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Good Practices in Soil and Water Conservation

A contribution to adaptation and farmers´ resilience towards climate change in the Sahel

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ACMAD	African Centre of Meteorological Application for Development
ANR	Assisted Natural Regeneration
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung - German Federal Ministry for Economic Cooperation and Development
CILSS	Comité permanent inter-états de lutte contre la sécheresse au Sahel - Permanent Interstate Committee for Drought Control in the Sahel
CVGT	Comité villageois de gestion du terroir - Village Land Management Committee
DED	Deutscher Entwicklungsdienst - German Development Service
FAO	Food and Agriculture Organization of the United Nations
FfW	Food for Work
FICOD	Fonds d'Investissement pour les collectivités décentralisées - Investment Fund For Local Authorities
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
IPRO-DB	Small-scale Irrigation Project in Dogon Country and Beledougou
IPRO-DI	Small-scale Irrigation Project in the Inner Niger Delta
KfW	Kreditanstalt für Wiederaufbau - German Development Bank

The implementation of measures for adaptation to climate change requires participatory analyses, Chad © GIZ/Klaus Wohlmann

LUCOP	Programme de lutte contre la pauvreté - Niger-Germany Poverty Reduction Programme
NAREN	Sektorprogramm Nachhaltige Ressourcennutzung in der Landwirtschaft - Programme for Sustainable Resource Management in Agriculture
NGO	Non-Governmental Organisation
PAPF	Projet autopromotion pastorale dans le Ferlo - Self-Help Project for Rangeland Development in Ferlo
PASP	Projet de protection intégrée des ressources agro-sylvo-pastorales Tillabéri-Nord - Project for the Integrated Protection of Agricultural, Forest and Rangeland Resources in Tillabéri-Nord
PATECORE	Projet d'aménagement des terroirs et de conservation des ressources -Project for Land Development and Resource Conservation
PDA	Programme de développement de l'agriculture - Agricultural Development Programme
PDRT	Projet de développement rural de Tahoua - Tahoua Rural Development Project
PGRNG	Programme de gestion de ressources naturelles, Guidimakha - Programme for Natural Resource Management through Watershed Development in the Wilaya of Guidimakha
PMAE	Programme mesures antiérosives - Programme for Erosion Control Measures
PMN	Programme Mali Nord - Mali North Programme
PRA	Participatory Rapid Appraisal
PRBP	Projet de réhabilitation des barrages et pistes - Project to Rehabilitate Dams and Tracks
PRESAO	Prévision saisonnière pour l'Afrique de l'Ouest - Climate Outlook Forum for West Africa
SIFEE	Secrétariat international francophone pour l'évaluation environnementale - Francophone International Secretariat for Environmental Assessment
SMEV	Schéma directeur de mise en valeur des ressources naturelles - Natural Resource Development Scheme
SNRD	Sector Network Rural Development Africa
SPR	Soil Protection and Restoration
SWC	Soil and Water Conservation

1 Introduction

The Sahel is a region where the population has always faced a high degree of climate variability, manifested both in terms of time (unexpected dry spells can occur during the rainy season) and in terms of space (rainfall can vary greatly from one area to another).

Over the last two decades, the effects of climate change have exacerbated the already difficult conditions. According to projections made by climatologists, the Sahel will experience a rise in temperatures combined with highly variable rainfall and an increase in extreme weather events.

Since the 1980s and 1990s, German cooperation has been providing support to people living in the Sahel for the development of technical, environmental and agricultural strategies and approaches. Efforts to achieve the sustainable management of the environment and improve different types of landscape unit have focused on *soil and water conservation* (SWC) and *soil protection and restoration* (SPR) techniques.

These SWC/SPR techniques have helped people in the Sahel to manage their ecosystems more effectively and improve their productive land. As a result, communities are better prepared to cope with environmental changes (changes in the climate, land degradation, etc.) and the impact of shocks, particularly droughts.

The purpose of this study is to present good practices in soil and water conservation and soil protection and restoration from the point of view of their contribution to reducing the vulnerability of the region's population and improving the resilience of its agro-silvo-pastoral systems.[1] The study was undertaken on the initiative of the working group on natural resource management of the Sector Network Rural Development Africa (SNRD) and funded by various GIZ sector projects.[2]

Vulnerability

Vulnerability refers to the susceptibility of individuals, households and social groups to external shocks and crises (environmental, macroeconomic and political) or internal threats.

Vulnerability comprises three components: (i) the **exposure** and (ii) the sensitivity in light of disturbances or stress, as well as (iii) the capacities to overcome them. The exposure to vulnerability always depends on the exposure of a group to disturbances or stress.

Vulnerability is always the product of structural, sociocultural and individual factors (ethnic group, sex, age). The **sensitivity** represents the degree at which a system is affected by disturbances.

Individuals, households and social groups generally have **coping strategies** to overcome crises. These strategies contribute to building their **resilience** to shocks and crises.

The vulnerability of individuals, households and groups is always manifested in relation to a specific threat and not in general terms.

The measures described in this study are some of the ones developed, implemented and disseminated as part of projects and programmes undertaken from the 1980s onwards to combat desertification and improve natural resource management. All the techniques developed to control erosion, reclaim and restore degraded land and improve water harvesting have been successfully implemented on a large scale in the field.

1 'Agro-silvo-pastoral' refers to crop growing, forestry and livestock raising.
2 This study is financed by the following sector projects: "Sustainable Management of Resources in Agriculture" (NAREN), "Rural Development" and "Convention to combat desertification" (CCD).

Millet harvest © GIZ / Klaus Wohlmann

The study draws on the experiences of German cooperation[3] projects implemented in Niger, Burkina Faso (SWC/SPR measures) and Mali (small-scale irrigation schemes).[4] Chapters 2 and 3 provide an overview of the historical context in which the techniques were developed in the Sahel and describe the lessons learned and the challenges posed by climate change. Chapter 4 deals with general aspects of SWC/SPR measures in the watershed development approach, and chapter 5 presents the seventeen selected techniques for soil protection and restoration and the development of valley bottoms.

3 GTZ, KfW and DED.
4 In Niger, the projects include Integrated protection of agricultural, forest and rangeland resources in Tillabéri-Nord (PASP) and Tahoua rural development project (PDRT). The activities of these projects are now being continued under the poverty reduction programme (LUCOP). In Burkina Faso, it is the project for land development and resource conservation in Plateau Central (PATECORE). In Mali, they include the project to rehabilitate dams and tracks (PRBP) and the Mali north programme (PMN). The activities of these projects are now being continued under the IPRODI and IPRO-DB projects as part of the small-scale irrigation programme.

2 Historical background

Most of the SWC/SPR techniques presented in this study were developed in the 1970s and 1980s in response to the humanitarian and environmental crises that brought severe famine and resulted in the loss of large areas of cropland, rangeland and forestland (source of wood and forage and habitat for biodiversity).

These crises that afflicted the Sahel were due to a combination of human and natural factors and dynamics and to political changes:

- a period of very low rainfall from 1970 to 1990;
- population growth of over 3% in most of the Sahel countries, putting great pressure on natural resources (shortened or no fallow, decline in yields and increase in inhabited areas);
- increase in the area of land cleared for farming, resulting in the disappearance of tree and grass cover and soil degradation caused by water and wind erosion;
- farming practices that failed to adapt to changing environmental conditions and accelerated processes of erosion;
- increase in the area of denuded land with a hardened soil crust in uncultivated areas, resulting in a decline in the production of wood (firewood) and forage;
- loss of local know-how about soil conservation practices;
- disappearance of services provided by the government, such as animal health, agricultural extension, supply of inputs and plant protection, as a result of structural adjustments.

In the area covered by the German programme in Burkina Faso (PATECORE), for example, 25% of families left their villages between 1975 and 1985 because of the droughts. An average of 20 tonnes of soil per hectare per year were lost, the expansion of denuded and degraded areas accelerated and the water table fell by 1 m a year.[5]

The projects studied in this report implemented land improvement measures on a wide scale. The project for land development and resource conservation in Burkina Faso (PATECORE) improved some 100,000 ha of land, mostly farmland, with contour stone bunds and permeable rock dikes and dams. The Tahoua rural development project (PDRT) and the project for the integrated protection of agricultural, forest and rangeland resources in Tillabéri-Nord (PASP) focused on improving communal land on plateaux and slopes and farmland, using contour stone bunds, zai planting pits, Nardi/Vallerani and hand dug trenches, semi-circular bunds and other techniques. The PDRT project improved an area of around 125,000 ha in this way, and the PASP project over 500,000 ha. The project to rehabilitate dams and tracks (PRBP) in Mali constructed around 80 small-scale dams, and the Mali north programme (PMN) improved around 13,000 ha of land with village irrigation schemes and measures to develop seasonally flooded depressions (mares).

The projects were initially organised in the form of 'autonomous' undertakings in collaboration with government bodies and agencies. To begin with, most of the activities were carried out by project personnel who had sizeable logistics units at their disposal and their own equipment and means of transport. The village land area was the basic unit for interventions, which were based on a simplified spatial planning approach and land management organisations. As time went on, the projects worked increasingly with local providers (carriers, consultancy firms, NGOs) to carry out part of the work and involved the commune authorities in planning and monitoring the measures implemented.

The projects, in cooperation with the beneficiaries, developed and implemented a large range of land improvement measures suited to the specific context in each area of intervention. The process undertaken to implement these measures included participatory planning and the active involvement of the beneficiaries at all stages. Local agreements were established as the basis for the management of community resources at the village or inter-village level.

5 Source: various PATECORE annual reports.

Restored areas are cultivated © GIZ / Martina Wegner

A look at the impact of these projects on land degradation in the areas of intervention reveals that while the process of degradation has been halted over vast areas, there has been no wholesale reversal. This was substantiated by a diachronic study based on satellite images carried out in the areas covered by the PDRT and PASP projects (Kusserow, 2010). Nevertheless, Chris Reij (2009) showed that villages that have invested in measures to rehabilitate degraded land are better able to cope in times of crisis; picking fruits and collecting firewood are activities that directly help households to survive difficult times.

It can therefore be concluded that the projects had a significant effect on reducing vulnerability and increasing the resilience of the people living in the areas of intervention. According to Kaboré & Reij (2004), the measures implemented enabled farmers to increase their yields, reincorporate trees into the farming system and intensify livestock raising. The enormous investments made by the projects and the local population in the productive resources of their land resulted in an overall intensification of farming. The water supply was improved thanks to measures taken to increase the infiltration of water into the soil and groundwater recharge.

3 Climate trends and their effects

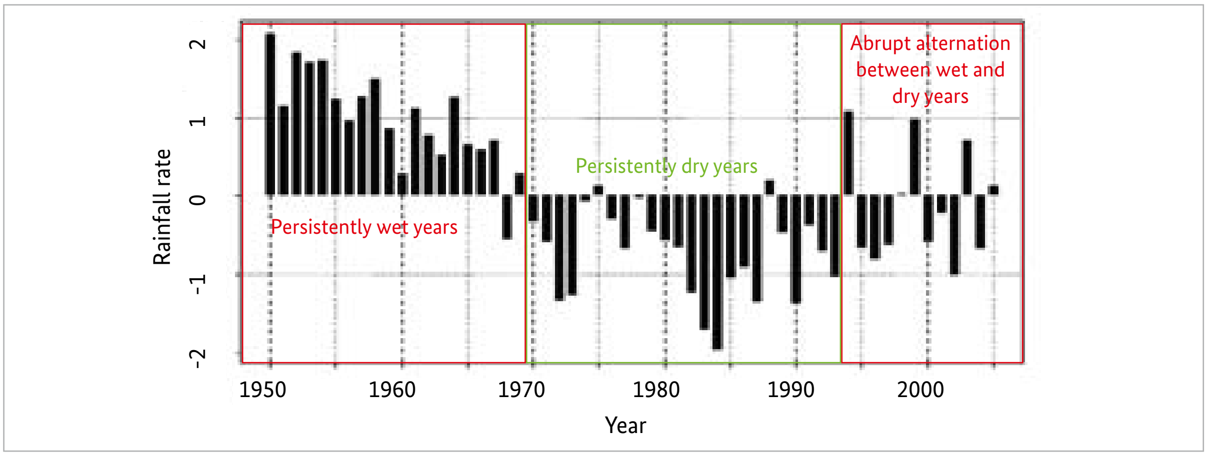
3.1 The perspective of climatologists

The Sahel has always been a region with a high degree of climate variability over the same year, from year to year and from one area to another. Meteorological analyses based on data beginning in 1920 show the existence of distinct periods for the Sahel in terms of rainfall, with a southward shift in isohyets of around 200 km.

Analysis of the rainfall rate in the Sahel[6] reveals the following climate periods (see diagram below):

1. 1950-1968: a period of high rainfall with year-to-year variability and an overall downward trend;
2. 1968-1993: a dry period with high year-to-year variability;
3. 1993-2006: a period of very high year-to-year variability with humid years alternating with dry years.

Figure 1: Rainfall rate in the Sahel



Source: Sarr & N'Djafa Ouaga (2009)

Abrupt changes in the climate, with wet years alternating with dry years, increase the likelihood of droughts and floods.

Temperatures in West Africa rose by an average of 0.5-0.7° C between 1951 and 2001, with an increase of around 0.7° C in the minimum temperature and 0.35° C in the maximum temperature (Sarr & N'Djafa Ouaga, 2009).

These changes in the climate increases risks to crop, forest and rangeland systems in the Sahel, which are already severely affected by soil degradation, the loss of vegetation cover and growing population pressure. Climate change makes it increasingly difficult for farmers to obtain and manage the water they need for their farming activities (Kunze, 2001).

6 Positive values indicate years registering rainfall levels exceeding the average for the period 1950-2006, and negative values indicate years registering rainfall levels lower than the average for that period.

The climate models developed by the Intergovernmental Panel on Climate Change (IPCC)[7] are of limited use in making climate forecasts for the Sahel. There is still a great deal of uncertainty, particularly with regard to rainfall levels. Some climate models predict that the effects of climate change will both increase and decrease rainfall levels. There is, however, unanimous agreement among climatologists that, by 2050, average temperatures will have risen by 3.5° C in the Sahel.

There are no widely accepted regional climate prediction models to provide more accurate climate projections and guide political decisions on how to adapt for climate change in the different sectors (crop growing, livestock raising, water management, health, transport, etc.). In the absence of relevant climate models, Hiernaux (2010) proposes the use of past scenarios to develop scenarios for the next two decades, assuming a 1.5° C rise in temperature by 2020.

Scenarios (according to Hiernaux, 2010)

Scenario 1: the situation prevailing since 1991 continues, i.e. rainfall levels vary sharply from one year to another, with a 90-day growing season.
Scenario 2: period of high rainfall comparable to that observed in the region between 1950 and 1967, with a growing season of between 90 and 120 days.
Scenario 3: period of low rainfall comparable to that observed in the region between 1968 and 1990, with a growing season of between 60 and 90 days.

In the absence of reliable projections for the Sahel area, this study analyses each SWC/SPR technique in terms of how it would fare in each of the three different scenarios. In this uncertain context, SWC/SPR measures are no-regret measures, which contribute to combating soil degradation, improving water management and optimising the efficiency of crop and livestock farming. This makes farmers better able to adapt to any climate changes that may occur.

No-regret measure

A measure with immediate benefits which, although adopted for other reasons, makes a positive contribution to climate change adaptation.

Source: Klein (2003) : 14

3.2 The perspective of farmers and livestock keepers

Regardless of scientific analyses, farmers and livestock keepers also have their own perceptions about the effects of climate change now and over the past few decades. Table 3 shows the findings of a survey on perceptions of climate change (Amoukou, 2009).

7 ACMAD, Niger, has analysed 23 climate models for the Sahel, five of which have proven to be useful in interpreting the climate of the Sahel satisfactorily. The IPCC has not yet taken these five models into consideration. Source: communication at the colloquium hosted by the Secrétariat international francophone pour l'évaluation environnementale (SIFEE) on 26-29 May 2009 in Niamey, Niger.

Table 1: Climate change as perceived by farmers and livestock keepers in Niger

Subject	Perception of climate changes by farmers and livestock keepers
Rainfall	• onset of the rainy season fluctuates • rainy season ends early • rainy season shortened by at least 4-6 weeks • less rainfall outside rainy season (such as 'mango rains') • dry spells at the start and in the middle of the season, lasting more than 15 days and sometimes up to 45 days • fewer days of rain and unevenly distributed • decreasing volume and intensity of rainfall • heavy rain less frequent
Wind	• strong, very dusty winds throughout the season • monsoon less frequent in the rainy season
Temperature	• rising temperatures • hot weather all year round

While some of the observations made by local people coincide with scientific analyses, such as rising temperatures, others, such as the decline in the total volume of rainfall, are not yet backed by statistics. Farmers refer more to creeping changes than to extreme weather events leading to floods or severe droughts.

According to information provided by the African Centre of Meteorological Application for Development (ACMAD), no clear definition has yet been formulated for extreme weather events, such as heavy rain, for the West Africa region. This can be explained by the fact that the impact of rainfall can vary from one area to another. For example, 20 mm of rain falling in an arid area that usually receives no more than 80 mm of rain a year can have adverse effects.

There is, however, unanimous agreement among experts that extreme weather events are becoming increasingly frequent in the Sahel. In 2009, it was observed that floods in certain areas of the West African sub-region coincided with droughts in neighbouring areas, an unprecedented phenomenon.[8] Local observations are therefore very important, because they can help to anticipate the difficulties farmers might face, facilitating the development of adaptation strategies.

GIZ developed the concept of climate proofing to analyse the effects of climate change in the areas covered by its projects and programmes and define appropriate climate change adaptation measures. The different categories of climate change commonly observed are shown in the Table 2.

Climate proofing

Climate proofing is a tool developed by GIZ, which provides a methodological framework to facilitate the identification and systematic analysis of the effects of climate change and the integration of relevant adaptation measures into development plans, programmes and strategies (country, sector and community level).

The results of climate proofing in various countries have highlighted the key role of SWC/SPR measures in increasing the resilience of agricultural and environmental systems to the effects of climate change. In the rural context, the choice of actors involved at the commune level, sectoral investments and development projects have led to SWC/SPR measures being systematically integrated into the range of interventions undertaken.

8 Information provided by the IFRC at PRESAO 13.

Table 2: Types of climatic changes, direct effects and examples of possible responses

Changes	Direct effects	Possible responses
• Onset of rainy season fluctuates • Rainy season ends early • Rainy season shortened by at least 4-6 weeks	→ Shorter rainy season ↓↓ Some local varieties of millet fail to complete their cycle	Research into and selection of short-cycle varieties Early sowing
• Long and frequent dry spells (lasting more than 15 days and sometimes up to 45 days) • Decline in the number of days of rain • Heavy rain less frequent • Rainy season ends early	→ Erratic distribution of rain ↓↓ Less/no water for plants at critical stages in the growth cycle ↓↓ Increased plant stress	Research into and selection of varieties more resistant to dry spells. Sowing of a wider range of varieties with different cycles and a greater diversity of varieties **Increase in the amount of water available to plants thanks to SWC/SPR techniques**
• Strong, very dusty winds throughout the season	→ Increased evaporation of water → Plants buried by sand ↓↓ Resowing required	Regreening (trees) of crop fields and rangeland Shelter belts/hedgerows
• Rising temperatures	→ Increased soil temperature → Increased evaporation of water ↓↓ Increased plant stress	Regreening (trees) of crop fields and rangeland Mulching Conservation agriculture *(zero or minimum tillage)*
• Heavy rain and violent downpours	→ Rainfall results in sheet runoff causing surface erosion ↓↓ Floods cause different kinds of damage depending on what stage of the growth cycle the plants are at	**Protection of land from erosion by means of SWC/SPR measures**

The table shows agronomic solutions only. It does not include other strategies developed by farmers and lifestock keepers on their own. Although far from exhaustive, this overview shows how SWC/SPR measures can contribute to addressing problems caused by dry spells and the early cessation of rains at the end of the season and providing protection against heavy rains. The table also shows that there is no cure-all remedy and that a range of measures is required to mitigate the effects of climate change.

4 Resilience-building SWC/SPR measures

4.1 How SWC/SPR measures work

SWC/SPR measures aim to achieve various goals: (i) improve water management, (ii) increase the productivity of cropland, forestland and rangeland and (iii) ensure sustainable management at the environmental, social and economic level. With regard to the beneficiaries, the goal is to improve food security by guaranteeing, increasing and diversifying production to enable them to cope better in the lean season. Their income increases and comes from more diversified sources, which contributes to reducing poverty. In social terms, the goal is to improve the organisation and capacities of rural communities, promote the rational use of natural resources and prevent conflicts over them. These measures also contribute to raising the water table and making water more readily available to people and livestock. In environmental terms, they improve the ecology of the areas in question by protecting the land against erosion, increasing soil fertility and conserving biodiversity.

SWC/SPR measures therefore provide people living in these areas with a more stable livelihood, reduce their vulnerability to external factors, such as climate change, and contribute to increasing their resilience.

SWC/SPR measures are implemented taking into account the topographical units of the entire watershed, which generally include plateaux, slopes, pediments and valley bottoms (Figure 2). The topographical units have different types of soil, vegetation and uses and are often exploited by different groups of users under different forms of land tenure.

The plateau areas are communal lands with shallow, infertile, stony soils. Uses include grazing for livestock and the collection of wood, straw, fruits, bark and other secondary products. The land and vegetation on the plateaux are often severely degraded due to overuse.

Slopes also have shallow, stony soils with some grass and bush cover. Runoff water flowing over the plateaux and steeper slopes hollows out gullies and causes landslides, which leads to serious degradation of the hillsides. These areas are of limited use as communal rangeland for livestock.

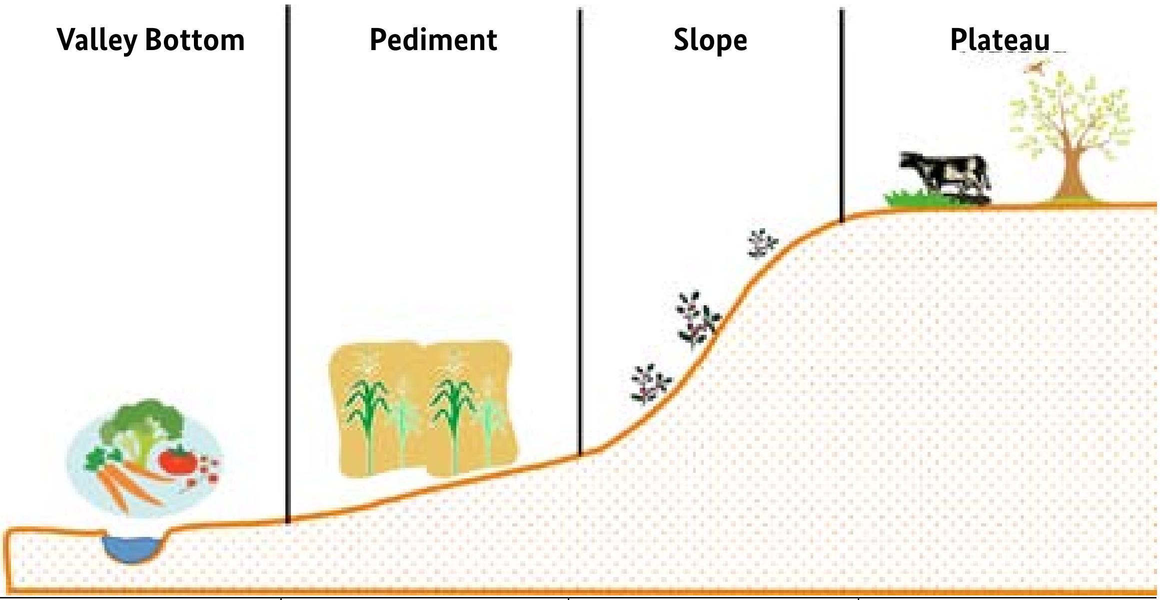
Pediments are located in the piedmont areas of the plateaux. They are gently sloping areas with deeper, more fertile soils. These are the main areas used for growing rain-fed crops. Plots are farmed by individual farmers who grow food crops. The straw is used as forage for livestock in the dry season. This type of land is prone to sheet erosion and gully erosion caused by surface runoff flowing over the plateaux and down the slopes.

The valley bottoms have deep, more fertile soils enriched by fertilising elements from upstream areas. Bottomlands are used to grow irrigation crops during the rainy season. During the dry season, the shallow water tables are used to irrigate off-season subsistence crops and cash crops. Plots of land in the valley bottoms are farmed by individual farmers, although there are also sometimes communal grazing areas for livestock. The concentrated flow of water from upstream areas can pose a serious threat to bottomlands. Although it carries fertilising sediment with it, it can also cause severe gully erosion and the siltation of land and hydro-agricultural infrastructures.

There is no one-size-fits-all technical solution; it is necessary to determine the most suitable measures in each case, taking into account the topographical units to be improved and subsequent land uses. An assessment of the watershed as a whole is made to choose a combination of techniques and approaches adapted to the area’s specific agro-ecological conditions (rainfall, topography, soil properties and structure, type of degradation, vegetation cover, watershed influence, etc.), which must also be feasible and within the means of the farmers and have perceptible direct effects.

The way in which SWC/SPR measures work is relatively simple. The overland flow of rainwater is slowed or stopped, increasing the infiltration of water into the ground. The loss of rainwater and fertilisers (manure and chemical fertilisers) is therefore reduced, and more water is available to both cultivated and wild plants. The infiltrated water is stored in the soil or drains deeper to recharge the water table, which can rise by several metres.

Figure 2: Toposequence diagram



	Valley Bottom	Pediment	Slope	Plateau
Type of soil	Fertile alluvial soil	Deep, fairly fertile collu-vial soil	Shallow stony soil (or sandy soil in the case of dune stabilisation)	Shallow, infertile soil, duricrust outcrops, barren areas with hardened soil crust
Use	Individual plots with: • irrigated crops • market gardens Communal grazing and watering areas	Individual plots with rain-fed crops	Communal land with some grazing areas	Communal land for: • grazing • collection of wood and other products (fruits, medicinal plants)
Risks	Gully erosion Siltation Flooding	Gully erosion Sheet erosion	Gully erosion Landslides	Sheet erosion Gully erosion Wind erosion
SWC/SPR measures	Water-spreading weirs Small-scale dams Village irrigation schemes Assisted natural regene-ration Permeable rock dams Contour stone bunds	Contour stone bunds Permeable rock dikes Zai planting pits, manure/ compost Mulching Grass strips Permeable rock dams	Hand-dug trenches Permeable rock dams Contour stone bunds Dune stabilisation	Semi-circular bunds Nardi/Vallerani trenches Contour bunds (Firebreaks)

4.2 Implementation approach adopted by German Cooperation

Experience has shown that the implementation of SWC/SPR measures requires a participatory approach and the close involvement of the beneficiary communities and the governmental, non-governmental and private actors concerned. The main stages of such a process are shown below (Table 3).

A crucial stage in the process is the diagnostic assessment of the watershed or area of land to be improved with the participation of all the different watershed users and, if necessary, users in adjacent downstream areas. It brings to light any potential conflicts over land tenure, particularly in relation to areas on the boundary between villages, and any conflicting interests that there may be over certain areas or strategic natural resources.

While joint planning for the development of individual plots is relatively easy, the implementation of SWC/SPR measures on communal land requires knowledge of land tenure, discussions, negotiations and agreements (contracts) on the future use and exploitation of the areas in question. This is particularly true in the case of forestland and rangeland, where exploitation cannot begin until several years after the measures have been introduced. In such cases, it must be clearly established who is responsible for the upkeep and oversight of the land during the first few years, who the beneficiaries are and how the resources can be used in a sustainable way once they are ready to be exploited. The outcome of this consensus-building and decision-making process is recorded in a local agreement, which establishes the rules governing the development, maintenance and exploitation of communal land once the improvement measures have been implemented.

There are various tools that can be used to plan improvement measures. Aerial photographs satellite images and thematic maps are often used to ensure that all the actors have all the relevant elements of information about the area. The farmers choose the SWC/SPR measures best suited to each landscape unit, taking into account problems of water and wind erosion, pedimentation, gully erosion, the degradation of valley bottoms and seasonally flooded depressions, etc.

On the basis of the assessment, land development schemes are formulated (Box 1), and yearly and multi-year plans are established to implement the SWC/SPR measures. It is important for these land development schemes to fit in with other territorial plans, such as commune and regional development plans.

Good organisation in the beneficiary community is crucial to the successful implementation of the measures. The degree of organisation required depends on the complexity of the SWC/SPR measures being implemented. The construction of complex communal structures, such as water-spreading weirs or dams, requires a more sophisticated level of organisation than the construction of contour stone bunds on individual plots, for example. The projects examined in this report worked with village and inter-village committees with different forms of organisation. This approach was strongly promoted to create permanent local development bodies at the village level, at the watershed level and, more recently, at the commune level.

In Niger, for example, a law was prepared to create village land management organisations, but its publication coincided with the decentralisation process undertaken in the late 1990s. Commune authorities were established, and fund providers adjusted to the new situation. Unfortunately, there was little transfer of knowledge of management approaches from the former land management bodies to the new commune authorities.

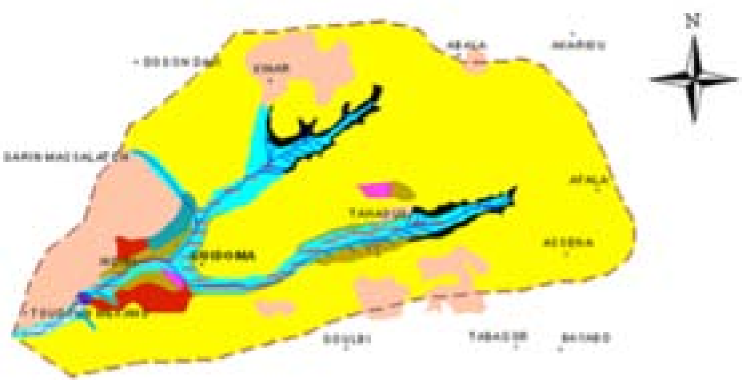
Box 1: Valley development schemes in Niger

A valley development scheme (SMEV) is a planning document that describes the different aspects of the development of a watershed as a whole. It includes a description of the different types of land use and legal reports on ownership, infrastructure and regulations governing access to resources. It establishes a medium-term plan of action with measures aimed at improving the area as a whole.

In the preparatory phase of the scheme, an analysis is made of the baseline situation with the participation of all the actors. The second step is to develop a common vision and decide on the actions required to achieve it. Representatives from the new land rights commissions, municipal authorities and the villages concerned, all the groups of users in the valley and government agencies responsible for sector planning are involved in this task.

The advantage of such schemes is the high level of ownership and acceptance, thanks to the participatory approach used to formulate the plan, capacity building and the involvement of all the stakeholders. The role of the land rights commissions, which are not yet properly established, has been strengthened. There are, however, also some disadvantages: the formulation of such schemes is costly and they are not officially recognised as a landuse planning tool in Niger. The Government of Niger is currently in the process of harmonising various territorial planning approaches, with a view to establishing an official approach.

Illustration: Land use scheme for the Guidoma watershed in the commune of Affala in Niger



(yellow)	Plateaux	Crops
(black)	Terraces	Pasture
(blue)	Valley bottomlands	Crops
(pink)	Dunes	Crops
(magenta)	Control plots	Pasture
(red)	Pebble plains	Pasture

Table 3: Main stages in the participatory process

- introduction (information, awareness);
- participatory rural appraisal (PRA), including interpretation of aerial photos and satellite images and participatory mapping (sometimes digital);
- clarification of land boundaries with neighbouring villages;
- yearly and multi-year planning;
- land management organisation;
- support for the implementation of improvement measures;
- annual self-assessment and replanning;
- strengthening and legal recognition of village natural resource management bodies;
- local agreements on the management of improved communal land.

Projects adjusted to the new decentralised government structure tended to assign project ownership and the responsibility for upkeep to the commune authorities. Since the communes were created, they have played the role of project owner in the implementation of complex SWC/SPR measures. It is their job to oversee the whole process from planning and identifying and selecting the plots to the implementation of the works.

Training and support to improve local organisation is all the more necessary in the case of major communal structures requiring regular upkeep and the establishment of funds to pay for repairs. Attempts by user committees and commune authorities to establish upkeep funds have not yet produced satisfactory results, and efforts to develop a more operational mechanism continue.

4.3 Replicating SWC/SPR measures

Ex-post evaluations of the projects studied reveal that the SWC/SPR structures put in place were on the whole well maintained, and supporting measures were adopted in almost all cases to continue with the development of the land. The replication of SWC/SPR measures by farmers in other areas, however, has fallen short of expectations. The wider implementation of SWC/SPR measures has been hindered by the failure of farmers to take the initiative and replicate the techniques themselves. The techniques that could be replicated by farmers on their own are physical measures, such as contour stone bunds, permeable rock dikes, hand-dug trenches and semi-circular bunds, which, unlike larger-scale works, do not necessarily require external support. Farmers cannot afford the investment required for the kind of large-scale structures constructed in valley bottoms, such as water-spreading weirs and small-scale dams; in interventions of this kind, their role is confined to maintaining and operating the structures.

Exit strategies assume that SWC/SPR techniques are sufficiently cost-effective to motivate farmers to continue to implement them on their own. However, experience has shown that only a minority of farmers continue to implement these techniques without outside assistance. A survey conducted in Niger in 2009 reveals that their failure to take the initiative when there was no project to support them was not due to a lack of knowledge; the majority of farmers admitted that they had the expertise to implement SWC/SPR measures. There are several hypotheses to explain this situation:

- The use of the food for work approach by some of the projects provides an incentive by enabling people to generate income while implementing the measures, but it also has a demobilising effect when the farmers have to continue the activities on their own after external funding has come to an end.

A contour bund inspected by engineers © GIZ / Martina Wegner

- Farmers may be deterred from making long-term investments in such measures by the fact that they have other immediate needs to meet and that land rights are not guaranteed.
- The technical complexity of some measures may deter farmers; external support is needed for some measures requiring a high level of engineering expertise (permeable rock dams, water-spreading weirs and small-scale dams).
- SWC/SPR measures requiring large-scale logistics or financial mobilisation are not easy to organise without the support of a project or partner. This is the case of measures involving the transportation of large blocks of stone from quarries located at a distance from the site or the purchase of cement (water-spreading weirs).
- In the case of very diversified livelihood systems based on several different economic pillars to minimise risk, commitment to just one of them is not as strong as in a system where agricultural production is the only means of living.
- The complexity of social relations can hinder the implementation of improvements; working together to improve a communal site is no easy feat. Community organisation entails the risk of disputes and conflicts and requires capable local leaders. Experience has shown that measures implemented on individually owned land are more sustainable and more easily replicable than those implemented on communal land.
- The allocation of limited resources, such as family help, to carry out the work is another factor to be taken into account. Using family members to implement SWC/SPR measures in the villages may be less profitable than allowing them to emigrate to work in urban centres.

In view of the rapid and relentless pace of land degradation and the fact that most farmers cannot afford to invest in SWC/SPR measures themselves, provision should be made to make funding from the government and the international community available for this purpose. This would permit the implementation of SWC/SPR measures on a wider scale. Private service providers and NGOs could be commissioned to implement SWC/SPR measures under the technical supervision of government authorities.

4.4 Conclusions

SWC/SPR measures have the potential to be effective in overcoming the effects of climate change, providing a more secure livelihood for the rural population and improving their standard of living. They can be implemented on a wide scale and benefit thousands of farmers and livestock keepers.

The strong participation of the beneficiaries in implementing the SWC/SPR measures is an effective means of mobilising the rural population. This cuts costs for the projects and is an enormous investment in the productive resources of the beneficiaries. The close involvement of the beneficiaries also serves to strengthen their organisational and management capacities and their expertise in SWC/SPR techniques.

SWC/SPR measures are an effective way of improving the management of water resources and reducing degradation of the soil, vegetation and biodiversity, which helps to increase and maintain crop, forest and forage yields. They therefore contribute to mitigating the effects of climate change and significantly improve food security and the resilience of the rural population to external shocks. Including the rational use of natural resources in territorial planning increases land tenure security, reduces the risk of conflicts and incorporates this component into commune and regional plans.

The implementation of SWC/SPR measures is a promising solution for countries in the Sahel, but it requires a long-term commitment. Implementing these measures over a wide enough area to achieve a significant impact, not just on individual plots but also on entire areas, is a task that will take several generations. It also requires a sustained national effort on the part of governments to ensure effective community organisation and oversee the efforts of communities to implement, operate and maintain SWC/SPR measures. Without this external oversight and guidance, the implementation of SWC/SPR measures will lose momentum. While international support is necessary to finance investments, experience has shown that it is long-term commitment that achieves positive results. The traditional short-term project can only contribute to a specific investment in the broader land improvement framework.

5 Main land improvement techniques

The following chapters provide a description of the main techniques in accordance with their position in the toposequence (see Figure 2).

A) Improvement of plateaux
1. Semi-circular bunds
2. Nardi/Vallerani trenches
3. Contour bunds
4. Firebreaks

B) Improvement of slopes
5. Hand-dug trenches
6. Permeable rock dams
7. Dune stabilisation

C) Improvement of pediments
8. Contour stone bunds
9. Permeable rock dikes
10. Zai planting pits
11. Use of organic matter: manure and compost
12. Mulching
13. Assisted natural regeneration

D) Improvement of valley bottoms
14. Water-spreading weirs
15. Small-scale dams
16. Village irrigation schemes

5.1 Semi-circular bunds (Demi-lunes) (for crops and forest/rangeland)

Description of the technique

This technique involves building low embankments with compacted earth or stones in the form of a semi-circle with the opening perpendicular to the flow of water and arranged in staggered rows. They are used to rehabilitate degraded, denuded and hardened land for crop growing, grazing or forestry. Depending on their purpose, the areas inside the semi-circular bunds, enriched with organic fertiliser, are used for growing cereals (crop crescents) and for planting trees, bushes and/or grasses (forestry and pastoral crescents).

Figure 3 : Semi-circular bunds on cropland and forest/rangeland

Source: PASP, 2003

Staggered semi-circular bunds for growing crops

Semi-circular bunds with millet growing in them

Forest/rangeland semi-circular bund

Forest/rangeland semi-circular bund with vegetation

How it works

Semi-circular bunds, positioned perpendicularly to the flow of surface water and in staggered rows, capture runoff, providing the plants inside them with the water they need. They therefore reduce the loss of water and the fertile layers of the soil. In the medium term, rich sediment builds up behind the semi-circular bunds, which helps to protect and restore the land. The bunds ensure that the manure placed around the plants inside them is not washed away by heavy rains, and the ridge of the bund protects young plants from the wind and wind erosion.

What it is used for

Semi-circular bunds are designed for use on crop, forest and rangeland. They are constructed on gently to moderately sloping pediments and plateau areas that are degraded, denuded and/or affected by soil crusting.

Potential for climate change adaptation

Like other erosion control measures, semi-circular bunds slow down runoff and enable the harvested water to be used to good effect. This is particularly advantageous when rain is scarce (scenario 3), as the semi-circular bunds channel water towards the plants, increasing the moisture available to them. When they are used for reforestation, they increase the rate of survival of the trees planted in them. Cropland bunds enable crops to survive dry spells. Earthen bunds are not, however, suitable in a scenario with heavy rainfall. They do not allow water to filter through, which can result in the soil inside them becoming waterlogged and the plants being flooded. This can lower yields in the case of crops that do not tolerate excess water. In such conditions, stone bunds are preferable.

Agro-ecological and socio-economic effects

Semi-circular bunds on forest/rangeland can achieve a remarkable regreening of the environment and promote biodiversity. Cropland bunds constructed on abandoned farmland increase millet yields by 180 kg and straw yields by 400 kg per hectare per year.

Sites improved with semi-circular bunds for reforestation produce one stere of wood per hectare per year after ten years. The value of this production can increase further from the fifth year onwards to around 850,000 CFA francs per hectare.[9]

Technical challenges

In the event of heavy runoff, a considerable amount of water accumulates inside the semi-circular bunds, and the ridges must be strong enough to withstand its weight. If the water overflows, it can create gaps in the bunds or cut out channels around the sides of them.

The maximum density and height of semi-circular bunds for a particular plot are calculated based on projected rainfall. Some plants, such as millet, do not tolerate excess water.

After dry years, forest/rangeland semi-circular bunds may have to be re-sown with grasses and replanted with trees, which means that they must be protected from grazing animals the following year.

Success factors

At some sites, rainwater infiltration increases in the first year after the semi-circular bunds have been constructed, but if the land is not hoed, this effect declines considerably in successive years. The land must therefore be hoed each year.

In the case of forest/rangeland semi-circular bunds, the availability of tree and grass seeds and seedlings is a vital factor. In the PDRT and PASP projects in Niger, the villages had nurseries, and members of the village land management committees collected grass seeds from rangelands to sow in the semi-circular bunds. Other projects in northern Niger promoted semi-circular bunds using the highly labour intensive approach in which those who work are paid (for example, food for work as a means of integrating former rebel fighters). The results were, however, questionable.

9 According to PASP figures

Sustainability

The earthen ridges around cropland bunds need to be rebuilt each year. It is recommended that the ridges of forest/rangeland bunds be maintained each year and raised if overflowing has occurred. Forest/rangeland sites should be protected from grazing animals in the first two to three years, until the vegetation is well established. This requires good community organisation.

Cost items

Cropland semi-circular bunds
Labour: 50 man-days per ha for the following work:

- marking out the contour line
- laying out the lines of the semi-circular bunds in staggered rows
- digging the microcatchment
- forming the ridge downhill of the microcatchment
- applying organic fertiliser (around 1 t per ha per year).

Other costs: 10 cartloads of manure.

Forestland semi-circular bunds
Labour: 100 man-days per ha for the following work:

- marking out the contour line
- laying out the lines of the semi-circular bunds in staggered rows
- digging the microcatchment
- forming the ridge downhill of the microcatchment
- digging the holes
- planting the trees
- sowing grass on the ridges.

Sylvo-pastoral semi-circular bunds (demi-lunes)

Other costs

- 625 tree seedlings
- 15 kg of grass seed
- cost of transporting 625 tree seedlings (2 cartloads)
- 120 seedlings to replace trees that die.

5.2 Nardi/Vallerani trenches

Description of the technique

Nardi/Vallerani trenches are microcatchments 4 m long and 0.5 m wide. They are made using a tractor-pulled plough specifically designed for this purpose. The Nardi plough cuts a furrow perpendicular to the slope, throwing up a ridge on the downhill side and thereby creating a barrier on that side of the furrow. The number of trenches varies according to the gradient of the terrain and the type of soil: the recommended number of microcatchments for flat or gently sloping terrain is between 250 and 400 per hectare, with the rows spaced 5 to 7 m apart; and for steeper slopes, the rows should be spaced 3 to 4 m apart, with a density of up to 600 microcatchments per hectare. In each Nardi/Vallerani microcatchment, two or three trees are planted or sown by direct seeding and then separated when they come up. Perennial grasses are sown a year later to allow the trees to become established first. The choice of species largely depends on the use to which the improved land is to be put and the priorities of the beneficiaries. It is recommended that the improved site be protected from grazing animals for at least three years to give the trees time to grow and the grass time to reproduce naturally, although the exact amount of time required will depend on the type of trees planted and how degraded the site is.

Nardi/Vallerani trenches are generally combined with scarification, which is carried out using a tractor-pulled scarifier. The strips between the trenches are scarified a year after they have been dug. These scarified strips are sown with perennial grasses at the same time as the trenches. The trees planted the year before are a year old, and the risk of the saplings being choked by the grass is minimal.

How it works

Runoff collects in the Vallerani microcatchments, improving the infiltration of water into the soil and the retention of water for the plants growing in them. They also serve to loosen the soil and improve the plants' access to nutrients. Windborne seeds are trapped in the microcatchments, which helps to build up the natural grass cover.

What it is used for

The technique is designed to restore degraded and encrusted forests and rangelands: hardened land on the plateaux, low-gradient slopes in highland areas and lateritic pediments.

Potential for climate change adaptation

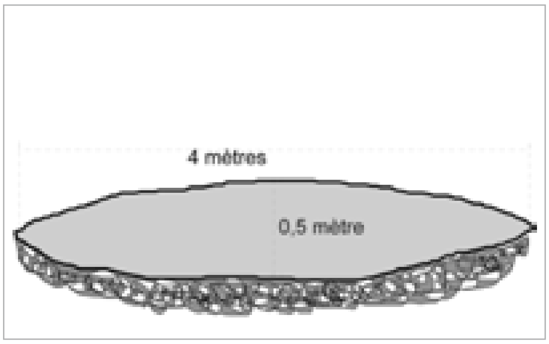
This technique is particularly effective in scenario 3, in which rainfall is low, as the microcatchments retain what water there is and make it available to the plants growing in them.

Like all revegetation and reforestation measures, in the medium term, this technique is effective in protecting the land against water and wind erosion and rehabilitating barren land with no vegetation. In wet years, the microcatchments protect the land downhill from excessive runoff by retaining part of the water.

Implemented on a wide scale, this technique can extend and improve the quality of forest and rangeland and reduce the problems for livestock keepers in years when the quality of pasture is not good. In the medium and long-term, the technique can increase the supply of firewood, timber and other wood products. Even in the short term, this technique increases the production of straw, which can be used as forage, for making roofing and mats or sold to generate extra income.

Figure 4 : Construction and effects of Nardi/Vallerani trenches

Source: PASP



Construction of Nardi/Vallerani trenches

Plateau with trenches recently dug using a Nardi plough

Plateau with Nardi/Vallerani trenches, which has been scarified and planted with grass and trees (age: 2 years)

Plateau with Nardi/Vallerani trenches, planted with grass and trees (age: 5 years)

Agro-ecological and socio-economic effects

This technique used on plateaux and pediments contributes to the revegetation of barren areas. According to PASP figures, the average additional output of dry matter in the form of herbaceous biomass was approximately 540 kg/ha, compared with less than 100 kg per hectare on land where the technique was not applied. Even in years when rainfall is low, the improved areas continue to produce between 200 and 450 kg of biomass per hectare.

These forest/rangeland sites help communities to bridge the hunger gap, and in lean years, the women collect forest products, such as leaves, pods and fruit to supplement their diet. Sometimes, small quantities of wood are sold to buy cereals. Straw is sold and/or used for roofing, doors and fencing. Ingredients for medicinal products and other secondary products, such as gum arabic, are collected from the trees and bushes.

Technical challenges

It is recommended that trees and bushes be planted and/or sown the second year after the microcatchments have been established, before the land is scarified to sow grass. This prevents them from being choked by the grass, and the absence of grass cover reduces the risk of the young trees being eaten by stray animals.

The Acacia holosericea species is not considered suitable for reforestation purposes, owing to its limited life span. Vallerani microcatchments are recommended for use on well-structured soils (soils with high clay content and lateritic and stony soils). On poorly structured soils (sandy, silty soils), the furrows tend to close over after the first rains, rendering them ineffective.

Success factors

The Vallerani microcatchment technique is designed for forest/rangeland sites. In order to ensure the sustainability of the investment, it is necessary to take the following steps before constructing the trenches:

- ensure that the communities are motivated to invest in the measure;
- ensure that the communities have the capacity to do the work and the technical expertise required to implement the measures and develop and manage the sites;
- ensure that there are sufficiently strong local and regional markets for forest/rangeland products;
- clearly define the objective (intended uses after improvement);
- clarify ownership of the land to be improved;
- jointly define who the beneficiaries will be;
- formulate an agreement establishing rules governing the protection, use and upkeep of the site.

The right grass species must be chosen to ensure the successful establishment of vegetation cover, taking the following factors into consideration:

- needs of livestock keepers and/or agro-pastoralists;
- species suited to environmental conditions, taking into account climate changes;
- palatability and nutritive value of the species and any secondary uses they may have;
- availability of seeds;
- potential for marketing products.

Sustainability

The success of the operation depends largely on effective management of the site by the management committee, which must ensure that the site is properly maintained, enforce the rules established for its management and impose sanctions when the rules are not observed.

Cost items

Microcatchments on low-gradient terrain
- 1 Nardi plough (imported from Italy)
- tractor hire.

Labour
- 8.5 man-days per ha.

Other costs
- 800 seedlings and 15 kg of seeds (plus transport and replacement plants).

5.3 Contour bunds for crops and forest/ rangeland

Description of the technique

Contour bunds for crops
A contour bund (*banquette* in French) is a rectangular structure consisting of bunds built with earth or stone or a combination of both, which can be permeable or impermeable. The bottom bund is up to 80 m long, and the wingwalls extend up to 15 m upslope. The contour bunds are built in staggered rows along the natural contour of the land with the open end facing uphill. Patches in the same row are spaced 6 m apart, and the rows are positioned about 25 m apart, depending of the gradient of the slope.

Downslope of the structure, a water collection ditch 0.50 m wide and 0.30 m deep is dug. The earth excavated from the ditch is piled up and compacted to construct the main bund. When used for growing crops, a third of the total surface area inside the contour bunds is loosened by subsoiling. The remaining two thirds of the surface are left unworked and serve as a catchment area. This doubles or triples the volume of water available to crops. Trees are planted along the main bund to stabilise the structure.

Contour bunds for forest/rangeland
The technique is as described above, except that the sizing is slightly different. The main bund of patches used for this purpose is up to 100 m long and the rows are spaced up to 30 m apart.

An advantage from the perspective of watershed development is that contour bunds constructed on plateaux areas protect areas downstream against heavy runoff. » *Figure 5*

How it works

The bunds capture and retain runoff for several days. Infiltration of the water into the soil increases, and there is a gradual build-up of sediment behind the bunds, creating favourable conditions for the establishment of vegetation.

Figure 5: Contour bunds capture water and contribute to rehabilitating degraded land

Rows of contour bunds es. Source: FAO

Construction of contour bunds. Source: CILSS

Contour bunds for crops increase the area of land that can be farmed and its productivity thanks to their capacity to retain runoff and the shelter provided by trees planted along the bottom bund, which protects the crops.

What it is used for

In Niger, contour bundsfor forest/rangeland are used to restore land in plateau areas which have been completely degraded and denuded by severe water and wind erosion. Contour bundsfor growing crops are recommended for the restoration of pediments, particularly in areas where land-use pressure is high. The technique is recommended for areas with a low gradient and rainfall of less than 600 mm.

Potential for climate change adaptation

In a low-rainfall scenario (scenario 3), the construction of contour bundsis an effective technique, as it increases the amount of water available to crops and vegetation. Patches with impermeable bunds are not appropriate when there are heavy rains, as the flow of water can destroy the bunds. In a high-rainfall scenario (scenario 2), contour bundsare not a very effective measure, because their capacity to retain water can cause them to become waterlogged, which can damage plants and crops that do not tolerate stagnant water.

Agro-ecological and socio-economic effects

The construction of contour bunds helps to restore vegetation cover on vast areas of denuded land from the first year after they are established. The catchments capture large quantities of water, promoting plant growth and replenishing the water table. The construction of contour bunds upstream of river basins reduces the risk of gully erosion and siltation downstream. According to the CILSS, the main advantage of contour bundsis that they protect land further downstream.

Contour bunds for growing crops can be used to restore land that has become unproductive. This technique is not, however, very cost-effective, because of the scale of the work involved.

Good vegetation cover established along the bunds contributes to lowering soil temperature and providing protection from wind erosion along the entire length of the patch.

In Niger, it is mainly women who have benefitted from efforts to rehabilitate land on the plateaux. With the support of development projects, women were able to secure five-year leases from land owners.

Technical challenges

When constructing the contour bunds, it is important to mark out the contour lines correctly and ensure that the earth is firmly compacted. The experience of the PDRT project in Niger shows that this technique using earthen bunds does not always produce satisfactory results:

- the distribution of water in the contour bunds is often uneven, because the terrain is not level, which means that production varies considerably from one area to another;
- when there is heavy rain, runoff accumulates at the lowest point of the collection ditch, which can sometimes cause rilling;
- there is a risk of the patches becoming waterlogged, which can damage the crops.

There are also disadvantages associated with subsoiling in the contour bunds:

- although subsoiling permits rapid, relatively deep infiltration, the water is situated below the level where the roots of young crops or grasses are growing, which means that the infiltrated water is not used optimally in the initial stages;
- the surface of the subsoiled land becomes hard again after several years of cultivation, because the soil structure is broken down owing to a concentration of fine particles of earth in the grooves of the subsoil, which can clog up the pores of the soil.

Success factors

Before constructing the contour bunds, it is essential to clarify the ownership status of the land where the measures are to be implemented and who the users will be, with a view to avoiding disputes later on. This technique transforms unproductive land into land that is economically valuable.

The extensive work required to construct the contour bunds means that the community must be strongly motivated and well organised.

Sustainability

With some upkeep, stone or stone-lined contour bunds last at least 20 years. Earthen bunds do not last as long. Good vegetation cover established along the bunds increases their lifetime. Potential for replication depends on the type of terrain, there being a nearby supply of the materials needed (stone) and finding a logistics partner for the subsoiling.

Cost items

Labour: 54 man-days per ha.
Equipment: pickaxes, shovels, wheelbarrows, water-tube level.
Other costs: hire of machine for subsoiling (1 day per ha).

5.4 Firebreaks

Description of the technique

Firebreaks are a precautionary measure designed to protect forage on rangelands during the dry season. Bushfires are frequent on good-quality rangeland with over 1t/ha of biomass. There are two techniques for creating firebreaks: (i) the manual method and (ii) the mechanised method. In both cases, a 10 to 15 m wide corridor is cleared perpendicular to the prevailing wind direction after the rainy season. The corridor is cleared of all herbaceous vegetation manually, using tools such as rakes, shovels and axes, or mechanically using a tractor pulling a large harrow, a four-wheel-drive vehicle pulling the blades behind it or graders. Trees are pruned, but left in place. » *Figure 6*

How it works

Firebreaks cut vast tracts of rangeland into smaller areas, with a view to limiting damage in the event of wildfire. They can also be established along traditional tracks. The gap in the vegetation makes it easier to put fires out along the corridor, which facilitates rapid access. When the fire reaches the firebreak, there is no combustible material to fuel it and it burns itself out. Firebreaks must be regularly maintained after they have been created.

What it is used for

This technique is used on rangeland with rainfall between 150 and 300 mm.

Figure 6: Creating a firebreak using a tractor or land grader. Source : PASF, Senegal

Creating a firebreak using a tractor.

Creating a firebreak using a land grader.

Potential for climate change adaptation

This technique is particularly important as a precautionary measure in scenario 2, in which rainfall is high, as bushfire only poses a threat in the Sahel area in the dry season following a good rainy season when grass growth is good. In this scenario, firebreaks should be maintained every year.

In a scenario with high year-to-year variability of rainfall levels, firebreaks are a precautionary measure that should be implemented after a rainy season with abundant rainfall.

Agro-ecological and socio-economic effects

Preventing wildfire contributes to safeguarding the fauna and flora over vast tracts of rangeland, which would otherwise be destroyed. It also avoids enormous economic losses in terms of livestock and infrastructure (herding villages, forage). When rangelands remain intact, nomadic livestock keepers tend to stay within their area.

Technical challenges

The lack of financial and logistic resources is a constraint on the creation of firebreaks, and it is often difficult to organise the beneficiaries (nomadic livestock keepers) asked to participate financially or physically in the work required to establish and maintain them.

Success factors

Once the financing has been secured, considerable efforts are required to raise awareness about the need to prevent fires and mobilise the livestock keepers in a particular grazing area to become involved in the work.

Sustainability

The sustainability of firebreaks depends on how well they are maintained. Once they have been created, they need to be cleared every year if grasses have grown over them again. If there is little vegetation growth, they can be maintained once every two years or as required. If they are cleared manually, the communities or commune authorities must be well organised to ensure that the work is properly carried out. Good organisation is also required to ensure an effective response in the event of a fire (mobile unit).

Cost items

Manual method:
- equipment, such as rakes, shovels and axes
- labour.

Mechanised method:
- four-wheel-drive vehicle, tractor or land grader
- harrow
- labour to clear the corridor.

5.5 Hand-dug trenches

Description of the technique

The technique involves manually excavating trenches 3 to 3.5 m long and 0.6 m deep, spaced 4 m apart in staggered rows. This results in around 625 trenches per hectare. The excavated earth is piled downhill of the trenches, which are aligned perpendicular to the slope. In the middle of each trench, a 0.40 m high step is left on which the tree seedling is planted. The tree receives the water it needs from the trench where it collects. The main purpose of this technique is to restore tree cover and prevent water erosion on slopes by reducing the flow of water that threatens land downstream. The trenches reduce gully erosion and pedimentation of areas with a fragile soil structure. The young trees must be monitored for several years to ensure that they are not damaged by stray grazing animals, and any dead trees must be replaced.

Figure 7: Design of hand-dug trenches. Source : PASP (2003)

Row of hand-dug trenches

Slope with hand-dug trenches

How it works

This technique permits the reintroduction of trees on degraded, unfertile land. It contributes to dissipating the force of runoff flow and increases infiltration. Areas restored using hand-dug trenches can subsequently be exploited to a limited extent in accordance with strict controls. This measure has a positive effect on land downstream, which is better protected against sheet and gully erosion. The infiltration of water in the hand-dug trenches also contributes to groundwater recharge.

What it is used for

This technique is designed to restore communal land on slopes and highland pediments.

Potential for climate change adaptation

Hand-dug trenches are beneficial regardless of the climate scenario. They are particularly useful in scenario 3, in which rainfall is low, as they retain water and make it available to the trees growing in them. In years when rainfall is abundant or there are violent downpours, the young trees are protected, as they are planted on a raised step within the trench, although there is a risk of flooding in the event of very heavy rain. Like all afforestation measures, in the medium term, this technique is effective in protecting the land against water and wind erosion. The shade provided by the trees also lowers the temperature of the soil.

Agro-ecological and socio-economic effects

This technique has proved effective in restoring forest/rangeland sites. The progressive development of grass and tree cover continues on the improved sites, where the tree population is up to 20 years old. After around ten years, the average annual production of wood is 1.3 steres per hectare (according to PASP figures).

Technical challenges

The technique is very labour intensive. Work must begin immediately after harvesting when the soil is still moist and workable. A protection and monitoring system is required to ensure that grazing animals do not damage the young trees. The mortality of trees after planting is relatively high (survival rate is about 60%), and dead trees must be replaced systematically during the first three years.

Success factors

Good community organisation is required.

Sustainability

Hand-dug trenches create favourable conditions for restoring vegetation. Although the trenches are progressively filled with sediment, which reduces their capacity to retain water, at the same time, the trees develop and become less dependent on stored water. Once the vegetation cover is established, there is no need for further work on the site.

Cost items

Labour: 110 man-days per ha
- marking out the contour line
- laying out the trenches in staggered rows
- digging two rectangular microcatchments separated horizontally by a flat surface
- making a hole in the central area
- planting the seedlings
- sowing grass on the ridges.

Other costs
- equipment, such as jumper bars, shovels and axes
- 625 tree seedlings
- 15 kg of grass seed
- cost of transporting 2 cartloads of seedlings
- 120 seedlings to replace dead trees.

5.6 Permeable rock dams

Description of the technique

The permeable rock dam is a structure built in gullies using loose rocks and stones and sometimes reinforced with gabions. A filtering layer (blanket of gravel or small stones) is laid in a foundation trench. Further layers of medium-sized and large stones and rocks are laid on top. They are between 0.50 and 3 metres high, and the width of the foundation and the crest depends on the estimated volume of water flow. The structure built across the gully is extended to the sides with the construction of wingwalls that spread the water over a larger area to the sides of the dam. The total width of the structure is generally at least three times its height. The dams can be constructed with or without a spillway. A spillway is required when floodwater flow is stronger. It costs less to construct this type of structure with loose stones and rocks than with gabions.

How it works

Permeable rock dams are used to fill in gullies and control water flow. They slow the flow of floodwaters and spread the water over adjacent land. This improves infiltration, and sediment builds up behind the dams. In time, the sediment fills in the gully. This stops lateral drainage from the land on either side, increasing its productivity. High infiltration upstream of the dam contributes to recharging the groundwater system. These structures are therefore also effective in raising the water table in wells.

What it is used for

Permeable rock dams serve to restore seriously degraded farmland and forest/rangeland. They are also used to raise the water table in the vicinity of wells and protect bottomlands from sand filling and gully erosion. They are used in combination with other measures, such as reforestation and stone bunds, to protect and improve the surrounding area.

Potential for climate change adaptation

Permeable rock dams can be used in scenarios 2 and 3. By dissipating the flow of floodwaters, they ensure better use of rainwater and are therefore important in dry periods (scenario 3). By slowing the flow of water, permeable rock dams also contribute to reducing gully erosion in wet periods (scenario 2) or when there are violent downpours. They protect the land around them and restore and increase the area of land that can be used for growing crops.

Agro-ecological and socio-economic effects

The conservation of water for longer periods and the fine particles of earth trapped by the structure favour the establishment of natural vegetation along it, which helps to stabilise the dam. Seeds are also trapped, favouring the spontaneous growth of grass and trees upstream and downstream, which contributes to restoring and conserving biodiversity. By dissipating floodwater flow, they also contribute to reducing sand filling in valleys further downstream.

As these dams are used in valley bottoms and the beds of seasonal streams to increase infiltration, they can also contribute to raising the water table. Such sites are particularly suitable for horticulture and market gardening, which is important in the off-season. The produce supplements the food available and is an extra source of income.

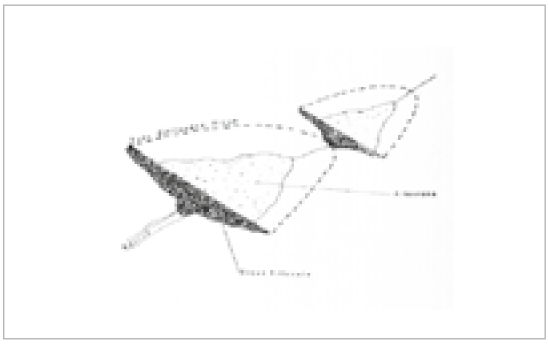
Technical challenges

Depending on the size of the dam, the construction of this type of structure may require a high level of engineering expertise (topographical surveying, calculation of floodwater flow). It also requires a large amount of quarry rocks, which means that the cost of the structure and the labour and transport required is significantly higher than for structures made with stones. As the data required for calculating floodwater flow is often unavailable, the dams must be observed during the first few years, so that they can be reinforced and repaired if necessary.

Success factors

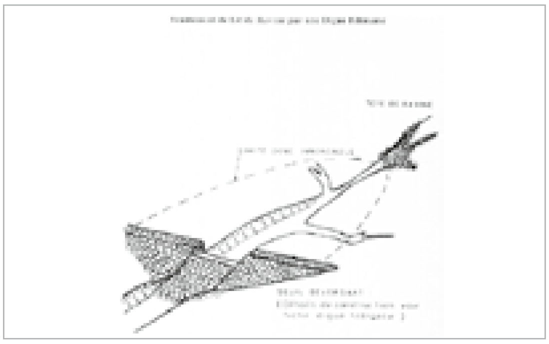
It is important for farmers to have access to partners providing the necessary know-how, means of transport and support for community organisation. The community must be trained to carry out repair work.

Figure 8: Construction of permeable rock dams



Permeable rock dam without spillway. Source: PATECORE

Closing off a gully with a permeable rock dam. Source: PGRNG Mauritanie



Permeable rock dam with spillway: PATECORE

Spillway of a permeable rock dam with stilling basin. Source: PGRNG Mauritanie

Sustainability

The sustainability of permeable rock dams depends on the quality of construction and whether they are maintained regularly. A certain amount of expertise and good community organisation is required to repair any cracks in the dam. Biological measures (sowing grass and planting trees) increase the stability of the structure. The potential for replication depends on the type of terrain and whether there is a supply of rocks nearby.

Cost items

The size of a permeable rock dam can vary considerably from one site to another. The cost is also affected by the distance of the site from the quarry, the topography of the terrain and the actual amount of rock carried in each lorryload. The use of gabions also increases the cost considerably.

Topographical surveying

Supply of quarry rock/stones: 113 m3 per 100 linear metres.

Labour: depends on the size of the dam.

Transportation by lorry: 23 lorryloads (skip loader – 4.5 m3 per load).

Other costs: Equipment (pickaxes, shovels, wheelbarrows, water-tube level, etc.).

5.7 Sand dune stabilisation

Description of the technique

Dune stabilisation is achieved by setting up windbreaks arranged in a checkerboard pattern, with each side measuring between 10 and 15 m. The windbreaks are formed by palisades made from millet stalks or other plant material or by hedges and trees (*Leptadenia pyrotechnica, Euphorbia balsamifera, Acacia raddiana, Acacia senegal, Balanites aegyptiaca, Prosopis juliflora,* etc.). They provide protection from wind erosion and reduce the amount of sand blown onto cropland, dwellings and other infrastructure. Grass and shrubs are planted in strips in the fenced-off areas, which must protected for at least three years (all forms of use prohibited).

Figure 9: Dune stabilisation using hedges and palisades

Euphorbia balsamifera hedge. Source: PASP, 2003

Dune stabilisation using palisades. Source: CARITAS

How it works

The millet stalk palisades, grass strips and rows of trees act as a barrier to prevent the wind from blowing sand away from the dune. The grass and shrubs planted inside the palisades serve to further stabilise the soil. It takes at least three years for vegetation to become established, and the organic matter and waste it provides improves the soil structure.

What it is used for

This measure is used to stabilise sand dunes in locations and villages where there is a risk of sand covering cropland or infrastructure (buildings, roads, irrigation systems, etc.).

Potential for climate change adaptation

With increasingly stronger winds and the accelerated degradation of the natural vegetation growing on sand dunes, it is very likely that the problems caused by shifting dunes will worsen in the future. Techniques to stabilise shifting sand dunes will therefore become more important. At present, there is no information on the importance of the development of shifting dunes in the different climate scenarios (low-rainfall period, high-rainfall period, period of high year-to-year variability).

Agro-ecological and socio-economic effects

The palisades and vegetation used to stabilise sand dunes contribute to reducing wind erosion, and the shade that they provide lowers soil temperatures. The protection they provide for farmland and infrastructure can prevent extensive damage.

Under the PDRT in Niger, a total area of 180 ha of shifting sand dunes was stabilised, preventing serious damage to dwellings and to the farmland and rangeland that are basic components of the population's livelihood system.

Technical challenges

Specific experience is required to assess the degraded area as a whole and choose the most appropriate techniques, the right species to plant and the most suitable locations. Sometimes, the protected area is rehabilitated, particularly when land-use pressure is high in neighbouring areas.

Success factors

The protected dunes must be closely monitored and rigorously maintained for at least three years. It is therefore necessary to ensure good community organisation and take the action required to enforce the rules established and impose fines. Partial use of the area for grazing is sometimes allowed (one day a fortnight). Some projects prefer to fence off the sites with wire fencing to ensure that they are completely protected.

The success of this measure depends to a large extent on climatic conditions. A rainy year after the windbreaks have been erected creates favourable conditions for the species planted to become established.

Sustainability

Once the surface of the dune has been stabilised with vegetation, the effect is lasting, provided that the area is not overgrazed.

Cost items

Labour: 50 man-days per ha
- 60 palisade stakes per ha
- 400 tree and shrub seedlings per ha
- transportation (by lorry) of palisades and seedlings
- protection: costly if the site is protected with wire fencing, which might be stolen.

5.8 Contour stone bunds

Description of the technique

Contour stone bunds are erosion control structures built with quarry rock or stones in series of two or three. They are constructed in lines along the natural contour of the land after 10-15 cm of the soil has been removed from the line where they are to be built. They should be built to a height of 20-30 cm from the ground and spaced 20 to 50 m apart depending on the inclination of the terrain.

The best results are achieved when contour stone bunds are used in combination with biological measures (planting of grass, trees and hedges) and the use of organic fertiliser and mulching.

How it works

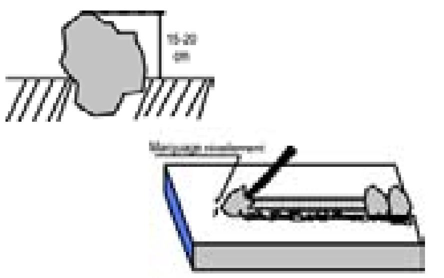
Contour stone bunds protect the land against sheet erosion caused by runoff. They form a barrier that slows down runoff and spreads it more evenly over the land. By slowing the flow of water over the land, it can seep into the soil and prevents the loss of rainwater. The bunds also act as a filter, trapping fine waterborne particles of soil and manure, resulting in a build-up of sediment. Excess water filters through the bunds and infiltrates into the soil. When rainfall is erratic, the stone bunds contribute to conserving more moisture in the soil for longer, which helps to alleviate water stress during dry spells. » *Figure 10*

What it is used for

This technique is designed for cropland, but can also be used on forest/rangeland. It is suitable for areas in the Sahel and the Sudan with rainfall ranging between 300 and 900 mm/year and low-to-medium gradient terrain.

Figure 10: Construction of contour stone bunds

Source: PASP (2003)



Stone bund with plants

Water-tube level used to establish contour lines

Series of stone bunds in a field

Potential for climate change adaptation

Contour stone bunds are useful from the perspective of climate change adaptation for a number of reasons. In scenario 2, in which rainfall is high, they protect the land in the event of heavy rain, a phenomenon that tends to increase with climate change. In scenario 3, with a decline in rainfall, they contribute to more effective rainwater harvesting. They improve water retention and infiltration into the soil, increasing the amount of water available to plants and guaranteeing the harvest. If good vegetation cover is developed on the stone bunds, they also lower soil temperature and provide protection against wind erosion.

Figure 11: Stone bund with vegetation. Source: A. Yeye/PDA/GIZ/Burkina Faso

Agro-ecological and socio-economic effects

The bunds retain water and trap fertile sediment and fertiliser, improving soil fertility and structure. The seeds of grasses and shrubs are also trapped by the bunds, favouring the establishment of natural vegetation along the structure. This further stabilises the soil and the bunds and contributes to conserving the biodiversity of plants and small wild animals (monitor lizards, birds, snakes and other reptiles).

The decrease in surface runoff in the treated area reduces the flow of floodwater and the amount of sediment carried by the water downstream, thereby protecting the fertile land in the valley bottoms from siltation and gully erosion.

Grain yields increase by more than 40% for millet up to 15 years after the bunds were established, and there is no evidence to suggest that yields decline with time (PASP figures). This can be explained by improved soil structure, which increases infiltration, even after the bunds are completely silted up.

The increase in sorghum yields varies between 33% and 55% in Burkina Faso's Central Plateau area. When stone bunds are used in combination with zai planting pits, sorghum yields can increase by 114-124%. When used in conjunction with the application of the right amount of organic fertiliser, sorghum yields can be doubled. In dry years, while unimproved land produces nothing, land protected by stone bunds can still produce a harvest.
Rainfall increased in the area covered by the PATECORE project over the last two decades (1991-2010), prompting farmers to cultivate sorghum rather than millet on the plots improved with stone bunds (Nill, 2005), as increased moisture in the soil made sorghum yields higher.

Higher crop production improves household food security in proportion to the area of a farm improved with bunds. Under the PASP in Niger, an average of 16% of the area of a farm was improved with stone bunds, resulting in an increase of between 8% and 33% in annual output with no other additional measures (Nill, 2005). In some areas, a reduction in temporary migration was also observed.

Technical challenges

In order to optimise the positive effects of stone bunds, it is important to ensure that they are constructed closely following the natural contour of the land and in accordance with the established technical standards. The means of transport required depends on the proximity of a quarry or a supply of stones (cart or lorry). In wet years, the bunds may cause waterlogging in some parts of the field, which can adversely affect some crops. If this happens, farmers must open up a gap in the bunds to drain off the water.

Success factors

The success of this measure and implementation on a wide scale depend to a large extent on whether grants are available to cover the cost of transporting the stones required to the site, good community organisation and the capacity of the community to mobilise the necessary labour, the contribution required from the farmers.
The farmers' commitment to implementing the measure largely depends on whether they are allowed to choose the sites to be improved in their area. Forcing them to begin the improvement work upstream, as dictated by the traditional watershed development approach, has often proved counterproductive. Most communities prefer to improve individual plots first in order to achieve immediate effects on crop production and leave the treatment of forest/rangeland areas as a second step.

In Niger, farmers were put in contact with a workshop that makes donkey carts and tipcarts. Using a loan granted by the project, the farmers were able to purchase the carts they needed. The transportation of stones would enable them to pay back the loan. Most of the stones required were transported using these carts, reducing the cost. Thanks to the carts purchased, farmers have been able to continue implementing the measure on their own. They also use them to carry manure to their plots, transport their produce and fetch water for household consumption.

Sustainability

There is evidence that bunds that have been in place for over 15 years have positive effects on yields. A minimum amount of upkeep is required, which essentially involves replacing stones dislodged by animals or water flow. The lifespan of a stone bund is over 20 years. There is a progressive build-up of sediment behind the bunds, resulting in the formation of terraces. Although the capacity of the bunds to retain water declines as the sediment builds up, soil infiltration capacity increases, thanks to improved soil structure, and the slope becomes gentler thanks to the terracing effect. Farmers can maintain water retention capacity by raising the height of the existing bunds. In some places, farmers take the stones from the original bunds when a ridge of vegetation has been established and use them to form new bunds between the old ones.

Cost items

The exact cost per hectare of constructing stone bunds depends on the distance of the site from the quarry, the size of the quarry, the inclination of the terrain, which determines the spacing between the stone bunds, and the actual amount of stones transported in each lorryload. The prices below are provided as a guide.

Supply of quarry rock/stones: 24 m^3 per 400 m of bund
Labour: 30 man-days per ha
- levelling and marking out the contour lines: 1 man-day
- collecting stones and loading them onto carts: 10 man-days
- transporting the stones by cart: 10 man-days
- constructing the bunds: 9 man-days
- applying manure.

Transportation by cart:
- 20 cartloads of stones
- 20 cartloads of manure (if used).

Transportation by lorry:
- 6 lorryloads (skip loader – 4.5 m3 per load).

Other costs: equipment (pickaxes, shovels, wheelbarrows, water-tube level, etc.).

5.9 Permeable rock dikes

Description of the technique

Permeable rock dikes are erosion control structures built along the natural contour of the land. They are built between 30 and 50 cm high and twice or three times as wide as they are high. They are made with different-sized stones and rocks, and the crest of the dike is horizontal. There are two main types of permeable rock dike: those without a filter layer, which are suitable for flat land with no gully erosion and those with a filter layer suited to land with heavy runoff.

The permeable rock dike differs from the contour stone bund in that it is bigger in size, is constructed with various layers of stones and is designed to control stronger water flow. For this reason, such dikes are often constructed upstream of stone bunds to dissipate the force of the water flowing from the plateaux and slopes.

How it works

The permeable rock dike is a structure designed to slow down runoff. Because of the way it is constructed, it dissipates the erosive force of the water. Sediment builds up behind it, resulting in the formation of terraces. It also increases the infiltration of surface water into the soil in the same way that stone bunds do.

What it is used for

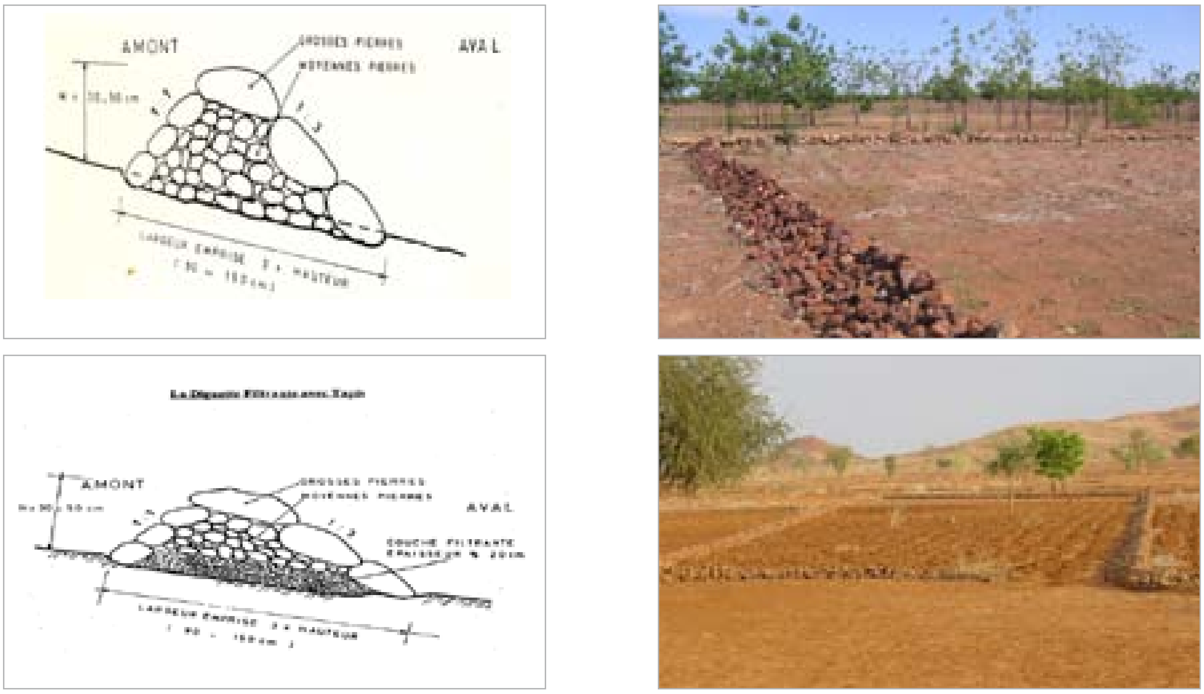
Permeable rock dikes are designed for use on cropland, but can also be used on forest/rangeland. They are recommended for ecological units with gravely and sandy-clayey soils and pediments. They can also be used to fill in small rills.

Potential for climate change adaptation

From the point of view of climate change adaptation, permeable rock dikes mitigate the effects of variations in rainfall. They are appropriate in the following scenarios:

Figure 12: Construction of permeable rock dikes

Source: PATECORE



Permeable rock dike without filter layer.

Series of dikes in a field

- wet period (scenario 2), heavy rain and violent downpours: permeable rock dikes constructed on the upper edge of the plot as a protective measure and a means of improving infiltration, protect land at risk from erosion;
- dry period (scenario 3): as they stop or slow down the flow of water, permeable rock dikes improve infiltration and therefore increase and prolong the availability of water for crops.

Good tree and grass cover developed along the dikes contributes to lowering soil temperature and reducing wind erosion along the entire length of the structure.

Agro-ecological and socio-economic effects

The retention of water and fertile sediment by the dikes facilitates the development of natural vegetation along the structure. Grass and bush seeds are trapped by the dikes, favouring the spontaneous growth of natural vegetation, which contributes to restoring biodiversity and provides a habitat for wildlife.

Studies conducted in the PATECORE area show that plots with permeable rock dikes averaged sorghum yields of 795 kg compared with 576 kg on control plots, which means that yields were 38% higher on improved plots. The production of straw for livestock increases in the same proportion as grain output. Permeable rock dikes are not as effective as contour stone bunds for the purpose of reforestation. This is because in the case of contour stone bunds, more linear metres are required per hectare than in the case of permeable rock dikes (GTZ, 2007).

The reduction in runoff downstream of the dikes contributes to reducing alluvial deposits in the valleys further downstream. Watershed development with permeable rock dikes reduces siltation and gully erosion.
Technical challenges

In order to achieve an optimal effect, it is essential to ensure that the dikes are built on the natural contour of the land and that the crests are horizontal. The technique is very effective as a flood control measure and is relatively easy to learn. Farmers are able to implement the technique themselves after two days' training.

The rocks can be transported by cart if the quarry is not too far away (less than 1 km). If it is further away, lorries are required.
Success factors

As with contour stone bunds, the construction of permeable rock dikes requires good community organisation. The community must also be able to mobilise the farmers, who must provide the labour required over several years. The intervention must continue long enough to ensure that a significant proportion of each farm is improved with dikes. This technique can only be implemented with highly motivated groups and villages, with strong working and mobilisation capacities.

Sustainability

With some upkeep, permeable rock dikes last at least 20 years. Before the rainy season starts, any stones dislodged by animals must be replaced. During the rainy season, the water can wear gaps in the dikes, which must be repaired immediately. The stability of the dikes can be reinforced by active revegetation (by sowing grass or planting trees). Without direct sowing, natural vegetation develops along the dikes after several years. The technique's potential for replication depends on the type of terrain and the availability of a supply of stones within a reasonable distance.

Cost items

The exact cost of constructing permeable rock dikes per hectare depends on the distance of the site from the quarry, the inclination of the terrain, which determines the spacing between the dikes, and the actual amount of stones transported in each lorryload or cartload.

Supply of quarry rock/stones: 48 m^3 for 200 m of dike.

Labour: 60 man-days per ha
- levelling and marking out the contour line: 1 man-day
- collecting stones and loading them onto carts: 20 man-days
- transporting the stones by cart: 20 man-days
- building the dikes: 19 man-days
- applying manure.

Transportation by cart:
- 20 cartloads of stones
- 20 cartloads of manure (if used).

Transportation by lorry:
- 11 lorryloads (skip loader – 4.5 m3 per load).

Other costs:
- equipment (pickaxes, shovels, wheelbarrows, water-tube level, etc.).

5.10 Zai or tassa planting pits

Description of the technique

Zai or tassa planting pits are an old farming technique rediscovered after the great drought of 1973/74 and later perfected by development partners working with the farmers. It involves digging planting pits with a diameter of at least 30 to 40 cm and 10 to 15 cm deep. They are spaced 70 to 80 cm apart, resulting in around 10,000 pits per hectare. Staggered rows of holes are dug perpendicularly to the slope.

Figure 13: Zai or tassa planting pits – a traditional technique

PPreparation of zai planting pits in a field. Source: PASP

Zai pits planted with millet. Source: PATECORE

The earth dug out of the hole is piled up to form a small ridge around the rim, which captures water. A couple of handfuls of organic fertiliser or compost are put into each pit. They are normally made in the dry season before the first rains start. However, it is recommended that the pits be made immediately after the rainy season, when the soil is still moist and the weather is not too hot. If the pits are in place early in the dry season, they act as traps during the windy period in February and March, retaining rich dust carried by the harmattan and wind-blown organic matter. At least 3 tonnes of compost per hectare is recommended. The planting pits are redug every two years. » *Figure 14*

How it works

The arrangement of the pits in staggered rows ensures the most efficient collection of rainwater and slows the flow of water over the surface. The zai technique concentrates and conserves nutrients and water near the roots of the plants grown in them. The application of organic fertiliser directly around the plants is an economical use of a factor of production to which most farmers have limited access. It also reactivates biological activity, increases fertility and loosens the soil.

What it is used for

Zai planting pits are used on marginal or degraded land that is no longer cultivated, such as low-gradient pediments and land with encrusted soil in areas with rainfall levels of less than 800 mm a year. They are not recommended for sandy soils, as they are not stable when dug in this type of soil, or for valley bottoms, where they risk being flooded. Zai planting pits are particularly useful in areas where land-use pressure is high, as they permit the rehabilitation of unproductive land for farming.

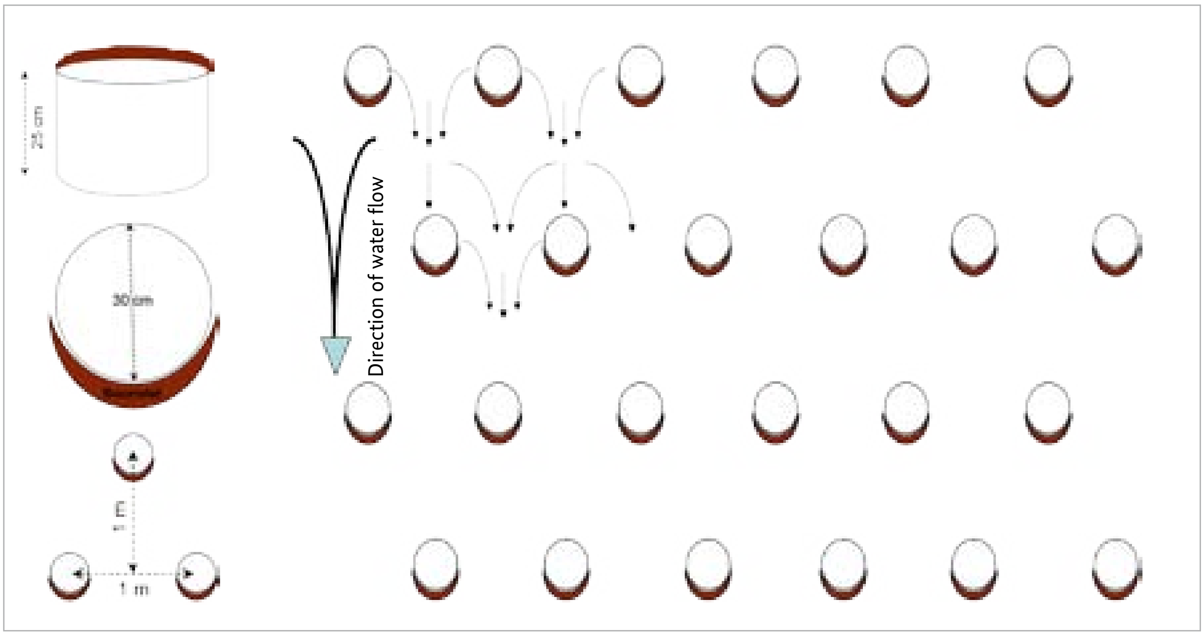
Potential for climate change adaptation

From the point of view of climate change adaptation, zai planting pits are particularly useful in areas with erratic or low rainfall (scenario 3), as they prevent the loss of water. As the fertiliser is placed inside the pits, it is not washed away by heavy rain.

Agro-ecological and socio-economic effects

As zai planting pits restore degraded, uncultivated land, they lessen the pressure to clear other land for farming. They also reduce the vulnerability of plants during dry spells and droughts, ensuring crop production and improving food security.

Figure 14: Design of zai planting pits Source: PASP (2003)



According to PASP figures for Niger, plots with zai planting pits (with fertiliser) average yields of 409 kg of millet grain per hectare, compared to 195 kg per hectare registered on control plots. Millet yields can therefore be doubled with this technique.

It permits a rational use of fertiliser. When fertiliser is spread on the surface of a plot without zai planting pits, it can be washed away by runoff.

Technical challenges

The zai technique requires high labour input. It is estimated that between 40 and 60 man-days per hectare are required, depending on the density of the pits. There is a mechanised system for making the holes, using a special animal-drawn plough, which considerably reduces the number of man-days required to 7 per hectare. There is little literature available on experiences using this mechanised technique.

Zai planting pits are not recommended for light soils, as they fill in too quickly. The use of poudrette (night soil) as a fertiliser can cause scorching. Owing to its high nitrogen content, this type of fertiliser is not very effective in improving the physical properties of the soil. Fertiliser that is not properly decomposed (raw litter) attracts harmful insects and reduces the availability of nutrients for crops, which suffer from a lack of nitrogen, phosphorus and other nutrients.

Success factors

Covering extensive areas with zai planting pits requires a high level of community mobilisation and effective organisation and logistics. Apart from this, the technique is very simple to implement and easily mastered by the farmers.

Sustainability

Zai planting pits are a technique used to reclaim abandoned land. If the pits are prepared each year or once every two years (using the same pits or making new ones in the spaces between the old ones), soil fertility is restored and the crop cycle can be resumed. The application of organic fertiliser in sufficient quantities enables the plot to be cultivated sustainably. After five years, it can be farmed in the normal way.

Cost items

Labour: 40 to 60 man-days per hectare
- marking out the rows perpendicular to the slope
- digging pits in staggered rows
- forming a ridge on the downhill side
- applying organic fertiliser every two years (1 to 2 handfuls per pit, amounting to around 3 tonnes per hectare).

Other costs: transportation of 30 cartloads of manure.

5.11 Grass strips

Description of the technique

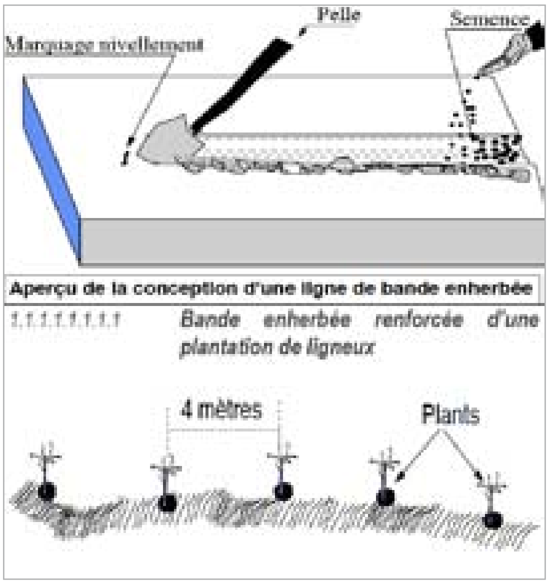
Grass strips measuring 0.80 m to 1 m wide are planted 20 to 80 m apart on low-gradient terrain. Local grasses (for example, *Andropogon gayanus, Cymbopogon schoenateus and Vetivera nigritian*a) are sown or planted (plantlets) at the start of the rainy season. Like stone bunds, grass strips are planted along the natural contour of the land to slow down runoff, increase infiltration and retain sediment. Grass strips get bigger as sediment builds up, which maintains their capacity to retain water, unlike mechanical structures (stone bunds and dikes).

The species of grass are chosen according to what the farmers want to use them for (straw, hay, mat weaving, roofing, construction of straw granaries, brooms, etc.). In cattle and sheep raising areas, the use of fodder plants can increase interest in this technique and ensure wider acceptance. It is recommended that the development of grass strips be combined with assisted natural regeneration (woody species) or the planting of trees.

How it works

Designed as an erosion control measure, grass strips slow down runoff in the event of heavy rain. They distribute rainwater more evenly over the land and improve infiltration. Sediment builds up behind the grass strips, thereby reducing the erosion of fertile soil layers. The roots of the plants bind the soil and hold it in place. Although the vegetation growing in the strips competes with the crops to some extent for water, the overall effect on yields is positive. Crops are also protected from wind erosion.

Figure 15: Grass strips Source: PASP (2003a)



How a grass strip is prepared

What it is used for

It is a technique designed mainly for cropland, but can also be used on rangeland, provided that the plants are protected when the grass strips are put in place. Grass strips are suitable for areas in the Sahel and the Sudan with rainfall ranging between 400 and 1,000 mm/year and gently sloping terrain (< 2%). Ecological units that benefit from the implementation of this measure include dune land, pediments and plains (highland pediments). Grass strips are particularly appropriate for non-stony land in areas with higher rainfall levels.

Potential for climate change adaptation

Like contour stone bunds, grass strips reduce the harmful effects of heavy rain and violent downpours, events that are expected to increase as a result of climate change. Grass strips improve rainwater harvesting and water retention in the soil. The latter is particularly important when there are dry spells in the rainy season. Thanks to the vegetation cover they provide, grass strips contribute to lowering soil temperature and are also effective in reducing wind erosion.

Agro-ecological and socio-economic effects

Grass strips contribute to creating vegetation cover, which provides a habitat for biodiversity. As the vegetation provides shelter from the wind, fine particles of soil accumulate behind the strips.

In the area covered by the PASP project in Niger, compared with plots without grass strips, millet yields were 50 kg per hectare per year higher, and straw yields 125 kg higher on plots with grass strips (without any other measures). Yields can be substantially improved by combining grass strips with the application of organic fertiliser, mulch or pen manure. The best results, an average increase of 280 kg of millet grain per hectare (370 kg of straw per hectare), were achieved by combining them with mulching and pen manuring. Grass strips therefore improve yields of cereals and forage for livestock (straw and grass growing on the strips).

Increased crop output increases household food security and improves livestock feeding. The straw cut on the grass strips can also be used for other purposes (fencing and roofing). It is also a source of income, as traditional products made with straw, such as woven mats, can be sold.
Technical challenges

Grass growth tends to be patchy, and resowing is required several times to fill in the gaps in the strip. Strips with bare patches are not effective in retaining water, and rilling can be caused by water gushing through the gaps.

With the use of certain types of grasses that grow in clumps, such as *Andropogon* grass, gaps are left between the tufts, and water spurting through these gaps can cause rilling. The clumps must therefore be arranged in staggered rows and the strips made wide enough to prevent this problem.

In order to protect the grass strips from grazing animals during the first year, it is recommended that the area be monitored, which requires strict control over the village herds and flocks and those of nomadic livestock keepers.

Some grasses tend to invade crop fields. It is therefore important to control them by cutting them down before they flower and to tend the strips regularly, straightening and cutting back the edges.

Success factors

In the Tillabéri area, in northern Niger, the adoption of grass strips varies greatly from one place to another. After three seasons of promoting this technique, grass strips had been established on a total area of 4,674 hectares (sometimes in combination with other measures). Over half of the improved land is located in the Filingué area (2,587 hectares), followed by Ouallam with 1,042 hectares. However, only small areas were improved with grass strips in Tillabéri and Tera (228 hectares and 817 hectares respectively), where acceptance of this technique was low.

In spite of good results in terms of increased production and soil improvement, grass strips have only been widely accepted in southern Niger (Maradi and Zinder). Farmers are of the view that grass strips could be confused with plot boundaries.

The availability of land in southern Niger may be another factor that facilitates acceptance of the measure is this area. Part of the plot is taken up by the grass strips, reducing the area left for growing crops. This hinders acceptance in areas where land is limited. The reduced crop-growing area is offset by better per-hectare grain, straw and hay yields. Certain grasses (such as *Andropogon gayanus*) have a harmful effect on nearby crops. The systematic exploitation of the grass strips as a source of straw or hay improves acceptance of the technique.

At first, people living in the areas covered by the PDRT project were reluctant to establish grass strips. They considered them to be weeds with no place on their farmland. With time and exchange visits within the country, they began to accept the technique.

Sustainability

Any dead plants in the grass strips must be regularly replaced. Grass strips are more likely to be maintained if they are economically profitable, for example, if they produce hay for livestock or their output can be sold as forage or construction material.

Cost items

Labour: 6 man-days per ha
- marking out the contour lines
- making 10-15 cm deep furrows in which to plant the seeds or seedlings
- sowing or planting 1 to 4 rows per strip.

Upkeep: 2.5 man-days per year.
Other costs:
- grass seeds or seedlings
- equipment: water-tube level.

5.12 Use of organic matter (manure and compost)

Description of the technique

There are two methods for obtaining organic matter for use as a fertiliser: the production of compost and the collection of manure. Manure is collected from improved livestock pens or sheds where livestock is kept on litter or bedding.

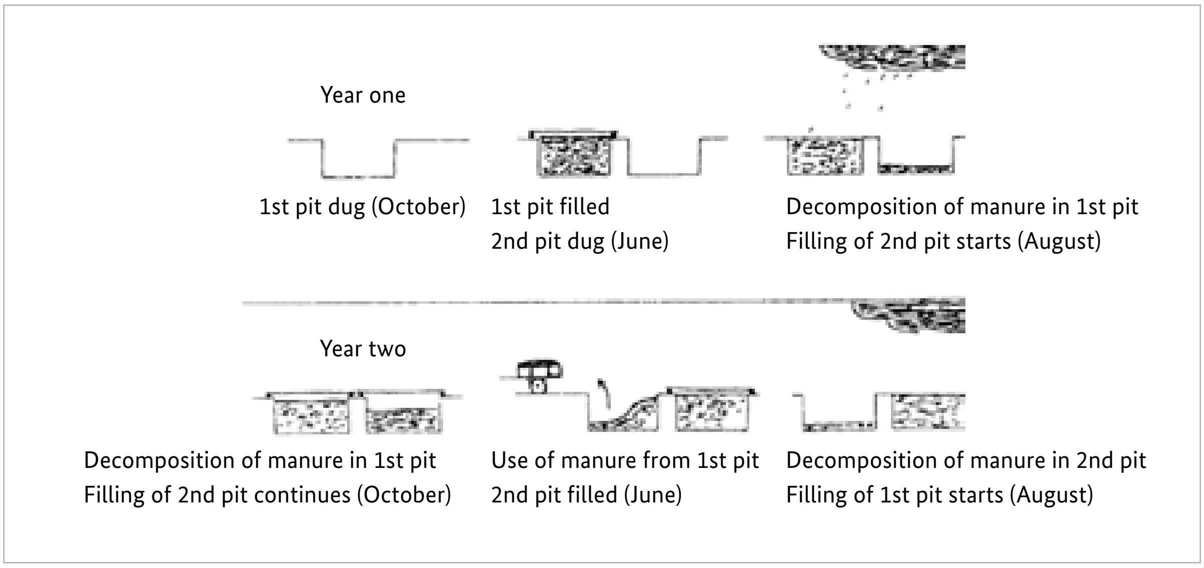
Compost can be made in the dry season or in the rainy season. Biodegradable matter is mixed with animal waste for rapid decomposition or just with millet, sorghum or other plant stalks for slow decomposition. Both types of compost can be enriched with ash and/or natural phosphate.

The biodegradable matter is placed in a pit. In the dry season, it is regularly sprinkled with water until decomposition is complete. It is then spread evenly over the land before sowing or planting. The recommended amount varies depending on the type of soil: 6 t/ha every third year (heavy clayey soils), 3t/ha every two years (sandy-clayey soils) or 2t/ha every year (light soils).

Unlike compost, manure collected from improved pens or livestock sheds is not completely decomposed, and the decomposition process continues over several years.
The use of manure on farmland entails some risks and disadvantages. As the manure is only partially decomposed – decomposition starts after the first rains begin – crops do not have enough nitrogen for a time.
The use of partially decomposed manure also exposes crops to certain pests and to the risk of being scorched. In spite of these drawbacks, manure is the form of fertilisation most commonly used by farmers, as it requires less work than compost.

The use of compost and manure is recommended in conjunction with all other SWC/SPR measures to achieve the maximum benefit from investments in land improvement.

Figure 16: Producing compost Source: PASP (2003)



How it works

The use of organic matter on cropland has three major effects: it reactivates biological activity, increases soil fertility by providing nutrients and improves soil structure by increasing the amount of organic matter in it. The improved soil structure also increases the infiltration of water into the soil. These effects favour crop growth and increase yields. The regular application of manure and/or compost in sufficient quantities makes farming more intensive and reduces the need to bring more land under cultivation.

Figure 17: Use of manure in a field with stone bunds pierreux. Source: PATECORE

What it is used for

Manure: all cropland.
Compost: recommended particularly for market gardening.
Potential for climate change adaptation
Soils treated with compost or manure produce better yields, because they retain water better and are more fertile. This improves household food security and increases the resilience of the population. In addition, the denser vegetation and improved soil structure make the land more resistant to water and wind erosion.

Agro-ecological and socio-economic effects

The use of compost and manure improves yields and output, thereby improving food security. The sale of surplus production also increases household income.

Technical challenges

Manure and compost are often not available in sufficient quantities.

Water is required to moisten compost during the dry season in order to ensure that it is kept at the right temperature for the decomposition of the biomass.

Success factors

Manure and compost: transporting manure and compost poses a major hurdle for poor farmers who do not have a cart. This is a particularly serious problem when plots are at a distance from the village (outfields).

Compost: farmers are deterred from composting in the dry season because a nearby supply of water is needed and it involves a considerable amount of work.

Sustainability

The amount required varies from 2 t/ha every year to 6 t/ha every 3 years, depending on the condition of the soil and the availability of manure and compost.

Cost items

Production of compost:
- constructing pits or basins
- water
- equipment (shovel, wheelbarrow, etc.).

Use of compost:
- transportation to plot by cart (100 kg of manure per donkey cartload)
- transportation to plot in head baskets (20 kg of manure per basket)
- spreading the compost on the plot (labour).

5.13 Mulching

Description of the technique

Mulching involves spreading millet and sorghum stalks, etc. on cropland after harvesting. Around 2 tonnes per hectare per year is recommended, which is 2 or 3 stalks per m2. The technique can be combined with any other erosion control technique, such as contour stone bunds and grass strips.

Figure 18: Mulching on cropland. Source: PASP (2003)

Mulching with millet stalks

Mulching combined with stone bunds

How it works

The stalks spread over the land at the very beginning of the dry season reduce the evaporation of moisture from the soil and act as a barrier to prevent wind erosion, retaining the thin layer of soil and trapping the rich dust carried by the harmattan wind. Through the action of termites, the stalks and branches decompose and are gradually incorporated into the soil, fertilising it and improving its structure. This technique is also effective for restoring infertile patches of cropland. The stalk remains improve the infiltration of water and the conservation of moisture in the soil during the rainy season and protect it from wind erosion.

What it is used for

This technique can be used on any kind of cropland.

Potential for climate change adaptation

Covering the soil with mulch protects it against wind and water erosion and provides nutrients. Mulching has a positive effect on yields and therefore contributes to improving household food security. It mitigates the effects of climate change and increased rainfall variability.

Agro-ecological and socio-economic effects

This technique is useful for restoring infertile patches of cropland. It also improves the soil's physical and chemical properties and reactivates biological activity. In the area covered by the PASP project in Niger, an analysis was carried out to assess the effectiveness of contour stone bunds used on their own and stone bunds used in conjunction with mulching. It was found that plots with contour stone bunds only produce an average millet grain yield of 266 kg per hectare, while those with contour stone bunds plus mulching average 395 kg per hectare. The difference between the two – 129 kg – can be considered to be the positive effect of mulching.

Technical challenges

Increasingly, there are competing uses for harvest waste. Straw can be used as forage, as a construction material and for mulching. It is now becoming increasingly common for straw to be collected and stored systematically to serve as forage reserves in the dry season.

Harvest waste is often a source of conflict between livestock keepers and farmers. In Niger, the date when crop fields are opened to livestock keepers is set in each region by representatives of different user groups and the government.

Success factors

This technique is implemented on individual plots. Livestock generally graze on the millet and sorghum stalks, or they are cut down and transported for use as fodder for animals being fattened in the dry season. This technique is therefore used in places where there is sufficient forage for livestock herds.

Sustainability

Mulching has to be carried out each year.

Cost items

- Labour for mulching: 1.5 man-days per ha.
- Straw for mulching: (2 t per ha per year).

Transport of stones © GIZ / Martina Wegner

5.14 Assisted natural regeneration

Description of the technique

Assisted natural regeneration (ANR) is an agroforestry technique, which consists in protecting and preserving tree seedlings growing naturally on cropland or forest/rangeland. It involves selecting which natural tree seedlings to leave and placing a stake next to them to identify them. The recommended density on cropland is between 60 and 80 trees per hectare. In order to ensure the success of this measure, it is important to protect the tree seedlings and saplings from browsing animals during the first few years. The young trees are pruned regularly to stimulate growth, so that they quickly achieve the height required to make them safe from browsing animals.
The choice of tree species depends on the intentions of the farmers (browse for animals, sale of fruits or byproducts such as shea butter, dawa-dawa, medicinal products, etc.). The technique requires no investment, apart from the work involved, and can be implemented by any landowner.

How it works

Tree roots and fallen leaves help to stabilise the soil and thereby reduce water erosion. Some tree species have a fertilising effect on the soil. Legume species (for example, *Faidherbia albida*) enrich the soil with nitrogen. Other species circulate nutrients from the subsoil into the topsoil thanks to leaf fall. The shade provided by trees lowers soil temperature and reduces the evapotranspiration of plants.

What it is used for

There are no restrictions.

Potential for climate change adaptation

Assisted natural regeneration is particularly useful in the context of climate change adaptation. According to climate change forecasts, the temperature in the Sahel area is expected to rise by an average of 3.5°C, which will obviously affect the temperature of the soil. The shade provided by trees (particularly large ones) contributes to lowering soil temperature and reducing water stress in plants. They also act as a windbreak and provide protection against water and wind erosion.

Agro-ecological and socio-economic effects

The environmental effect of ANR depends to a large extent on tree density. The reintegration of trees and shrubs into any ecosystem has positive ecological effects and improves and protects the soil. The vegetation provides shelter and forage for animals and contributes to biodiversity.

Trees have positive effects on crop yields, when they do not compete with the crops for water. They also provide products and byproducts, such as wood, fruits, leaves, forage, ingredients for medicinal products, etc. *Faidherbia albida*, for example, has no leaves in the rainy season, which is beneficial for crops. In the dry season, it is green and provides sheltered places for animals to rest. Leaves that fall from this type of tree fertilise the soil.

The wood, leaves, pods and fruits provided by trees in crop fields help the owners to meet their family's needs during the lean season.

Technical challenges

There are two essential challenges associated with ANR. First, during the dry season stray animals often wipe out ANR efforts made by farmers on their land. Second, in some places, anyone can collect fruits, leaves and pods from trees, and this discourages farmers from investing in ANR.

In some places, only the owner of the land is allowed to establish trees on cropland.

Success factors

ANR is carried out mainly on individual plots where monitoring and upkeep are easier. In order to implement this technique, there must be a very clear legal framework governing land tenure. In the 1990s, the PDRT in Niger trained farmers to prune their trees. However, forestry officers, enforcing the law, fined farmers for each branch they cut. The law was subsequently changed, allowing farmers to make use of the products of their trees, and this favoured the spread of the technique.

Assisted natural regeneration: Arabic gum in Niger © GIZ / Martina Wegner

Scientific studies show that ANR is successful in areas with a very high population density and seriously degraded land, such as Zinder and Maradi in Niger, where around 10 million hectares of land have been regreened by means of ANR over the past thirty years (Botoni & Reij, 2009).

Sustainability

ANR contributes to sustainable farming. It is one of the most widely accepted of the land improvement techniques promoted by development projects. It does not require a high level of organisation to implement it and it is not costly.

Cost items

Labour: 5 man-days per ha.

- Cost of awareness raising, training and dissemination.
- Shears for pruning.

Assisted natural regeneration: Acacia albida in a millet field in Niger © GIZ / Martina Wegner

5.15 Water-spreading weirs

Description of the technique

The water-spreading weir technique was developed in Burkina Faso, Niger and Chad in the late 1990s and early 2000s. These weirs regulate floodwater in medium-sized watercourses and in wider degraded valley bottoms with a pronounced low-water channel. They are constructed with local materials and have a spillway in the middle, abutments on either side and long wingwalls to spread the water over a large area.

In order to reverse the degradation process in a valley, it is necessary to ensure the comprehensive rehabilitation of the degraded parts of the valley. This is why the technique requires an overall assessment of the valley in order to identify the causes of degradation. In order to restore the water system in a degraded valley, a series of weirs is generally required.

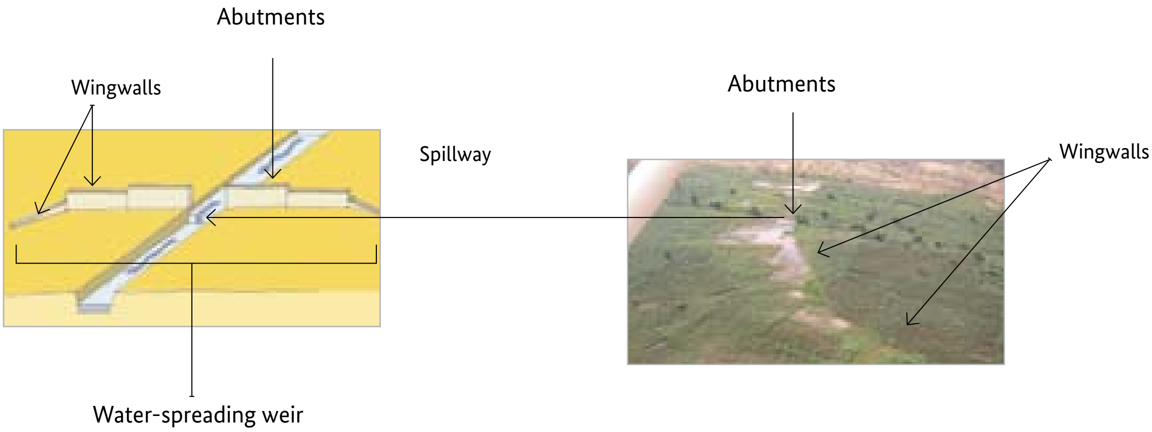


Figure 19: Parts of a water-spreading weir. Source: Bender (2011)

How it works

Water-spreading weirs slow the flow of water in valleys and spread it over a wider area where it can infiltrate into the soil. In this way, they control river floodwater, and this reduces erosion and the loss of water. At the same time, sediments improve soil fertility and replenish the water table.

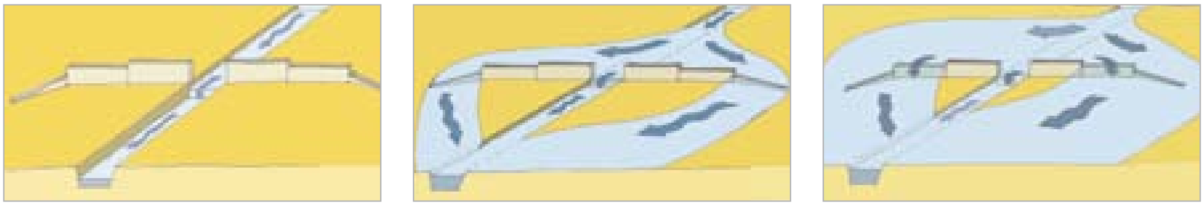
When water flow is low in the valley, all the water passes over the spillway. When floodwater flow is stronger, the water is channelled towards the sides and flows over the outer lower wingwalls. When the floodwaters are at their heaviest, the water flows over even the higher walls. Downstream, the waters rejoin the low-water channel.

Water-spreading weirs permit the reclamation and rehabilitation of degraded land and the restoration of vegetation cover. Thanks to the weirs, water flowing through the valleys can be used for crop growing, livestock raising and forestry.

What it is used for

Water-spreading weirs are suitable as a land improvement measure for 90% of valleys in the Sahel area. They are very effective in wide, severely degraded valleys with medium-sized watercourses.

Figure 20: How water-spreading weirs work. Source : Bender (2011)



Potential for climate change adaptation

This technique has great potential for climate change adaptation in two scenarios:

- Water-spreading weirs distribute the watershed's water over wide areas of land in the valley bottom. This enables water resources to be used more efficiently in low-rainfall periods (scenario 3), during dry spells and when the rainy season ends early.
- In high-rainfall periods (scenario 2) and/or in the event of heavy downpours, water-spreading weirs slow the flow of water, thereby preventing or reducing gully and river bank erosion and protecting areas downstream.

Agro-ecological and socio-economic effects

Thanks to the infiltration of considerable amounts of water, water-spreading weirs contribute to raising the water table by several metres and improving ecological conditions in adjacent areas. As a result, vegetation cover is restored, which has a positive effect on biodiversity.

By 2010, German cooperation had established water-spreading weirs in Niger to improve 10,000 hectares of land in valleys. Sorghum yields increased by between 50% and 100% per ha, from 400 kg to 800 kg per ha. The production of sorghum was 10 to 15 times higher in the improved areas than it had been before. As water-spreading weirs raise the water table, areas can be developed (or abandoned farmland restored) for market gardening and horticulture, with two or three crop harvests a year. The produce is used to supplement the food available and can also be sold (especially market garden produce).

The amount of time spent by women and girls fetching water is reduced by several hours a day. Horticulture generates extra income to cover family expenses, such as education and health care. Growing crops outside the rainy season generates work all year round, which reduces temporary migration.

Figure 21: Effects of water-spreading weirs.

Source: Axel Brückmann

Source: Klaus Wohlmann

Technical challenges

This technique requires accurate preliminary studies to design the system. The more degraded the valley, the more complex the work is. Improving severely degraded valleys requires extensive experience, and any necessary technical adjustments must be made when flaws are detected.

The evaluation carried out by the FICOD (investment fund for local authorities) in 2010 highlighted the serious problem of sand filling siltation in valleys when additional measures are not implemented in a watershed's upstream areas to ensure the overall development of the whole watershed area.

Success factors

Assessing a valley within the watershed as a whole, determining the best place to construct the weir, mobilising technical and financial resources and building and maintaining the structure requires a high level of organisation which is generally only possible after intensive training provided by a technical partner.

Sustainability

To ensure that the effectiveness of water-spreading weirs is long-lasting, upstream watershed development is essential to prevent sand filling of the bottomlands.

If the weirs are built to a high standard, with a certain amount of upkeep, they will last. Major repairs are beyond the means of the communities, which is why commune authorities are often assigned the role of project owner. However, this is not yet a satisfactory solution, as in most countries in the Sahel, commune authorities are still weak. Without external support, the potential for replication is very low.

Cost items

The cost of improving land with water-spreading weirs is 0.25 to 1.5 million CFA francs[11] per hectare.

Labour:
- team formed by 25 people for 2 to 3 months, depending on the size of the structure.

Lorries to transport stones:
- 150 to 200 lorryloads (skip loader – 4.5 m³ per load) at a rate of 10 to 15 lorryloads a day.

Cost of construction:
- 1 medium-sized weir 50 m long and 1 m high with 200 m long wingwalls plus basin: 15 million CFA francs
- 1 weir 100 m long and 1 m high with basin: 30 to 32 million CFA francs
- stonework: 25,000 CFA francs/m³
- basin: 15,000 CFA francs/m³.

5.16 Small-scale dams

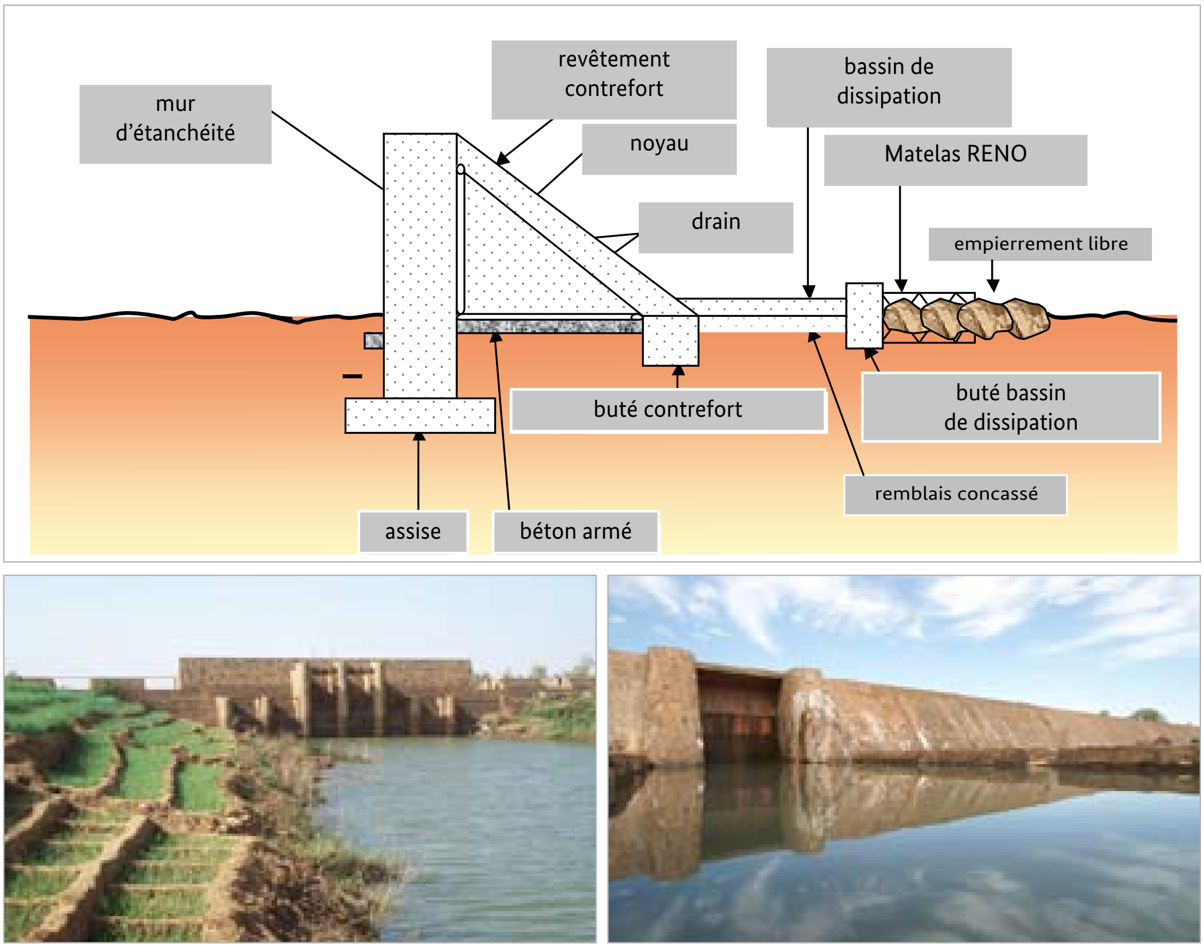
Description of the technique

Small-scale dams are moderately-sized barriers built across valley bottoms to retain water from permanent watercourses or seasonal flows. They can range in length from 100 to 200 m, and the dam wall is usually between 2 and 4 m high. Small-scale dams impound permanent or seasonal water behind them, covering areas from 5 to 15 hectares. They are built with buttresses and a stilling basin. Depending on local conditions, the dam wall can be made of quarry stone joined with mortar or concrete. The dikes are made of earth and can be reinforced with stones. Some such structures are built as bridge dams, providing a means of crossing the valley. The effect on the water table depends on the depth at which the dam is anchored. The deeper the foundation, the more groundwater is retained. Sometimes, they are fitted with geomembranes which extend down deeper to retain more groundwater.

11 1 € ~ 650 FCFA

Figure 22: Masonry dams

Source: PIPRO-DB



How it works

In the rainy season, water gradually accumulates behind the dike, increasing the availability of surface water during the rainy season and groundwater in the dry season. The land is farmed upstream and downstream both in the rainy season and the dry season. During the rainy season, rice is grown, and the areas around the body of water are used for other crops (flood-recession cropping). The recharged water table feeds market garden wells, enabling farmers to grow vegetables in the dry season and permitting two or three crop harvests a year. Dams increase the area of farmable land, yields and production. The water is also used for livestock, for fish farming and sometimes for household needs.

A management committee controls the opening and closing of the gates. It organises the maintenance of the structure and the implementation of any additional measures necessary to protect the gabion structures and stone bunds. It also collects and manages funds for the maintenance of the dam and organises meetings of farmers.

What it is used for

These small-scale dams are suitable for use in narrower valleys, as a considerable volume of water can be impounded with a relatively short structure. They are not as well suited to wide, gently sloping valleys, as very long dikes are required and this increases the cost.

Potential for climate change adaptation

The small-scale dams create water reserves. When there is not enough rain or during dry spells in the rainy season, the dams retain enough water for crops throughout their growth cycle. If rain-fed crops fail, production in the valley bottoms can mitigate these losses. In wet years, the dams regulate the flow of water, preventing heavy floodwaters from causing damage to land downstream.

In the dry season, the recharged water table makes a second and even third crop harvest possible, increasing the availability of food, providing income for farmers and guaranteeing work all year round.

Agro-ecological and socio-economic effects

The water impounded by small-scale dams makes it possible to farm a much larger area in the valley bottoms and ensures better yields in the rainy season and also in the off-season. The production of food staples and market garden output increases significantly. More intense production ensures employment all year round, which improves the stability of local communities, increases their income and raises their standard of living.

Replenished water tables not only improve crop output, they also reduce the time and effort that women devote to fetching water and make it easier to water livestock. In the areas around the dam, there is natural vegetation growth, which enhances biodiversity.

Technical challenges

A high standard of technical planning and construction is required for small-scale dams to avoid subsequent damage. In order to maximise the value of the investment, well-organised management committees must be set up to ensure efficient crop production and oversee maintenance work.

At the planning stage, the condition of the valley upstream and downstream and all user groups must be taken into account. In dry periods, it is important to manage water resources in such a way that downstream areas have enough water. When a series of dams are built on the same watercourse, an inter-dam committee may be required to manage the distribution of water and avoid conflicts between the users of the different dams.

Success factors

In addition to environmental and technical considerations, the socio-economic context is also key to ensuring the effective operation of small-scale dams. The question of land tenure, in particular, must be settled before construction begins. It must be determined who the owner of the bottomlands is, who will be entitled to use them once the dam has been constructed, what uses will be permitted and under what conditions.

The question of project ownership and upkeep must also be clarified. Today, the role of project owner is normally assigned to the commune authorities, although management of the dam is often delegated to a management committee.

In order to avoid conflicts, it is essential to take into account all the user groups, livestock keepers in particular. Watering corridors must be established to prevent animals from damaging the crops.

All this requires a participatory approach involving all partners and users at the planning, implementation, operation and maintenance stages. The beneficiaries commit to the project by participating physically and/or financially in the investment. All the planning, operation and maintenance stages require intensive support, in the form of technical and organisational training and oversight to ensure that they are implemented successfully.

Once the dam is in operation and crop production underway, the storage and marketing of products become success factors. Support measures (storage facilities, drying areas and produce delivery channels, for example) should be planned from the start, and contacts established with merchants. Output must be adapted to market demand if it is to be easily marketed.

Sustainability

Well-constructed small-scale dams last at least 50 years with a certain amount of upkeep. Sustainable operation and management depend directly on the participatory approach. Depending on the natural characteristics of the watershed, small-scale dams may require additional SWC/ SPR measures upstream to protect them from siltation.

Cost items

The cost of small-scale dams varies greatly depending on the physical characteristics of the site, the size of the structure and the local availability of materials. In Dogon country, in Mali, the PDRT project constructed dams with cyclopean concrete costing an average of around 20 million CFA francs and between 3 and 5 million CFA francs per hectare. The internal rate of return of the dams built averaged 17% (Nill & Kobilke, 2002). Larger dams built in the Beledougou area cost 100-140 million CFA francs. Helvetas Swiss Intercooperation reports costs of around 20 million CFA francs for areas of 10-80 hectares (PASSIP, 2012).

5.17 Village irrigation schemes

Description of the technique

Village irrigation schemes provide irrigation for areas of between 20 and 40 hectares, surrounded by low earthen dikes. The system includes a stilling basin, which receives water from a motor pump, a main channel, secondary channels and irrigation ditches. The scheme gives total control over the water available in the area, using a motor pump to move it around the system. The channels are open earth, and stretches where infiltration is high are lined with riprap. The structures are made of concrete. Village irrigation schemes require a source of water, and are therefore generally located along rivers or near permanent bodies of water.

Irrigation systems of this kind were constructed in Mali after the droughts in the 1970s under numerous development projects implemented to increase rice and wheat production. Between 1996 and 2010, for example, the IPRODI project established 450 irrigation schemes in northern Mali, creating an irrigated area of over 13,000 ha farmed by 55,000 farmers. This technique makes it possible to develop unirrigated land at low cost to meet the demand for higher agricultural production and improved living conditions.[12]

How it works

Village irrigation schemes use water from nearby sources, which is pumped into the system by a mobile pumping unit. The water is pumped into the stilling basin and driven by the force of gravity into the main channel and the secondary and tertiary channels to the plots of individual users.

12 Source of information: IPRODI and http://www.programm-mali-nord.de/home.html.

Figure 23: Construction and operation of village irrigation schemes in Mali. Source: IPRODI

The beneficiaries receive support from a project to plan and construct the irrigation system, purchase and install the pumping units (with financial contribution), purchase the tools and establish a start-up fund for the first season. Two technicians are trained per scheme. The village irrigation systems are operated and maintained by the beneficiaries and their management committee.

A quarter-of-a-hectare plot is assigned to each 'able-bodied person' who participated in the work to construct the system. The total area assigned to each family therefore depends on the number of able-bodied people in the household.

The process to select an area to be developed begins with a request submitted by the community through the commune authorities. A feasibility study is conducted to determine potentially viable sites. The final choice is made in consultation with the regional and commune authorities and the villages concerned and in accordance with the financial resources available. The highly labour intensive approach is used, with beneficiaries participating in the construction work. Once the system is in operation, technical services provide support to farmers for a time to teach them adapted farming practices.

What it is used for

Village irrigation schemes are suitable for sites with a permanent source of water nearby and with little difference in level between the water supply and the areas to be irrigated, as this reduces pumping costs. In Mali, there are numerous village irrigation schemes in the Inner Niger Delta and along the banks of the river Niger.

Potential for climate change adaptation

Village irrigation schemes are an effective means of expanding the area of irrigated farmland and increasing production. As they permit the total control of the water available, farmers are practically unaffected by variations in rainfall, as long as the water source remains available. They therefore guarantee the production of food crops and straw for livestock.

Agro-ecological and socio-economic effects

Village irrigation schemes create new irrigated farmland, which enable farmers to achieve high rice yields: around 6 tonnes per hectare. With an average price of 125 CFA francs a kilo for paddy rice, the value of output per hectare is around 750,000 CFA francs. Profit is estimated at around 300,000 CFA francs per hectare. At some sites, a second harvest is possible. Other plots are used for market gardening, with the production of onions, tomatoes, herbs, spices, etc. After the crops have been harvested, animals are allowed to graze on the plots.

Technical challenges

A high standard of technical planning (topographical surveying and soil studies) and construction is required to prevent cracks from appearing in the stilling basin or the main channel and avoid the problem of uneven water distribution within the irrigation area. The most serious risk for such schemes is failure of the pumping unit. A local repair and maintenance service stocking a supply of spare parts must be available to provide assistance when the problem is beyond the abilities of the technicians trained for the scheme by the project.

Success factors

Like any other technical solution, IPRODI-type village irrigation schemes require a high level of technical expertise, effective management and a high standard of maintenance once they are in operation. Effective operation of the system depends to a large extent on how well the management committee works, as it is responsible for carrying out maintenance work and organising the supply of inputs (seeds, fertilisers, fuel, etc.). The ability of the technicians to ensure the effective operation and maintenance of the pumping unit is a key success factor.

Those who participated in the construction work are given preference when the plots are distributed among the village's families. The management committee must set up an operating and maintenance fund to purchase fuel and carry out any repairs. Farmers are required to pay a charge of seven sacks of paddy rice (around a third of their harvest) into the fund. In this way, the pumping units can be replaced after a number of years. The improved areas sometimes become a source of conflict after the irrigation system has been put in place. The assessment carried out during the identification and planning stage must take into account any existing and potential conflicts.

Sustainability

The earliest village irrigation schemes implemented under the IPRODI project in Mali are now 15 years old. They are still operating and in good condition. The low investment and maintenance costs and the assimilation of the operating techniques by the farmers ensure high sustainability. The beneficiaries use their own funds to replace the pumping units when necessary and to extend the schemes. However, sustainability depends on the participatory approach adopted for the construction and management of the irrigation systems.

Cost items

The cost of implementing a village irrigation scheme is around 1.5 million CFA francs per hectare.

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