BMZ Federal Ministry for Economic Cooperation and Development

Water-spreading weirs for the development of degraded dry river valleys.

Experience from the Sahel

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Acronyms

DETA	Development-oriented Emergency and Transitional Aid Project (ENÜH by its German initials)
FICOD	Fonds d'Investissement pour les Collectivités Décentralisées
GIEC	Groupe d'experts Intergouvernemental sur l'Évolution du Climat
HIMO	Haute Intensité de la Main d'Œuvre (intensive use of manual labour)
LUCOP	Programme de Lutte contre la Pauvreté (Niger)
PADL/UE	Programme d'Appui au Développement Local de l'Union Européenne (Chad)
PDRD	Programme de Développement Rural Décentralisé (Chad)
PDRT	Projet de Développement Rural de Tahoua (Niger)
PMAE	Projet de Mesures Anti-Erosives
PNSA	Programme Nationale de Sécurité Alimentaire (Chad)
PROADEL/BM	Programme d'Appui au Développement Local (Chad)
PRODABO	Programme de développement rural décentralisé d'Assoungha, Biltine et Ouara (Chad)
SMEV	Schéma de Mise en Valeur des Vallées

Foreword

The present study is an outcome of a joint KfW and GIZ initiative that has been implemented on behalf of the German Federal Ministry for Economic Cooperation and Development / (BMZ). Its purpose is to describe the new approach involving the construction of water-spreading weirs that was developed in recent years in the Sahel region, and thus to make it an attractive option for other semi-arid regions as well.

The joint initiative was supported by KfW's Agricultural and Natural Resources Division and sub-Saharan Africa governance team. The following GIZ sector projects contributed to the initiative: 'Sustainable Management of Resources in Agriculture', 'Rural Territorial development', the 'Convention project to combat desertification' and the development-oriented emergency and transitional aid (DETA) project *Sécurité alimentaire et gestion paisible des ressources naturelles dans les zones des réfugiés á l'Est du Tchad*.

The present study also provides the basis for a capacity development programme which is to be developed jointly by the participating national and international engineering firms. This programme shall focus on engineers and consulting firms in the countries in question.

The approaches of the following programmes were studied:

- **Niger:** LUCOP/GIZ and FICOD/KfW
- **Burkina Faso:** FICOD/KfW
- **Chad:** PDRD/GIZ and the DETA project Sécurité alimentaire et gestion paisible des ressources naturelles dans les zones des réfugiés á l'Est du Tchad/GIZ

This study is based on the following substudies:

- **Bender, Heinz:** Flussschwellen zur Überflutung von Talsohlen. Technisch-ökologischer Teil. Mai 2011. [River weirs for flooding valley bottoms. Technical-ecological section]. May 2011.
- **Kambou, Fiacre:** Etude sur le concept de réalisation des seuils d'épandage en ses aspects organisationnels (soft) au Burkina Faso. April 2011.
- **Lütjen, Heiko:** Inwertsetzung von Flusstälern im Sahel durch die Errichtung von Flussschwellen als neuer Ansatz zur landwirtschaftlichen Produktionssteigerung und Ernährungssicherung im ländlichen Raum. April 2011. [Rehabilitation of river valleys in the Sahel by the construction of river weirs: A new approach to increasing agricultural production and food security]. April 2011.
- **Bureau Consult International:** Expérience des seuils d'épandage au Tchad. June 2011.

Summary

Over the last 12 years water-spreading weirs have been introduced and improved as a new rehabilitation technique for degraded dry valleys in Burkina Faso, Niger and Chad. They complement the previously available, proven rehabilitation measures for drainage basins. As a result, a set of measures is now available for the future stabilisation of such basins – from the plateaus to the slopes to the valley floor. Water-spreading weirs are an additional, economical and effective water management option for valleys, where they supplement retention basins, small impoundment dams and microweirs as means of intensifying agricultural production in the valleys. In contrast to other techniques, water-spreading weirs are especially well-suited for the large-scale rehabilitation of wide and shallow dry valleys that have been seriously degraded and in which severe gully erosion prevents the regular flooding that would normally be typical there.

Substantial degradation of drainage basins in the Sahel due to population growth and intense land-use pressure has been observed since the 1960s. Climate change has further amplified this trend. The expansion of agriculture and intensification of grazing and logging have caused the natural vegetation cover to decline. This process has been accelerated by severe droughts and has led to the degradation of the soils. Sparse vegetation cover and structurally damaged soils reduce rainfall infiltration into the soil, resulting in more runoff and soil erosion on plateaus and slopes. Runoff is concentrated in the valleys, in which heavy floodwaters wash away fertile soils and lead to deep erosion of the riverbed. The annual, recurrent small and medium-size floods that normally cause temporary inundation of the valleys and deposition of fertile sediments no longer occur. Due to the rapid runoff of the water, there is also less infiltration in the valley and the water table there drops. This in turn harms the natural vegetation and limits agricultural use. Within a few years fertile valleys turn into desert-like landscapes.

These dynamics can be reversed with water-spreading weirs and stabilisation measures in the drainage basin. Water-spreading weirs are structures that span the entire width of the valley. They consist of a spillway in the actual riverbed and lateral abutments and wings. Floodwaters are spread over the adjacent land area above the structure, where they eventually overflow the lateral wings and then slowly flow back towards the riverbed below the structure. As a result the land area below the water-spreading weir is flooded. The lateral spreading of the water causes the land area above and below the structure to be flooded and supplies it with sediment. Water infiltrates, gullies in the valley are filled and the riverbed is raised. Thanks to the infiltration, the water table also rises in a few years.

Water-spreading weirs alter the basic runoff and sedimentation processes in the valley. Specific adaptation to the various alterations of natural processes and agricultural optimisation of the water-spreading weirs are frequently beyond the scope of a single construction campaign, and subsequent adaptations may be required. In constructing water-spreading weirs, the first step is to identify basically suitable valleys in a region and inform the respective villages, communities and technical services about the possibilities and prerequisites for rehabilitation. Interested communities then submit a written request to the project in charge, which is examined by an approval committee. The socioeconomic conditions and structures in

the valley and the willingness of the local people to cooperate are assessed in the subsequent feasibility study. Then the basic construction parameters are defined and the anticipated costs are estimated in a preliminary technical study. The information delivered by these studies provides the basis for the final approval of the construction.

After approval a detailed technical study is conducted, on which the invitation to tender and ultimately the selection of a construction company is based. One of the principles of implementation is intensive participation by the communities and villages so that the responsibility may be transferred to the local level as soon as possible. The community is the client, issues the invitation to tender and accepts the work in the end. It also assumes a portion of the construction costs. A management committee made up of representatives from the local villages and communities is set up in the chosen valley. It acts as the contact for all external stakeholders and helps in the organisation of the work. Under the leadership of the management committee, future rules of use are agreed and documented. This can be in the form of a local use agreement, or may take place in the scope of a more comprehensive land-use planning process for the entire drainage basin system.

The construction work is performed with intensive manual labour (HIMO by its French acronym) by workers from the local villages, thus generating local income-earning opportunities during the construction phase. During the construction phase, local craftsmen are trained for the future maintenance of the structures. Water-spreading weirs are usually built in series in order to rehabilitate as much land area in the valley as possible; moreover, structures in series are less susceptible to damage. In combination with the water-spreading weirs, areas in the drainage basin that are especially susceptible to erosion and the areas between the weirs are stabilised in order to regulate runoff more effectively and minimising silting. Users who do not own any land in the valley benefit from the additional stabilisation measures outside the actual valley.

The construction of water-spreading weirs ensures that soils are regularly flooded and supplied with water and sediment. The arable land area and the yields of the rainy season crops serving as staple foods increase. For example, 4,731 farms in a valley system in Niger (which were direct beneficiaries of such rehabilitation measures) each had approx. 0.6 ha of arable valley land prior to the rehabilitation. Thanks to the water-retaining weirs, this was increased to 2.2 ha. Millet and sorghum yields increased on average by 85–90% and 25–30%, respectively.

The more frequent flooding of the soils results in increased infiltration, and the groundwater level rises substantially in most of the valleys. In 15 rehabilitated valleys in Niger, for example, the average depth of the water table level from the surface was 12.5 metres prior to the rehabilitation. A few years after the stabilisation measures, the average depth of the water table in the valleys was 3.5 metres below the surface.

In most of the valleys, prior to the rehabilitation it was only possible to grow a rainfed crop and perhaps an irrigated crop on some small areas of land. After the rehabilitation, in addition to the rainfed crop grown on larger areas of land, it became possible to grow a post-rainy season crop (*culture de décrue*) and, once the water table had risen, an irrigated crop (*culture de* *contresaison*) in most cases as well. Hence, prior to the rehabilitation, it was not possible to grow a crop during the dry season in 8 out of 15 valleys in Burkina Faso, whereas in others it was only possible to grow an irrigated crop to a limited extent on small fields in direct proximity to the river. Since the rehabilitation, at least one additional crop cycle is now possible on larger fields during the dry season in 13 out of the 15 valleys. The experiences in Niger and Chad are similar.

Post-rainy season crops and irrigated crops diversify agricultural production. They are used primarily for marketing and thus as a means of earning of cash incomes. The growing of staple crops during the rainy season is mainly done by the landowners themselves. However, they are only able to use a portion of the land area for intensive post-rainy season and irrigated crops with the available labour, and they therefore pass this land on to other farmers to use.

Water-spreading weirs thus increase and diversify agricultural production by making more arable land area available, increasing yields and making 1 to 2 additional crop cycles per year possible. This contributes substantially to food security and higher incomes for the beneficiaries. Thanks to the rising water tables, the natural vegetation of the valleys and the availability of fodder for livestock improve. Water for drinking and for watering livestock is more readily available, which in turn eases the workload of women. The more intensive production stimulates other business activities and generates income, helping to reduce poverty and stabilise the local population. With their capacity to regulate annual floodwaters and harness them to stabilise production, water-spreading weirs are an effective measure for adapting to climate change in regions experiencing increasing variability in rainfall.

The challenges lie in ensuring that the management committee is still able to function after the end of the project and that the local structures (e.g. the communities) are able to maintain the water-spreading weirs, particularly in the event of severe damage. At the present time the organisational and technical know-how for the construction and use of water-spreading weirs exists in only three countries (Burkina Faso, Niger, Chad) and is limited to a few stakeholders. This study aims to introduce the approach and describe it in detail so that it can be spread to other semi-arid regions. The idea is for the approach to be more widely adopted through intensive exchange of experience and by capacity development of companies and engineers.

Stagnant water in water-spreading weir

© GIZ / Klaus Wohlmann

1 INTRODUCTION

Valleys often constitute favourable environments for agriculture and settlement. The deposition of nutrient-rich sediments from the surrounding plateaus and slopes of the drainage basin and the inflow of surface and slope water form fertile alluvial soils. The availability of water for people, livestock and crops is improved. The alluvial plains in arid regions like the Sahel, where it only rains a few months a year, are production sites with an outstanding potential for intensive farming. Multiple harvests are even possible.

Increasing population pressure, inappropriate land uses and climatic fluctuations have resulted in the increasing degradation of the Sahel region drainage basins and their valley floors over the last 40 years. Clear-cutting, over-exploitation and recurring droughts have brought about a decline in the vegetation, which in turn has led to increased surface runoff and soil erosion, and, in the valleys, to highly variable drainage conditions, gully erosion, silting and a drop in the groundwater. The ultimate result was a drastic reduction of the production potential of the valleys.

In order to deal with the degradation, biological and physical soil and water conservation measures for restoring and maintaining production potential, especially on the plateaus and slopes of drainage basins, have been implemented since the 1980s. Reforestation, hedgerows and grass strips, rows of stones, filter dams and stabilisation of gullies serve to reduce runoff and the erosion that it causes. Previously, various types of irrigation dams, small impoundment dams, water retention basins and microweirs were constructed in the valleys to store water, raise the water table or control runoff and thus improve irrigation, water availability and flood protection.

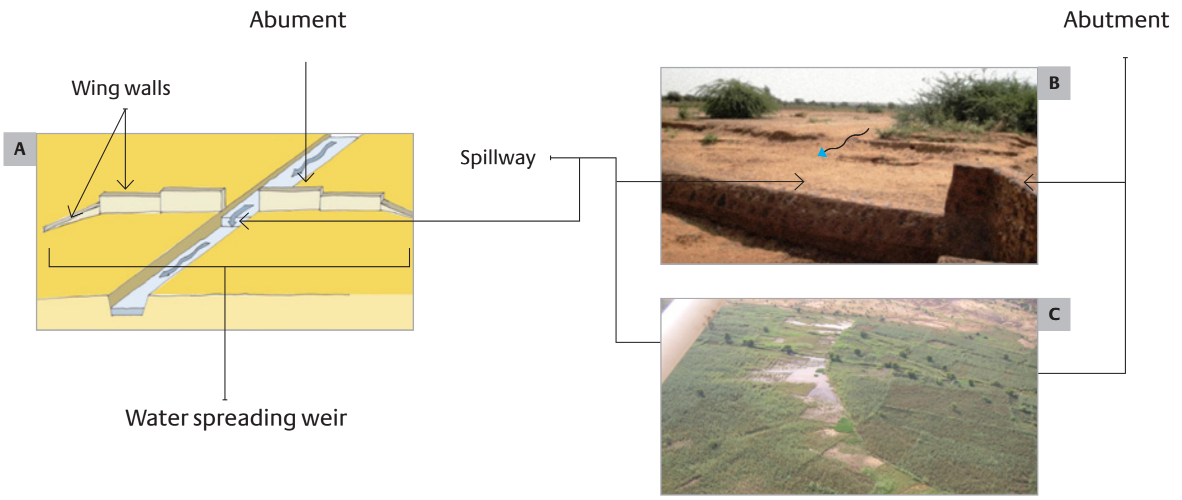
To supplement the existing set of measures, water-spreading weirs[1] were introduced during the last 12 years as a new measure for the rehabilitation and sustainable use of degraded dry valleys, and have been improved based on experience gained in Niger, Burkina Faso and Chad. With the option of effectively rehabilitating wide and degraded dry valleys, they complement the existing measures and thus present an opportunity for holistic rehabilitation of degraded drainage basins throughout such valleys – plateaus, slopes and valley floors.

Water-spreading weirs are low retention walls designed to reduce runoff and erosion. They are made of natural stones and cement, and consist of a spillway in the dry riverbed itself, lateral abutments for stabilisation and wing walls that span the width of the valley (Figure 1). In dry valleys in which water flows in the rivers for only a few days a year, they serve to distribute the incoming runoff over the valley floor and allow as much water as possible to infiltrate the soil. The groundwater is thus replenished and is then available for agricultural use. In contrast to the various types of dams, the goal of water-spreading weirs is not to create reservoirs for later use. What water-spreading weirs do is cause a temporary flooding of the adjacent land area above and below the weir.

1 In German there is presently no standard term for water-spreading weirs, and the structures are known as Talschwellen, Sohlschwellen or Flussschwellen. Talschwelle is used in the German version of this text, as the structures span the entire valley (Ger: Tal). Water-spreading weirs are known as seuils d’épandage in French.

The aim of this study is to introduce the new approach of water-spreading weirs to the interested professional audience consisting of development experts, consultants and planners, and to summarise the experience acquired with them since the late 1990s. The results are based mainly on the work of four preliminary studies that were conducted in Burkina Faso, Niger, Chad and transnationally,[2] as well as on comments and suggestions from numerous stakeholders. At this point we would like to thank all of them for their contributions and input.

Figure 1: Components of water-spreading weirs. A) schematic with spillway, abutments and wing walls. B) spillway in the riverbed with lateral abutments. C) water-spreading weir with spillway, lateral abutments and wing walls. Source: after Bender (2011)



2 Burkina Faso: Kambou (2011), Niger: Lütjen (2011), Chad: BCI (2011), transnational: Bender (2011)

2 Water-spreading weirs for the rehabilitation of dry valleys

2.1 Development of water-spreading weirs – a timeline

Water-spreading weirs have been used and improved in Chad, Niger and Burkina Faso since the 1990s.

The first water-spreading weirs were introduced during the 1990s in Chad through Swiss cooperation.[3] In Niger, the use of water-spreading weirs began in the Tahoua region in 1997. In that region, the first water-spreading weirs were constructed in an area in which the slopes and plateaus of various drainage basins had already been stabilised through measures for conserving soil and water implemented as part of the *Projet de Développement Rural de Tahoua (PDRT)*. Thanks to the weirs, the fertile but heavily damaged valleys were also rehabilitated in addition to the plateaus and slopes, thus stabilising the drainage basins in their entirety.

The first generation of water-spreading weirs were built with stone-filled wire baskets known as gabions and were prone to damage. From 2000 on the weirs underwent continuous improvements in terms of both efficacy and durability. The gabions were replaced with cement-reinforced natural stone walls, the planning process was refined, engineering and construction firms were trained, and the local people were taught how to maintain the structures. By 2010 more than 200 water-spreading weirs had been constructed in the Tahoua region, with approximately 10,000 ha of arable land area and nearly 5,000 users.[4]

In 2003 the KfW-funded project 'HIMO' (later FICOD) adopted the already improved method in Burkina Faso and constructed a total of 65 water-spreading weirs in 23 valleys between 2003 and 2010.

German development cooperation incorporated water-spreading weirs into its programme in Chad in 2004. By 2010, 104 water-spreading weirs had been constructed in the scope of the two development projects DETA and PDRD.

Water-spreading weirs have since been widely adopted and are now used as an approach by German, Swiss and French cooperation as well as the World Bank and other donors in the three African countries.[5]

2.2 Ecological processes in dry valleys

Land-use pressure and climate change have led to the degradation of drainage basins in the Sahel in just 40 years.

The successful use of water-spreading weirs demands a holistic understanding of the ecological and hydrological processes of a drainage basin. Water flows in the dry valleys of the Sahel for only a few weeks a year. After the heavy isolated downpours typical of the region, the runoff collects in the valley and there it drains away as concentrated floodwater. In ecologically intact valleys, the valley plains are repeatedly inundated during the three to four-month rainy season. The valley soils are infiltrated and thus store additional water; excess water seeps

3 Picard (no date), p. 1
4 Lütjen (2011), p. 37
5 LUCOP (2010a), p. 77f

deeper and replenishes the groundwater. Fine soil and organic matter are deposited and improve the fertility of the soils every year. Salts that would otherwise accumulate near the surface in certain regions are leached out.

Valleys with a largely intact ecology develop a dense vegetation cover that uses the available soil moisture or is able to access the groundwater via deep-penetrating roots. The vegetation enriches the soil with additional organic matter and nutrients and stabilises the soil structure, thereby improving water absorption capacity and resistance to erosion.

Traditionally, agriculture used to utilise only a small portion of the drainage basins and thus the soils were able to recover during the long fallow periods. Most of the land area was used as forest and pasture land. The basins, including the valleys, thus remained ecologically stable for long periods.

Aggravated by the first severe droughts in the years 1968–1973, rapidly progressing degradation due to a growing population and increasing land-use pressure has been noted in the Sahel region ever since. In the Tahoua region in Niger, for example, the practice of leaving fields fallow was abandoned over 15 years ago and agricultural land area has been expanded to the detriment of pasture and woodland. Declining vegetation cover and more intensive use caused a rapid deterioration of the soils. Water permeability is declining, causing surface runoff and increasingly more intense floodwaters. Due to the heavy runoff and the sparse vegetation cover, soil erosion is on the rise and gullies are forming.

In valleys these heavy floodwaters erode the riverbed, thus concentrating the runoff even more. Because of the sunken riverbed, the smaller and medium-sized floodings of the valley floor with their fertile sediment deposits no longer occur. The rapid runoff rate aggravates gully and bank erosion. Fertile alluvial plains are destroyed. Because of the lack of periodic flooding, the low rate of infiltration and the rapid runoff, the groundwater level drops. Formerly fertile valleys are transformed into desert-like landscapes within a few years (Figure 2).

Figure 2: A) (before) gully erosion in damaged valley floor; B) bottom: rehabilitated valley floor with dense vegetation (Fulachi, Niger). Source: Lütjen

The degradation of fertile valley floors is thus directly correlated with the degree of the degradation of the entire drainage basin. Degraded valleys therefore require, depending on the extent of the erosion risk, various soil and water conservation measures in the basin itself in order to increase infiltration then and there and reduce the runoff and silting in the valley. Without such supplementary measures, water-spreading weirs in degraded basins are subject to rapid damage from gully erosion, undermining and silting.

2.3 Action mechanism and technical characteristics of water-spreading weirs

Water-spreading weirs are designed to stop gully erosion in valley floors and to establish a drainage pattern corresponding to that of intact valley floors; in other words, they promote the inundation of the valley floor and the deposition of fine soil and organic matter. In order to do so, the structures must span the entire width of the valley floor. Depending on user preferences, the primary goal may be: i) agricultural use, ii) sylvo-pastoral use, or iii) the replenishment and raising of the water table (Box 1).

The flooded land area, the volume of impounded water and hence sedimentation and infiltration can be influenced by the height of the weirs and the distances between the structures. In contrast to various types of dams, however, no further regulation of the water is possible after the weirs are constructed, and longer-term surface detention of water for irrigation use at a later date is not the goal. The achievable yields are therefore less than those that are possible with controlled irrigation. However, water-spreading weirs are easier to manage and maintain than dams. They are also more economical to construct.

Box 1: Water-spreading weirs are adapted to various use priorities

Depending on the climate zone and farming system, farmers use natural resources for various purposes:

- Rice growing is the main goal of the farmers in north-eastern Burkina Faso. Hence they prefer weirs as high as possible that retain water on the flooded land for several days or weeks.
- In Tahoua, Niger, sorghum is grown in years in which water is plentiful, and millet in other years. If the water retained by the weirs remains on the land for too long, it is no longer possible to grow sorghum. Because the design of the first water-spreading weirs was not sufficiently adapted to the priorities of the users, they were initially dissatisfied. Scepticism faded, however, once the users found that they could grow an additional crop on the flooded area without having to irrigate once the water receded. They then adapted their farming systems to the new conditions.
- In Aïr, Niger, onions are planted in the rainy season because early onions command a high sales price. The main production, however, takes place during the dry season with irrigation. The farmers in Aïr thus wanted most of all to raise the level of the water table so that they could irrigate as easily as possible from shallow wells. Hence the water-spreading weirs were designed so that a large volume of water would infiltrate but also so that only minor flooding of a portion of the valley floor would occur in order to enable the production of early onions during the rainy season.

Source: Bender (2010), p.15

In villages that are otherwise cut off during the rainy season, water-spreading weirs can also be designed as fords so that the valley can be crossed during the rainy season as well (Figure 3).

Figure 3: A water-spreading weir designed as a ford for crossing the valley. Source: Bender (2011), S. 16

Water-spreading weirs consist of a spillway, which is located in the riverbed, lateral abutments and wing walls, which gradually decrease in size with increasing distance from the main structure (Figure 4). As the floodwater rises, the various structural elements overflow one after another: (i) with little runoff all of the water is conducted over the spillway and remains in the riverbed; (ii) with increasing runoff first the lower, outer wing walls overflow, and (iii) finally the higher wing walls as well as runoff increases even further.

The abutments at the sides of the spillway are designed to protect both it and the riverbanks below from erosion. The abutments are only flooded in exceptional cases with extremely high floodwaters.

The water-spreading weir diverts the water to the sides in order to inundate as much surface area as possible above and below the weir. Water infiltrates, and fertile sediments are deposited on the flooded land area.

Because the water flows back to the lower riverbed after it overflows the wings, the soil in the zone of return flow below the weir is especially susceptible to erosion. To prevent this from happening, water-spreading weirs are preferably constructed in series, thus reducing the flow gradient. The areas between the weirs are also stabilised (Box 2).

The specific adaptation of the structures to the individual site conditions and use requirements is often beyond the scope of a single construction project, as the structures cause alterations to the valley floor and the drainage pattern. The experiences of the users continue to change and evolve as well. As a result of these alterations, subsequent adaptations such as elevation or reinforcement of the structures may be justified in order to optimise use and sustainability. This leads to a multi-year process wherein the structures and their use need to be monitored and possible adaptations considered.

Technical aspects in the construction of water-spreading weirs

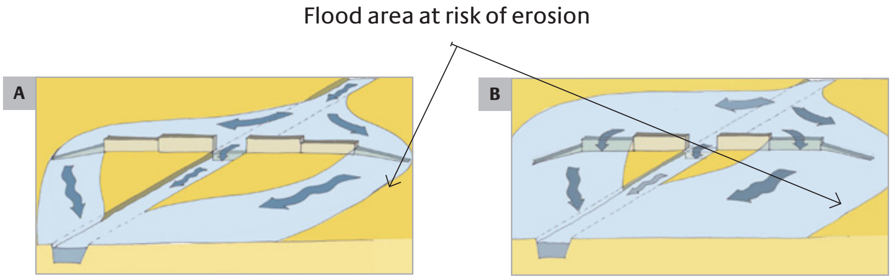
Water-spreading weirs require detailed technical planning and experienced engineering and construction firms. The bulk of the work is performed using local materials and by village craftsmen and helpers.

A series of preparatory steps[6] nis necessary before construction of the weirs can start. The technical planning starts with a preliminary technical study once the people of a valley on an extensive area of the valley floor have agreed to the rehabilitation work. In the scope of the preliminary technical study, the approximate sites of the weirs, the weir type and the rough dimensions are determined, wherein it is necessary to gauge how the individual weirs will interact. This ultimately leads to the overall design of the planned series of water-spreading weirs. The inundation area to serve as potential production area is determined, and the cost of the entire system is estimated using per hectare cost values derived from experience. The soil quality and the depth of the water table are assessed and the anticipated impact of the weirs on the groundwater level is estimated. Groundwater levels that can be raised rapidly and clayey soils are indicative of valleys with a high production potential of up to three possible harvests.

After a valley is selected, the next step is the detailed technical study, which is necessary for preparing the tender documents. In this study the type of weirs and the dimensions of the structures are established and the exact sites of the individual water-spreading weirs are marked on the landscape. The cross-section of the valley at the height of each weir is measured. The individual plans of the water-spreading weirs are drawn (Appendix 2) and the work is described in the tender documents. The drafting of the study requires considerable practical experience, which must be taken into account in the selection of the engineering firm. New project engineering teams must therefore be supervised and given practical training by an experienced engineer. Local experts should be included in the studies. Because the studies will be conducted prior to the rainy season and the construction will not take place until after the rainy season, the fact that several years of such supervision will be necessary must be taken into account. The structure will not be tested in actual practice until the following rainy season. Furthermore, water-spreading weirs alter the drainage pattern of the water, soil erosion and silting, and land uses in the valley. Hence it is necessary to commit to several years of observation and subsequent adjustments to the structures may also be required.

6 Appendix 1 gives a schematic timetable for the implementation of water-spreading weirs, which can also serve as an aid for interested projects and partners.

Figure 4: A) with moderate runoff, the spillway in the actual riverbed and the lower wing walls located on the outsides of the weir overflow. B) as runoff increases, the higher wings overflow as well. Source: Bender (2011), p. 13



Box 2: Water-spreading weirs alone do not stop erosion completely

Gully erosion and sedimentation pose a danger to individual water-spreading weirs in degraded valleys. Hence water-spreading weirs are constructed in series (Figure 5) in which neighbouring weirs protect each other by reducing the gradient between the weirs and thus slowing the runoff velocity.

Even in series, however, erosion processes still occur between individual weirs. The areas directly above and below the water-spreading weirs are well protected (green area in Figure 6). The retained water stagnates above the weir; the water immediately below the weir has very little flow velocity and erosion force. With increasing distance from the weir, however, the velocity picks up again and the water concentrates more and more, and thus the risk of erosion increases in direct proportion to the distance from the weir. The river banks below the weir are also in danger of being eroded by the return flow of the water.

In order to prevent erosion from starting anew, small stone walls are built between the weirs and also below the last weir, and deep gullies between the weirs are stabilised with filter dams. Stabilisation measures are required outside the immediate area of the valley as well (not shown in the figure), in areas at high risk for erosion and gully erosion in order to reduce runoff and silting in the valley.

Figure 5: Water-spreading weirs constructed in series – an example from two dry valleys in Chad (Wadi Chock and Wadi Chaou – yellow lines).
Source: PRODABO in BCI, 2011, p. 7

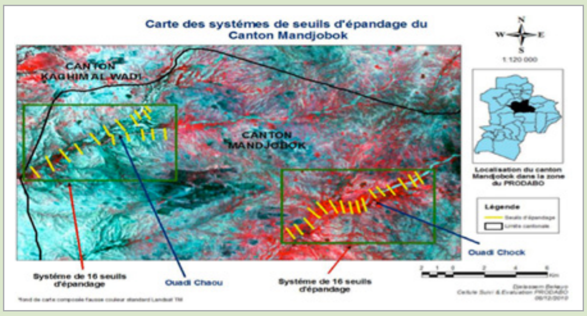


Figure 6: Areas above and below the weirs are well protected (1, 2); the risk increases in direct proportion to the distance from the upper weir (3) and gullies may form (4)
Source: Bender, 2005, p. 24

The invitation to bid on the construction work is issued on a national level in order to build up the expertise of local firms. As the client, the municipal authority issues the invitation to bid. In Niger, for example, a representative from each of the following takes part in the bid evaluation process in order to ensure transparency: the community, the state specialist authorities, the supervising engineering firm,[7] the project and the office in charge of the planning. The contract with the construction company is concluded between the latter and the project, on behalf of the client. It is important that the invitation to bid and the awarding of the contract phases be completed by the end of the rainy season so that the actual construction of the water-spreading weirs can begin early in the dry season and be completed by the next rainy season. Adaptations can then be made in subsequent years.

The contracted local construction companies are contractually obligated to use manual labour as much as possible for the work and to hire and train mainly local workers (HIMO approach).[8] This provides a temporary supplemental income for local households, whose members also acquire the necessary craftsmanship skills for the future maintenance of the structures. The contracted engineering firms, municipal authority representatives, members of the newly formed management committee and the project supervise the construction. Final acceptance is by the client (community), with the assistance of the project/engineering firm.

When the work starts, setting up a training site has proven invaluable. Here local helpers and experts, as well as construction company employees, receive instruction and practical training from technical specialists with experience in water-spreading weir construction. Local masons are also included in this training so that they are able to perform repair work later on.

The use of local materials and the inclusion of the local population are key implementation principles for easing future maintenance. Because water-spreading weirs alter both the natural processes and the uses in the valley, it is essential to assess the impacts of these changes on the structure after one or more rainy seasons. This takes place in the scope of a technical evaluation, in which weak places are investigated and adaptation measures are established to ensure optimum utility. For instance, if high weirs are planned, it may emerge that the structures cannot be built to the final height right away for safety reasons. Instead it may be necessary to build lower weirs first. Following the construction the height differences will be lessened as soil builds up, and then additional height can be added on to the structures.

Figure 7: Training site for local craftsmen. Source: Lütjen

7 Because the communities as clients in Niger do not have the necessary expertise to supervise the construction, this task is delegated to an engineering firm ('delegated clientship').
8 HIMO – Haute Intensité de la Main d'OEuvre (intensive use of manual labour)

Where are water-spreading weirs especially useful?

Water-spreading weirs are especially well-suited for the large-scale rehabilitation of severely degraded, wide valley floors.

Compared to small impoundment dams, retention basins and microweirs, water-spreading weirs are especially well-suited for shallow, wide valleys that, due to severe gully erosion, are no longer inundated by small and medium volume floodwaters. The flooding no longer takes place because the actual riverbed has been deeply eroded and enlarged. However, water-spreading weirs are also suitable for improving agricultural productivity in more or less intact valley floors.

Water-spreading weirs are successful in regions where precipitation during the growing season is erratic and where the weirs ensure a more evenly distributed water supply for crops, as well as in zones in which water enrichment makes one or two additional growing seasons possible. At the present time they are in use in a broad area where annual rainfall ranges from 50 to 1,200 mm/year.

The difficulty in the construction of water-spreading weirs lies chiefly in the extent of the degradation and gully erosion. The slope of the valley, runoff volume and soil properties are secondary factors. For example, the slope in the valleys that have been rehabilitated to date lies between 1 and 8%. It merely influences the distance between two weirs and thus the cost per hectare.

There are various approaches and techniques for rehabilitating valleys that can be used in combination with one another. Water-spreading weirs are one of the possible, proven options that should be considered.

Complementary rehabilitation measures in the drainage basin

Complementary stabilisation measures in critical areas of the drainage basin are required to protect water-spreading weirs.

An important reason why rehabilitation measures in drainage basins must include valley floors is the high production potential of such areas and the potential contribution to food security that this represents. The per hectare production potential of valley floors is higher than that of the other areas in the basin, as valleys have the most fertile soils and the best water supply. By the same token the valley area is small compared to the rest of the basin, thus limiting the scope of necessary measures. Hence there is much to be said for securing this important production potential. Nevertheless, measures outside the valleys are still critical because the condition of the rest of the basin exerts a considerable effect on the valley floors.

A degraded drainage basin increases the risk of damage to measures implemented in the valleys. Heavy surface runoff from the slopes leads to intense flooding and silting in the valleys, and in turn to more stress on and damage to the water-spreading weirs. In contrast, basins in which stabilising soil and water conservation measures have been implemented reinforce the positive effects of water-spreading weirs on the hydrological regime. A portion of the water infiltrating the drainage basin flows un-

Water-spreading weir facilitates water supply and soil fertility © GIZ / Klaus Wohlmann

derground as slope water to the valley floor and thus continuously replenishes the valley floor's groundwater supply.

In order to protect the valley floors from excess runoff and sedimentation, rehabilitation measures must be implemented at least in those areas of the rest of the drainage basin that are particularly susceptible to erosion. Such measures are essential for protecting the water-spreading weirs. Furthermore, they also serve to improve agricultural production for households that do not own any valley land.

When planning rehabilitation measures in a drainage basin, the dimensions of the land area in the valley and the rest of the basin need to be taken into account. The relatively small valley floor compared to the rest of the basin can be rehabilitated in the course of a few years and is hence feasible in the scope of 'development projects'. In contrast the large-scale rehabilitation of entire drainage basins frequently requires decades, which should be taken into account when planning new projects. Such a challenge can only be mastered through long-term commitment on the part of the local people as well as the government, and it requires long-term functioning funding mechanisms. In the scope of water-spreading weir 'projects' with their generally short runtimes, all that can usually be accomplished is to start stabilising plateaus and slopes in critical areas, and to use this work as a basis for introducing necessary technology and for training the local people.

In special cases, water-spreading weirs can be incorporated as a supplementary element in already rehabilitated drainage basins. This was possible to some extent in Niger, where the first water-spreading weirs were built in regions where the PDRT *(Projet de Développement Rural de Tahoua)* had already stabilised a large portion of the basins. This project demonstrated that water-spreading weirs can be used as an element in a holistic approach to drainage basin management and also as a specific measure (in combination with the stabilisation of areas particularly at risk of erosion) for rapidly restoring the productivity and ecology of valley floors.

2.4 Use and management of rehabilitated valley floors

Prior to rehabilitation, the degraded valleys were generally only used for the production of a rainfed crop consisting predominantly of millet, sorghum and cowpea (black-eyed pea). Such crops were grown on the remaining land areas of the valley (areas not yet lost to degradation). In valleys in which the groundwater table was still relatively shallow, some vegetable production was still possible in the vicinity of the river, with irrigation from wells in the riverbed.

After the rehabilitation, as many as three crops a year could be grown in most of the valleys: a rainy season (rainfed) crop,[9] a post-rainy season crop and a third (irrigated) crop[10] that can be watered from shallow wells thanks to the replenished water table. Post-rainy season crops and irrigated crops are usually grown only on a portion of the land area, whereas the majority of the land area inundated by the water-spreading weirs is used for the rainfed crop.

In Niger and in Chad, the rainy season crops are still millet, sorghum and cowpea, whereas the rehabilitated valleys in Burkina Faso are predominantly used for rice production. Maize, sweet potato, pumpkin, hibiscus varieties and other vegetables are planted as post-rainy season crops. Tomatoes, onions, chillies, eggplant, cabbage, lettuce and beans are the principal irrigated crops.

Production during the rainy season primarily serves as a means of self-provision with staple foods. Excess production can be marketed in good years. The yield of the post-rainy season and irrigated crops also serves as a supplement to self-provision, but is mainly intended for marketing.

The use of the flooded land areas is adapted to the prevailing exploitation system of the users. Whereas villages oriented to agronomic production use all of the land for growing field crops, villages that are predominantly geared to agropastoral production only use a portion of the land area for field crops, and other portions are reserved for pasture and for growing forage crops.

During the rainy season the land area is primarily cultivated by the field owners themselves. Only in Burkina Faso are plots also provided to others for intensive rice production, simply because insufficient labour is available on the farms for cultivating all of the land area. The owners are likewise unable to use all of their land area for post-rainy season and irrigated crops, and plots are rented or lent to other users in this case as well.

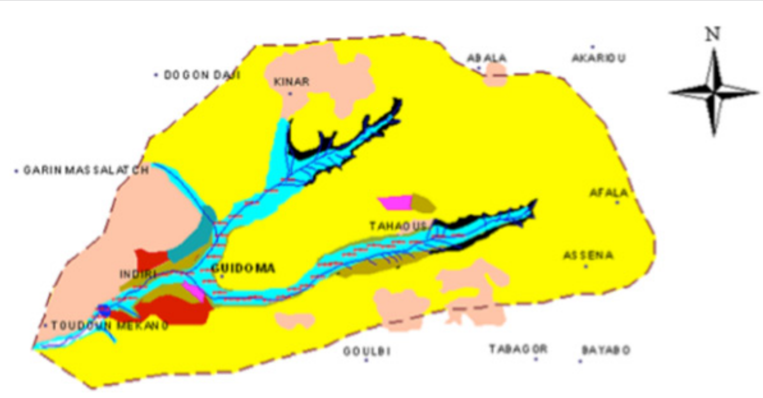
An intensification of agricultural production is generally seen after the rehabilitation due to the increased production potential. Organic and inorganic fertilisers as well as animal traction are being used to a greater extent. A few farms have purchased motor-driven pumps for irrigation.

9 Post-rainy season crops (culture de décrue) are grown on the borders of rivers and lakes. They use the land area that becomes available as the floodwaters recede and which still has adequate soil moisture or a sufficiently shallow water table for growing a crop.
10 The main crops grown as irrigated crops (culture de contre-saison) are vegetables and herbs. They are watered from hand-dug or cemented wells, either by hand or with motordriven pumps.

Box 3: Land-use planning for drainage basins (SMEV) in Niger

An SMEV (Schéma de Mise en Valeur des Vallées) is a planning document that integrates aspects of drainage basin development in an overall strategy. This includes types of land use, ownership aspects, infrastructure, and rules of access to resources. It contains a medium-term action plan with measures for improving the area.
To develop an SMEV, the starting situation is analysed in collaboration with all of the stakeholders in order to formulate a common vision and the necessary actions to carry it out in the second phase. Representatives of the newly-formed land law boards, local councils, representatives of the villages and all other user groups in the valley, as well as specialised government authorities, participate in the process.
The advantages of an SMEV are the characteristic ownership and high level of acceptance of the plan that come from the participatory development, the intensive capacity building, and the inclusion of all stakeholders. The role of the land law boards, of which only a few have been established thus far, was strengthened. The disadvantages are that the development of SMEVs is cost intensive and that the strategies are not recognised as an official land-use planning method in Niger (thus far there is no official communal land-use planning method in that country) and are therefore exclusively project-driven.

Figure 8: Land-use scheme for the Guidoma drainage basin in the community of Affala (Niger)



Upland plains	Arable
Slopes	Pasture
Valley plains	Arable
Dunes	Arable
Relict mountains	Pasture
Scree	Pasture

2.5 Legal-institutional aspects in the construction of water-spreading weirs

Water-spreading weirs must comply with the national statutory framework. The allocation of use rights by the users themselves has worked thus far.

The construction and use of water-spreading weirs are subject to different legal regulations in every country. In all three countries studied, the rehabilitation of valley floors supports the goals of various national policies such as poverty reduction, environmental protection, and combating desertification or climate change.

National land legislation or laws governing access to and exploitation of natural resources such as environmental law, forest law, water law, etc. must (as with dams and similar structures) also be considered in the use and exploitation of water-spreading weirs. Regulations that set forth the duties and rights of rural entities such as communities, village administrative bodies, cooperatives, or farmers' associations likewise play an influential role.

Institutions and bodies with jurisdiction over the construction and the use of water-spreading weirs should therefore be included in the planning and implementation phases. The water-spreading weirs should be integrated in the respective development schemes and action plans. This applies especially to municipal development plans, but also to the work plans of specialist authorities.

A special effort was made in Niger to develop a land-use planning methodology for drainage basins in which water-spreading weirs were constructed that takes account of both physiographic and social conditions. Representatives of communities, the target villages and all stakeholders in the basin area took a survey of the situation and then produced a rehabilitation scheme (*Schéma de Mise en Valeur des Vallées – SMEV*). SMEVs are a type of land-use planning on drainage basin level that can be used as a subunit of communal planning or as a cross-municipality planning instrument (Box 3). Initially developed and implemented on a project basis, the methodology is now being aligned with similar approaches in order to complement the national set of planning tools. Problematic is the fact that including a greater number of stakeholders entails greater effort for coordination, which in turn leads to additional costs and delays in decision-making processes.

Land law aspects

In the impact zone of water-spreading weirs, land ownership rights can range from traditional rights of tenure, registered deeds, government-owned land and common/municipal land.[11] In actual practice the majority of the valley land is in the traditional ownership of different families. Some areas may be common land (now municipal land) or government-owned land. The ownership of private land is handed down from generation to generation and can be farmed by the owners themselves, leased, or lent either free of charge or in return for money and shares in the harvest.

11 Municipal (community) land did not exist prior to the introduction of communities (communes), which have only been in existence for a few years in most of the countries. Previously it was common land.

The rules in Chad differ somewhat from this general framework. Only the rainfed fields are in private family ownership and inheritable. Reclaimed irrigated fields and vegetable production fields go back to the community and can be redistributed.

The projects do not get directly involved in ownership issues of the rehabilitated land in any of the three countries studied. The allocation of use rights within the villages has thus far offered all interested parties access to the land, at least during the dry season. The only known case of tension was in Chad. In the first year after the construction of the weirs, all that formed initially were isolated 'oases' with good growing conditions, and there were disputes as to how these were to be allocated.

In Burkina Faso, the intention at the outset of the project was to redefine the ownership conditions on the rehabilitated land area. It later emerged, however, that the committees in charge only regulated the use of the land area, and the actual ownership conditions remained unchanged.

In Niger and in Chad, it is mainly the owners themselves, or in some cases other users designated by the owners, who use all of the land area during the rainy season. During the post-rainy season and irrigation season, the owners are only able to farm a small portion of their land themselves due to limited manpower. Other users from the village or even from outside can apply for plots, and the use thereof can either be free or in exchange for payment in kind or cash. All users of rehabilitated valley land pay a fee, which is administered by the management committee and used for repairs.

Rice is grown in the valleys of Burkina Faso during the rainy season. Because rice is a more labour-intensive crop than either millet or sorghum, the owners are unable to use all of their land even during the rainy season. They therefore allow other farmers to use it during the rainy season as well. Because additional users must first be found, the number of users increases during the first years. As Figure 9 shows, the number of users in three sites in Burkina Faso increased from less than 50 farmers to more than 100 farmers during the rainy season, and from around 10 to as many as 30 or 50 during the dry season.

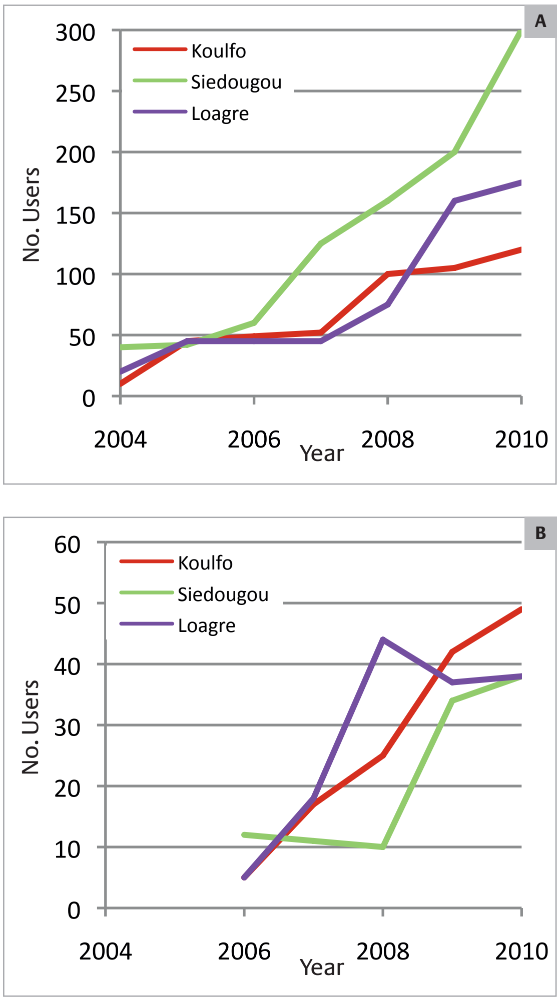
Water-spreading weir in Kalfou (Tahoua region, Niger)
© Heinz Bender

Ownership and maintenance

There is still no clear answer to the question of who owns the initial structures. During the first years, water-spreading weirs were constructed in the valleys upon request by the village communities. The villages were the owners of these weirs and were thus obligated to maintain them, but they were only able to take care of minor repairs. The property owners on whose land the structures were built had to give their consent and the land for the construction. Whether they received any compensation from the villages for doing so is not known.

Over the course of time and in the scope of increasing decentralisation, communities emerged as new players. In Burkina Faso, for example, all villages have been members of communities since 2006. The communities have been in charge of the construction ever since, and have taken on the responsibility of performing more extensive maintenance work. But because the budgets of the communities are hardly sufficient to cover their numerous tasks, funds for more extensive repairs are seldom assured.

Figure 9: A) Trends in user numbers in rehabilitated valleys in Burkina Faso during the rainy season. B) and the dry season. Source: Bender (2010)



3 Organisational aspects of water-spreading weirs

The village community and the weir committee participate intensively in the planning and implementation phases in order to generate a sense of ownership and to build capacity.

The successful use of water-spreading weirs requires high quality planning and technical implementation of the structures as well as active participation by the local people and the competent communal and government stakeholders in the planning, realisation, use and maintenance aspects. While sufficiently qualified engineering and construction firms with practical experience in weir construction are able to take care of the technical part, the more complex task is the organisation of the users and incorporation in the local institutional environment, with the aim of handing over the structures and the long-term operation and maintenance thereof. How the details of this task are worked out depends on the legal, socio-economic and cultural conditions and the institutional environment. Hence the following examples are merely schematic illustrations of the most essential processes, and they need to be adapted on a case-by-case basis. Active participation by the stakeholders in all phases, however, is recognised as a universal principle.

The preparatory phase

From the project standpoint, the work starts with a rough inventory of suitable valleys and with informing government services, the responsible communities and/or potential villages about the possibilities and terms of the cooperation. Villages that are interested in the rehabilitation of their valleys submit a written request for valley rehabilitation through their village committee. In the past this request went directly from the village to the project, but now it is sent to the municipal authority for approval, which then officially submits it to the project as a request from the municipal authority. How water-spreading weirs are handled in communal development plans (which are valid for 3 to 5 years) is different in each coun-

Participatory planning process with local population © GIZ / Klaus Wohlmann

try. Chad requires the official statement of the rehabilitation proposal in the local communal development plan. The community agrees to assume 10% of the costs, not to exceed 500,000 CFA francs (€ 760). In Burkina Faso, the villages submitting the request undertake to assume 3% of the costs, and the proposals are then inscribed in the communal development plans when these are updated each year. In Niger, the valleys to undergo rehabilitation are selected on the basis of the priorities of communal development plans, and a more comprehensive land-use planning process is conducted in a participatory manner with all stakeholders for the drainage basins that are candidates for rehabilitation (see Section 2.5).

In response to the request, the project conducts a feasibility study, in which information on the socio-economic situation and the ecology of the valleys is obtained, and also a preliminary technical study (also see Section 2.3). In the preliminary socio-economic study, the ethnic, socio-professional and social makeup of the villages, land ownership situations and conflicts are analysed jointly, with participation by representatives from the municipality and the village population. The willingness of the villages to cooperate is also assessed. The preliminary technical study assesses technical feasibility. These studies are usually conducted by local service providers. On the basis of these studies, the project approval committee evaluates the request from the municipal authority and decides whether or not to approve it.

Water-spreading weir © GIZ / Klaus Wohlmann

If the request is approved, a management committee is set up in the village (or villages). Its members are representatives, male and female, of the village and the municipal authority. The management committee serves as the contact partner for the project, government agencies and construction companies. It is responsible for establishing rules of use and for organising the people during the construction, use and maintenance of the weirs. Diverse organisational-administrative training sessions on topics such as rights and duties, planning and administration, and also technical training sessions on the use and maintenance of weirs are provided to the committees. The committees collect and administer the plot fees paid by all users and organise minor maintenance and repair work.

Man harvesting groundnut © GIZ / Klaus Wohlmann

Horticultural crop: onion © Marc Cleriot

Before any work begins, the various groups of the villages involved meet several times in order to discuss and establish the terms for the construction, the procedures of the construction work, and the rules for future use and maintenance. The rules are set forth in a use agreement. This also includes a use plan and provisions for allocating the plots. The allocation of the plots is mainly worked out among the users, wherein the project may act as a moderator.

Once the procedures for the work and the rules of use are finally established, the detailed technical study is conducted, the invitation to bid is issued, and the construction companies are chosen and contracted.

The construction phase

The first step in the construction phase involves setting up training sites in order to provide training to masons and company craftsmen by experienced professionals. The local construction companies contracted for the work are contractually obligated to employ local workers and to use manual labour as much as possible (HIMO).

The municipal authority, the village committees and the management committee oversee the work with support from a local engineering firm, which is the official supervisor of the construction. Representatives from the village(s) and the municipality organise the selection and deployment of construction site helpers. They take part in all meetings and on-site discussions and help solve problems. The purpose of their intensive involvement is so that the responsibility for the weirs is transferred to the local level at the outset in order to ensure sustainability. As clients, the municipal authority representatives and the management committee also officially accept the work.

The use and maintenance phase

Once the water-spreading weirs are finished, the management committees, with project support, organise the use of the land area. Various use zones (e.g. fields, pasture, forest, or animal corridors to waterholes) are designated and the rules are announced once again.

Technical training in the growing of new crops, animal traction, fertiliser and pesticide application, etc., is provided to ensure optimum use of the investments. In Niger, connections with equipment dealers and purchasers/processors of agricultural products were established in the scope of a value chain approach.

The management committee collects the user fees, inspects the structures for possible damage and sees to the repair of minor damage, convenes routine user meetings, and acts as a moderator when there are differences of opinion. The municipal authority is involved in the event of more extensive damage. As has been shown with dams and other agricultural investments, the majority of the management committees function well as long as they are supervised by the responsible project. The sustainability of the committees after the end of the project, however, varies greatly, and some of the committees do not perform satisfactorily.

Girl with pearl millet © GIZ / Klaus Wohlmann

Water for irrigation © Marc Cleriot

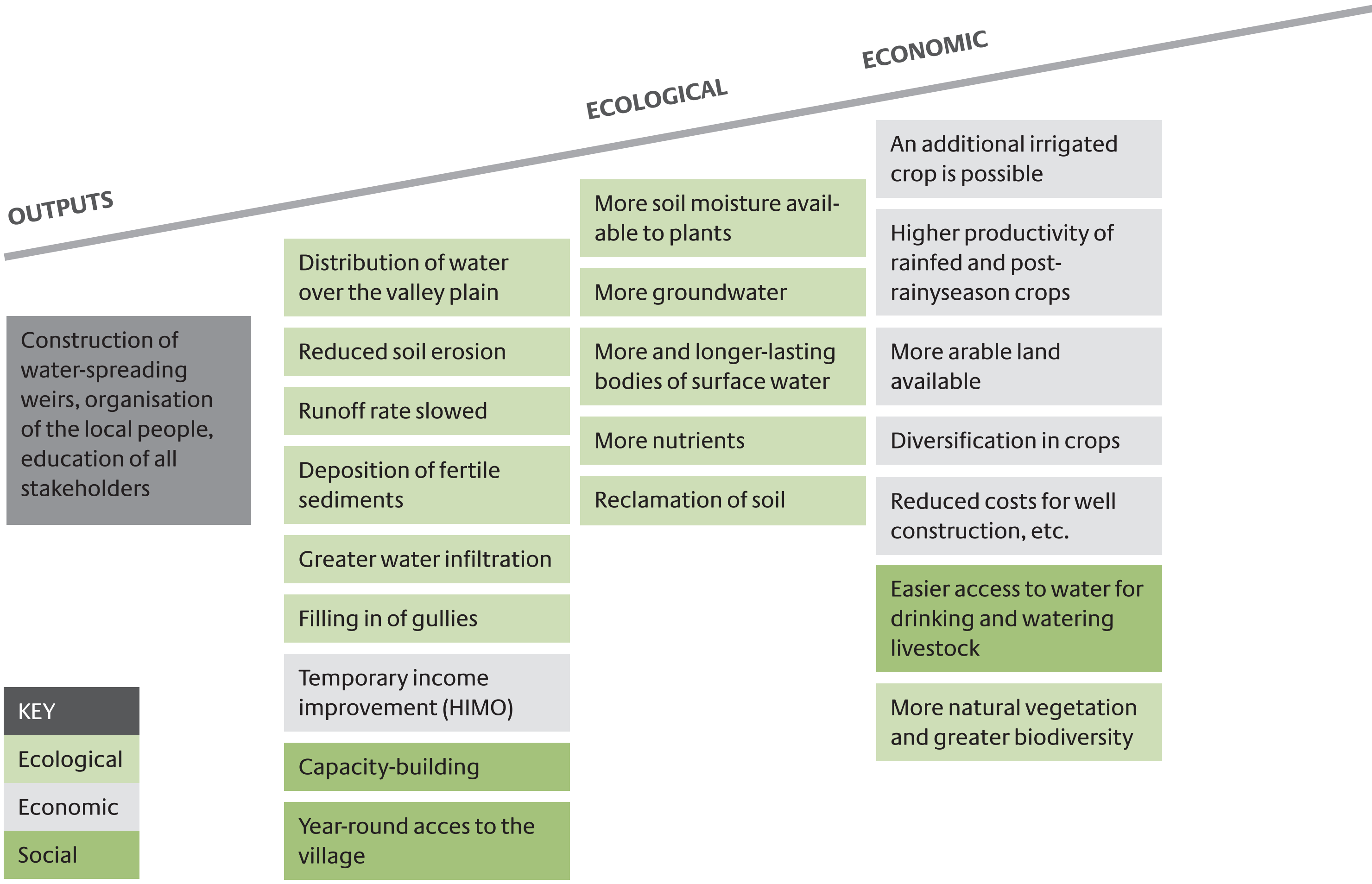
4 Water-spreading weirs affect ecology, yields and living conditions

Water-speading weirs have far-reaching positive ecological, economic and social effects. They influence the local economy and contribute to the emergence of local centres of growth.

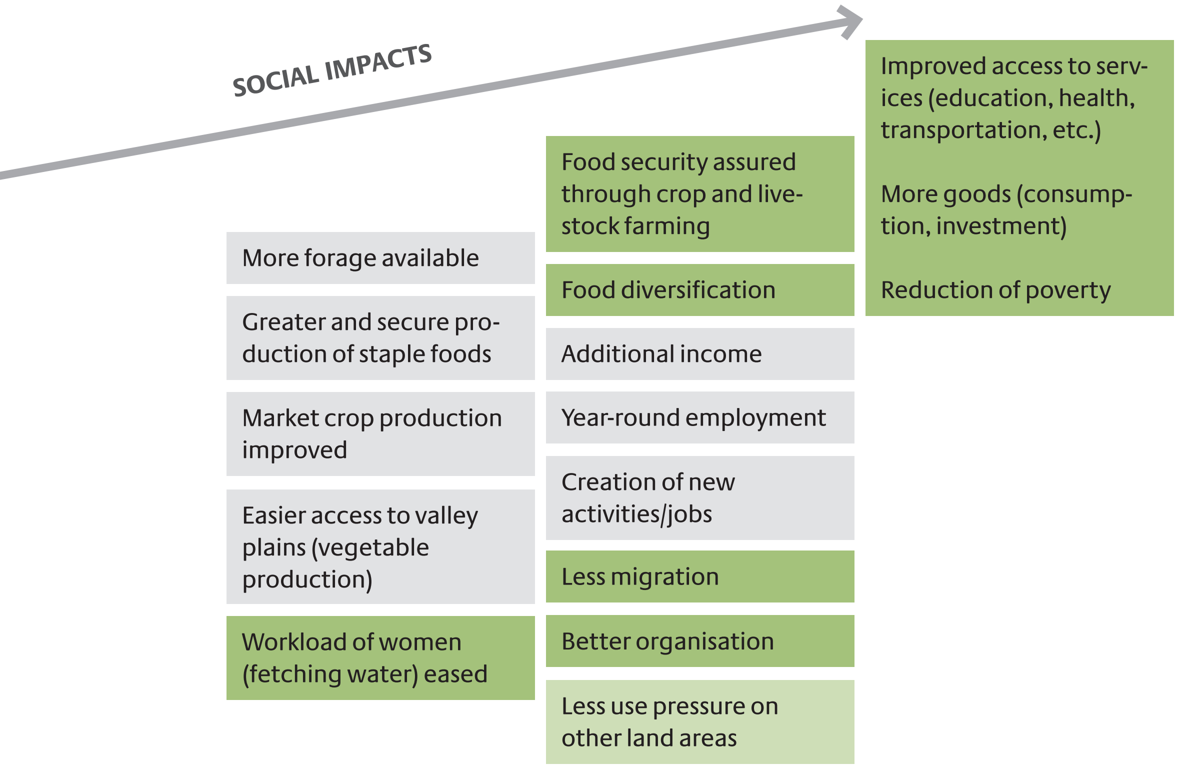
Experience to date from Burkina Faso, Niger and Chad shows that water-spreading weirs bring about substantial ecological, economic and social improvements within a few years (Figure 10).

During the construction, numerous households benefit from the supplemental income generated from the work intensive approach. Because the work takes place during the dry season, it does not compete with agricultural activities. Village residents are trained as masons and helpers, and company employees are schooled in the new technology, thus advancing their professional skills. If the weirs are designed as fords, they provide those villages that are isolated during the rainy season with a year-round connection to the outside world.

Figure 10: Results of water-spreading weirs



The impact of the water-spreading weirs manifests itself immediately during the first rainy season after completion, and increases during subsequent years. The distribution of the water over the land area above and below the weirs causes fertile deposits to form. Gullies are filled in and substantial volumes of water infiltrate. A portion of the water is stored in the soil; excess water infiltrates more deeply and contributes to raising the water table. Thanks to the extensive flooding and the silting up of gullies, land areas that have long since fallen out of production can be reclaimed, thus increasing the arable land area available to the farms. The annual depositions of fine soil and organic matter supply nutrients. The retained water remains in natural sinks outside and within the riverbed, forming ponds that last for weeks and which are used as water holes or for fishing.



Greater water reserves in the soil and additional nutrients enable higher yields of the crops grown during the rainy season and of the successive post-rainy season crops (see above). The agricultural production potentials have already been described in detail.

Other positive effects are as follows: The improved growing conditions also favour the spread of natural vegetation around the rehabilitated valley plains, and vanished plant and animal species return. Natural growth outside the rehabilitated areas and between the weirs (assuming the entire area is not used for agriculture) means more forage for grazing animals, which also benefit from the greater number of agricultural byproducts produced.

The higher groundwater level is used for more than just irrigation. It substantially improves the water supply for both households and livestock. The high water level in the wells makes drawing water easier and long walks to waterholes are no longer necessary, which makes life easier for women in particular. The costs for well construction are lowered, as existing wells once again provide water and new wells do not need to be dug as deeply.

The markedly greater, dependable and more diverse production of foods improves food security and quality. Market vegetable production generates additional income, which in turn enables access to social and economic services and goods. The two to three crops per year and the work in the upstream and downstream sectors of transport, trade and crafts create new jobs.

Not all of these effects have been systematically monitored to date. Some are based on consistent observations and reports by the local people. However, there are also quantitative analyses on key effects, and these will be described in more detail in the following.

4.1 Impacts of water-spreading weirs on groundwater and surface water

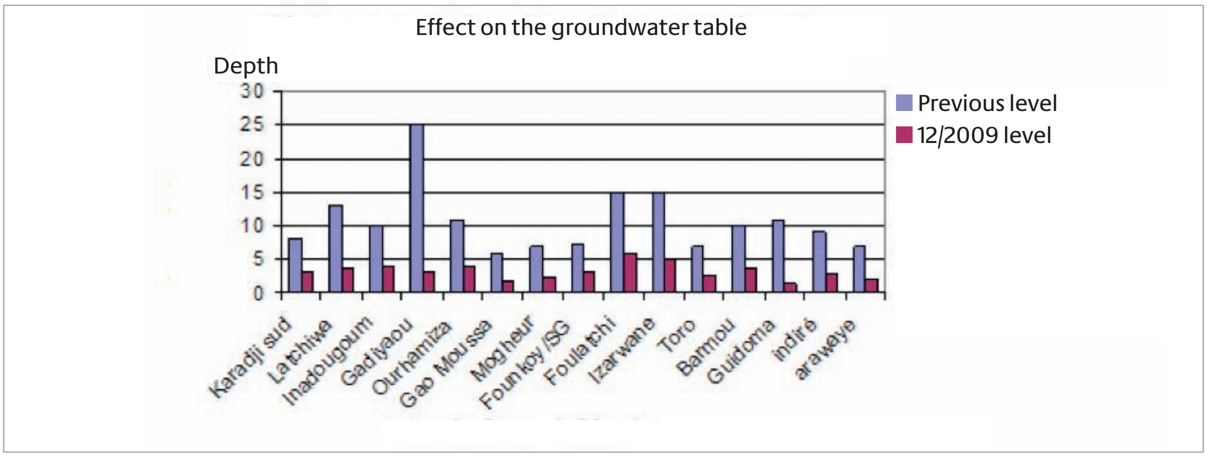
Water-spreading weirs prolong the residence time of surface water and gradually raise groundwater levels by several metres.

The raising of the groundwater level by water-spreading weirs is being systematically investigated in all three countries with test wells and observations by the local people. Prior to the start of the work, in Niger the average depth of the groundwater in all rehabilitated alluvial plains in December was 12.5 m. By 2009 the groundwater had risen by 8.5 m on average, and the average depth from the surface to the groundwater was 3.5 m (Figure 11).[12]

The measurements in Burkina Faso revealed that the groundwater levels, all of which were more than 8 m below the surface by the end of the dry season prior to the work, rose steadily each year and are now 2 to 5 m below the surface. In addition, there is more surface water in waterholes and ponds for longer periods of time. Whereas the surface water used to disappear 1 to 2 months after the dry season, these water sources now retain their water for 2 to 4 months. Substantial rises of the water table were also measured in Chad (Box 4).

12 Lütjen (2011), p. 35

Figure 11: Rise of the groundwater table in rehabilitated valleys in Niger. Source: Sulser, p. 9, according to Betifor (2010)



Box 4: Impacts of water-spreading weirs on groundwater in Chad

Since 2004, several valleys in Chad have been stabilised with water-spreading weirs in the scope of the PRODABO Project.

- The village of Irang in Departement Biltine had to fetch drinking water from Sélélé, which is 6 km away. After the construction of two water-spreading weirs to raise the groundwater level, water is now available in the village year round.
- Sixteen water-spreading weirs were constructed in the Wadi Chock region. Since then the groundwater level has steadily risen, and in March 2011 it was at an average depth of 6 m below the surface.
- In the Wadi Chaou region, only a slow rise in the water table was achieved with the weirs. Nevertheless post-rainy season crops (cultures de décrue) can now be grown on 13 ha in the vicinity of the weirs.

Source: BCI (2011), p. 10f

The height and the rapidity of the rise of the groundwater level vary from valley to valley and depend on numerous factors, such as the size of the drainage basin, the weir design, the permeability of the soil and the subsoil, and the amount and distribution of rainfall. In individual valleys in Niger the rise varied between 4.5 and 22 m, and it was not possible to establish a clear correlation between the rise and the elapsed time since rehabilitation.

4.2 Increases in usable land area and users

Water-spreading weirs multiply the usable and used land area as well as the number of users. Instead of just one crop, as many as 2 or 3 can be grown on a portion of the land area.

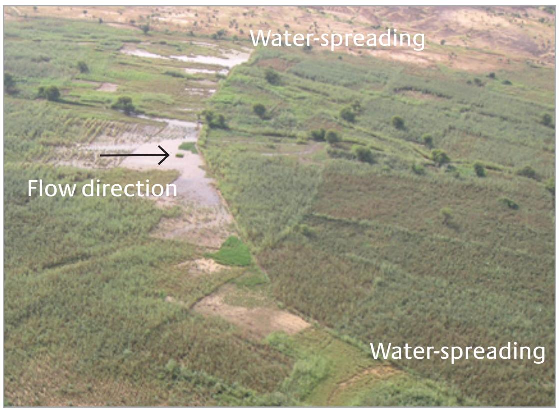
One of the most important economic effects of water-spreading weirs is the expansion or reclamation of productive land thanks to the widespread distribution of the water. The land area above and below a weir thus benefits and becomes useful once again (Figure 12). The flooded land area, however, is not necessarily the same as the cultivated area. It merely reflects the approximate use potential. In Niger rainfed crops are grown on as much as 90% of the flooded land area, whereas post-rainy season and irrigated crops are grown on <10% to as much as 50% of the flooded land area, depending on the valley.[13]

The degree of agricultural use of the flooded land area also depends upon the farming system. For instance, only around 50% of the flooded land area was farmed in nine out of fifteen sites studied in Burkina Faso, even during the rainy season. This was because the local villages wish to conserve and use the forest and pastureland within the land area.

Depending upon the users' experience and the availability of labour, it may take anywhere from 2 to 10 years before the rehabilitated land area reaches its optimum use potential. This time period is due on one hand to natural factors such as the gradual rise of the groundwater level and the enrichment of sediments, and on the other hand to the adaptation of the use systems by the farmers. In some valleys use has since spread beyond the actual rehabilitated area, as at the border additional land is irrigated with motor-driven pumps. In some valleys the goal is not to achieve maximum arable land area, but to reserve a portion of the rehabilitated area for local and migrating herds. The valley zones often serve as important retreat and passage zones for the livestock owners.

Figure 13 gives an example of the trends in land area use in four valleys in Burkina Faso. The land area farmed prior to rehabilitation had shrunken to between 5 and 10 hectares due to progressive erosion. After rehabilitation it increased to 20 to as much as 85 ha. The most spectacular case was Siedougou, where this corresponded to an eight-fold increase. The increase was dramatic in Koulfou and Barhiaga as well, where the arable land area was doubled or even quadrupled.

Figure 12: The water is distributed over the entire width of the water-spreading weir, resulting in more infiltration above and below. As a result crops can be grown (in this case sorghum and some rice) over the entire width of the valley floor above and below the weir. Source: Bender (2011)

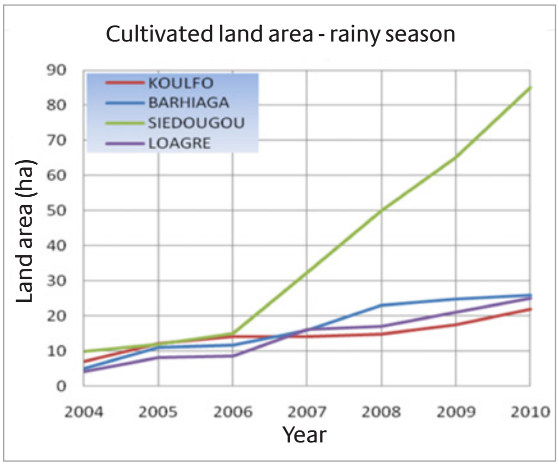


13 Betifor (2010), p. 38

Young men harvesting tomatoes © GIZ / Wohlmann

By the end of 2010, around 4,731 farms in Niger were experiencing the benefits of the rehabilitated valley floors. On average each of these farms had 0.6 ha of valley land prior to the rehabilitation. Thanks to the rehabilitation, this was increased to 2.2 ha per farm, which corresponds to 7,000 ha of additional valley land for rainfed agriculture.[14] In contrast to Burkina Faso, where the number of users during the rainy season also increased due to labour-intensive farming, the number of users in Niger remained relatively stable because millet and sorghum are the predominant crops grown. These two crops are less labour-intensive, hence larger land areas can be farmed by the landowners themselves.

Figure 13: Increase in the arable land area during the rainy season in Burkina Faso. Source: Bender, 2011, p. 16



14 Lütjen (2011), p. 36f

Thanks to the better water supply, not only does more land area become available for rainfed agriculture, but also up to two additional crop cycles become possible. In Burkina Faso prior to the rehabilitation, no farming was possible during the dry season in 8 of the 15 valleys studied, and was only possible on small fields in the other valleys. After the construction of the water-spreading weirs, at least one additional crop could be grown in 13 of the 15 valleys.[15] In Niger, the water-spreading weirs enabled an increase of the hectarage of irrigated crops from approx. 710 ha to 2,320 ha. The substantial expansion of the irrigated hectarage in Chad is evident in the satellite images of the Wadi Chock region taken before and after the rehabilitation (Figure 14).

Figure 14: Vegetable production area (in red) in the Wadi Chock region of Chad prior to the construction of water-spreading weirs (2003) and afterwards (2010).
Source: BCIE (2011)

15 Kambou (2011), S. 15

4.3 Increases in yield and production

Yields

Water-spreading weirs increase and diversify production by expanding the arable land, increasing per hectare yields, and enabling 2 to 3 harvests per year.

Water-spreading weirs increase per hectare yields through the better water supply and the annual deposition of fine soil and organic matter. Organic or inorganic fertiliser remains on the fields where it is applied thanks to the stabilisation measures and the reduced rate of runoff. High-yielding crops that had been abandoned due to inadequate water supply can be grown again. The growing of rainfed, post-rainy season and irrigated crops results in greater crop diversity. On the Burkina Faso sites 12 new crops (including rice and sweet potato) were noted during the rainy season, plus 16 new vegetable crops during the irrigation season.

The water-spreading weirs also extend the growing season from a single crop cycle during the rainy season to two or three crop cycles (i.e. a post-rainy season crop and an irrigated crop). Only a portion of the potential land area is used for post-rainy season and irrigated crops, however.

Surveys of the rainfed crops in the three nations reveal considerably higher yields:

- In Burkina Faso grain yields increased 2.5-fold (Table 1).
- In Niger, millet and sorghum yields were measured in the three years prior to and in the three years subsequent to the construc-

tion of the water-spreading weirs. Thanks to the weirs, 1.9-fold and 1.3-fold increases were achieved in millet and sorghum yields, respectively.

- Comparable to the situation in Niger, grain yields in Chad were on average 1.8-fold higher in normal years. The effect was even more dramatic in dry years (3.1-fold higher yield/ ha). This shows that the water-spreading weirs not only bring about a yield increase, but also yield security in dry years. Not all crops, however, are able to exploit the improved availability of water brought about by the water-spreading weirs. Cowpea (black-eyed pea) is a species adapted to adverse conditions and actually produces lower yields in response to more moisture (Figure 15).

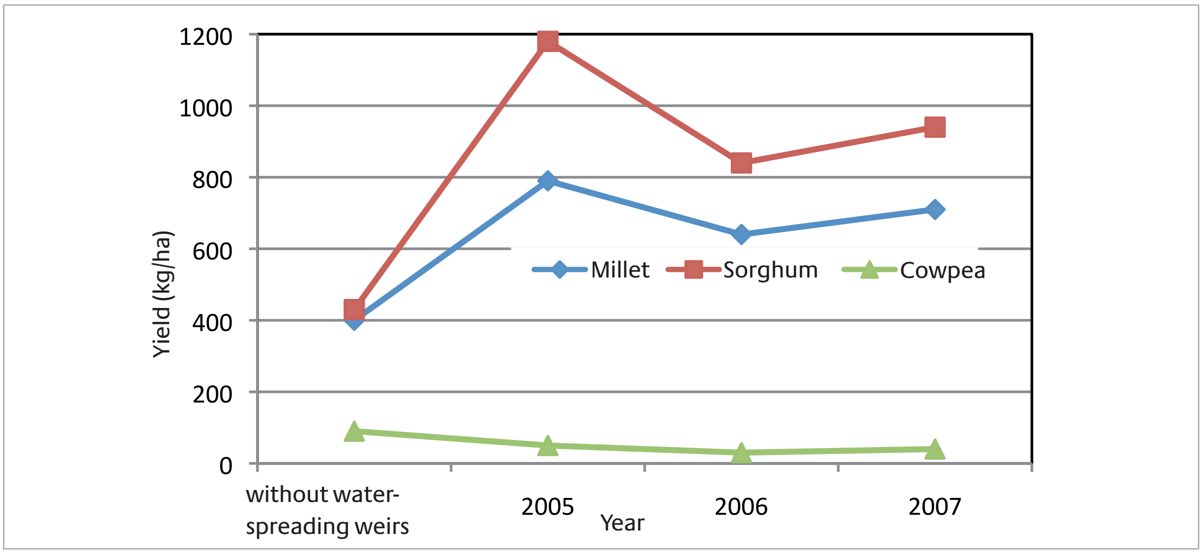
Table 1: Yield increases in rainy season crops with water-spreading weirs [16]

Country	Yield	
	without water-spreading weirs	with water-spreading weirs
Burkina Faso	Rice: 800 kg/ha	2.000 kg/ha
Niger[*1]	Millet: 333 kg/ha	675 kg/ha
	Sorghum: 362 kg/ha	481 kg/ha
Chad[*2]	Millet: 158 kg/ha	653 kg/ha

[*1] Mean yield of three years in eight valleys and of one year in three valleys before and after weir construction

[*2] Mean yield from three valleys in a drought year

Figure 15: Yield trends in millet, sorghum and cowpea after the construction of water-spreading weirs in the Karadji Valley of Niger. Source: Sulser (2010), p. 8



16 According to BCI (2011), p. 19, Kambou (2011), p. 19, and Betifor (2010), p. 31f

The advantages also vary greatly from year to year and are specific for each valley. Whereas sorghum in the Karadji Valley in the example (Figure 15) clearly out-produced millet, this result was reversed in the eight-valley average, where millet had clearly superior yield increases compared to sorghum (Figure 16).

The yield increases achieved with the water-spreading weirs are likewise evident in the vegetable crops. Although they varied from crop to crop, in general they ranged from 20% to 30% in Niger. The only crop in which little yield increase was noted was sweet potato (Table 2).

Figure 16: Millet and sorghum yields averaged over eight valleys in Niger Source: Betifor (2010), S. 35

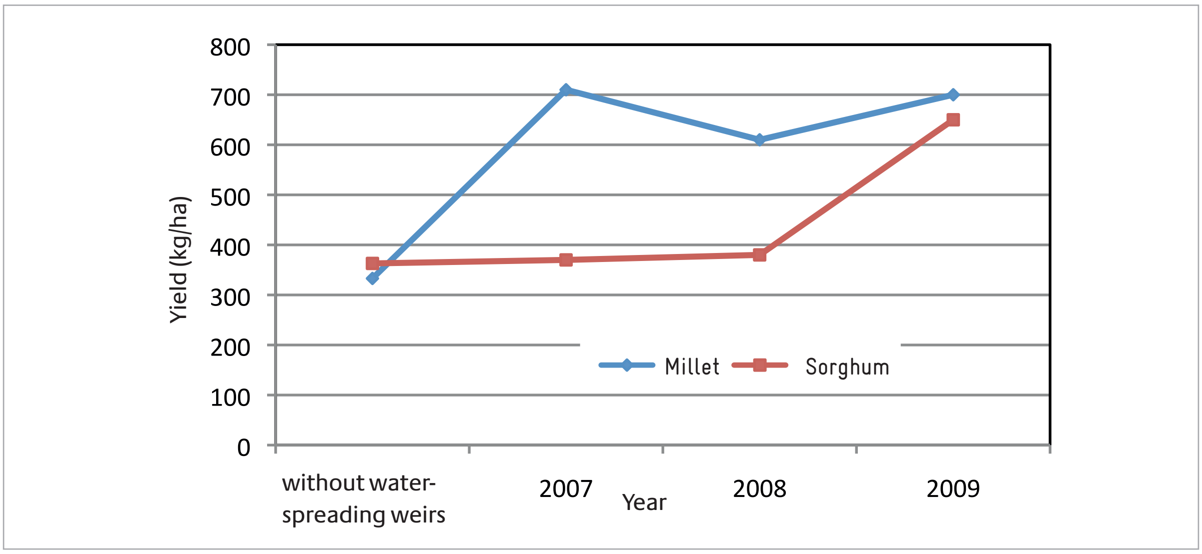


Table 2: Yield increases in dry season crops in Niger with water-spreading weirs[17]

Crop	Yield before water-spreading weirs (t/ha)[*1]	Yield after weir construction (t/ha)[*2]	% increase
Onion	20.5	26.8	1.30
Pumpkin	16.1	21.1	1.31
Tomato	2.5	3.0	1.20
Sweet potato	7.9	8.3	1.06
Cowpea	1.8	2.3	1.24

[*1] Mean yield of the three years prior to weir construction

[*2] Mean yield of the years 2007–2009

17 Betifor (2010)

Production

As a result of greater yields and more available arable land, production on the rehabilitated valley plains is increasing greatly. Data from Niger, which are based on millet as the main grain species, indicate production growth by a factor of 5.8 (Table 3). The 2.9-fold increase in arable land contributed more to the production growth than did the increase in yield (two-fold).

This increase in rainy season production is supplemented by the additional production during the dry season. Prior to rehabilitation, a second crop was grown on small fields in seven out of nine valleys studied in Niger. After rehabilitation, all nine valleys produced a second and generally a third crop as well. The total land area farmed during the dry season increased from an average of 0.15 ha to 0.49 ha per user.[18] Assuming 20% increases in vegetable crop yields (by a factor of 1.2) and an expansion of the land area by a factor of 3.3, a nearly four-fold increase in vegetable production can be expected if the number of users remains the same.

Irrigated horticulture with motor pump © GIZ / Marc Cleriot

Table 3: Changes in arable land, yield and production in 11 rehabilitated valleys in Niger Source: Betifor (2010), S. 17, 29

Element	Situation before water-spreading weirs	Situation afterwards	Difference	Growth factor
Area under cultivation (ha)	2,847 ha	8,132 ha	5,285 ha	2.9
Yield (kg/ha)	333 kg/ha	675 kg/ha	342 kg/ha	2.0
Production (t)	948 t	5,489 t	4,143 t	5.8

18 Betifor (2010), p. 40

4.4 Impacts on livestock husbandry

Water-spreading weirs are predominantly built in arid regions in which the local people not only earn their living through growing crops, but are also considerably dependent on animal husbandry. The majority of the population consists of agro-pastoralists, for whom the valleys serve as passage and refuge zones during the dry season in the search for crop residues, pasture and water.

The weirs have had a confirmed positive impact on livestock husbandry in all three countries, even though no systematic monitoring data have been collected thus far. The availability of animal forage is improving. The higher grain and vegetable production in turn produces more crop residue. Plus the natural vegetation in the valley region is recovering, producing more forage in the grass/herbaceous layer as well as in the form of shrub and tree fodder. At some sites in Burkina Faso, a portion of the land area flooded by the water-spreading weirs is being reserved for forage rather than put entirely into crop production.[19]

The second advantage of water-spreading weirs is the improved water supply. Water retained in puddles and ponds after the flooding remains available to livestock for weeks after the rainy season.

Users in Burkina Faso report that nowadays some of the livestock herds in the rehabilitated valleys are no longer managed under transhumance, but remain in the villages even during the dry season. In addition, animals from neighbouring villages are being brought to the rehabilitated valleys to drink.

4.5 Water-spreading weirs as a measure for adapting to climate change

According to current climate change projections, the temperature in West Africa, including Burkina Faso, Niger and Chad, is expected to be 2.5 to 3.5 °C higher by the end of the century. Depending on the region, absolute precipitation will increase or decrease slightly, but the variability in precipitation within and between years is expected to increase in every country.[20] The evaporation of water will also increase due to the higher temperatures. Furthermore, intense precipitation events and hence surface runoff will continue to increase, whereas the duration and consistency of the rainy seasons will decrease. Water management in arid regions will therefore become more critical. Water-spreading weirs effectively buffer peak runoffs from the drainage basins, reduce erosion and improve the availability of water for people, livestock, agriculture and nature. The ecological improvement of alluvial plains protects against changes in environmental conditions and stabilises the food supply and the living conditions of the local population. Water-spreading weirs are therefore effective measures for adapting to climate change.

19 Kambou (2011), p. 12
20 GIEC (2007)

Harvesting pearl millet © GIZ / Klaus Wohlmann

4.6 Income and profitability

Income

The expansion of the land area by the water-spreading weirs, the increase of yields and the resultant additional production improve the nutritional security and increase the cash incomes of the users. Whereas the rainfed crops are grown primarily for subsistence, the post-rainy season and irrigated vegetable crops are mainly grown for marketing. Initial study results indicate substantial increases in income. A study conducted in Chad revealed that users of water-spreading weirs had 112% higher incomes compared to farmers outside the impact zone of the water-spreading weirs. This income was generated from sales of both vegetables and surplus grain.[21] In addition to the increases in individual incomes, also worth mentioning is the fact that the total number of users increased greatly. This means more income per family and many more families taking part in the total production.

Because the rainfed crop production is used primarily for subsistence, the revenue estimates in Niger were based solely on the dry season production. For these estimates, the land areas and yields per crop were measured in nine valleys, and the value was assessed using the low sales price at the time of harvest. It was assumed that a portion of the harvest would be used for own consumption and gifts, and that only the re-

21 BCI (2011), p. 14

mainder would be sold.[22] Under these assumptions, an average gross revenue of approx. €760 per user was achieved, but the variation was considerable and ranged from €200 – €1,900 (Table 4).[23] It is necessary to remember, however, that these estimates are gross revenues, from which the expenses for growing the crops still need to be deducted.[24]

In additional to the permanent additional income generated through the use of water-spreading weirs, temporary income was also generated for the local workers during their construction. In Niger, these transfers have thus far amounted to approx. 1 billion CFA francs (M€1.53) or €231 per user family.[25]

Medium- to long-term extra revenue from the valleys for the communities due to higher success rates in collecting capitation taxes and extra revenue from market and transport taxes have thus far served as an unsubstantiated impact hypothesis.

The earned incomes are being invested in farm supplies (motor-driven pumps, tools, fertiliser), new activities (trade, processing), in consumer goods (bicycles, motorcycles) and social services (health, education).

Table 4: Estimated income from vegetable crops in Niger

Valley name	No. users	Mean cropland area/user (ha)	Gross revenue/ user (CFA francs)	Gross revenue/user (€)
Karadji south	160	0.26	1,263,177	1,929
Latchiwa	53	0.27	352,523	538
Founkoye/SG	207	0.57	350,384	535
Inadougoum	45	0.61	130,755	200
Izarwane	62	0.28	512,490	782
Ourhamiza	133	1.19	881,950	1,346
Mogheur	306	0.71	649,064	991
Barmou/Tk	211	0.11	201,372	307
Guidoma	103	0.18	146,400	224
Total	1,280	Mean	498,679	761

22 Own consumption and gifts were estimated at 10% of the onions, 40% of the sweet potatoes, white potatoes, cabbage and manioc, and 30% of all other crops (Betifor, 2010, p. 55).
23 According to data from Betifor (2010), p. 52ff.
24 For vegetable crops in Burkina Faso, the profit ranges from between 50% and 80% of the gross revenue, from which at least the order of magnitude of the earnings can be estimated (Kaboré, 2007, p. 14).
25 Lütjen (2011), p. 33

Profitability

There are no meaningful calculations on the profitability of water-spreading weirs available at the present time. A study on this is in the planning stages for the water-spreading weirs in Niger.

The costs of water-spreading weirs vary greatly, depending on physiographic settings, structure, and level of cost for companies. In Burkina Faso and Niger, the costs per weir range from 600 to 1,500 €/ha, depending on construction (e.g. with or without a ford) and physiographic setting.[26] Individual water-spreading weirs in Burkina Faso cost on average approx. 12 million CFA francs (~ €18,000) per weir, and between 30 and 36 million CFA francs (€46,000 and €55,000) per weir in Chad. The average annual maintenance costs are estimated to be 0.5% of the construction costs.

Nine weirs costing 253 million CFA francs (M€0.39) were built in Gagna, Burkina Faso.[27] The value of the total production in 2010 from rainfed crops, post-rainy season crops, irrigated crops and fishing was an estimated 245 million CFA francs (M€0.37). Assuming that the sum of production costs, salaries and wages, and net income without weirs is one half to one third of the total production, the investments will clearly pay for themselves within a few years.

4.7 Social impacts

Water-spreading weirs generate additional employment and earning opportunities, reduce emigration, and promote interaction among villages.

Besides ecological and economic impacts, water-spreading weirs have other important effects on the villages concerned. Additional employment and income-earning opportunities during the dry season stabilise the local population. For instance, reports from Chad indicate that temporary emigration to Sudan and Libya has declined, and that in some villages people who had long since emigrated were returning home when they learned of the changes.[28]

The decline in migration due to additional activities is also being observed in Burkina Faso. In that country 60% of the users of the rehabilitated fields belong to the younger 20 to 30 year old generation, who would otherwise emigrate during the dry season due to lack of work.

Other smaller opportunities for work have developed in the vicinity of the weirs. Examples include the trading of agricultural products, fishing, watering livestock, or making clay tiles. As a whole, the rehabilitated valleys become centres of greater local business activity, which in turn affects transport, trade and processing (Box 5).

26 Bender (2011), p. 20ff
27 The nine weirs cost 316 million CFA francs. However, they consisted of 1,000 m of valley fords, which accounted for 20% of the costs. The 20% was deducted because it does not contribute to the profitability of agricultural production.
28 BCI (2011), p. 13

Box 5: Impacts of water-spreading weirs on poor households

Kulfo, a village in eastern Burkina Faso, used to have hardly any business activities. The local people lived from subsistence and in extreme poverty. The local market had only a few products for sale.

With the construction of two water-spreading weirs and the repair of a dam (that had been damaged for 20 years) by the Fonds d'Investissement pour les Collectivités Décentralisées (FICOD) in 2004, production and incomes of the valley users have increased dramatically. After just a few years many households now have agricultural equipment, motorcycles, and other goods. The booths in the market are now well-stocked and solidly constructed. Some have become permanent stores.

One of the farmers in the valley, Mr Ouedraogo, has since become one of the largest rice and vegetable growers in the village and runs his own store.

Figure 17: Man with child returning from the market with goods for his shop. Source: Heinz Bender

Because the new production potential during the rainy season and especially during the dry season is not being fully exploited by the local villages, more and more users are arriving from neighbouring villages. In Burkina Faso, for example, the number of villages jointly using the rehabilitated valleys has gone from 27 to 67 and has thus more than doubled. The water-spreading weir areas are thus becoming an element of interaction and social integration for the villages. Thus far there have been no conflicts. There has actually been a decline in conflicts between farmers and livestock raisers over water rights owing to the fact that sufficient water is now available and that clear rules for use have been established.

The workload of the village women is eased thanks to the availability of and easier access to water due to the shallower water table. Water can be fetched from nearby and no longer has to be hauled up from great depths. The

Young women sitting on a water spreading weir © GIZ / Klaus Wohlmann

women also report that their children now have a healthier, more diverse diet due to the vegetable production and the introduction of new crops.

Thanks to the numerous training events before, during and after the construction of the water-spreading weirs, the village people, the participating service providers, communal representatives and government technical sectors are improving their skills in organisation, planning and implementation, and various technical fields. For example, the training of numerous local masons in Niger's Tahoua region was especially successful. Niger also has a planning office that is very competent in the approach. Thanks to their excellent qualifications, planning offices as well as local masons from the Tahoua region have been helping with the construction of water-spreading weirs in Burkina Faso and Chad as skilled workers and construction site foremen.

5 Sustainability of water-spreading weirs

Whereas technical and economic sustainability are high and are improving steadily, institutional sustainability needs further improvement.

As we already mentioned, in order to ensure sustainability, all stakeholders are involved at the outset in the planning and implementation, local helpers and craftsmen are trained during the construction process, and a management committee is set up and trained for the tasks of supporting construction, organising the use of the weirs and maintaining them.

Experience with water-spreading weirs dates back 15 years. These weirs were built in eastern Chad by Swiss Cooperation. The masonry of these weirs is still in relatively good condition, although the original wire cage stilling basins have since been replaced with masonry. Other damages are primarily the result of inadequate maintenance.

A study of 34 water-spreading weirs constructed by PRODABO in Chad in 2010 revealed that approx. 40% of the weirs had damages.[29] One weir had collapsed; the damage to the other weirs was less severe. Two of the 66 weirs constructed by DETA Project had burst.

Some of the damage took place during the first rainy seasons after the weirs were built and are part of the initial adaptation processes of the structures. Although values based on long-term experience are lacking, it can be reasonably assumed that a third of the weirs will require

Wind separating the chaff from the millet © GIZ / Klaus Wohlmann

29 BCI (2011), p. 8

complete renovation every 20 years, which can be done for approx. 10% of the initial construction costs.

Water-spreading weirs are now in their third development generation and improvements have been made with each generation. Such improvements consist of using different construction materials and construction techniques, and adapting the latter to the terrain. A study of the last generation of weirs showed that they have very little tendency to be damaged. Additional improvements are being planned for the fourth generation.[30]

While it has been possible to make continuous improvements in terms of technical sustainability, maintenance by the management committees is still a weak area in all three countries. Funds expected from user fees for the plots are often inadequately collected and too low to cover costs. Some management committees lose their drive and neglect their duties. Whether the new communities will be capable of funding more extensive maintenance work with their low budgets remains to be seen. It is not certain as yet.

Harvesting pearl millet © GIZ / Klaus Wohlmann

30 Bender (2011), p. 17

6 Success factors and challenges

Long-term commitment, expertise and active participation are required for development.

The ongoing funding and improvement of the initial approach by a long-term project have thus far been key factors in the development of water-spreading weirs. The technical measures and the 'software' (advisory and organisational components) were improved through financial and technical cooperation, respectively, thus enabling initial weaknesses in the approach to be remedied. Also important were the professional skills of all parties involved and the personnel continuity of the participating international and national engineering firms, as well as their willingness of the latter to share acquired know-how.

The participatory approach, with all stakeholders involved as much as possible, generates a greater sense of ownership and lays the foundations for successful future use and (within limits) maintenance. This also involves the training of local craftsmen and the advanced training of engineering and construction firm personnel until the country has a pool of experienced experts to draw from. The fact that the measures were implemented in regions where the local people had already been organised and trained to some extent in land-use planning and self-help measures in the scope of a previous project (PDRT) helped in Niger.

The lack of sufficient capacity on the part of numerous management committees and (in the future) communities for ensuring that the weirs are properly maintained is still a weak area that needs to be addressed. Most of the communities lack the necessary means and expertise to supervise and fund the activities in the valleys.

At some sites the extensive vegetable production has caused local market prices to drop, which presents a need for improvements in marketing, storage and processing.

In spite of the great potential for the use of water-spreading weirs and the very promising results, implementation will continue to depend in the medium term on outside funding, as it is unlikely that the communal budgets will be able to fund investments of this size. Other sources of funding must therefore be tapped.

Know-how and experience for the construction of water-spreading weirs are still concentrated among a few countries, engineering firms and construction companies that participated directly in the improvement of the technology. This is still a limiting factor in the spreading of the technology to other countries. Nevertheless stakeholders from the private sector as well as German development cooperation are interested in documenting this know-how and making it accessible to a wide spectrum of interested professionals. This document is designed to serve as a first step in this effort.

Harvesting groundnuts © GIZ / Klaus Wohlmann

7 Appendices

Appendix 1: Construction of water-spreading weirs – key steps

The following diagram gives a brief overview of the key steps in the installation of water-spreading weirs.

Step	Responsibility
Preselection of suitable valleys Tales	Project
Submission of the request to the project	Community (with representatives from the villages involved)
Feasibility study (socio-economic/technical)	Project, engineering firm
Approval or not of the request	Approval committee
Setting up the management committee	Community, village delegation
Establishment of the rules for use (land-use planning)	Management committee, community, and project
Detailed technical study and preparation of bid documents	Project, engineering firm
Invitation to bid	Community, project
Selection and awarding of the contract	Selection committee with representatives from the community, technical authorities, and the project
Setting up of a training site	Project, construction company, village craftsmen
Supervision	Engineering firm, community, management committee, and project.
Acceptance	Same.
Supporting consultation	Project, technical services, service providers
Monitoring and evaluation	Community, project, management committee

	Comments
	The project takes an inventory of potential valleys and informs the communities and villages in suitable valleys about cooperation opportunities and terms and conditions.
	The community submits a request for valley rehabilitation to the project.
	Study to determine whether rehabilitation is technically feasible. Study to determine whether the community and the local people are motivated, whether there are latent conflicts in the villages, and whether all parties agree to the terms and conditions. Is the proposal part of the communal development plan?
	Evaluates requests and decides on funding.
	Founding of a management committee composed of representatives of the community and the villages concerned. Writing of a charter and education of the members.
	The rules of use of the rehabilitated land are worked out and established. Some countries elaborate a more extensive utilisation plan with a rehabilitation plan, which should tie in with the communal land-use plan.
	An engineering firm is contracted to conduct the detailed technical study, which will serve as the basis for preparing the bid documents.
	The invitation to bid is issued nationally, in accordance with national regulations.
	Tender opening session and selection in accordance with national regulations.
	Particularly when starting work projects with new, inexperienced companies and local craftsmen.
	A competent engineering firm is in charge of supervising the construction. Representatives of the community and the management committee are very much involved in order to generate know-how and a sense of ownership.
	As the client, the community accepts the construction, with participation by the management committee, engineering firm and the project.
	For optimum use, the users are provided with supporting consultation, which can include agricultural techniques, product preservation techniques, and marketing (value chain). Organisational support is provided to the management committee.
	All stakeholders have monitoring tasks. This means that the management committee ensures that the rules of use are followed, checks the functionality of the structures and collects the fees. The community monitors to ensure proper use. The project inspects the structures, ensures that all bodies are functioning properly and performs corrective measures.

Performance of the individual steps requires systematic adherence to the work schedule in order to ensure that the construction work starts early in the dry season and is finished before the next rainy season. The rainy season lasts approximately from June to September (~ 3rd quarter, Q3).

Activities	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Preselection of the valleys												
Submission of the request to the project												
Feasibility study												
Drawing up of the rules for use												
Detailed technical study and preparation of the bid documents												
Invitation to bid and awarding of the contract to a construction company												
Training site												
Construction of the water-spreading weirs and supplemental erosion protection measures												
Agricultural consultancy												
Support and monitoring of the implementation of the master plan												

Appendix 2: References

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Appendix 3: Technical drawings of water-spreading weirs

Figure 18: Longitudinal and cross-sections of a water-spreading weir and longitudinal sections of single and double spillways
Source: Bender, 2005

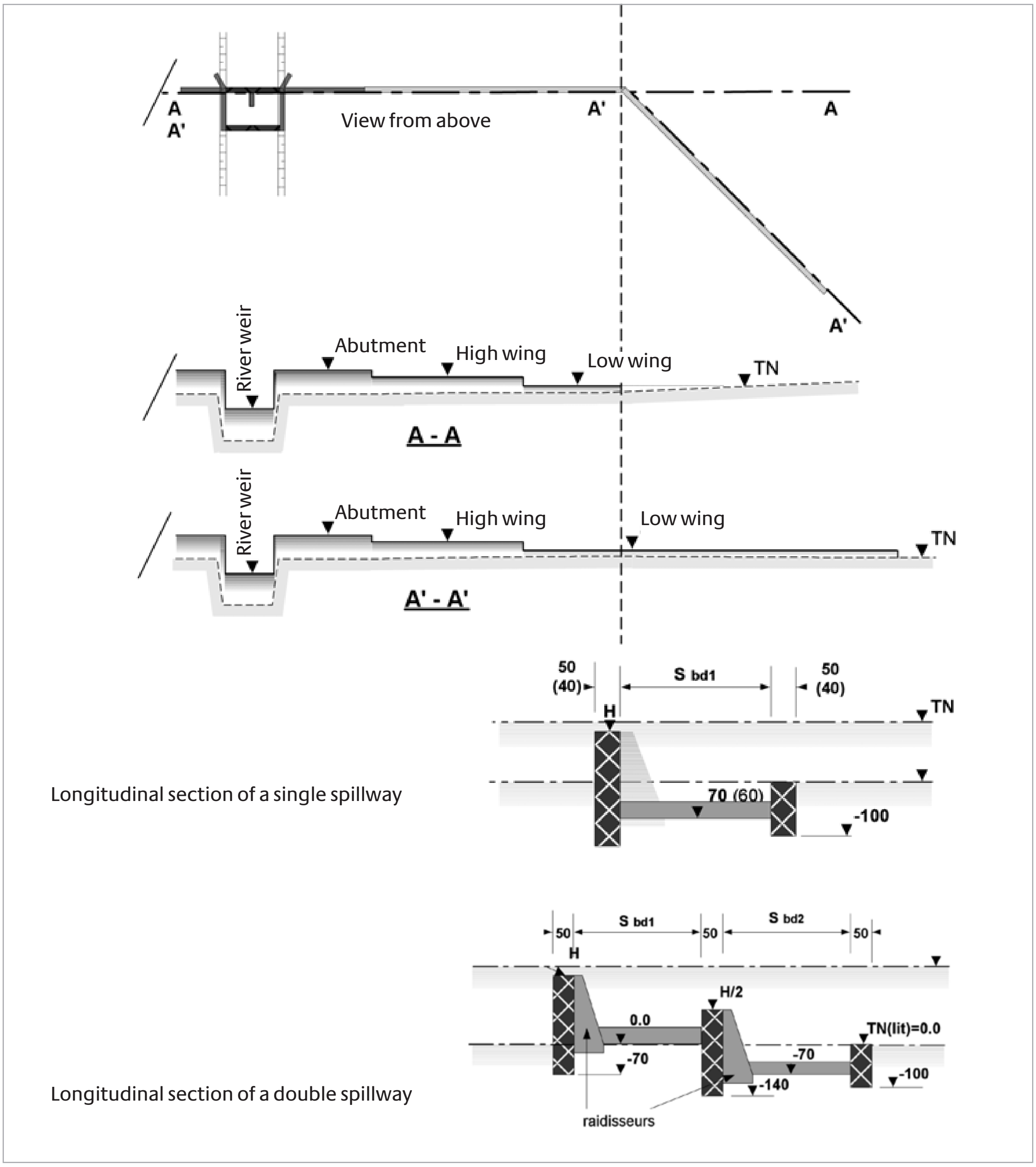
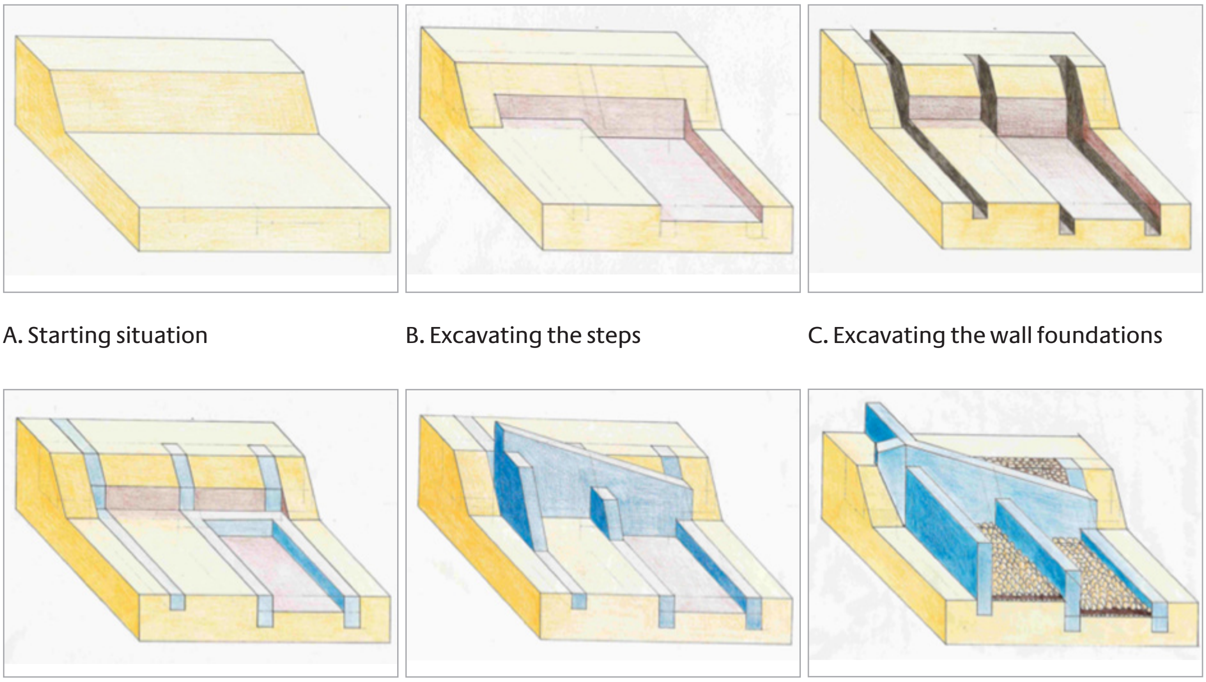


Figure 17: Steps in the construction of a double spillway. Source: Bender, 2005



A. Starting situation

B. Excavating the steps

C. Excavating the wall foundations

D. Pouring the foundations

E. Building the walls

F. Finishing the walls and filling the stilling basin

For more technical details and recommendations, see Bender (2005) and Bender (2008).

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