through the AVCF, mainly due to the existing practices and conditions:

— logistics and marketing costs are high due to scattered production;

— heavy subsidy to competing crops and lack of farm inputs;

— marketing is hampered by the poor transport and road network system and infrastructure, inadequate communication, lack of storage facilities, lack of adequate market support services and questionable practices among some public marketing boards' officials;

— lack of a grading and standardization system within the industry;

— lack of storability of grain during barber harvest;

— poor image of sorghum and millets among consumers;

— unavailability of a suitable processing technology;

— pest and diseases, e.g. grain mould, and poor quality of harvest;

— nutritional myths, e.g. high content of tannins, poor digestibility;

— too many intermediaries and lack of transparency and traceability, or multiple intermediaries and lack of transparency and traceability, in smallholding farmers;

— high amount of food wastage and losses in the food chain;

— civil society weakness, resulting in lack of development of inclusive value chain;

— lack of poverty reduction and growth opportunities in rural areas;

— low productivity and quality of the produce, where product quality is a problem due to poor product handling;

— lack of consistent, uniform quality of grain supplies;

— limited capacity and resources;

NOTE The very poor lack assets and resources relative to others in their communities. Smallholders are often less able to access services to help them increase those resources, such as credit.

— current farm management and post-harvest practices as well as lack of farm inputs;

— delays resulting from excesses of land border agents (phytosanitary and certification);

— high transportation costs and scarcity of resources.

10.5.3 Agricultural value chain finance analysis

An agricultural value chain analysis was conducted which identified the agencies and actors involved in the production and final delivery of the agricultural products from Pandematenga farms. Three main stages were categorised in the agriculture-food chain link:

a) raw material production, involving farmers, farms and suppliers' inputs;

b) processing stages, involving food processing and packaging;

c) post-processing, logistics/transport, retailers and consumers, involving farmers, farms and suppliers' inputs.

The different agencies and stakeholders contributing to these roles were identified (see Table 3). It is important to ensure full participation of key stakeholders throughout the value chain. The involvement of the multiple stakeholders' platforms in the value chain coordination enhanced the investment in goods and complementary investments, engagement in resource-providing contracts, allowed for acquirement of shared competencies, and the achievement high quality standards.

Table 3 — Example of the multiple stakeholders at different stages

Stage a) **Raw material production**	**Stage b)** **Processing stage**	**Stage c)** **Post-processing, logistics/transport, retailers and consumers**
— seed providers — fertilizer, pesticide and agro-chemical manufacturers; — machinery and equipment manufacturers; — packaging suppliers — transport companies — farmers' marketers and sellers	— food processors — suppliers of food additives — grain millers — bakeries — pasta manufacturers	— bakeries — supermarkets — grocery shops

After analysis of the actors and systems in the value chain, the key interventions that can enhance the effectiveness and efficiency of the value chain among the Pandamatenga agro-based farmers were identified as follows:

— Access to inputs: Farmers' access to quality inputs from government subsides under the Integrated Support Programme for Arable Agriculture Development (ISPAAD), improved technologies and high yielding crop varieties have been found to increase productivity and net income. The government ISPAAD programme support farmers with inputs.

— Access to credit and finance: Value chain finance is viewed as one of the most sustainable and effective means for financial institutions to improve outreach to smallholders and other chain actors. Financing enabled farmers to adopt improved technologies, raise productivity, and improve the quality and efficiency of agricultural value chains. The National Development Bank (NDB), Citizen

Entrepreneurial Development Agency (CEDA) and other commercial banks tailored their financial products (loans and credits) to suit the requirements of different stakeholders in the cluster.

— Access to insurance: The government establishment of agricultural grant scheme would help farmers to mitigate their business from disaster impacts such as droughts, fire and others.

— Access to markets: Regulated markets play a supportive role in the development of value chains through farm-to-market linkage through contract farming (with the Seed Multiplication Unit) and domestic support measures which the government put in place (for the BAMB to buy 80 % of the produce from the Pandamatenga agro-based farms). Through the improved link to experienced extension services and market information, farmers can take advantage of market opportunities.

— Streamlining of local and national agri-supply value-chains: Improvement of the Pandamatenga value chain is not effective unless other linked local and national value chains are also improved. This is only possible through action at a national level, through agencies such as the BAMB.

10.5.4 Infrastructure and technologies

The interventions and technologies used included the installation of electric fences around farms, scaring birds that invade crops, drainage systems to de-water fields and improved infrastructure. The major infrastructure works included the following:

— Drainage improvements: The land is relatively flat, which makes the area susceptible to water logging when there is heavy rainfall due to inadequate soil drainage, and has particular soil conditions such as duplex soil, which significantly reduced crop yield. Drainage systems were improved to de-water fields and to divert on-field waters through field bunds into the drainage channels/culverts. Drainage and infrastructure development were funded by the Government of Botswana/African Development Bank.

— Land management practices: The farms are situated in the plains with few trees and ground cover of grasses. When the virgin land was converted to agricultural uses, the cover was removed. As rain-fed agriculture is practised, the crop provides the primary ground cover. Farmers were taught and encouraged to practise conservation agriculture, including mulching using crop remains in order to improve soil health and reduce soil erosion. Unsustainable land management such as overuse of fertilisers and pesticides can result in pollution and deplete soil nutrients, which affect crop growth and development, resulting in low production. Adoption of CSA practices was encouraged through extension education, provision of information and contacts. All the farmers practise rain-fed, arable farming and grow common crops such as maize, sorghum and beans. Scale-appropriate farm mechanization can help reduce land mismanagement aside from reducing drudgery. Minimum tillage is practised by many farmers.

— Pest and diseases: The farms are surrounded by wilderness areas that provide habitats for common pests (such as quelea birds) and possible sources of diseases. The government assists in the control of diseases and pests (including quelea birds) of economic importance on behalf of the farmers. Crop or plant damage commonly leads to loss of crop productivity, and affects carbon sequestration in the area. The farmers have adopted an integrated pest management (IPM) approach for all diseases and pests, including pests of economic importance in the area, which are controlled by the government. This approach reduces the negative impact to biodiversity. At a micro-scale, this involves players such as agro-chemical manufacturers and suppliers, to minimize the crop damage from production to marketing. An example of IPM is using drones or falcons to scare off birds that invade crops. To keep out wild animals and protect the farms, electric fences have been installed around farms, negating any elephant damage to crops.

— Communications and logistics networks: The tracks between fields were gravelled to allow access to crops during the rainy season and to facilitate the maintenance of the electric fence. The Pandamatenga area is linked to Kasane, 100 km to the north, and Francistown, about 400 km to the southeast by tarred road. An airstrip is available with three aeroplanes operating from it for crop spraying. The construction of the infrastructure in the area interfered with the movement of the water downslope. This led to flooding of the fields. The road infrastructure, however, improved communications in the area and access to the market. The government has sponsored the building of grain silos for storage of the farmers' produce.

10.5.5 Market-based interventions

In addition to the infrastructural projects and capacity development in use of newer technologies, market and financial interventions were also generated as follows:

— Market access: The Pandamatenga Farms currently contribute to around 50 % of the country's cereal production. The farm cluster adopted mechanization to improve efficiency, but this is tied to the farmers and the market readiness. The domestic support measure which the government put in place was to establish the BAMB to buy 80 % of the produce of the farm cluster. Produce from these farms is also sold to Foods Botswana (Pty) Ltd, a major retailer in food manufacturing and distribution. The BAMB increased storage capacity by an extra three silos to accommodate enough grain storage, in order to cover the volume even during good production seasons. Through the improved link to experienced extension services and market information, farmers will be able to take advantage of market opportunities. Access to markets reduced the cost of land degradation and led to wider adoption of SLM practices. Surplus mung beans were exported to Canada, China and India.

— Government subsidies: These included subsidies/social transfers to facilitate consumption in lean seasons, third-party quality assurance, strengthening the capacity of processors to minimize food safety concerns for cereal for the local market, wholesaling to reduce marketing cost, agri-food value chains which are expected to provide nutritious food to poor consumers through information campaigns, support to chain actors to reduce risk and incentive production, processors and promotion, and investments in local marketing and transportation infrastructure.

— Access to credit: It is well established that access to credit plays an essential role in development. Increasing the availability of credit allows investment capital to be used by individuals and businesses, which leads to growth in economic activity in Botswana. Financial institutions, such as the NDB, Barclays Bank, Standard Chartered Bank and CEDA, provided support to the Pandamatenga farmers.

10.5.6 Climate smart agriculture

A CSA value chain analysis was also developed, which considered the weather, water and energy resources, and the application of nitrogen and carbon. The farming community adopted the approach to cope with impacts of climate change. The interventions were to minimize the possible negative impacts of value chain operations on non-participants and/or adjacent communities by creating new value chains. The interventions identified focused on multiple local food chains to address nutrient gaps using smart practices (see Table 4).

Table 4 — Interventions for climate smart agriculture value chain

Aspect	Interventions
Weather smart	— weather-based crop advice to farmers — crop-specific insurance to compensate farmers' income loss — early warning system connected with mobile phones
Water smart	— rainwater harvesting improve/control run off — drainage management through water control structure — cover-crop methods to reduce evaporation — improved soil and water management

Table 4 *(continued)*

Aspect	Interventions
Energy smart	— adopting improved cropland management practices, e.g. zero tillage/minimum tillage to improve energy use efficiency — reduces amount of energy — improvement in water/nutrient movement and organic matter retention into soil — improve post-harvest practice — improve energy use in agricultural production
Carbon smart	— intervention to reduce greenhouse gas emissions — promotion of carbon sequestration — sustainable land use and management (LDN) — reduce deforestation and forest degradation
Nitrogen smart	— intercropping with legumes to improve nitrogen supply and soil quality — green manuring to improve nutrient supply and soil quality — improved agronomic practices

10.5.7 Resources for addressing the problem

There were three main types of resources which were provided to the farmers:

— Funds/finance: These were for capital expenditure, operational and maintenance costs. Diverse funding sources and financial incentives were provided (e.g. government subsidies/sureties, local and international financial institutions).

— Technology: Adaption and adoption of appropriate technology was able to improve productivity and efficiency).

— Knowledge and human resources: Expertise and capacity development supported the community in planning/forecasting, developing business portfolios and other relevant knowledge for the workforce. CSA approaches were introduced.

10.5.8 Project monitoring and review

The monitoring and review practices are based on:

— weather forecasts;

— early warning system analysis and weather forecasts;

— moisture level;

— monitoring the water quality in the drainage system;

— soil health and fertility;

— crop yields, in terms of production and productivity;

— grain quality analysis (based on moisture content, grain temperature, initial condition of the grain, insects, pests and moulds);

— pest surveillance, and analysis of pest and weed thefts;

— interventions forging;

— vulnerability assessments at the market level.

10.6 Results

The focus on the holistic systems that integrate the entire value chain allowed for identification of the key intervention measures, such as adoption of new technologies, new methods, good agricultural practices and traceability. The interventions were successful in improving the overall productivity and employment opportunities for the community. The Pandamatenga agro-based cluster farms transformed from traditional production to a modern value chain system, anchored on multi-stakeholder participation, with key outcomes and benefits, including:

- agricultural and rural transformation:
  - smart agricultural practices, upgrading of infrastructure and/or conservation agricultural practices by farmers, and reduced water-logging, human/wildlife conflicts and crop damage by wildlife and pests;
  - transition from traditional marketing chains to modern marketing chains;
  - focus on building efficiencies and controlling costs (e.g. switch from traditional to high-value agriculture, reduced food wastage during harvesting);
  - increased production and productivity due to market accessibility by farmers in the area, with cereal output meeting 50 % of the national demand;
  - value chains developed which resulted in outcomes such as poverty alleviation, meeting the national demand of cereals, elimination of abject poverty and a reduced importation bill, and which created jobs in the tourism and agricultural sectors and related activities;
  - increased income and employment opportunities with the development of multiple income opportunities in the local rural economy (farm and non-farm), including for drivers/owners, clerical workers and farm labourers who are mostly employed seasonally;
  - improved workability on the farm since the tracks between fields were gravelled to allow access to crops and facilitate farm maintenance;
  - improved crop production and efficiency through mechanization, resulting in minimum losses of crop as the processes can be carried out in a shorter time;
- improved risk management:
  - increased emphasis on quality and quality assurance along the chain with continued focus on cost control and efficiency;
  - increased focus on product and process development;
  - emphasis on market flexibility to meet and respond to changing consumer demands in terms of improved quality, quantity and food safety;
  - decreased vulnerability through building resilience;
  - improved ability to respond and customize products to the end user through optimization of the logistics and transportation/distribution system;
- changed attitudes and perspectives:
  - development of cooperative/collaborative attitudes and perspectives with more emphasis on information and information sharing;
  - capacity to trust and to be trustworthy;
  - increased emphasis on information and information sharing;

  - increased skills in negotiation and joint decision-making;

- sustainable CSA:
  - direct and indirect benefits from agro-tourism activities and learning of commercial sustainable agriculture methods;
  - increased productivity due to smart agricultural practices and/or through conservation agriculture practised by farmers in the area;
  - carbon sequestration through continuous cropping of the area, through the use of supplementary irrigation, which creates a carbon sink in the area;
  - building resilience against climate change and unreliable rainfall through supplemental irrigation (management of the addition of small amounts of water to rain-fed crops during times when rainfall fails to provide sufficient moisture for normal plant growth, in order to improve and stabilize yields);
  - protection against natural hazards, such as floods, drought and fire hazards, through government facilitation of infrastructure development and improved farming methods, to significantly improve the country's food supply/security.

10.7 Lessons learnt and benefits

The Pandamatenga Farm value chain and supply chain analysis was instrumental in identifying all the key stakeholders and actors, and the possible intervention points that can result in the best benefits. Agriculture has potential as a growth engine for Botswana's economy as well as in providing livelihoods and sustenance to many farmers and rural communities. In order to achieve this, the following considerations can be included:

- adoption of a digital transformation can be a useful catalyst, not only to empower farmers with better access to information, markets, credit, finance and insurance, but also to streamline local and national agri-supply chains;
- knowledge and information have a key role in increasing profits, reducing risk and building trust;
- pest surveillance;
- disadvantaged smallholder farmers can focus not only on high crop productivity, but also on enhanced farm profitability, to become a key part of the overall farming eco-system, and truly progress towards sustainable agriculture.

Incentives for value chain formation appeared to surface in a three-phase sequence:

- capturing efficiencies and controlling costs;
- reducing risk (quality, quantity and food safety);
- responding to consumer demands for attributes.

Some key sustainable farming best practices identified in the area include:

- formation of a strong farmers' association;
- involvement of all stakeholders at all stages;
- clustering of smallholders' farms for a specific produce;
- contract farming agreements for smallholders;
- development of a value chain of the different produce (cereals);
- identification of each of the production processes and improvements to be made;

- — focus on increasing production efficiency to maximize value for the least possible cost and conducting activities aimed at making higher profits;
- — adoption of technology in the value chain;
- — adoption of the primary activities of Michael Porter's value chain;
- — add value to produce products eventually sold to the consumer supply chain;
- — employee empowerment through the introduction of reward and recognition and an employee satisfaction system;
- — development of food safety practices and regulations for value-added food production;
- — development of markets for all products;
- — promotion of a customer-focused culture and a customer satisfaction system;
- — conservation agriculture, through minimal soil disturbance, crop rotation and the integrated production of crops;
- — healthy soil, through integrated soil nutrition management, which enhances crop growth, bolsters stress tolerance and promotes higher input-use efficiency;
- — improved crops and varieties adapted, with high-yield potential, resistance to biotic and abiotic stresses, and higher nutritional quality;
- — efficient water management that obtains “more crop per drop”, improves labour and energy-use efficiency, and helps reduce agricultural water pollution;
- — IPM based on good farming practices, more resistant varieties, natural enemies, green pest management (e.g. use of drones) and judicious use of relatively safer pesticides when necessary.

Some of the lessons learnt during the project were:

- — information on types of machinery suitable for the area which is dominated by clay soil (a larger volume of land can be ploughed within a shorter time);
- — increasing productivity through soil enrichment;
- — approaches for the reduction of labour costs and human efforts;
- — more efficient utilization of resources through the clustering of big farms, such as by sharing input costs, infrastructure and knowledge.

Thinking on a larger scale, and the creation of sustainable landscapes, is the key. The availability of a large area for ploughing resulted in:

- — better economic viability of the enterprises;
- — increased credit worthiness, such that banks compete for financial servicing;
- — better economics of scale, which increased the possibilities of diverse income avenues.

The other benefits accrued were:

- — commercial farmers influenced small-scale production in the landscape in a sustainable way;
- — promotion of tourism through the creation of a tourism destination, both locally and internationally;
- — promotion of research opportunities;
- — initiation of the Pandamatenga Commercial Farmers Association harvest day as an annual event;

— establishment of Pandamatenga as a centre for commercial arable agriculture which had the potential to feed the country and eliminate abject poverty in Botswana;

— earmarking of the area as a special economic zone (SEZ) for horticulture and agro-industry in recognition of the good, fertile soil and good climate.

Good communication was an important aspect of the transformation process and this was conducted through documentation, and information sharing with internal and external stakeholders (see Table 5).

Table 5 — Communication strategy examples

Category	Description
Types of documents	The relevant requirements of interested parties can be available as inputs into the management system planning process, as potential risks and opportunities. There can be no requirement to retain documented information, but the following types of documentation can help to evidence this: — minutes of meetings (from meetings from each group of interested party); — requirements spreadsheets and databases; — external communications and documentation; — quality manual; — flow down and capture of requirements relevant to the management system defined in contracts, orders, statements of work, terms of business, etc.; — records of meetings where interested parties and their requirements are routinely discussed and monitored; — stakeholder mapping to determine importance; — records of surveys, networking, face-to-face meetings, association membership, attending conferences, lobbying and participation in benchmarking.
Information sharing	There are a number of ways to share information among employees and work groups used in the Pandamatenga agro-based cluster farms, such as: — face-to-face meetings and information sharing, which is the safest and most efficient method of information sharing in a farm environment; — sources of information as radio, television, extension workers, cooperative societies, friends, colleagues, newspapers, magazines, books/leaflets, phones, libraries and institutes; — forums, telephones and conference calls; — email.
Internal communication	At the farm level, relevant information can be effectively communicated to all levels and functions of the management system, through communication media such as: — verbal (i.e. meetings, briefing, etc.); — formal memorandums; — posters or bulletin boards; — suggestion boxes.

Table 5 *(continued)*

Category	Description
External communication	Externally, farms can communicate as required by their compliance obligations. The process can ensure that all received communications are responded to appropriately by using, for example: — annual reports of performance sent to external stakeholders; — open house meetings for interested parties and focus groups; — availability of regulatory submissions, or results of audits; — policies published in the media and industry association publications and press releases; — focus groups.

10.8 Conclusion

In conclusion, significant structural changes occurred in agriculture, not only in size and ownership of holding farms but also in the linkages/coordination of farm production activities with input suppliers and product purchasers. The linkages occurred through personal negotiated/contractual/ownership arrangements rather than impersonal open markets. Establishment of a food business is sophisticated and complex, hence more knowledge and information is needed about detailed processes as well as how to combine those processes in a total system (i.e. a food chain approach) based on its comparative advantage. The Department of Agricultural Research was able to enhance its knowledge and information base for researchers based on the Pandamatenga research centre. The project was able to provide a platform for farmers to engage in an integrated market system which led to stakeholder participation in the national food system.

The approach of "no-one left behind" of financing the agriculture value chain meant small holders in the Pandamatenga agro-based farms had ready financial access. The agricultural value chains were linked to financial services providers for the betterment of the rural people. The strengthened value chains were able to promote better interlinkages between public and private players and resulted in benefits to the farmers and workers in rural areas. Ownership/contract-coordinated production/processing/distribution systems can source knowledge and information from a combination of internal and external sources.

The role of knowledge and information as the key to success in the agricultural industry is more important today than ever before, as there has been a dramatic growth in knowledge of the chemical, biological and physical processes involved in agricultural production. Independent producers obtained knowledge and information from external sources in much the same fashion as they have sourced physical and financial resources and inputs. As information becomes more valuable, the incentive for the private sector to provide that information and capture some of that value increases. The vast expansion in knowledge and understanding means that those who can sort through that knowledge and put it to work in a practical context have a further comparative advantage. For independent producers in the farm sector, knowledge and information is obtained from public sources as well as from external sources such as genetics companies, feed companies, building and equipment manufacturers, packers and processors, etc. Consequently, the growth of private sector data gathering and information service firms is not surprising, given the growing value of information through the web and social media.

Education, changes in agricultural policy and technological innovations are instruments that can be used for the restoration of degraded land and to stop further land degradation, in line with LDN targets. The management strategies which were adopted for Pandamatenga to reduce crop damage were effective. Consideration of the climatic variations have led farmers to adopt interventions for CSA practices to build resilience against the effects of climate change. This is consistent with LDN objectives at the project level.

The project demonstrated that there can be successful establishment of Pandamatenga commercial farms within the wildlife management area. The establishment of the Pandamatenga Farms led to improved national food security and supported rural livelihoods, with wildlife in critical coexistence landscapes. The value chain approach was successful in demonstrating a viable mechanism of reaping more sustainable benefits through clustering of farms, resulting in an increase in productivity, food security and revenue generation.

11 Case study F — Restoration after woody clearing to improve livelihoods in the D'Nyala Nature Reserve and Shongoane village, Limpopo Province, South Africa

11.1 General

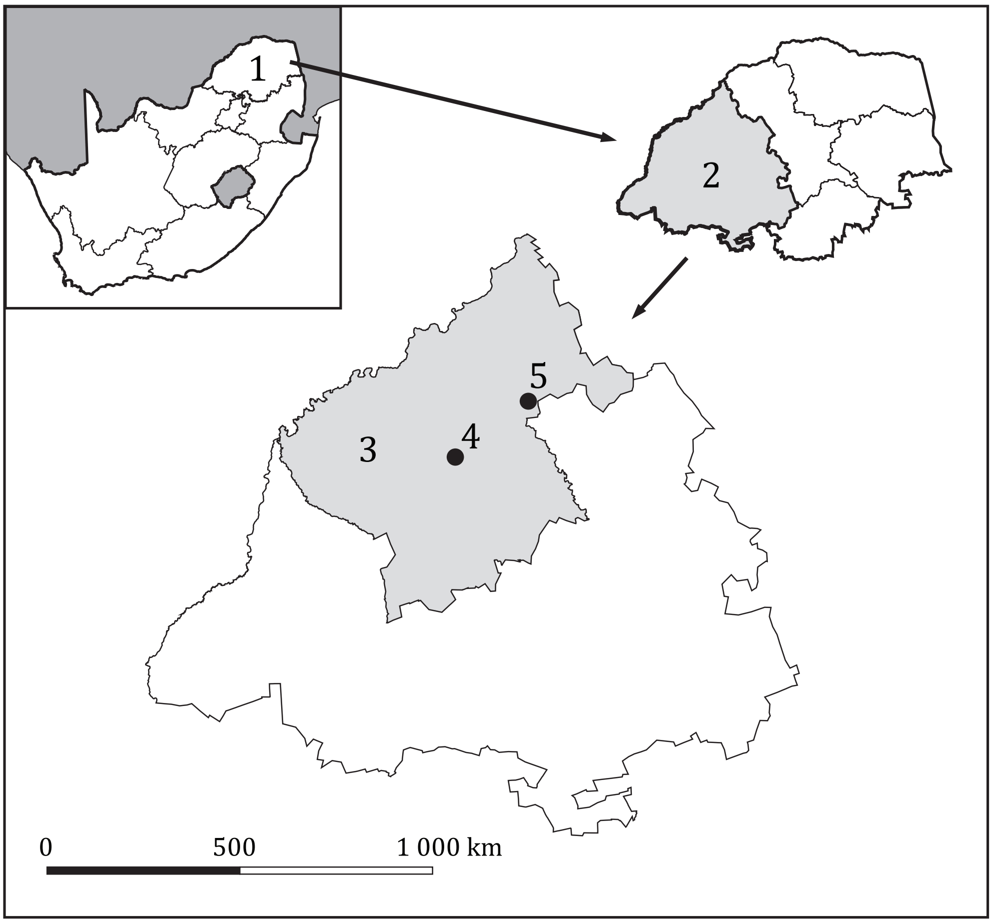
Bush encroachment, resulting in densification of woody species and the invasion of alien plant species, alters the balance of natural ecosystems. It is a type of land degradation that disrupts the tree/grass balance and causes a loss of ecosystem services that provide benefits to the well-being of the people. This study investigated the socio-economic benefits and increased fodder production stemming from bush clearing (combatting bush encroachment) and restoration by "brush packing" in a nature reserve and in a village near Lephalale city, in the Limpopo province of South Africa. Ultimately, the goal was to improve the well-being of people using the land through income generation (job creation ventures) and increase fodder production for livestock and wildlife grazing.

The semi-arid savanna western areas of Limpopo are mainly used as grazing and/or browsing for livestock and wildlife and, due to the vegetation types and structure, include many regions that are heavily bush encroached. This province relies heavily on eco-tourism and hunting as economic enterprise. Rural communities mainly depend on livestock but, due to poor land management practices, the rangelands are degraded and bush encroached (densification of woody species and loss of herbaceous cover).

11.2 Context

11.2.1 Location

The case study area is conducted in the Lephalale municipality, in the Limpopo Province, South Africa. Lephalale is located in the northeastern part of Limpopo Province in South Africa and situated between 23° 30′ S and 24° 00′ S latitude and 27° 30′ E and 28° 00′ E longitude (see Figure 20). The interventions for two sites are presented: one in the village of Shongoane and the other in the D'Nyala Nature Reserve.



Key

1 Limpopo Province in South Africa

2 Waterberg District in Limpopo Province

3 Laphalale Municipality, Waterberg District, Limpopo Province

4 Site 1, D'Nyala

5 Site 2, Shongoane

NOTE Base maps: https://commons.wikimedia.org/wiki/File:Map_of_South_Africa_with_provinces_shaded_and_districts_numbered_(2016).svg; https://commons.wikimedia.org/wiki/File:Map_of_Limpopo_with_districts_shaded_and_municipalities_numbered_(2016).svg; K. Magano and R.T. Mangani, Geoformation Science Unit, Agricultural Research Council-Soil Climate & Water.

Figure 20 — Study sites in the Lephalale municipality, Limpopo province, South Africa

11.2.2 Physical features

11.2.2.1 Climate

Lephalale has a semi-arid climate. The annual average long-term summer rainfall is around 437 mm but varies among years. The mean minimum and maximum temperatures range from 2,1 °C to 39,2 °C for June and December, respectively.

11.2.2.2 Topography

D'Nyala Nature Reserve lies on the hills of the southeast Waterberg Lephalale, and the communally managed area, Shongoane village lies on the flatter area towards the north of the Waterberg in Lephalale.

11.2.2.3 Soil

The Shongonae study area is underlain by soil classified as black vertic clays and high calcium carbonate ($CaCO_3$) content. The soil at D'Nyala is classified as reddish-yellow sandy clay loam (see Figure 21).

a) Black vertic clay, high calcium carbonate ($CaCO_3$) soil at Shongoane

b) Reddish-yellow sandy clay loam soil at D'Nyala

NOTE Photo credit: R.T. Mangani, Bush Expert, Project Team, North-West University.

Figure 21 — Soil types found at the two study areas

11.2.2.4 Natural vegetation

A larger portion of the area is characterized by degraded rangelands with woody species forming bush clumps and thickets. D'Nyala's woody vegetation is dominated by *Dichrostachys cinerea* while Shongoane is dominated by *Senegalia mellifera.*

11.2.3 Socio-economic features

The Lephalale municipality has a population of 140 240 with 43 002 households in total and a dependency ratio of 33,2 %. The unemployment rate stands at 22,9 % which is below the provincial average. The community mainly depends on livestock farming for income. This puts pressure on the condition of the land and often leads to overgrazing and encroachment of woody species. Low financial support to develop the land makes subsistence farming even more difficult.

In the Shongoane village, the population is local and non-European, with strong cultural norms and standards. The site is communally grazed rangeland and there is a free land tenure system.

In the D'Nyala Nature Reserve, the conservation area is owned and maintained by the government, mainly for eco-tourism.

11.2.4 Interested parties

The interested parties implementing the interventions are both the local and regional governments, in order to benefit the local villagers and the sustainable tourism industry.

11.3 Land degradation problems faced

11.3.1 Types of land degradation observed

The main type of land degradation observed is the increase in woody density or bush encroachment. This phenomenon is predominantly caused by indigenous species, but it can also be due to invasion by alien species in the savanna and grassland regions.

11.3.2 Drivers of land degradation

The main driver of bush encroachment is land mismanagement, over-stocking and overgrazing of rangeland areas as well as the impacts of climate change. Bush encroachment decreases grass biomass production, which negatively influences the carrying capacity of the rangelands. Bush encroachment causes a decline in the land productivity, which negatively affects ecosystem services.

11.3.3 Risk of future land degradation — Resilience

Bush encroachment also results in vegetation species composition changes which affect the biodiversity of the area. It also increases erosion and causes a reduction in the water table. Land degradation will increase if the land is not protected. This land degradation process disrupts the balance of species in the vegetation system and biodiversity, with a resulting loss of ecosystem services. This in turn affects the well-being of the inhabitants who depend on benefits from the ecosystem services.

In conservation areas, where the grazing intensity is better managed, the impact to the vegetation is less damaging.

11.4 Objectives

The main objectives of the project were:

— to maintain or improve productivity, e.g. improve fodder production for grazing animals (game and domestic);

— decrease vulnerability to climate variability;

— increase resilience to climate change;

— maintain or improve ecosystem services, and quantify the socio-economic benefits addressed by the bush-clearing activities in bush encroached areas;

NOTE This would also contribute to improving the well-being of the people using the land through income generation (job creation ventures) opportunities.

— improve visibility of game for eco-tourism in the conservation area.

11.5 Interventions

The “brush packing” restoration technique is mainly used as above-ground obstruction by packing branches on bare patches of land to let seedlings establish well without the threat of herbivores. Brush packing can be used as a cost-effective method to restore degraded land after bush control[44][45][46]. Brush packing creates a micro-habitat that is favourable for the growth and recruitment of grass species. Additionally, it serves as an effective protection barrier to shield off new grass seedlings from herbivory, decreases higher soil surface temperatures and improves the soil moisture content created by the shade effect of the woody branches. As the branches decompose over time, it also increases the nutrient and carbon content of the degraded soil. Brush packing helps in manipulating plant-growing conditions to increase above ground biomass or plant cover. It also improves production quality by reducing weed growth, improving soil structure and enhancing organic matter content.

Woody plants causing the bush encroachment of height lower than 3,5 m and stem thickness of less than 10 cm were mechanically cleared using handsaws, loppers and a chainsaw to prepare for the brush packing. After clearing, a chemical, Kaput®

This is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

gel arboricide, was applied on the stumps by a hand-spray technique. Six different brush packing restoration methods (replicated three times) were tested with all treatment combinations being equally represented based on the landscape, as follows:

a) clearing, soil disturbance, re-seeding and brush packing (CSRS-BP);

b) clearing only (CO);

c) clearing and brush packing (C-BP);

d) clearing and re-seeding (CRS);

e) clearing, re-seeding and brush packing (CRS-BP);

f) no clearing (control plot) (UC).

Quantitative sampling and data analysis techniques were used to determine the biomass production of the increased fodder production and changes in the soil parameters.

A qualitative thematic content analysis approach was used, including semi-structured interviews held with participants from the local communities surrounding the study area to determine changes in the socio-economic conditions. The study was carried out over a period of two years, from 2018 to 2019.

11.6 Results

Brush packing was considered a cost-effective restoration method to remediate the land degradation due to bush encroachment. The brush packing project was implemented at the study sites during 2017 to 2019 representing the two land use types, i.e. conservation and communally grazed areas, after controlling bush encroachment by clearing of the woody species. Results which were achieved included the following:

a) Grass diversity was lowest in the plots which were not bush cleared, compared to the brush-packed plots at both sites (see Figure 22). Grass richness only improved at the communal site. A higher number of perennial type grass species were identified in the brush-packing treatments. The results suggest that brush packing promotes grass diversity under continuous grazing pressure in communal areas compared with conservation areas. The higher grass biomass production increased the grazing capacity and improved biodiversity, reduced erosion, increased the soil surface parameters and contributed to SLM practices.

b) Above-ground biomass (g m^{-2}) collected from the plots in two seasons (i.e. 2018 and 2019) revealed that the bush C-BP had significantly higher above-ground biomass than the just clearing with no brush packing at both sites. Likewise, the above-ground biomass deviation among the brush-packing plots with reference to the plots which were not bush cleared was greater than 100 % in both seasons at both sites. However, while above-ground biomass was highest for the brush-packing plots, the total person time and set-up costs were also the highest, with each plot taking more than 1,5 h and costing more than USD 6,66 per plot.

c) The socio-ecological results indicated that the sites in the D'Nyala Nature Reserve benefited from the bush-clearing activity via the improved visibility of the landscape features and wildlife viewing, making the reserve more attractive for tourists, and resulted in increased revenue. The costs of buying feed for wildlife can also be curbed since the grazing capacity has increased. Since the nature reserve sourced temporary labour from the local village to execute the restoration project, the community benefited in terms of its members being able to earn a wage, which led to an improvement in their livelihoods. Another indirect benefit for people living in the Shongoane village near the communally grazed area was the morale and behavioural changes observed among community members. The people who helped with the implementation of the restoration project also earned wages, contributing to a better well-being of the community in general.

a) Only bush-cleared plot

b) Brush-packing plot

NOTE Photo credit: R.T. Mangani, Bush Expert, Project Team, North-West University.

Figure 22 — Comparison of two treatment plots

11.7 Lessons learnt and benefits

The bush clearing and restoration project also contributed to skills development and provided formal training, which led to an improvement in the community's livelihoods. Another indirect benefit was the morale and behavioural changes observed among the community members. It was obvious that the socio-economic benefits derived from projects such as these far outweigh the negatives and that there is every reason to institute projects of a similar nature elsewhere.

Nevertheless, challenges and constraints were faced in up-scaling and in out-scaling of the restoration technologies.

Among the lessons learnt was that in order to restore degraded land on a large scale, implementation and coherence to a restoration plan is essential. Recommendations were made by the Terrestrial Ecology Research Team to assist in the future development of restoration plans by practitioners, land users, contractors, scientists and policymakers in a policy brief issued by the National Office of the Department of Environmental Affairs and the School of Biological Sciences and Unit for Environmental Research and Management, North-West University[47].

11.8 Conclusion

The results indicated that in all the brush packing restoration treatments, the above ground biomass was higher compared to the non-brush packed treatments. The grass biomass production increased the grazing capacity and biodiversity, reduced erosion, increased the soil surface parameters and contributed to SLM practices. The visibility of the landscape features and wildlife viewing was improved in the nature reserve, making the reserve more attractive for tourists and resulting in increased revenue.

Overall, the project was able to:

— generate sustainable solutions (technologies and approaches) through increased fodder production for grazing animals, allowing for better sightings for tourism, and improved income and well-being for the communities;

— increase ownership of the interested parties in the local communities and tourism industry;

— increase ways of sharing experiences and enhancing communication through feedback sessions with the local participants;

— provide recommendations and guidelines for future restoration projects.

12 Case study G — Regional cooperation to combat desertification and drought: The ECONORMAS programme in Argentina, Brazil, Paraguay and Uruguay

12.1 General

The ECONORMAS-MERCOSUR programme is part of the cooperation initiatives between the European Union (EU) and the MERCOSUR, a South American trade bloc, to foster economic integration and sustainable development. The general objective of the programme is to improve the quality and safety of products from MERCOSUR and strengthen its capacity to reconcile the growth of trade and economic activity with the sustainable management of resources and promotion of environmental protection. This case study presents the regional project on combatting against desertification and drought, through demonstrative physical interventions for prevention, mitigation and rehabilitation in areas at risk of desertification and drought in the MERCOSUR countries of Argentina, Brazil, Paraguay and Uruguay.

12.2 Context

12.2.1 Location

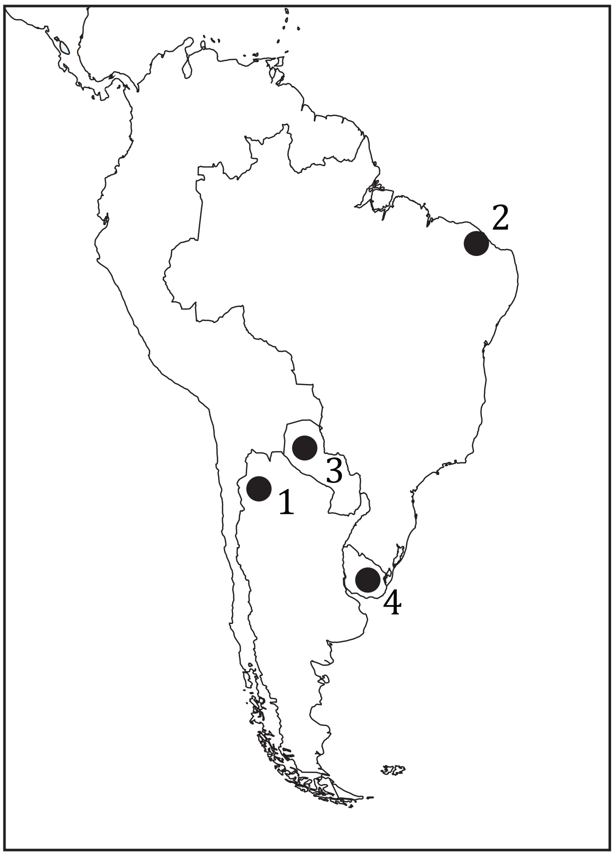
One region was selected in each of the four participating countries for implementation of the interventions. The ECONORMAS project areas (see Figure 23) for combatting desertification and drought are:

a) Valles Calchaquíes, Argentina;

b) Municipio de Irauçuba, Brazil;

c) Chaco Paraguayo, Paraguay;

d) Tala, Uruguay.



Key

1 Valles Calchaquíes, Argentina

2 Irauçuba, Brazil

3 Chaco Paraguayo, Paraguay

4 Tala, Uruguay

NOTE Source: equal-earth.com.

Figure 23 — Location of the ECONORMAS project areas

12.2.2 Physical features

12.2.2.1 Valles Calchaquíes, Argentina

There were four locations served by ECONORMAS in Valles Calchaquíes, Argentina, which were El Pichao, El Bañado, Colalao del Valle and Cafayate. In all areas, the climate is semi-arid with strong daily temperature variations. The average annual rainfall depth is about of 200 mm to 250 mm.

— El Pichao is located on the eastern slopes of the Sierra de Quilmes, at 2 200 m above sea level and about 202 km west of the city of San Miguel de Tucumán by land. The soil consists of sandstone and a steep sloped topography, in some cases over 20 %. The temperature in winter varies between 4 °C at night and 20 °C during the day, with some frosts. In summer, temperatures vary between 15 °C and 30 °C.

— El Bañado is located in the Calchaquí Valley, 10 km from Colalao del Valle, at 1 850 m above sea level and about 182 km west of the city of San Miguel de Tucumán by land. The territory has a gentle sloping topography and sandstone formations.

— Colalao del Valle is located in the Calchaquí Valley, 1 800 m above sea level and about 202 km west of the city of San Miguel de Tucumán by land. The soil is sandy-silty and the slopes are gentle.

— Cafayate is located in the Calchaquí Valley, 1 600 m above sea level, southwest of the Salta province, north of Argentina-Cafayate. Several rural communities are located in remote areas.

12.2.2.2 Irauçuba, Brazil

In the Irauçuba–Ceará area, the rainy season is heavily overcast and the dry season is humid, with strong winds and partly cloudy skies. The average annual precipitation depth along the coastline is 1 400 mm. Approximately 93 % of State of Ceará territory is within the northeast semi-arid region of the country, with an uneven geographical distribution of rainfall. In the semi-arid hinterland, the values range between 600 mm and 800 mm. There is a high evaporation annual rate of about 2,5 mm and an aridity index of 0,25 %. Throughout the year, the climate is hot, and the temperature generally ranges from 21 °C to 36 °C, and is rarely below 20 °C or above 37 °C.

In terms of water balance, the time series shows a persistent deficit which has accumulated during a recent long dry spell that lasted several years. A vast portion of the territory is susceptible to desertification, requiring measures to control and reclaim intensely degraded areas.

The natural vegetation is typical of the Caatinga Biome which is the main ecological feature of this region, where the local and resilient population coexists with the periodic and intense dry spells.

12.2.2.3 Chaco, Paraguay

The climate in Chaco is characterized by rainy summers and dry winters. The dry spells occur between May to October, the bulk of the annual rainfall is concentrated between November to April, and there is a potential evapotranspiration rate of 1 140 mm per year. A significant water balance deficit shows up in the time series of precipitation data.

Water scarcity represents a major concern for the local population and indigenous people. The ECONORMAS programme provided the construction of Tajamales, large surface reservoirs (up to 50 000 m^3) conceived to collect rainfall from small catchment areas, for water supply.

The high temperatures, long periods of drought and strong winds have a detrimental effect on the production and productivity of agricultural outputs. The adverse climate and soil conditions contribute to the low agricultural yield and productivity.

12.2.2.4 Tala, Uruguay

The climate in Tala is characterized by hot summers whereas the winters are usually cool. Throughout the year, the weather is rainy and partly cloudy, the temperature generally ranges from 5 °C to 31 °C, and is rarely below −2 °C or above 37 °C.

The topographic features are defined by a gently undulating landscape and low hills, and a relatively dense natural drainage system including some ravines and gorges which constitute the main features of the catchment basin. In addition, the altitude is approximately 50 m above sea level on the Santa Lucía River (intersection with Route 7, Bolivar town) up to a maximum of 85 m on Route 7, at kilometre 84.

The soil structure consists of deep, black soil, degraded, and developed on quaternary sediments with moderate erosion (Vertisols and Brunosols) that shape the hills.

12.2.3 Socio-economic features

12.2.3.1 Valles Calchaquíes, Argentina

In terms of governance, all levels are well represented in the local context.

12.2.3.2 Irauçuba, Brazil

The land use and governance are characterized by the following main aspects: subsistence agriculture and livestock, animal husbandry (pig farming, goat and sheep farming) and of dairy cattle. The local production of handicrafts is also among the economic outputs.

Access to water is a basic requirement to carry out these activities, therefore the community has organized itself into associations that strive for improvements in their quality of life and living standards within the semi-arid region context.

The estimated population is some 24 305 inhabitants, and the municipal human development index (HDI) is 0,618. Thus, the community faces a series of social, economic and adaptation constraints, which are of concern, such as lack of sanitary services, limited or no access to clean water and high unemployment rate.

12.2.3.3 Chaco, Paraguay

In Chaco, the intensification of land use and the sustainable management and use of soil has been largely overlooked up to present. The Chaco soil is prone to erosion, exacerbated by climatic factors, such as high temperatures, long periods of drought and strong winds, which make the soil a fragile natural resource in an unfavourable climate for agriculture.

The basis of the demographic and socio-cultural setting is formed by a diversity of the population made up of Mennonites, mestizo Paraguayans and indigenous peoples.

12.2.3.4 Tala, Uruguay

In Tala, the basis of the demographic and socio-cultural setting is formed by farmers who have their customary income level affected due to the occurrence of frequent and lengthy drought events. In 2008, the farmers set up a group of agricultural producers in order to find a solution to ensure a continuous and timely access of water for irrigation. The group nicknamed themselves “for water” and represents an organization that, although lacking legal regulation, still holds strong ties between its members who share traditional knowledge as a result of years of experience and neighbourhood work. This group is part of the Sociedad de Fomento del Tala. Indirectly, at least 142 families have benefited from belonging to the Sociedad de Fomento Rural Tala (SFR Tala), as well as other development societies in the surrounding area and throughout the country, which undertake similar multi-network associative systems.

12.2.4 Interested parties

In Argentina, for project implementation, the interested parties are the former Secretary of the Environment and Sustainable Development of the Nation, the current Ministry of Environment and Sustainable Development, and the Valles Calchaquíes: Municipal Commission of Colalao del Valle in the Province of Tucumán, the Department of Cafayate in the Province of Salta, and local communities and associations.

In Brazil, for the project, the government is represented at the federal level by the Ministry of Environment, at state level by the Secretariat of Water Resources, and at the municipal level by the mayor.

In Paraguay, aside from the Secretariat of the Environment at the federal government, the interested parties include the Municipal Government of Teniente Primero Manuel Irala Fernández in the Paraguayan Chaco Region.

In Uruguay, the interested party in the project is the Ministerio de Vivienda y Ordenamiento Territorial (Ministry of Housing and Territorial Planning).

12.3 Land degradation problems faced

12.3.1 Evaluation approach

12.3.1.1 The drivers/pressure/state/impact/response framework

The following description applies to all four countries beneficiaries of the ECONORMAS Programme were the drivers/pressure/state/impact/response (DPSIR) approach was applied and utilized as a guideline for the planning, decision-making and project implementation of all interventions carried out in the selected critical areas. Therefore, the gathering of diagnostic data for critical zones was based on socio-economic and physical-environmental indicators linked to the desertification process in the nuclei of areas susceptible to desertification in the four MERCOSUR countries, considering the DPSIR aspects. The purpose of presenting the indicators under this structure presents itself as an opportunity to have an integrated assessment of socio-economic and environmental information, and to visualize the cause and effect relationships of the interaction between community and the environment[49].

12.3.1.2 Driving-force indicators

Most of the findings related to the selection process of the critical areas were based on secondary data[49]. It was not possible to define with technical precision the driving-force indicators regarding the socio-economic and environmental characteristics of the nuclei from the technical literature. In order to obtain these indicators, a more in-depth study would be necessary to cover the process of historical development of the territories in each of the critical areas: in terms of the productive activities developed over time, the relationship of dependence on communities with the productive sectors, and the weight of these activities in the local socio-economic and environmental context. With these data in hand, there can be field research conducted to check the data in loco and to define, in each area, the driving forces (processes and standards) that direct, directly or indirectly, the socio-environmental problem of desertification in these critical areas.

Thus, considering that desertification is not a punctual phenomenon and that there are dynamics and several processes that interact previously, it was decided to present in this work, from the diagnosis of critical zones, a brief summary of the elements of pressure, state, impact and response.

12.3.1.3 Pressure indicators

The main elements of pressure on the identified natural resources are related to human activities that directly influence the state of the environment. Thus, the following indicators were presented and analysed:

— water demand/availability ratio;

— degraded areas susceptible to desertification processes;

— average frequency of fire outbreaks;

— animal bearing capacity: number of animals per hectare;

— land ownership: percentage of the area for agricultural purposes;

— agrarian structure: percentage of the area for agricultural purposes;

— vegetative extraction: production of charcoal and firewood (t) and log production (m^3).

12.3.1.4 Status indicators

To describe the state of the environment and the conditions that prevail when there is pressure, and to assess the current levels of quality of life of the population in the three centres, the following indicators were selected:

— aridity index;

— surface water availability: average annual runoff (mm) and average annual flow (m^3s^{-1});

— water quality: qualitative balance;

— groundwater availability: number of wells, average depth (m), average flow (m^3s^{-1}) and quantity of desalinators;

— demographic density: inhabitants (km^2);

— urbanization rate (%);

— percentage of women responsible for households.

12.3.1.5 Impact indicators

The impact indicators describe the final effects of changes in state and indicate the consequences of the degradation of natural resources, i.e. how desertification impacts the social system. The following indicators were selected to describe the impacts in the desertification zones:

— illiteracy rate of people over 10 years of age (men and women);

— infant mortality rates (number of deaths per 1 000 live births);

— number of doctors per 1 000 inhabitants;

— hospital morbidity due to infectious and parasitic diseases (total value of confirmed cases of compulsory notification diseases that are related to infectious and parasitic diseases);

— economically active population (inhabitants) from 10 to 65 years of age, employed and unemployed;

— extreme poverty measures, the proportion of the extremely poor population, percentage of extreme urban and rural poverty (international extreme poverty line of USD 1,90 in 2011 purchasing power parity terms, following the World Bank[51][53]).

12.3.1.6 Response indicators

From observing the impact indicators, the elements of society's response were identified, i.e. the concrete measures taken to combat the problem of desertification, themes with an interface, and society's efforts to minimize the serious effects on the population and the environment. Considering that this study was based on the documents or National Action Plans to Combat Desertification and Mitigate the Effects of Drought, from the four countries, it was possible to select the following indicators:

— existence of regulations (laws, plans, programmes, projects) and initiatives related to water, soil, flora and fauna at the state level (state and municipal scale);

— existence of regulations (laws, plans, programmes, projects) and initiatives to combat desertification (state and municipal scale).

The four MERCOSUR countries (Argentina, Brazil, Paraguay and Uruguay) engaged in the current EU-ECONORMAS project have adhered to the UNCCD in accordance with their commitments towards the Convention, and guided by national policies targeted to control the continuous land degradation associated either with natural climatic variations or anthropogenic activities.

This, among other objectives of the EU-ECONORMAS Project, targets the harmonization or alignment of the individual country into a common action plan, viewing the region as a whole.

Based on a set of socio-economic and environmental indicators identified by the participating countries, a common baseline of indicators was adopted in order to establish a common ground for the process of identifying critical areas in the region potentially prone to desertification ("diagnosis") and for the simulation of future scenarios ("prognosis"). This is particularly of importance regarding the climate indicators such as temperature, precipitation and evaporation that constitute components of the aridity index used to delimit the arid, semi-arid and dry sub-humid areas in the region.

The global warming trend is likely to change the distribution patterns of such indicators and redefine the boundaries of the aforementioned areas.

12.3.1.7 Reducing climate-related desertification risk

Improving natural resources management, adopting policies to confront vulnerability and applying preventive measures will lessen the impact of natural disasters on people and ecosystems. The vulnerability of areas susceptible to land degradation or desertification of both natural and human origin is lessened by adopting the series of measures as implemented by the ECONORMAS programme.

12.3.2 Valles Calchaquíes, Argentina

The drivers of land degradation are major forest fires, which have occurred in recent years, destroying large parts of native forests. In addition, due to the production chain of the wine industry, native forest areas are slashed down to provide new vineyard areas. Rural populations exert additional pressure by exploiting the forests in search of firewood for cooking and heating.

12.3.3 Irauçuba, Brazil

The Irauçuba area is prone to soil degradation processes that can still be kept under control by strict measures to avoid slash-and-burn practices. The reintroduction or planting of native species to ensure proper vegetation soil cover is essential to halt the ongoing degradation trend. Therefore, all interventions that were adopted to enhance productive systems also addressed conservation and restoration/reclamation. The principal driver of land degradation is extensive cattle ranching in the Brazilian semi-arid regions. It is a major economic activity but places significant pressure on the exploitation of natural resources and on autochthonous vegetation, both by eliminating plants and by compacting the soil due to excessive trampling. In terms of land use, degradation means the reduction or loss of biodiversity and productivity, increasing the rate of erosion and reducing the ability to produce sustainably.

12.3.4 Chaco, Paraguay

In the Chaco region, the types of land degradation observed are land degradation and frequent long-lasting droughts, which are becoming an increasingly worrying and critical reality. The drivers of land degradation are the production of fuel sources, which has led to slash-and-burn practices in deforestation. The loss of surface coverage is resulting in the exposure to other natural effects, such as aeolian erosion, surface-water laminar erosion, soil compaction, water salinization and loss of fertility, which represent significant challenges to the production system and the development model.

12.3.5 Tala, Uruguay

In the Tala region, the types of land degradation observed are due to the erratic nature of production in the face of frequent drought events, as a result of which producers have seen their income affected. The driver of land degradation was a severe drought in 2008 which motivated the local farmers to organize themselves and create a proactive group, nicknamed "Por el Agua". The main purpose was to draw attention to the desire to have better access to water. The members developed strong ties among themselves based on an extensive record of lessons learned and depended heavily upon each other. This internal partnership as a group resulted in their engagement with the local Rural Development Society (SFR) of Tala, which is local in scope and which in turn is part of the National Rural Development Commission (CNFR) which has the national scope. This critical site is located on Route 7 of the outskirts of the city of Tala. By means of the ECONORMAS programme, a water supply line of about 10 km length was constructed in order to ensure a continuous supply of water. A water intake was designed and located on the bank of the Santa Lucía River (Pueblo Bolivar). The water withdrawn is delivered to the irrigation areas and to supplement the drinking water requirements of livestock.

12.4 Objectives

The global objective of the programme is control desertification processes and mitigation of the effects of drought through demonstrative interventions based on good and sound practices[50][52][54][55][56]. The experience gathered through empirical observation has generated a knowledge basis included in traditional capacity building programmes[57].

The specific objectives are as follows:

— Rehabilitate, adapt and mitigate desertification processes in critical areas identified in the four countries of Argentina, Brazil, Paraguay and Uruguay, through physical intervention actions for environmental control and recovery. This covers demonstrative prevention, rehabilitation, adaptation or mitigation interventions in MERCOSUR, in relation to the problem of drought (in reference to the effects on health, loss of biodiversity, erosion, soil fertility, impact on the local economy and the amount of water available).

— Prepare and disseminate pilot plans for each of the interventions carried out, aimed at identifying the use and techniques of SLM to promote the recovery of degraded areas.

— Promote the exchange of experiences among stakeholders involved in the different levels of government and related institutions, to provide inputs for the preparation and dissemination of good practices and tools for sustainable soil management, in line with the SLM and LDN approaches.

12.5 Interventions

The interventions differed among the countries depending on the specific situations assessed. Table 6 provides a summary of the different activities undertaken.

Table 6 — Intervention activities undertaken in each region and country to combat desertification and drought

Location	Intervention activity	
Valles Calchaquíes, Argentina	Activity 1:	Improvements in irrigation use efficiency, El Pichao, Tafí del Valle-Tucumán
	Activity 2:	Improvement of the quality, quantity and timely supply of water for irrigation, El Bañado, Tafí del Valle-Tucumán
	Activity 3:	Eco-efficient stoves, Valle Calchaquí, Colalao del Valle-Tucumán
	Activity 4:	Access, supply and efficient use of water in isolated places, Cafayate-Salta
	Activity 5:	Improvement in the efficiency of water use, Quebrada de Chuscha, Cafayate-Salta
	Activity 6:	Reforestation and vetiver wind barriers to control aeolic erosion, Cafayate, Calchaquí Valley-Salta
	Activity 7:	Eco-efficient stoves Valle Calchaquí, Cafayate-Salta
	Activity 8:	Municipal Nursery of native flora species, Cafayate, Calchaquí Valley-Salta
	Activity 9:	Management and Training in Demonstrative Physical Interventions to be carried out in Argentina
Irauçuba, Brazil	Activity 1:	Ecologically efficient stoves
	Activity 2:	Construction of cisterns
	Activity 3:	Agro-ecological practices
	Activity 4:	Construction of small rockfill dams or sand traps to control sediment transportation
	Activity 5:	Beekeeping
	Activity 6:	Rainwater harvesting
	Activity 7:	Production of fruit seedlings, reforestation, ornamentals and animal feed
	Activity 8:	Training for the use of local raw materials (leather and hides)
Chaco, Paraguay	Activity 1:	Rainwater harvesting for domestic purposes and irrigation
	Activity 2:	Efficient use of water for sustainable consumption and production
	Activity 3:	Beekeeping
	Activity 4:	Construction of large off-stream water reservoir fed by rainwater harvesting
Tala, Uruguay	Activity	Design, construction and operation of a water intake, water supply line and distribution system for irrigation purposes and water supply to households and livestock.

12.6 Results

12.6.1 Successful experiences

There were several successful experiences resulting from the ECONORMAS project, including the implementation and adoption of tools, good/best practices, and the monitoring and review measures conducted.

Cooperation and technical-financial support from institutions with a direct presence in areas susceptible to desertification strengthened the technical capacity for the implementation and monitoring of actions. The population of the affected or threatened areas is the centre of concern in the fight against desertification and mitigating the effects of drought, taking into account social and environmental vulnerability.

The ECONORMAS project provided a set of tools to the communities of the selected critical areas in the four MERCOSUR countries, enhancing the quality of livelihoods and grassroots-based economies. These proved effective in controlling and restoring areas affected by desertification processes through the implementation of activities/actions carried out as listed previously and highlighted in the following topics addressed by the ECONORMAS programme's key topics:

a) demonstrative physical interventions (IFDs) in each identified area of each of the four countries: based on a basic and executive project (PBE) prepared, validated and implemented in a participatory manner with national and local authorities;

b) citizen mobilization and participation workshops for intervention: prepared, validated and implemented in the critical areas identified in the four countries;

c) monitoring, evaluation and technical support in the critical areas identified in the four countries: based on the indicators carried out;

d) a pilot plan called "learning while doing" for the sustainable use and management of natural resources, and workshops given in the critical areas identified in the four countries: validated and implemented;

e) successful experiences and good practices derived from interventions in the critical areas identified in the four countries: validated, systematized and disseminated;

f) workshops for training and dissemination of successful experiences and good practices derived from interventions in the critical areas identified in the four countries: planned, organized and carried out;

g) exchange of experiences between the different actors involved in the different levels of government and related institutions: carried out in three virtual activities and a regional workshop.

12.6.2 Examples of good practices

Several good practices were applied, as follows:

— In Argentina, one good practice was related to reforestation by the implementation of wind barriers on barren hills devoid of vegetation due to aeolian erosion in the region of Cafayate, Calchaquí Valley (see Figure 24).

— In Irauçuba-Ceará, Brazil, several small rockfill dams or sand traps were built in the thalwegs of dry riverbeds to intercept the sediments carried by the intermittent stream flows during the rainy season (see Figure 25)[58].

— In Chaco, Paraguay, a good practice was the construction of off-stream reservoirs (see Figure 26) with volume capacities varying between 50 000 m^3 and 100 000 m^3, located in small catchment areas fed by the harvesting of rainwater. Local communities and indigenous people were the main beneficiaries of this reliable source of water.

The monitoring and review practices (see Table 7) of the programme were conducted by the Inter-American Institute for Cooperation on Agriculture (IICA) Regional Technical and Management Coordination team. In order to ensure a smooth implementation of the programme's schedule, permanent contact with the national and local authorities and the communities involved was a priority throughout the execution period. Due to the remoteness and isolation of the selected areas in Argentina, Brazil and Paraguay, a local-specific monitoring activity was included.

a)

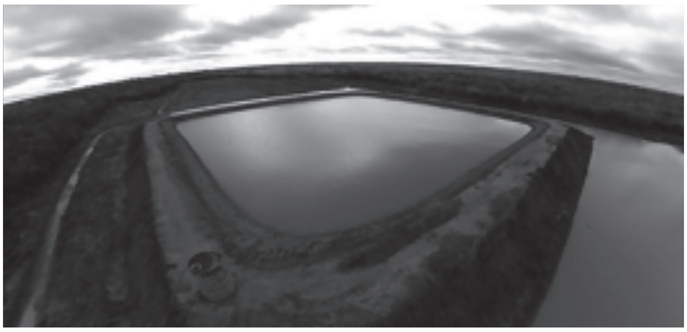
b)

NOTE Photo credit: ECONORMAS-IICA project team.

Figure 24 — Wind barriers in the region of Cafayate, Calchaquí Valley

NOTE Photo credit: ECONORMAS-IICA project team.

Figure 25 — Rockfill dams to intercept sediments



NOTE Photo credit: ECONORMAS-IICA project team.

Figure 26 — Offstream reservoirs in Paraguay

Table 7 — Monitoring and review practices and activities adopted in each region and country

Region	Activities
Valles Calchaquíes, Argentina	The eight initiatives carried out in Argentina are characterized by being located in very distant and isolated areas. Therefore, specific management and training activities had to be provided for each initiative.
Irauçuba, Brazil	Due to the characteristics and the remoteness of the intervention area for monitoring and technical support, in situ, of the interventions, the hiring of a consultant was deemed necessary. The responsible person was referred to as “Responsible for Monitoring and Evaluation of Physical Intervention in Brazil” and worked in synergy with local authorities, with contact with the UNCCD focal point in Brazil, and in consultation with leaders of potential beneficiary communities and the Regional Technical Coordination.
Chaco, Paraguay	Due the remoteness of the area of intervention for the monitoring and technical support services, for on-site activity, a consultant was hired as “Responsible for Monitoring and Evaluation of Physical Intervention in Paraguay” and worked jointly and in permanent contact with the local authorities, technical staff from the IICA representation in Paraguay and the Regional Coordination.
Tala, Uruguay	When the award for the construction of the water supply pipe line was made, the evaluation, monitoring and technical follow-up was carried out following the schedule of the workplan, in accordance with the decisions made by the monitoring commission and the continuous follow-up of the direct beneficiaries. The overall procedures adopted by the ECONORMAS programme were similar for the four countries and adapted according to local conditions.

12.7 Lessons learnt and benefits

Through the creation of formalized inter-institutional alliances as set up by the evaluation and follow-up committee of the project, it was possible to ensure the strengthening of the technical capacities installed in the intervention area. The focus was on optimization and effective management of financial and technical resources available, aimed at the sustainability of the interventions carried out, and ultimately making sure that the ECONORMAS programme approach can be replicated in other similar critical areas.

The regional pilot plan has a national approach with the perception and experience of the first level of decision-making, comprising authorities (national, federal) for institutionalization and governance of the implementation of policies related to the combatting of desertification issues.

12.8 Conclusion

The best practices identified and endorsed by the beneficiaries/communities are related to water productivity, and access to reliable and safe drinking water, either through water harvesting means or desalinization of brackish water wells. In addition, the eco-efficient stoves proved their far-reaching benefits are not limited or restricted to cooking, nor to pressure reduction on the environment in terms of cutting/slashing and burning shrubs and trees to produce coal. The overarching benefit is the positive impact on the health of the population: a measurable indicator at the local medical/health centres.

A Regional Pilot Plan Combat Desertification and Drought in MERCOSUR, containing a set of recommendations, was prepared and a regional strategy envisaged for a regional plan of actions and policies to combat desertification processes. Mitigation of the effects of drought is one of the highlighted outcomes of the ECONORMAS programme.

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