REVIEW OF WATER CONTROL TECHNOLOGIES IN THE FAO PROGRAMMES FOR FOOD SECURITY

Experiences and best practices in the introduction of water control technologies under the FAO Assisted Food Security Programmes with a focus on Sub-Saharan Africa

INTEGRATED FOOD SECURITY SUPPORT SERVICE (TCSF)
POLICY AND PROGRAMME DEVELOPMENT SUPPORT DIVISION
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ACRONYMS AND ABBREVIATIONS

APPROTEC	Appropriate Technologies for Enterprise Development – NGO Kenya
AfDB	African Development Bank
BTO	Back to Office
FAO	Food and Agriculture Organization of the United Nations
GRAF	*Groupe de Recherche et d'Action sur le Foncier*- Burkina Faso
IDE	International Development Enterprise
IPM	Integrated pest management
NRLW	Water Resources, Development and Management Service (FAO)
NPFS	National Programme for Food Security
OFWM	On-Farm Water Management
PAN	*Programa de Acçao Nacional Segurança Alimentar* (Special Programme for Food Security, Mozambique)
SAFR	Sub-regional Office for Southern Africa
SPFS	Special Programme for Food Security
SPIN	Special Programme in Nepal
SSC	South-South Cooperation
TCOS	Special Programme for Food Security (SPFS) Management and Coordination Service (FAO)
TCP	Technical Cooperation Programme (FAO)
TOT	Trainer of trainers
WARDA	West African Rice Development Association (Africa Rice Center)
WCC	Water control component
WUA	Water users' association
WUG	Water users' group
W-3-W	Water for the Third World (Swiss NGO)

PREFACE

Water management and water control technologies have been a main component in the FAO-assisted food security programmes. Since improved water control is the first factor to achieve a rapid increase in food and crop production, in most countries, the water control component has been a main focus of action to increase and stabilize agricultural production, both at individual farm level and at the national level.

In the 15 years of assistance in the introduction of water control technologies under the Special Programme for Food Security (SPFS) and National Programmes for Food Security (NPFSs), a wealth of valuable experiences has been compiled on how the technologies have evolved and been adopted in the various countries.

To capitalize on the experiences in water management and control in the SPFS programme, a review was undertaken at the initiative of the Land and Water Development Officer for the Central African Sub-Region, Sourakata Bangoura, and the Responsible Officer for SPFS Management and Coordination Service, Madhy Bamba. The aim was to consolidate lessons learned and best practices in the introduction of water control technologies and to provide further guidance in the process of upscaling successful technologies and approaches in the NPFSs.

In view of the specific conditions of African agriculture and the priority of promoting food production in Africa, the review focused above all on the experiences in Africa, collecting the information from 43 African countries where the SPFS has been introduced. SPFS evaluation reports, technical review reports, mission reports and documents from over 200 projects were consulted for this purpose. Further information was collected from a selected number of countries in Asia.

This publication presents the results of the review and provides an extensive list of the different technologies introduced under the FAO-assisted food security programmes and related programmes, and provides specific, illustrated information on the conditions and constraints for the introduction of the technologies, the design and dimension characteristics, and on investment and operating costs.

Special attention is given to the procedures for introducing and demonstrating the technologies and involving smallholder farmers and communities in the implementation through training and capacity-building programmes for farmers and staff.

The review and report has been prepared by Martin Smith, a retired FAO water management specialist, in close consultation and supervision of the responsible officer in the Sub-regional Office for Central Africa and TCSF, and with further contributions from the FAO Sub-regional Water Management Officers in Africa, FAO's Water Service and TCSF staff.

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EXECUTIVE SUMMARY

The introduction of water control activities was implemented as a main component of the FAO-promoted food security programmes. Its main focus has been ***the introduction of low-cost water control technologies that can be readily adopted by smallholder farmers and contribute to a rapid increase in crop production.***

The experiences in the introduction of the water control component (WCC) of the SPFS provides many lessons and likely represents a realistic picture of the constraints encountered in the implementation and development of irrigated agriculture in Africa and elsewhere. The institutional and socio-economic context of the country can in most cases directly be linked to success, constraints and failures of the technologies introduced. Many of the negative experiences, however, contain positive lessons of what works and what does not, in which country, for which target group, and under which socio-economic conditions thus providing a useful and valuable view on the opportunities and constraints in the development of irrigated agriculture for smallholders in Africa, Asia and in the Near East.

A main focus in the WCC in the SPFS has been on ***micro-irrigation technologies***, introducing small irrigation pumps, shallow well development and low pressure pipe systems. This has proved most accessible to smallholder farmers, in particular for vegetable and cash crop production, and is rapidly expanding in countries (Niger, Nigeria) where the private sector can provide relevant services. Treadle pumps have had initial successes, but farmers who can afford it prefer the small motorized pumps, which prove more efficient and cost-effective, in particularly when linked with a low-pressure pipe system. Fuel costs of motorized pumps have proved a constraint and resulted in the abolishment of the pumps in a few cases (Malawi, Mali). Average investment costs of micro-irrigation systems varied from US$ 600 to US$ 500 per ha.

Wetland development, introducing improved water control for rice production in the wet season by field bunding and levelling, drainage and flood protection works and vegetable production in the dry season has proved successful in a range countries in the more humid and semi-humid eco-zones (Guinea, Cameroon, Burkina Faso, Burundi) and where adequate technical and effective social support could be provided. Women's groups were particularly receptive to this type of development (Guinea). Wetland development can largely be carried out by local farmers and require limited investments in structural works, in particular in the initial phase. Average investment costs were US$ 300 to US$ 600/ha. In many cases, wetland development includes micro-irrigation technologies with shallow well development and small pumps for dry season irrigation.

In several countries, the WCC of the SPFS adopted the ***rehabilitation of smallholder irrigation schemes***, developed in many African countries over the past decades. It has proved more difficult to achieve sustainable results under this type of irrigation. Civil works undertaken under the smallholder schemes suffered from delays and cost overruns in several WCC programmes. Contractual requirements and procedures of FAO, donors and national agencies contributed to the delays. Investments costs were often considerable, at US$ 500 to 3 000 per ha. Farmers' motivation, participation and in the rehabilitation and improved water management were below expectations, although with some noticeable exceptions (United Republic of Tanzania, Burkina Faso). Despite considerable efforts in the formation and training of water users associations (WUAs), not many have proved sustainable and effective in the operation and maintenance of the schemes.

Water conservation and water harvesting include technologies such as earth dams and contour bunding, which have proved relevant, in particular in the more arid regions.

Results under the WCC have shown mixed results with some failures (Nigeria, Ghana), but also with promising results, such as the introduction of large-scale chiselling of hard soils in Sudan and the promotion of traditional practices in water harvesting such as stone bunds in Burkina Faso and spate irrigation systems in Sudan and Djibouti. Investment costs varied widely: chiselling US$ 300/ha, stone bunding US$ 600 and spate irrigation over US$ 2 500/ha.

With an emphasis **on national execution**, national agencies and institutes have played a lead role in the implementation of the WCC and SPFS. In countries with a weak institutional structure, results have been more difficult to achieve (Chad, Democratic Republic of the Congo, Liberia).

To assist countries in the implementation of the SPFS and NPFS, FAO introduced an innovative programme of technical support through **South-South Cooperation (SSC) agreements.** To support the WCC, a total of 241 water control experts and technicians from 12 different countries were assigned in 39 countries, of which 22 in African countries. 105 WCC specialists from China were assigned in Nigeria. Useful support was provided by SSC experts, although flawed in several cases by communication problems, lack of facilities and delays in construction works.

FAO technical assistance was further provided by the **FAO water specialists in the regional and sub-regional offices.** They carried out numerous technical support missions, and their mission reports provided valuable background information on WCC implementation. ***FAO's Investment Centre*** played a key role in the formulation of many of the larger water control investment programmes, such as those financed for the African Development Bank (AfDB) and the Libyan Trust Fund. ***FAO's Evaluation Service*** (PBE) has been instrumental in the implementation and coordination of evaluations of the SPFS programmes, which provide interesting information on results and constraints, and occasionally, depressing reading.

The experiences of the SPFS, in particular in Niger and Nigeria, showed the importance of involving **the private sector** for successful and sustainable irrigation development.

Cooperation with **international NGOs** specialized in the development of appropriate water control technologies has been productive in several countries. Treadle pumps were manufactured with assistance provided by the International Development Enterprise (IDE) in Zambia, W3W (Water for the Third World) in the United Republic of Tanzania, Lesotho and Madagascar, Enterprise Works in Niger, Burkina Faso, and Practica Foundation in Madagascar.

Particular emphasis in the SPFS projects has been placed on the establishment and strengthening of the WUAs in order to institutionalize effective farmers' cooperation in operations and maintenance (O&M), and to contribute to O&M costs. Capacity building of WUAs has been time-consuming, and although successes can be reported (Indonesia, Sri Lanka, Malawi, Lesotho), performance of many WUAs was well below expectations,, raising doubts on the sustainability and profitability of smallholder irrigation schemes in Africa, but also in some countries in Asia (Lao People's Democratic Republic and Cambodia).

A great merit in the concept of the SPFS programme has been the integration of the water control component into the **intensification of agricultural production,** promoting the inputs of improved seeds and fertilizers with both organic (composting) and inorganic fertilizers. Better water availability can lead to a substantial increase in production, income and food security if combined with adequate inputs and improved cultural practices. Irrigation investment proved only profitable if high yields and adequate prices are obtained. Substantial increases in crop production are reported in several countries where the WCC is effectively integrated in the *intensification component*. The *constraint analysis component* has highlighted the need for better marketing outlets and in particular, better access to credit through rural credit institutions. Group savings schemes and revolving funds as promoted in several programmes proved less sustainable. In some SPFS programmes, mechanization, marketing information systems and storage facilities were successfully introduced.

A particularly valuable element in the SPFS has been the introduction of improved cultural practices through the **Farmers' Field School (FFS) approach.** Several

SPFS programmes showed good results with the FFS and interesting examples can be found in Mozambique, Sierra Leone, Kenya and Indonesia. Some FFSs addressed irrigated crop production and irrigation technologies (treadle pumps). There were good examples of FFS in fertility management (Kenya, Mozambique, Sierra Leone). There is, however, a tendency in FFS implementation to focus more on integrated pest management (IPM), social issues and groups interactions, and less on innovative technologies in water control, which reduces the impact of the FFSs, as was clearly demonstrated in the SPFS programme in Mozambique (PAN I). The FFS approach could be instrumental in introducing micro-irrigation technologies and for the capacity building of WUAs, as shown in the early SPFS programmes in Zambia, Cambodia and Nepal, where a participatory training and extension programme for farmers' water management was developed. Based on these experiences guidelines and manual were prepared and published by the FAO's Water Service (NRLW) in the Land and Water CD-Rom Series No 14: *Participatory training and extension in farmers' water management*.

Many of the SPFSs have a specific focus on **women's groups,** in particular, in horticultural production. (Guinea and many other country SPFS projects extensively report on this aspect.) Another interesting example was the Women in Irrigation (WIN) programme implemented under the early SPFS programmes in Zambia, Nepal and Cambodia.

1. INVENTORY AND REVIEW OF AVAILABLE DATA

1.1 BACKGROUND TO THE SPFS WATER CONTROL COMPONENT

In 1996, the Special Programme for Food Security (SPFS) was launched in the wake of the World Food Summit, with the specific aim to increase food security and reduce hunger by piloting technologies that would lead to a rapid increase in agricultural production and farm income. A first phase would involve the piloting of appropriate technologies in key elements of production in selected areas and farming systems. In a second phase, the successful technologies would be upscaled through investments in national food security programmes (NFSPs).

Since the start of the SPFS in 1994, over 100 countries have requested and received FAO assistance in the implementation of the SPFS pilot phase. Presently, 55 countries are implementing or formulating NFSPs.

Within the national context and according to priorities and constraints identified in food security and agricultural production, the SPFS pilot phase typically addresses four core components:

- water control and irrigation;
- intensification of food production through yield improvements and sometimes by growing two or three crops in the same year;
- diversification of farming systems into small animal production, artisanal fisheries and aquaculture, and high-value crops; and
- application of constraints analysis to determine the obstacles to adopting the demonstrated technologies.

In most SPFS-implemented countries, *water management and water control* have been adopted as one of the initiating and principal components to increase and stabilize agricultural production, both at individual farm level and at the national level.

In many cases, the *water control component (WCC)* was integrated with the *intensification component* introducing improved cultural practices to boost crop production under improved water control and to extend the cropping season to two or even three crops per year. Through the *constraint analysis component,* factors that restrict or may promote the successful and sustainable adoption of the technologies (access to inputs, markets, credit and information as well as socio-economic and institutional constraints) are evaluated and addressed following a diagnostic and participatory approach with all actors involved.

In the 15 years of assistance in the introduction of water control technologies, a wealth of experiences has been compiled and valuable lessons learned on which technologies can be successfully introduced, under which conditions, and how the technologies have evolved and adopted in the various countries.

To capitalize on the experiences in water control in the SPFS programme, a review was undertaken to consolidate lessons learned and to assess best practices in the introduction of water control technologies in order to provide further guidance in the process of upscaling successful technologies and approaches in the NFSPs.

In view of the specific conditions of African agriculture and the priority of promoting food production in the continent, the review on water control technologies has focused above all on the experiences in sub-Saharan Africa (SSA), collecting information from 43 African countries where the SPFS has been introduced. In addition, the specific experiences in water control from seven countries in Asia have been included in the review.

1.2 REVIEW PROCEDURES

The review was carried out by an experienced water management expert under the overall supervision/ responsibility of SPFS Management and Coordination Service (TCOS), with technical support from the FAO Water Service (NRLW), and in close collaboration with the Water and Land Resources Officers in the Sub-regional Offices for Africa, who provided valuable inputs and comments.

Of the 54 countries on the African continent, of which five are in the Near East Region, 42 countries requested and received SPFS assistance for the implementation of pilot activities in food security; 40 countries (80 percent) have indicated a keen interest for upscaling into NPSFs; in 11 countries, the NPFS has become operational.

Information on SPFS and water-related activities have been collected from 43 countries in Africa including, Mauritania, Morocco, Egypt, Sudan and Djibouti. In addition, information from a number of Asian countries – Bangladesh, Cambodia, Indonesia, Lao People's Democratic Republic, Nepal, Pakistan and Sri Lanka – have been used in the review. There are over 200 projects in Africa with exclusive WCC or WCC-related activities, an impressive number, for a total cost of almost US$ 150 million.

A summary of the projects is provided in Annex 1, with a short description of the main WCC activities and the WCC-related projects for the 43 countries reviewed. This should give an idea of the scope and diversity of the programmes in the different countries. In terms of budget devoted to WCC activities, no accurate figures can be provided, but it is estimated that 30 to 40 percent of the total SPFS and NPFS budget was devoted to water control activities. Nigeria appears on top of the list with the largest budget, at US$ 48 million for its NPFS, followed by Malawi and Mali.

A large amount of information is available on SPFS water control activities in different formats, such as project documents, back-to-office (BTO) reports, and progress and terminal reports. The size and diversity of information available has made the systematic analysis of impact, success and/or failures of the different water control technologies a difficult task. To assess best practices of successful procedures and technologies, the review was based largely on the SPFS documents, including the TCO country briefs, evaluation reports, project documents, project progress and terminal reports from the projects listed in Annex 1. Technical details were collected from, BTO reports and discussions with FAO staff. The main documents consulted, include the FAO evaluation reports, technical documentations and manuals as well as various external reports and are listed in the bibliography in the Annex 2.

1.3 SPFS WATER MANAGEMENT SYSTEMS AND WATER CONTROL TECHNOLOGIES

Almost all the 43 countries in Africa where a SPFS and/ or NSPFS programme was initiated have a WCC, often as a first initiative through a project under the Technical Cooperation Programme (TCP) project. Only three countries lack a clear WCC component, namely Angola, Equatorial Guinea and the Central African Republic.

As shown in Table 1, for the 40 countries with distinct WCC activities, emphasis has been placed on smallholder irrigation development (53 percent) and, in particular, on the introduction of micro- or on-farm irrigation techniques and technologies, which has been promoted in 64 percent of the programmes, in particular through treadle and motor pumps (56 percent), well development (53 percent), drip irrigation (19 percent) and pipe distribution systems (16 percent). In the humid and sub-humid regions wetland development has been successfully introduced (40 percent), with the promotion of improved water management for rice production in the wet season by field bunding and levelling, and by providing drainage and flood protection, as well as irrigation in the dry season with shallow well development, pumps and small water control structures. In the more arid countries and regions, water harvesting

TABLE 1. Types of water control activities

SUMMARY OF MAIN WATER CONTROL COMPONENT (WCC) ACTIVITIES IN AFRICA	NO. OF COUNTRIES	%
Total no. of countries with WCC activities	40	100
Smallholder irrigation scheme development	21	53
Wetland development	16	40
Water harvesting and water conservation	13	33
Small dams development and rehabilitation	9	23
Micro-irrigation and on-farm irrigation Technologies	27	68
Treadle and motorized pumps	17	43
Well development	15	38
Drip irrigation	5	13
Pipe distribution systems	4	10
Peri-urban and school gardens	9	23
Rice irrigation	15	38
Horticultural crops	4	10
Staff training	13	33
Formation and training of water users' associations	18	45
Farmers' field school training	7	18

and water conservation technologies (33 percent) and small dam construction or rehabilitation (23 percent) were undertaken.

Main crops incorporated under the WCC activities are predominantly horticultural crops (56 percent) and rice (33 percent). Irrigation of peri-urban and school gardens were also promoted in a number of countries (15 percent)..

An essential aspect for the success and sustainability of the programme has been the group approach and the promotion of water user associations (WUA) or water users groups (WUGs), and was included as a specific activity in 45 percent of the WCC programmes. Training of technical and extension staff was reported for 33 percent of the country programmes with the aim to familiarize and guide staff in the introduction and demonstration of irrigation technologies and to provide direct technical assistance to farmers. Farmers' Field School (FFS) training has been successfully introduced in 18 percent of the countries.

The implementation of the water control technologies in the framework of the SPFSs and NPFSs has provided a wealth of experiences and much information. The results confirm that WCC technologies can substantially increase production and income, and contribute effectively to food security. Success stories, but in particular also failures, have contributed to providing better insight into which technologies would be most effective under which conditions and for which group of farmers.

Chapter 2 provides a review of the different technologies, according to the following classification:

- micro-irrigation technologies;
- wetland development;
- smallholder irrigation development and rehabilitations;
- water harvesting and water conservation techniques.

1.4 PROCEDURES FOR INTRODUCING WATER CONTROL TECHNOLOGIES

The planning and selection of the water control technologies and the evaluation of their performance, the investment and operation costs, and their profitability are critical in demonstrating successful technologies.

Chapter 3 reviews the procedures for the selection, introduction, investment as well as operating costs and performance of the various technologies.

Profitability of the water control technologies is determined by an increase in production, productivity and revenues obtained. A specific, successful element in the SPFS has been the integration of the WCC in the *intensification* and the *diversification components,* which made it possible to demonstrate that with improved water control and access to water, production could be increased substantially due to the availability of improved seeds, fertilizers and improved cultural practices.

Successful technologies can only be sustained and replicated if the investment costs in water control equipment and operation costs are economically viable. This has often proved a formidable handicap, which requires availability and access to credit and markets. Several SPFSs have raised attention to this important issue, and in some cases groups savings and revolving fund operations were actively promoted.

Chapter 4 briefly reviews the impact of WCC on agricultural production and productivity and the experiences in accessing markets and credit with respect to water control activities.

With an emphasis on national execution, national agencies and institutes have been entrusted with the main responsibility in the selection, installation and demonstration of the water control technologies. Consultation, coordination of all agencies involved and planning of the technical support and services proved essential, including training and capacity building of national staff and the private sector.

FAO has provided important technical assistance through the innovative South-South Cooperation Programme as well as an impressive number of technical support missions, in particular, from the water specialists in the regional and subregional offices.

In several countries, valuable support was obtained from non-governmental organizations (NGOs) and private sector agencies specialized in the promotion of appropriate water control technologies.

Through demonstrations, farmers were introduced to the use and management of the new technologies and shown the potential for increased production and revenues. Assisting farmers in adopting the new technologies requires effective communication tools and capacity-building programmes. Most programmes paid adequate attention to this aspect and some have been particularly successful.

Capacity building of water users' associations (WUAs) is an important aspect to ensure farmer cooperation in the effective operation and maintenance of smallholder irrigation schemes and wetland management. SPFSs have been successful in piloting participatory tools and group communication methods, such as the FFS introduced in a range of countries targeting farmer groups and farmer organizations, including WUAs.

Chapter 5 provides a further review of the technical support, training and capacity-building programmes.

2. REVIEW OF WATER CONTROL TECHNOLOGIES

In most countries, a mixed range of water control technologies has been introduced, with an emphasis on **micro- or on-farm irrigation technologies**, such as small, affordable pumps, well development and localized irrigation techniques (drip irrigation). In particular in areas with **wetlands and valley bottoms**, on-farm water control technologies have shown important potential for irrigation development.

Several countries have targeted the construction or rehabilitation of **smallholder irrigation schemes** varying in size from 5 to 200 ha and managed by groups of smallholders, with water diverted from rivers, lakes, or groundwater using gravity flow or pumps, or from small dams and reservoirs. Large- and medium-sized irrigation schemes have not been included, since the time frame and costs involved in the design and construction of such schemes would not be consistent with the objectives of the SPFS. In some cases, however, such as in Pakistan and Indonesia, on-farm irrigation development has been undertaken on large-scale irrigation systems.

A special type of water development has been the use of technologies related to **water conservation and water harvesting**, with various techniques for conserving or collecting rainwater for more effective crop production.

2.1 MICRO-IRRIGATION TECHNOLOGIES

In over 60 percent of the SPFS projects, micro-irrigation technologies have been introduced at farm level, providing smallholder farmers with low-cost technologies that can bring immediate results in providing access to water for increased crop production. They proved cost-effective and sustainable, were readily accepted by farmers and involved the private sector in sales and services.

A wide range of micro-irrigation or on-farm water control technologies have been introduced under the pilot phase of the SPSF and related FAO field projects in the different countries. They include the following technologies:

- low-cost well development techniques;
- water lifting devices;
- low pressure distribution systems and canal lining;
- localized irrigation methods and improved surface irrigation.

The topics are elaborated in further detail in the following chapters, with a short review of experiences in the different countries.

2.1.1 Shallow well development techniques

Shallow well development has been one of the more successful technologies for irrigation development. It proved cost-effective, can be readily initiated by individual farmers and provided opportunities for the private sector in manufacturing, sales and services of irrigation equipment. It has been widely introduced, and was promoted in around 20 countries as a specific component under the WCC of the food security programme.

In many cases, the exploitation of groundwater for irrigation goes together with the introduction of appropriate water lifting techniques such as treadle and motorized pumps.

Traditionally, farmers have developed open wells, up to 15–20m in depth, for drinking water and for garden irrigation using buckets (Figure 2). Open well development is most common, in particular, in the valley bottoms and wetlands where groundwater is at a shallow depth and farmers dig simple pits for bucket irrigation (Figure 35).

In unstable and sandy soils, the shallow pits easily collapse and improved well development techniques have been introduced by lining of the pits by concrete rings, bricks or stone setting (Figure 3).

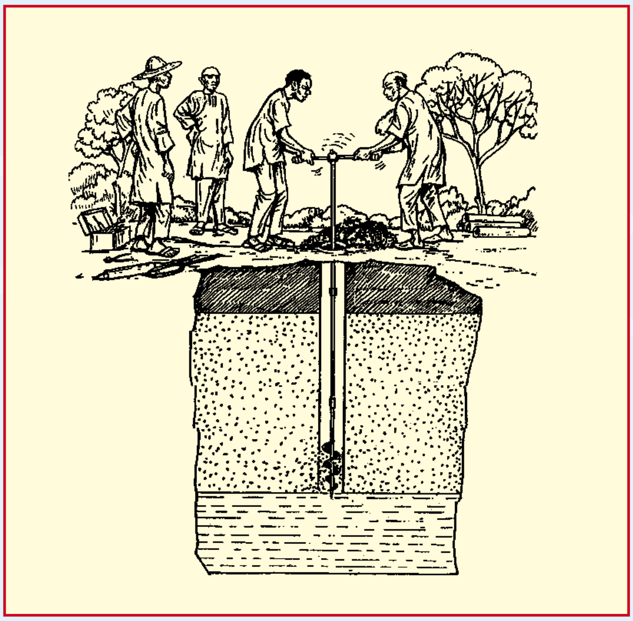
Tube well development has proved particularly effective with PVC tubing now widely available, even in rural areas. Several new and cost-effective techniques for tube well drilling have been developed for different hydro-geological conditions, allowing drilling in various soil conditions in sand as well as in hard stone layers.

The most important well development techniques as introduced under the SPFS include:

- open well development (Figure 3);
- augering of tube wells (Figures 1 and 6);
- rota sludge drilling for tube wells (Figure 4)
- percussion drilling (Figure 5);
- jet wash boring;
- stone hammer drilling (Figure 5); and
- rotary rigs.

Specialized international NGOs such as Practica Foundation, IDE and Entreprise Works, have played an important role in the WCC_SPFS by the training of local entrepreneurs in the introduction of new well development techniques, such as the rota sludge technology (Figure 4). With training of local drillers (Niger, Nigeria, Madagascar, Burkina Faso), the technologies can be made readily available for farmers at affordable costs (Figure 6).

FIGURE 1.
Concept of well development by hand auger – Naugle/LWR, 1996



Individual farmers in Niger and Nigeria increasingly engage local drillers for well development for irrigation, buying small pumps from local traders and installing small PVC underground networks.

Since the late 1980s, Bangladesh and India have shown spectacular growth in shallow tube well development, with simple rota sludge drilling carried out by village drilling teams. This has intensified agricultural production and made a major contribution to food security.

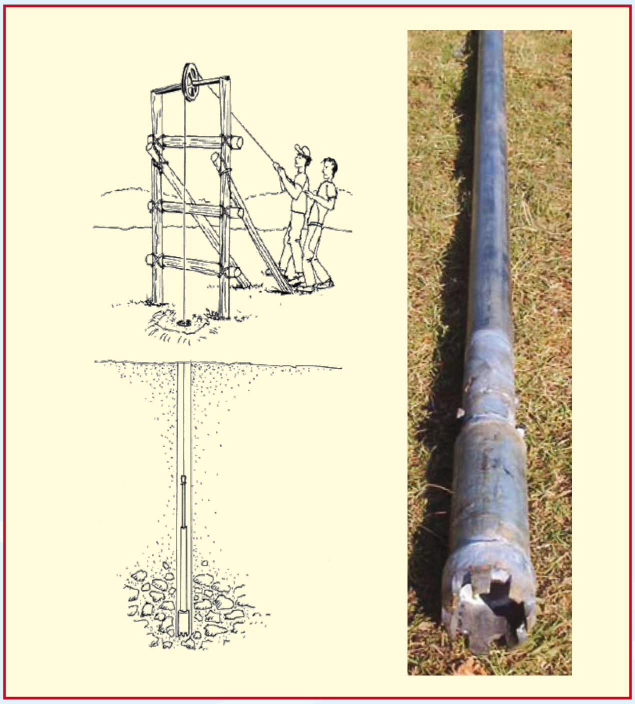
FIGURE 2.
Bucket irrigation from open well – Zambia

FIGURE 3.
Open well development and lining with concrete rings – SPFS in Sierra Leone

FIGURE 4.
Training of drilling team in rota sludge technology for we ll development – Practica Foundation

Costs of well drilling can vary considerably depending on the depth and equipment to be mobilized for the drilling. In Mali, wells developed by contractors cost US$ 000 to US$ 500 per open well fitted with concrete lining; in Ghana costs amount to US$ 625 per unit. On the other hand, in Niger and Madagascar, shallow (20 m depth) tubewell drilling implemented by locally trained drilling teams fitted with 150 mm PVC pipes, cost only US$ 300–400 per unit, typically irrigating 1 ha of vegetables with a motorized pump (US$ 250).

FIGURE 5.
Stone hammer for well drilling – Practica Foundation



GROUNDWATER DEVELOPMENT has proved one of the most important opportunities for small holder irrigation development

Under the NPFS in NIGERIA, the following have been developed:
- 189 washbores
- 89 boreholes
- 41 open wells

in NIGER:
- 1050 boreholes and open wells.

In BURKINA FASO:
- 110 boreholes and open wells.

In MALI:
- 28 open wells, at an average cost of USD 1 000–1 500.

In SUDAN:
- 27 deep wells for 168 ha.

In SENEGAL:
- 50 open wells.

In TOGO:
- 847 small open wells for vegetable production.

In CAMEROON:
- 14 open wells rehabilitation by lining.

THE UNITED REPUBLIC OF TANZANIA, ZAMBIA, MOZAMBIQUE, MADAGASCAR, GAMBIA AND BENIN all have promoted well development under the water control component confirming the potential of this technology.

FIGURE 6.
Installation of tubewell with locally adapted materials – SPFS in Madagascar

2.1.2 Small dams and reservoirs development

Water conservation by small dam development is another means to store water from the rainy to the dry season, and to improve access to water for drinking water for animals and for irrigation.

Small dams are particularly suitable in areas with pronounced dry periods and uncertain rainfall. They are common in regions with 600 to 1 200 mm of rainfall andwith suitable rolling or hilly land formations that allow the construction of the small dams in small valleys and natural streamways.

SMALL DAMS AND RESERVOIRS

- Dam rehabilitation has been undertaken under the SPFS in ZAMBIA (12 dams), GHANA (two dams) and SENEGAL.
- Under the NPFS in NIGERIA, 24 micro-dams have been constructed.
- The SPFS in ETHIOPIA, with help from SCC experts, conducted studies on five small earth dams.
- In LESOTHO and MADAGASCAR, small dams and ponds have been used for the introduction of gravity drip irrigation.
- In BURKINO FASO, retention reservoirs (casiers) were successfully introduced in wetland development at a low cost.

The small dams can be found in many shapes and sizes, varying from earth dams of 100 m long and 5 m high, stocking 100 000 m^3 of water and capable of irrigating 15 ha, to small retention reservoirs and ponds used for gravity drip irrigation (Lesotho). In wetland areas, diking retains water in larger shallow reservoirs and ponds for irrigation in the dry season ("*casiers*" in Burkina Faso).

Many dams have been used for smallholder irrigation, in particular, in Burkina Faso (Figure 7), Nigeria, Zambia and Zimbabwe, and many SPFS water control activities have been linked to smallholder dams.

There are a number of constraints in small dam development that limit their success, in particular for the larger small dams, These constraints include:

- high investment costs, as dam construction is carried out by specialized contractors with appropriate earth moving equipment often to be mobilized in remote, difficult to access areas;
- design and tendering procedures often result in considerable delays and exceeded project duration under the SPFS projects of three years or less (Ethiopia);
- excessive rains and floods provide high risks of overtopping and breaches, requiring professional design and frequent maintenance;
- the Spillway, preventing overtopping of the dam is a critical component of the structure, but | subject to damaging flashfloods, requiring frequent and costly maintenance (Figure 8);

FIGURE 7.
Small earth dam for irrigation – Burkina Faso (from GRAF-B.W. Sanou)

FIGURE 8.
Spillway in dam – NPFS in Nigeria

- siltation from erosion and flash floods can reduce considerable the effective storage and life time of the reservoir;

- the volume of water effectively stored is mostly limited, and reservoirs often run dry well before the end of the dry season, as evaporation and seepage losses can be considerable;

- the areas irrigated by small dams is limited and in most cases restricted to 5 to 10 ha.

The cost for dam construction and dam rehabilitation varies significantly from US$ 2 000 to US$ 8 000 per ha, depending on the dam shape, volume of water effectively stored, and implementation by contractors.

The construction of small dams for ponds and diking in wetlands has been much more successful and cost-effective, since implementation can be carried out in most cases by the farmers themselves, with some further technical advice. Costs can be as low as US$ 300/ha (e.g. in Guinea).

Using small reservoirs for gravity drip and sprinkler irrigation, as introduced in Lesotho and Madagascar, has proved a viable solution to reduce pumping costs.

2.1.3 Water lifting devices

Water-lifting devices concern the technologies that bring water to a level from which the crop can be directly irrigated or conveyed through a gravity canal system or a pressurized pipe system. Water can be lifted from a river, lake, dam, canal or from groundwater resources. Lifting the water requires energy either by human force (watering can, treadle pump), a combustion engine (motorized pump) or from electricity provided by a national grid or from wind or solar energy.

Watering cans or bucket irrigation

Irrigation by watering can or bucket represents the simplest way to irrigate a garden plot. It is very widely applied and is a first step to growing irrigated crops. In most cases, cans are locally produced from galvanized iron, plastic or sometimes from local available materials such as the *calebasse*[1] (Mali, Burkina Faso). Carrying the cans from the water source to the crop is labour-intensive and requires daily irrigations, typically in the evenings and early mornings (Figures 9 and 10).

The human labour required limits the area that can effectively be irrigated by a household, and the area irrigated by watering cans is typically a vegetable garden of 50 to 100 m^2.

Watering cans have been supplied in many SPFS projects in combination mostly with vegetable production and for smallholder farming groups, such as women's groups. It has been applied in the peri-urban projects, in the school gardens and under the wetland development programmes in Guinea, Burkina Faso, Mozambique and Angola, among others.

1 A calebasse is a ball or bottle-shaped gourd used as water container.

FIGURE 9.
Watering of vegetables with watering can – SPFS in Burkina Faso

FIGURE 10.
Watering by water can from concrete reservoir – FAO in Senegal

The costs of the watering can are minimal and do not exceed US$ 5. The labour costs are more substantial, however, and depending on the distance of the water source to the field, vary from US$ 200–1 500 per ha (assuming US$ 1 per workday and a water requirement of 3 000 m^3/ha crop).

Treadle pumps

The treadle pump has been extensively introduced in the SPFSs in many countries, showing the important potential of this micro-irrigation technique, which requires a relatively modest investment of around US$ 100 and allows the smallholder to irrigate a more substantial area than is possible with the traditional watering can method. Lifting water from up to a maximal depth of 7 m, the use of the treadle pump permits a typical area of 2 to 3 000 m^2 to be irrigated with 3 to 4 hours pumping daily and an output of around 1 liter per second.

The use of the treadle pump, developed originally in Bangladesh and spread to other Asian countries in the 1980s, was introduced in 1996 in the SPFS in Zambia with the International Development Enterprise (IDE) and in Zimbabwe with assistance from the FAO Sub-Regional Office (1997). It was introduced in a range of WCC programmes including Malawi, Mozambique, the United Republic of Tanzania, Kenya, Madagascar, Senegal, Mali, Niger, Burkina Faso and Guinea. Table 2 summarizes the introduction of the treadle pump in the different SPFSs.

The treadle pump technology evaluated considerably over the years and a range of models were developed by various organizations, including FAO (Figure 13), using the same concept, but applying different materials and improving design and manufacturing. The further spread of the technology was facilitated by promoting local manufacturing, often through separately financed projects but linked to the SPFS and with the assistance of specialized international NGOs such as IDE (Zambia) (Figure 12), Enterprise Works in Niger, Senegal, Burkina Faso, APPROTEC (Kenya) and the Practica Foundation in Madagascar (Figure 11) and Niger). The Swiss NGO Water for the 3rd World (W-3-W) has supported a number of FAO projects related to SPFS programmes in United Republic of Tanzania (Figure 14), Madagascar (Figure 15) and Lesotho for the local manufacturing of the concrete pedal pump.

The initial enthusiasm for the treadle pump has been tempered as the technology showed a number of set-backs and limitations, as demonstrated in several SPFS programmes.

These constraints included:

- poor quality of local manufacturing that sent farmers away to buy the technology (Malawi);
- inadequate technical advice for the installation and operation of the equipment where farmers were provided with treadle pumps for wells well below the maximum allowable depth of 6 m, in particular in the dry season (Burkina Faso, Mali, Chad);

FIGURE 11.
Pressure treadle pump – SPFS in Madagascar

FIGURE 12.
IDE River pump – SPFS in Zambia

TABLE 2. Introduction of treadle pumps in the Special Programme for Food Security

Burkina Faso	110 wells equipped with treadles, in several cases poorly adapted to deep water levels and less appreciated by women farmers.
Burundi	20 treadle pumps provided for vegetable production in five sites.
Djibouti	Demonstration of 50 treadle pumps in six demonstrations with limited results.
Gambia	Provision of treadle pumps for peri-urban vegetable irrigation.
Lesotho	introduction of Swiss treadle pump manufacturing and linked to barrel or reservoir with appropriate controlled pipe d conveyance system for vegetable irrigation.
Liberia	20 treadle pumps distributed among five farmers' groups with training provided to six front-line extension workers, 20 farmers and six foremen in the use and repair of the pumps.
Madagascar	Around 150 sites equipped with different treadle pump models, local manufacturing promoted with 2 international NGOs actively promoted by training of local craftspersons.
Malawi	30 sites provided with treadle pumps with a significant impact on irrigated crop production.
Mali	65 treadle pumps installed on wells, mixed results with problems in deep water levels.
Mozambique	29 treadle pumps (US$ 125) distributed through FFSs for the irrigation of vegetable gardens.
Senegal	Treadle pumps provided on a number of sites; most producers abandoned them in favour of motorized pumps.
Sierra Leone	70 sites provided with low-cost, small irrigation systems through FFSs for vegetables.
Swaziland	5 ha of wetlands equipped with treadle pumps allowing vegetable production during the dry season.
United Republic Of Tanzania	The Swiss Concrete Pedal Pump introduced with its manufacturing unit in Morogoro.
Uganda	Three sites provided with treadle pumps for vegetable production, local manufacturing initiated.
Zambia	Treadle pump introduced in SPFS in 1996, with the importation of 100 pumps from Bangladesh. Local manufacturing was promoted subsequently by IDE (see Figure 13).

FIGURE 13.
Testing pressure treadle pump by FAO-SAFR in Zimbabwe

FIGURE 14.
Operating the concrete treadle pump — FAO-W3W in the United Republic of Tanzania

FIGURE 15.
Manufacturing concrete treadle pump — FAO-W3W in Madagascar

- limitations, in particular, of the open suction model, requiring water to be carried through open channels to the crops, resulting in considerable water losses;
- considerable daily labour still required to pump water, which still results in high operational costs of own or hired labour;
- the high position needed for operating the treadles pump, in particular in the early models, giving discomfort to women;
- sharing of the treadle pump among a group of users, proved less successful.

The treadle pump has been particularly successful in the wetland development projects where water can be found at a limited depth, in combination with well development and where the pressure treadle pump has been combined with a set of low pressure pipe distribution system and flexible hoses to distribute the water by sprinkling (Figure 16).

Investment costs for the pressure treadle pump including a set of flexible hoses are around US$ 120 (US$ 500/ha); labour costs to operate the treadle are US$ 150 per treadle (around US$ 600/ha).

Motorized pumps

Motorized pumping has revolutionized irrigated agriculture and made an important contribution to food security under the SPFS in many countries.

THE EVOLUTION OF TREADLE PUMP TECHNOLOGY IN MADAGASCAR

- A range of different treadle pumps have been tested, including the Swiss concrete pump by W-3W, the Kenyan APPROTEC pump, and the metal pressure treadle developed by Practica Foundation.
- The metal pressure pump adopted by Practica Foundation proved the most successful (Figure 11).
- Special efforts were made in the training of local craftspersons in the manufacturing of treadle pumps in the SPFS areas. A total of 30 craftspersons have been trained in the concrete treadle pump production, with a two- year follow-up procedure (Figure 14).
- Quality control of locally made treadle pumps have proved the greatest bottleneck in local manufacturing. Only a few workshops could successfully maintain the production of treadle pump.

In particular, the small low-lift motorized pumps driven by small petrol or diesel engines with a capacity of 2 to 5 HP and a typical discharge of 2–15 l/s have become cost-effective (Figures 17 and 18). The price of this centrifugal pump has decreased considerably with importations from China and India, and is typically between US$ 200 to US$ 500. They are within the financial reach of many

FIGURE 16.
Watering of vegetable crops by treadle pump – SPFS in Madagascar

FIGURE 17.
Small 1.5 HP petrol motorized pump – SPFS in Madagascar

FIGURE 18.
Motorized pump, 2.5 ha module – NPFS in Nigeria

NIGERIA

Under the NPFS in NIGERIA, a total of 643 pumps were introduced through two modules:

- **2.5 ha module pumping from surface water (rivers, lakes and ponds); (total 340 units, (Figure 18);**
- **1 ha module combined with the installation of tube wells from shallow aquifers (Figure 50).**

In NIG ER, more than 1 200 small pumps were installed under the SPFS WCC at an average price of less than USD 600 per unit and often combined with the low-pressure pipe system and shallow tube wells.

individual smallholder farmers, allowing them to irrigate a substantial area of 1 to 5 ha.

The small low-lift motorized pumps have been introduced in several SPFS programmes, including Malawi, Uganda, Mali, Senegal, Mauritania, Niger, Nigeria (Figure 18 and 50), Madagascar (Figure 17), Chad, Sudan, Burkina Faso, typically for the irrigation of dry season vegetable irrigation or supplemental irrigation of rice.

Pumping is carried out from surface water, rivers, lakes, ponds and reservoirs, or from shallow groundwater resources, placed on open wells or tube wells (Figure 50), not exceeding 7-meter depth. In exceptional cases (Sudan), water is pumped from considerable depth (30–80 m) at very high costs using multi-stage pumps.

Many village irrigation schemes in Senegal, Mauritania and Mali are equipped with a motorized pump serving several smallholders (5 to 10 ha).

Pump development has been particularly successful in combination with shallow well development, as introduced in Nigeria, Niger and Burkina Faso.

Installation of the motorized pumps fitted with flexible hoses (Figure 18) for intake and discharge is straightforward; the pump can readily be installed and moved to another location. Efficiency of the pump can be greatly improved, however, when connected to buried PVC pipe systems, as widely applied in Niger, which allows water to be conducted efficiently to the fields and results in a much larger area to be effectively irrigated.

Motorized pumps have often been allocated to groups of farmers, and often to women farmers for irrigating vegetables. This can be successful when farmers and water distribution are organized and operating costs shared. Where this organization was lacking or where plots were too fragmented (Mali), pump schemes were sometimes abandoned.

A common constraint in the case of motorized pumps mounted on wells is the lowering of the groundwater level in the dry season below the maximum suction lift of 7 m, making pumping for irrigation impossible in periods when water is most needed.

The role of the private sector has been a very important factor in promoting the sales and ensuring after-sale services of the motorized pumps in Africa, as clearly demonstrated in Niger and Nigeria. Where the private sector is less developed (Chad), investment costs are much higher, delays occur in delivery and pumps are wrongly dimensioned.

The energy costs for operating the pumps are still a major constraint and the reason for some SPFS farmers to abandon the technology, as for some of the sites in Malawi, where motorized pumping was introduced. Pumping irrigation water for a second rice crop in the dry season, when irrigation requirements are high and irrigation supply is required over the full season, was economically unfeasible in most cases (e.g. Chad), because revenues from rice do not cover the high irrigation costs in the dry season. Pump irrigation has proved particularly feasible for fruit and vegetable crops and supplemental irrigation of rice or maize.

Investment costs of small motor pumps is around US$ 200 to US$ 500 for a 1.5 to 5 HP engine irrigating 1–5 ha. Operating costs including labour are approximately US$ 500 per season. Investment costs for the 2.5 ha units under the NPFS in Nigeria amounted to US$ 1.800 per unit, or US$ 720 per ha, including fittings and hoses.

Hand pumps for drinking water and irrigation
A primary need for many food-insecure people is to have access to clean drinking water. A number of SPFS programmes promoted and introduced equipment for safe drinking water supply.

In Nigeria, in each of the 109 sites of the NPFS, a drinking water point was established (Figure 19). Also, in several other SPFS programmes, drinking water was an additional item of the WCC, such as in Angola, and may deserve more specific attention under the WCC.

Installed equipment for drinking water can provide an interesting opportunity for the irrigation of small garden plots, particular in the case of groundwater at larger depth.

The hand pump is a common device for drinking water, allowing it to be lifted from a 10 to 50 m depth; in specifically designed pumps, even up to 100 m. The discharge is limited, however, at 1 to 1.5 m³/hour, or 0.3 to 0.5 l/s. The manufacturing of the hand pumps requires sturdy materials and quality craftsman ship, which is not always available. Many hand pumps have been imported from Asia, in particular from India. The costs of the pump are considerable higher, at around US$ 500 to US$ 2 000.

The hand pump has been successfully applied for irrigation in some countries (Niger, Burkina Faso, Zambia) in areas where groundwater is at a considerable depth (> 7 m). Small home vegetable gardens or school gardens can be irrigated with hand pumps filling a watering can, a small reservoir or water tank, and in some cases have been combined with a bucket drip irrigation kit.

NIGERIA

In the NPFS in NIGERIA, each of the 109 sites included provisions for drinking water from boreholes or open wells fitted with hand pumps(Figure 19); the average costs for drilling of boreholes and the hand pumps amounted to over US$ 3 300 per unit.

Hand pumping, in contrast to pedaling on a treadle pump, cannot be continued for any length of time by the same person, which makes it less suitable for continuous pumping for irrigation.

The small discharge and the considerable labour involved in hand pumping exclude its application for irrigation on any sizable scale.

Rope and washer pump
Suction pumps such as the treadle and centrifugal motorized pump do not allow lifting water from a depth exceeding 7 m. An alternative has been developed with the rope and washer pump that can typically lift water manually from 10 to 35 m depth from an open well and can be made from locally available PVC pipes and materials, allowing local repair and services. With a cost of US$ 150 to US$ 250 per unit, the pump is within the financial reach of rural households. The pump has successfully been introduced with the assistance of international NGOs in several countries, and an estimated 60 000 pumps have been installed in Africa (Burkina Faso,

FIGURE 19.
Hand pump for drinking water – NPFS in Nigeria

FIGURE 20.
Rope and washer pump – Practica Foundation in Senegal

GHANA

The SPFS in GHANA tested the rope and washer pump, which allows water to be lifted from a groundwater depth of over 10 m.

- **The cost of the installation was USD 225 per unit.**
- **Farmers complained about the drudgery of the manual labour and limited discharge for irrigation.**

Ethiopia, Ghana, Senegal, Zambia, Zimbabwe). Figure 20 shows the rope and washer pump introduced by Practica foundation in Senegal.

The pump has been introduced under the SPFS in Ghana, but was not considered suitable for irrigation.

2.1.4 Localized irrigation (drip and sprinkler irrigation)

With localized irrigation methods, water is applied close to the plant and its roots through a piped distribution system. Drip irrigation, spray or micro-sprinkler irrigation, and bubbler irrigation belong to this category of irrigation methods, but pot and plastic funnels can also be used to bring water close to the crop and its rooting system.

The method allows accurate water application and can bring considerable water savings, particularly under arid conditions. Sophisticated drip and spray irrigation systems often combined with computerized water and fertilizer applications are applied in greenhouse and hydroponics, where highest yields can be achieved..

Specific drip systems have been developed for smallholder farmers, such as the family drip irrigation system of NETAFIM and the bucket drip irrigation kit of IDE (Figure 21) for the irrigation of small vegetable gardens. They have been introduced and tested in several SPFS programmes in Niger, Nigeria, Mauritania, Ghana, Egypt, Lesotho, Cape Verde, Madagascar, Sierra Leone (Figure 23) and Zimbabwe.

FIGURE 21.
The bucket drip irrigation kit for garden irrigation

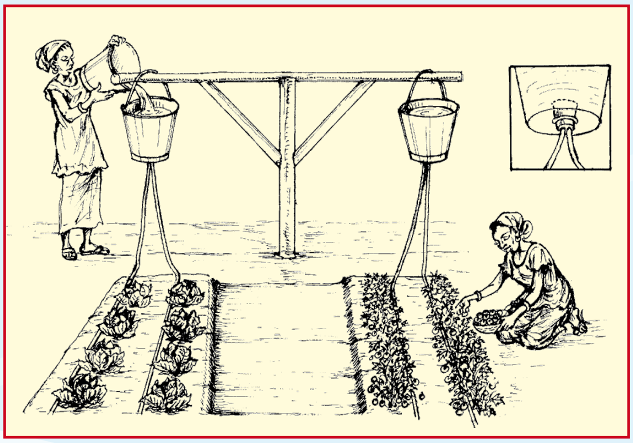


FIGURE 22.
Filter to prevent clogging of the drip irrigation system

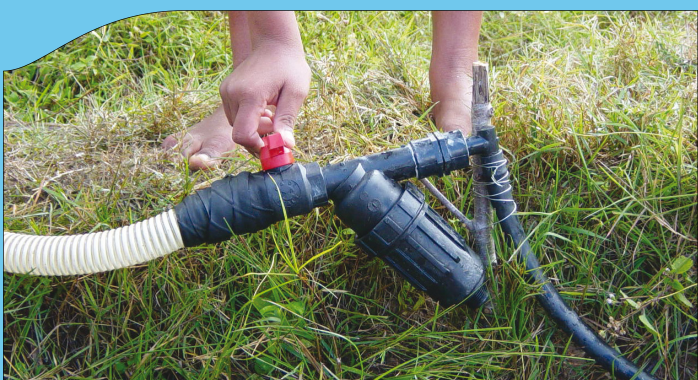


FIGURE 23.
Installation of drip irrigation lines – SPFS in Sierra Leone

CAPE VERDE

In the islands of CAPE VERDE, the introduction and adaptation of drip irrigation under the SPFS has been very successful, as the country has very limited water resources and is dependent on food imports. Results included:

- **drip irrigation installed over 107 ha benefitting over 1 000 farmer families**
- **water savings of 25 to 40 percent;**
- **increase in yield of vegetable production from 15 to 20 tonnes/ha with the demonstration and introduction of fertigation and appropriate farm inputs;**
- **formation and training of water users associations (WUAs) to ensure effective water use and management;**
- **credit schemes established allowing farmers to invest in the initial high investment costs.**

With the exception of Cape Verde where conditions are favourable, due to its scarce water resources and appropriate technical and financial services, results of the introduction of low-cost drip irrigation kits have been generally disappointing and have not been sustained in most SPFS programmes for a number of reasons:

- high installation costs per ha (US$ 4 000/6 000 per ha): although the costs of the small family drip kits are relatively low (US$ 80 to 165), the system can only irrigate a small area (100 to 500 m^2);
- returns of produce for the small gardens are limited, as size of the gardens is small and marketing of produce problematic;
- lack of technical support and follow-up for the proper installation and use of the equipment;
- clogging of drippers due to improper filter maintenance (Figure 22);
- lack of support by farmers who, being used to garden watering, do not appreciate the dry surface and return to overhead bucket watering;
- introduction in areas with ample water resources do not justifying high investments in localized irrigation methods.

The high yields obtained under drip irrigation in combination with fertigation (fertilizer applied through the irrigation water) and accurate water applications require sophisticated management, which generally cannot be achieved under smallholder farmers conditions.

Although **sprinkler irrigation** has also been widely introduced in smallholder irrigation schemes, few systems prove sustainable as operating costs of sprinkler irrigation with medium to high pressure (20–30 bar) prove economically unfeasible and are often abandoned (Zimbabwe).

The gravity sprinkler systems using small reservoirs uphill and a piped distribution system, as introduced under the SPFS in Lesotho, have proved successful, however, as operating costs are minimal in such case (Figure 25).

LESOTHO

In LESOTHO under the SPFS, Gravity Drip and Gravity Sprinkler Irrigation was successfully introduced in 7 sites for a total of 46 ha.

- **Small reservoirs constructed upstreams and low pressures GI and PVC pipe systems minimized operating costs and simplified operation as water was delivered to individual farmers fields.**
- **The success of the pilot phase is to be followed by a wide ranging expansion phase covering technical solutions, policy measures, investment and capacity building programmes.**

2.1.5 Low pressure pipe systems

The low pressure pipe distribution system (*système Californien*) have shown to be an effective and efficient irrigation technology for smallholder farmers and small farmers' groups in conveying water efficiently to the field and the crop. In most cases, all materials are locally available and can be installed by farmers with minimal technical assistance.

Used in combination with a small motorized pump or a pressure treadle pump, or by gravity from a higher placed small reservoir, the system efficiently conveys and distributes water directly to the irrigated areas (> 0.5 ha) and fields, rotating irrigation among the different pipe outlets. As shown in Figure 24, pipe outlets or hydrants are placed at a regular distance (±20 m.) on a fixed underground PVC system, typically with a 1.5 to 2-inch diameter. The outlets can be directly opened to the field or connected to a flexible hose (diameter 20–25 mm, length 12–15 m) that can be dragged around to irrigate the individual fields and crops (Figures 26 and 27).

Low pressure pipe systems have been introduced under the SPFS in Niger, Madagascar, Chad, Senegal, Ghana, Mozambique, Gambia and Lesotho, in combination with small motorized pumps (Niger, Madagascar, Ghana, Chad) or upstream reservoirs (Lesotho, Cape Verde) to convey water up to the field, or in small village irrigation schemes to reduce water losses from the pumping station to the main irrigation canal (*canal tête morte*, or head channel), as introduced in Mauritania, Senegal and Mozambique.

In cases, where pumps were provided without provisions for water conveyance such as in the NPFS in Nigeria, farmers were reported to procure—at their own initiative and costs—inflatable hoses to improve water conveyance, showing the importance of this technology, which reduces water losses and facilitates considerable operation and mobility of the pumps. In Mauritania, the introduction of underground pipes for the conveyance of water from the pump outlet to the main distribution canal was reported as the most important technical innovation of the SPFS programme, highly appreciated by farmers.

FIGURE 24. Lay-out of low-pressure pipe system

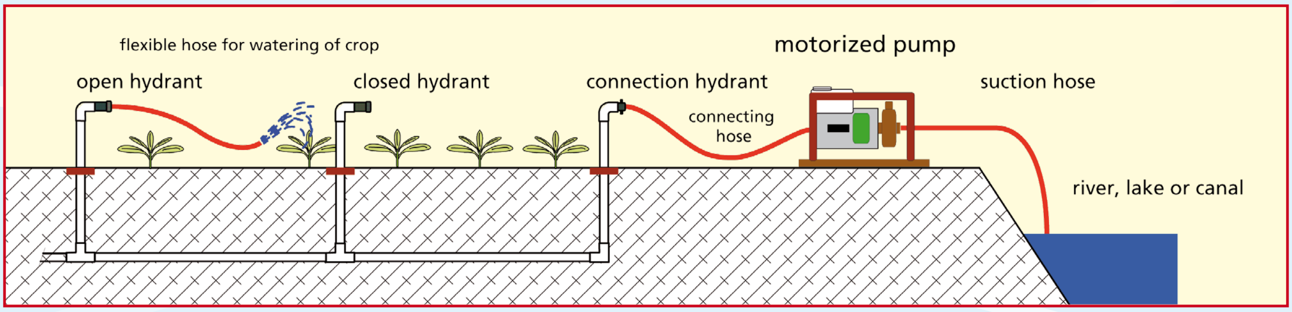


FIGURE 25.
Gravity sprinkler irrigation – FAO Malawi

FIGURE 26.
Watering citrus orchard with flexible hose connected to the PVC low pressure system – Madagascar

FIGURE 27.
Hydrant of low-pressure pipe system with flexible hose connections

NIGER

Under the SPFS in NIGER, a total of 1 150 PVC low-pressure pipe systems were introduced on a total area of 758 ha:

- **Combined with small motorized pumps lifting water from groundwater (boreholes) or surface water resources, highly efficient micro-irrigation systems were established.**
- **Credit provided to individual farmers was to be repaid in three years at an interest rate of 15 percent.**
- **Seasonal inputs in seeds and fertilizers with seasonal credit were provided.**
- **Yields and income, in particular of vegetable crops, increased by 100 to 200 percent;**
- **Great efforts were made in farmers' demonstrations, including FFSs.**
- **Training of technicians in the private sector and local craftspersons have ensured a rapid expansion of the technologies.**

NGOs in Niger (Enterprise Works) and Madagascar (Practica Foundation) (Figure 29) have been instrumental in developing and introducing the technology in the SPFS programmes and in training local technicians and field teams in the design and installation of the systems ensuring the sustainability and further dissemination of the technique.

Adequate technical advice and support is required. In Chad, for example, installed pipe systems were a failure due to poor installation and weak technical support.

Investment costs at around US$ 1 000 to 1 500 per ha are still high (in Ghana, US$ 930 per unit; in Madagascar, US$ 1 200), but were easily recovered as water allocation and the easy operation ensured more accurate water application, resulting in higher yields, water savings and larger areas irrigated.

2.1.6 Canal lining and on-farm canal structures

Water is distributed from the water source to the field mostly under a gravity system of open canals and field ditches. Water regulation and water distribution is carried out through a series of canal structures (outlets, drop structures, division boxes, gates, siphons, water level regulators).

Losses occurring in the canal system can be substantial, particularly in open earth canals. Often, as much as 30 to 50 percent of water is lost in the canal system due to seepage and evaporation, but in particular due to poor regulation of water flow and inadequate water regulating structures, resulting in large overflows into the drainage system. Irrigation efficiencies in on-farm irrigation systems in most cases do not exceed 50 percent due to poor water management and lack of maintenance.

FIGURE 28.
Installation of low pressure pipe system – SPFS in Madagascar

FIGURE 29a.
Brick canal lining – CARE in Madagascar

FIGURE 29b.
Brick Canal lining –S PFS Malawi

Canal lining has proved an effective solution in order to:

- reduce water losses, e.g. in sandy soils;
- reduce the erosive action of high water velocities, e.g. at pump outlets or when there are steep canal slopes;
- facilitate the conduct of water through difficult canal stretches, e.g. high embankments and unconsolidated canal banks;
- canal lining of earthen canals is costly however, and in most cases, will be restricted to only part of the canal system.

Canal lining is included in several SPFS programmes as a first step to improve water management and reduce water losses. Different materials were used, such as concrete, masonry and bricks. SPFS in Malawi included a standard 200 m brick lining at the pump or stream intake in each small-scale irrigation scheme (Figure 28). The SPFS (SPIN) programme in Nepal promoted soil cement lining as a cost-effective material. (Figure 30).

Since the 1970s, the On-Farm Water Management (OFWM) Programme in Pakistan implemented large investment programmes for OFWM improvement of over 600 000 watercourses by canal lining and installation of outlet structures and division boxes. The NPFS for Pakistan included an important element for water course improvements (Figure 31).

MALAWI

- **Under the SPFS in MALAWI (AFDB), a total of 1 400 m brick lining (Figure 29) was constructed including control structures in seven small-scale irrigation systems, for a total irrigated area of 133 ha.**
- **Under the SPFS in NEPAL (SPIN), soil cement was introduced as a more cost-effective canal lining material (Figure 30).**
- **Under the On-Farm Water Management Programme (OFWM) of the SPFS in PAKISTAN, watercourse canal lining and standard field inlet structures (Pacca Nacca) (Figure 31) were constructed.**

Few SPFS projects report on on-farm canal regulating structures, which certainly deserves more focus, since delivery of irrigation water in time and in the right quantity depend on adequate regulating structures combined with good operation practices.

2.2 WETLAND AND VALLEY BOTTOM DEVELOPMENT

Development of wetland areas and valley bottoms for improved crop production with water control technologies has been undertaken in the SPFS programmes in many West and East African countries with a pronounced wet and dry season and annual rainfall above 1 000 mm.

FIGURE 30.
Soil cement lining – SPFS in Nepal

FIGURE 31.
Water course improvement – FAO Tanzania

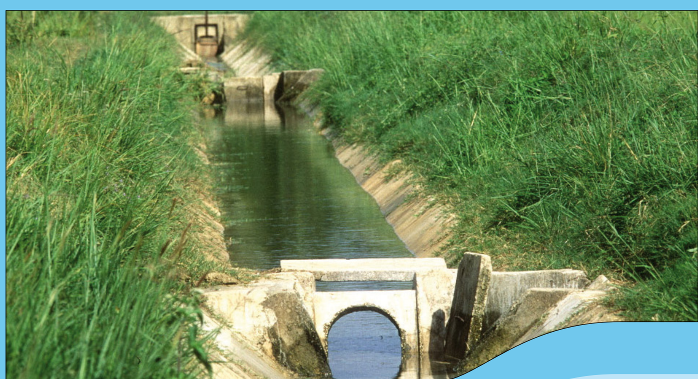


TABLE 3. Wetland development under the SPFS programme

	SITES	FARMERS	AREA (ha)	AREA/ FARMER
Benin	21	287	128	0.45
Burkina	47	600	75	0.13
Burundi	5	1 886	189	0.10
Chad	2	912	169	0.19
Democratic Republic of the Congo	2	1 794	150	0.08
Gabon		306	150	0.49
Ghana				
Guinea	96	6 000	260	0.04
Guinea Bissau	9	1 800		
Liberia			50	
Mali	3			
Malawi				
Nigeria				
Republic of the Congo	15	1 684	100	0.06
Senegal	50	400	75	0.19
Sierra Leone				
Zambia	8	80	25	0.31

The wetlands are found in the valley bottoms and natural depression where water accumulates and include swamps, marshes and bogs, and are partly and/or seasonally waterlogged, The wetland development programme constitutes one of the more successful experiences in the SPFS and positive lessons can be drawn to guide further development because they proved cost-effective and can, for a large part, be developed by the local population with some technical assistance.

Wetlands, valley and river bottoms, and coastal plains provide ready access to water both in the rainy season and dry season. In many countries, they constitute the natural conditions for crop production and in most cases, agriculture is already practiced. With improved water control during the rainy and dry season, crop production can be carried out during the whole year. Wet season crops are predominantly rice (Figure 32) with water control needed to prevent flooding and evacuate excessive water by drainage. In the dry season, the wetlands provide ready access to water from streams, ponds and shallow groundwater for irrigated crop production, in particular vegetable crops in small garden plots..

Water control activities in the wetlands are usually low-cost and can be developed by individuals as well as groups of farmers. They have been promoted and reported in a range of SPFSs in 17 countries, covering an estimated 20 000 farmers, of which a majority are women.

FIGURE 32.
Wetland rice production – FAO Kenya

FIGURE 33.
Diversion weir & Intake structure in Wetland Development - SPFS Guinea

GUINEA

Typologies of phased wetland development in Guinea:

- **type 1: improved water control for wet season rice cultivation (Figure 32) through the construction of bunds and dykes for flood control and improved drainage outlets and some simple regulating structures;**
- **type 2: introduction of dry season irrigation with improved water control through the construction of intake structures and shallow well development;**
- **type 3: construction of diversion weirs (Figure 33) and micro-dams with regulation of water in retention reservoirs.**

Water control works in wetlands are diverse and water control is applied through an often complex system using various water sources and different water control structures. Local streams, springs and shallow wells are used for irrigation in the dry season. By bunding and levelling of fields, water is contained to the fields, while canals are dug for drainage of excess water, and dams and dikes constructed for flood protection in the wet season. In the dry season, water may be retained in ponded areas for irrigation, or shallow wells are dug to reach the groundwater. Structural works in masonry and concrete (Figure 33) are generally simple and limited to intake structures and drainage outlet gates, bridges and siphons.

In many Asian and African countries, the wetlands have been the traditional areas for rice cultivation during the wet season, since rice is uniquely suited to the waterlogged areas of the wetlands. In the dry season, wetlands are used increasingly for vegetable production, provided that suitable markets are available.

The wetland development programme in Guinea may serve as noteworthy example: much emphasis was placed on organizational strengthening and training, which provided the base for the successful increase in food production and revenues through vegetable marketing. An important aspect has been the phased development of low-cost technologies mostly implemented by farmers (bunding, small earth works, simple masonry structures). As a result, investment costs have been very modest, at an average of US$ 300 to 600 per ha.

The typical water control works in wetland development included:

- Improved water control for rice cultivation

Rice production, practised in the partially flooded areas during the wet season can be increased with improved water management by: simple bunding and levelling of fields to maintain constant water levels; improving diversion of natural streams to the rice fields; and improving drainage of excess water and protection for floods.

- Promotion of dry season irrigation

Simple diversion structures of small streams and springs can improve water supply and increase irrigated areas. Water availability can be further improved by retaining water for the dry season by constructing low dikes and bunds, and simple regulating structures (*casiers*), or by constructing small dams and reservoirs. Irrigation of crops is carried out by flooding of basins and furrows or by using the watering can for vegetable production (Figure 34). The introduction of small pumps (treadle pumps or motorized pumps) have been particularly successful in promoting dry season irrigation, allowing pumping water from streams, ponds, small dams and shallow groundwater resources. Treadle pumps have been introduced in a range of wetland development programmes in Burundi, Sierra Leone, Liberia, Kenya, Zambia, Guinea and Burkina Faso, among others.

- Groundwater and well development

In most wetlands, groundwater is available at shallow depth and farmers already often dig open wells for the irrigation of their vegetable gardens (Figure 35). With the introduction of low-lift pumps (treadle and motorized pumps) and new low-cost well development technologies, groundwater development has been particularly successful in the wetland development programmes.

Groundwater development needs to be carefully monitored, since larger development affects the limited groundwater resources, disturbs ecological balances, and disrupts availability of drinking water for humans and animals. In a number of cases (Burkina Faso, Mali), the installation of treadle pumps for dry season irrigation failed for this reason, as water levels in the dry season dropped well below the maximum allowable depth of 7 m.

Adequate technical support and training of farmers in appropriate water control techniques were an essential element for the successful development of the wetlands. In a number of countries, this has proved to be a strong limitation, considerably reducing the impact of the WCC programme (Chad, Congo, Liberia).

The FFS approach was instrumental in introducing appropriate water control technologies, as demonstrated in the wetland development programmes in Kenya and Sierra Leone.

Many women farmers were involved in wetland development producing rice and vegetables, In several countries, women's cooperatives have been established and trained in improved cultural practices for rice, maize and vegetables under the SPFS in Guinea, Burkina Faso, Chad, Congo.

Improved rice varieties (Nerica) have been introduced in cooperation with The Africa Rice Center (WARDA).

In several examples, credit schemes for inputs (fertilizers) and storage of produce were initiated.

Under the SPFS, yields have considerably increased for Burkina Faso, Ghana, Guinea and Senegal, as shown in Table 4.

TABLE 4. Reported Rice yields and yield increase in Wetland development

	TON/HA
Burkina Faso	3.65
Ghana	2.1 to 7
Guinee	from 0.5 to 2.4
Senegal	up to 7

2.3 SMALLHOLDER IRRIGATION SCHEMES

A principal target of water control activities of the SPFS has been the **smallholder irrigation schemes** and were included as part of the WCC pilot in many countries, including projects financed by AfDB in Libya, Spain and Italy. The main emphasis was on the rehabilitation and possible extension of small schemes; new scheme development was only included in a few cases since rehabilitation was considered less costly and could be realized in a shorter time frame.

Table 5 outlines the various smallholder irrigation projects carried out under the WCC together with the number of sites, acreages and households covered. The average size of the small schemes covered, generally from 5 to 100 ha, with an average plot size per household from 0.11 to 0.50 ha.

According to the water intake, small-scale irrigation schemes can be classified as follows:

FIGURE 34.
Dry season vegetable production – SPFS in Guinea

FIGURE 35.
Shallow well for irrigation in wetlands – SPFS in Madagascar

TABLE 5. Results of smallholder irrigation development under the SPFS

	NO. OF SITES	NO. OF FARMERS	TOTAL (ha)	AVERAGE SCHEME SIZE	AVERAGE FARM SIZE	FARMERS' FIELD SCHOOL	AVERAGE COSTS (USD/ha)	STATUS
1 Burkina Faso	7	1 650						Improved maintenance
2 Cape Verde	5	1 000	107	21	0.11		1 900	Localized irrigation schemes
3 Chad	3		120	40				Incomplete
4 Djibouti	7							Oasis, incomplete
5 Ethiopia	7	2 520	735	105	0.29			Studies, largely incomplete
6 Ghana	5		117	23			2 600	Completed
7 Lesotho	5		110	22				Completed
8 Madagascar	5	150	75	15	0.50			Completed
9 Malawi	11	774	133	12	0.17	900 FFS		Rehabilitation
10 Mali	5	1 557	198	40	0.13	480 FFS		Delays in implementation
11 Mauritania	6	598	260	43	0.43		2 750	Partially completed
12 Mozambique	2	400	12	6	0.03			Not fully realized
13 Senegal	7							Village irrigation schemes
14 South Africa	7	5 200				69 FFS		
15 Sudan	27		168	6			2 000	Pump schemes
16 Swaziland		180	30		0.17			Full participation of farmers reported
17 United Republic of Tanzania	7	2 418	470	67	0.19		700	
18 Zambia	12		78				1 500	
19 Zimbabwe	1		24					
Total (indicative)[1]	(129)	(14 029)	(2 637)			1 449	1 908	

1 The totals presented are those of SPFS countries that did provided actual information on the number of sites, acreage and households, and do not represent the totals for the whole SPFSs

- **Diversion schemes:** an intake from rivers and streams and a gravity canal system conveying water – often over a considerable distance (1–5 km) – to the irrigation scheme. Many traditional schemes are based on this type of irrigation schemes (Madagascar, Ethiopia, United Republic of Tanzania, Indonesia), as shown in Figure 36. Investment and maintenance costs are often considerable.
- **Pump irrigation schemes:** pumping from rivers, streams lakes, reservoirs. Many village irrigation schemes in Senegal, Mauritania, Mali, Chad, Mozambique, Malawi, Nigeria United Republic of United Republic of Tanzania and Sudan belong to this type of scheme (Figure 37). Although investment costs are less than those of the diversion schemes, energy costs for pump operations proved a heavy

burden for farmers and have been a reason for its abandonment in some cases.

- **Dams and reservoir schemes:** water retained in dams and reservoirs and conveyed through gravity or by pumping to the irrigation areas (Zambia, Lesotho, United Republic of Tanzania, Burkina Faso, Zimbabwe) (Figure 7). High investment costs for dam and spillway construction, heavy maintenance, risks of dam failure and the relative small areas that can be irrigated from the small dams have been the main constraints for this type of scheme.

- **Groundwater schemes:** water pumped from shallow, medium or deep groundwater resources, as in Sudan; operating costs are high, however. In most cases, shallow tubewell irrigation concerns micro-irrigation schemes (less than 5 ha), which have proved more cost-effective and easier to operate with often a single owner.

Rehabilitation works include the improvement of the intake structures, realignment and lining of canals, canal regulating structures and field inlets, as well as improved drainage provisions, structures and rural roads.

Rehabilitation of small-scale irrigation schemes was problematic. Evaluations of the WCC of several SPFS programmes (Mali, Chad, Mauritania, Ethiopia, Burkina Faso) show considerable delays and cost overruns, resulting in incomplete projects and considerable smaller areas effectively implemented than originally planned.

Small-scale irrigation schemes are managed by a group of smallholder farmers who form a formal water users association (WUA) or informal water users' group (WUG) with a recognized structure, and rules and regulations to operate the scheme (Figure 38). The WUAs and WUGs are responsible for maintenance of the irrigation system and share the costs for the operation and maintenance of the irrigation infrastructure. Traditional irrigation systems, which have been constructed with local available means and materials through communal, and individual efforts and often strong local leadership, have proved much more sustainable and may exist over many years. Over the last 30 years, many of the smallholder irrigation schemes have been constructed through public development programmes and foreign assistance. Handing over the management and operation of these schemes to the smallholders and WUAs has proved a serious bottleneck, however, and in some cases, has resulted in a rapid deterioration of the irrigation infrastructure and breakdown of the pumps. Several of these smallholder

MALI

The evaluation mission for the SPFS Project in MALI financed by Libya concluded that:

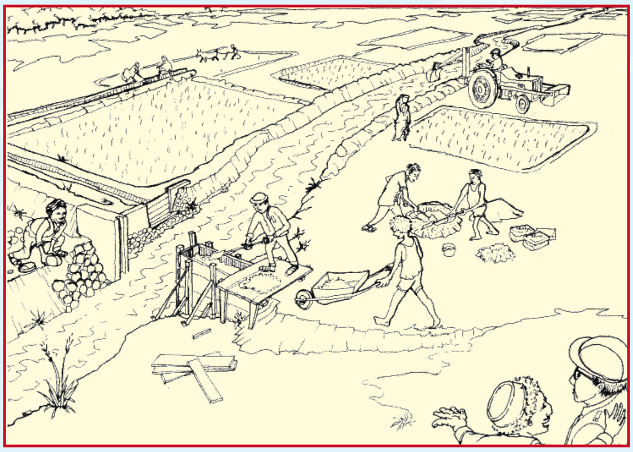
- **water control structures and equipment proved less sustainable due to deficiencies in cost estimates, design and poor maintenance;**
- **inadequate perception of the technical and social aspects of the project;**
- **unrealistic costs estimates and time frame for implementation of studies, tendering, and implementation of construction work.**

FIGURE 36.
Smallholder River Diversion Scheme – FAO OFWM in Indonesia

FIGURE 37.
Smallholder Pump Irrigation Scheme – Nigeria

schemes were adopted for rehabilitation in the SPFS because rehabilitation works were limited and were designed to be relatively quickly implemented.

FIGURE 38.
The participation of farmers in irrigation rehabilitation works – FAO Manual and guidelines on Participatory training and extension in farmers water management



The formation and training of WUAs were recognized in all WCC-SPFSs as key elements to ensure sustainability. Considerable efforts have been devoted to awareness-raising and diagnostic planning of irrigation rehabilitation works with training and capacity building of local committees and farmer representatives responsible for the operation and maintenance of the system. Despite these efforts (Mauritania, Burkina Faso), results are still limited and several countries report that continued efforts are needed over longer time frames (United Republic of Tanzania, Chad, Ethiopia) in order to succeed.

Several reasons can be identified as the underlying causes of the often disappointing performance of the smallholder irrigation schemes:

- lack of local leadership and inadequate capacity and experience in irrigated agriculture;
- the technical complexity of irrigation technologies and equipment with a lack of technical support and lack of training and extension (Chad);
- high investment costs requiring considerable financial support and implementation through a process of tendering and construction by contractors;
- high costs of operation and maintenance, in particular, for motorized pumps, in some countries resulting in farmers abandoning pumps (Malawi, Mali);
- low productivity as farmers use low inputs for fertilizers and good seeds;
- low prices for agricultural produce and difficult access to markets.

Several SPFS programmes introduced the FFS approach to strengthen WUAs and to increase productivity — Malawi (900 FFSs), Mali (480 FFSs) South Africa (69 FFSs). Results were often limited as technologies introduced were limited to IPM techniques

2.4 WATER HARVESTING AND WATER CONSERVATION

Water harvesting includes a specific group of water control technologies that use rain and floodwaters for irrigation and water conservation in the soil or reservoirs. It is practised in particular in the semi-arid and drought-prone areas, where rainfall is irregular and unreliable, and often occurs in singularly heavy downpours, resulting in heavy flash floods. Water harvesting methods have shown to be effective in can increase substantially yields and reliability of production.

In water harvesting, rainfall runoff from a larger area is collected and harvested for a smaller area, using specific structures (Figures 39 and 40) and land cultivation methods to collect the water and use for improved crop production. The effectiveness of the techniques still depends on available rainfall; years with low rainfall will result in lower yields, while excessive rainfall may cause severe erosion and damage to the structures.

Water harvesting techniques have been introduced in several SPFSs, where different techniques have been promoted. Results have been mixed, including failures of structures due to inadequate design and concept, as well as high investment costs in the case of spate diversion structures (Sudan, Ethiopia, Djibouti).

SUDAN

Under the SPFS in North Kordofan, SUDAN:

- chiselling of hard soil allowed better rain infiltration and increased yields of groundnuts and maize;
- 35 000 ha of land were chiselled for 30 000 farmers through contractual tractor services.

BURKINA FASO

Under the SPFS in BURKINA FASO:

- stone barriers erected for 100 ha increasing rain infiltration and settling erosion;
- retention bunds (casiers) erected for 35 ha for water conservation in the dry sea;
- training of 47 technicians and 600 farmers in soil and water conservation techniques.

The innovative technique introduced in North Kordofan in Sudan has been highly successful. The SPFS has promoted the chiselling of the hard soils, allowing a better rain infiltration, which has been greatly appreciated by farmers. Through contractual services, 35 000 ha have been treated in one year with additional financial support from the local government.

Results have been most successful where the technology is based on traditional practices as in Burkina Faso, where 100 ha were developed with stone barriers, erected to promote better water infiltration and settling of erosion. Cameroon reported similar activities.

Under the SPFS in Ghana, 10 ha of land was improved with bunds for water harvesting at a low cost (<US$ 200 per ha). In Benin and Burkina Faso, retention bunds were erected with 32 small collection basins for vegetable irrigation in the dry season.

Under the NPFS in Nigeria, water harvesting works were carried out with the participatory construction of micro-earth dams, contour bunds and infiltration ponds. Several have collapsed, however, due to flaws in design and maintenance, and the programme was not pursued.

A number of countries carried out erosion protection works, including Guinea, where erosion protection was linked to the wetland development programme and 486 ha of land were planted with tree crops.

In Ethiopia, the Government planned an ambitious programme for water harvesting, with 1 500 micro-dams in two regions (Tigray and Amhara Region). In addition, South-South Cooperation experts developed extensive studies for integrated watershed management for these regions. The plans were not further implemented for several reasons, however. Similar studies were carried out for Djibouti and are planned for Eritrea.

FIGURE 39.
Water harvesting by stone bunding – FAO Training Course on water harvesting

FIGURE 40.
Water conservation in small dams – FAO Training Course on water harvesting

3. INTRODUCTION OF WATER CONTROL TECHNOLOGIES

The careful planning of the different steps needed for introducing the water control technologies within the SPFS and the involvement of all actors in the programme have been keys to the success and can be directly linked to the results. Considerable experience has been obtained in the implementation of the SPFSs, from which useful lessons can be learned concerning the planning, introduction, demonstration and adoption of new technologies, and which technologies will work, under which conditions, and for which target group. Many of the evaluation reports carried out or coordinated by the FAO evaluation service of the SPFS (seen Annex 2, Bibliography) present success and failures, and provide useful recommendations how to improve procedures.

3.1 THE PLANNING PROCESS

In most cases, planning for the introduction, installation testing, demonstration and adoption of water control technologies is a lengthy process, requiring a much longer time frame than normally allowed in the two-year (TCP) or three-year SPFS projects such as those funded by Libya, the African Development Bank, Spain and Italy. In the project design, the importance of a proper phased approach was often insufficiently recognized, resulting in an unrealistic time frame and inadequate resources to implement the various phases of the pilot process to introduce new technologies. The different phases and stages in the pilot process include:

- **Planning:** involving the consultation of the local authorities, the selection of regions, the selection and consultation of the target groups, the selection of the WCC technologies, analysis of the institutional framework and human resources and capacity to implement the project. Consultations with all agencies involved need to be continued throughout the project cycle through regular national and district seminars in order to provide guidance, to identify constraints and to allow adjustment of the programme during implementation; (Figure 41).

- **Design, surveys and participatory diagnostics**: This involves the detailed designs of structures and specifications of equipment, consultation and awareness-raising of partners and target groups, and participatory diagnostics and detailed planning of activities.

- **Tendering and contracting** for structural works and engagement of services: ordering equipment, identifying qualified contractors and preparing detailed terms of reference. The regulations and requirements of the financing agent, the executing agent (FAO) and the implementing agent (governments) for contractual services have in some cases been major bottlenecks (AfDB projects), causing considerable delays.

- **Installation:** This involves the construction of structural works and installation of equipment. In most cases, a participatory approach has been adopted where farmers and farmer groups are committed to contribute substantially in construction works and equipment installation, including earthwork for canal and drain

FIGURE 41.
Planning of the Special Programme for Food Security in national seminars – SPFS in Madagascar

excavation, erection of dams and dikes, and provision of construction materials (stones, gravels, sand). This has often proved difficult, in particular where farmers have shown limited interest in the works and/or have time constraints due to their other farm activities.

- **Demonstration, testing and adaptation:** After installation of the equipment and structures, farmers are shown how to use the new technologies in combination with improved cultural practices in order to increase production with better water availability. The tests with the new technologies usually also require some further adaptations to suit local conditions and farmers preferences; operation and maintenance procedures need to be worked out in detail over several growing seasons.

- **Performance evaluation and constraint analysis:** An assessment is needed on technical and economic performance of the equipment to evaluate the sustainability of the introduced technologies. Although several projects provide optimistic data on increase in yields, few projects provide systematic data on the cost of installation, operation, production increase and revenues.

- **Follow-up support:** Most evaluation reports conclude that more time is required for follow-up actions in order to sustain the first promising results or to enhance further technologies.

- **Up-scaling of the technologies from the pilot phase to a national scale:** This requires further planning to define conditions and resources. Although success has not been uniformly positive, in many countries, the results of the WCC in the SPFS have given sufficient evidence of the importance of water control development, and many NPFS have included ambitious water control programmes with large investments (Nigeria, Pakistan, Niger).

The **time frame** for the introduction of water control technologies was shown to be critical and in several cases, largely underestimated, resulting in incomplete and unsatisfactory outcomes. In particular, for infrastructural works to be implemented in the irrigation schemes, serious delays occurred in establishing contract procedures between agencies and national governments — in completing the detailed studies, in tendering and contracting, and in the duration of construction works or procurement of equipment and materials. In almost all countries where more complex engineering works were undertaken, as in the Libyan and AfDB-financed projects (Mali, Chad, Burkina, Ghana, Mozambique), the three-year project period was insufficient to complete construction works on time and to assist farmers in the proper use and management of the newly installed construction works and increasing agricultural production.

The social adoption and follow-up on water technologies was another lengthy process, and in almost all cases, there was a clear need to ensure that technologies be sustainable and adjusted in a timely manner to ensure success. In theory, the constraint analysis would identify such constraints in performance and assess conditions for sustainability. This often proved inadequate, and there is a need to formulate more specific performance and sustainability indicators for the introduction of water control technologies.

Formation of sustainable WUAs and WUGs was another lengthy process. Despite specific efforts in several countries (Nigeria, Malawi, Ghana, United Republic of Tanzania, Mauritania, Cape Verde, Chad, Ethiopia, Mozambique and Swaziland) in the formation and training of the WUAs, many reported that time was insufficient to consolidate them.

The evaluation reports clearly show the shortcomings of several project designs, whereas short-term external missions formulate detailed projects prescribing areas and costing for the introduction of technologies without taking into account the capacity and requirements of the local target groups to adopt the technologies.

3.2 SELECTION OF WATER CONTROL TECHNOLOGIES

In line with the concept of the SPFS to identify and test appropriate technologies that can readily improve agricultural productivity and food security for smallholder farmers, the WCC was identified as a first entry point to increase agricultural productivity and constituted a main component of the SPFS piloting programme.

The guiding principle adopted in most countries was the selection of low-cost accessible technologies that could be readily and sustainably adopted by smallholder farmers. In most countries, this proved to be a learning process, since conditions varied widely and showed as many successes as constraints and failures.

3.2.1 Agro-ecological conditions

Agro-ecological conditions determine the choice of the water control technologies to be piloted under the SPFS

- In arid and semi-arid regions with rainfall below 600 mm rainfall, as in Sudan, northern Sahel and the Horn of Africa, technologies included full-scale irrigation from groundwater (deep tubewell schemes in Sudan) and surface water (Nigeria, Mali), small dams (Zambia, Burkina) and water conservation/harvesting schemes (Ethiopia, Djibouti, Burkina, Nigeria).

- In semi-arid and semi-humid areas (600–1 200 mm) with a pronounced dry season, supplemental full-scale irrigation was selected with river diversion, pump schemes (Senegal, Mali), smallholder irrigation schemes, micro-irrigation techniques and groundwater exploration in valley bottoms and river valleys (Niger).

- In humid areas (rainfall > 1 000 mm), wetland development was typically selected with rice production in the rainy season and vegetable production in the dry season introducing micro-irrigation technologies (Guinea, Togo, Chad, Benin, Burundi, Cameroon).

With climatic and agro-ecological conditions often highly variable, several countries have opted for a wide range of water control technologies:

- Ghana, Burkina Faso and Nigeria implemented water harvesting techniques, micro-irrigation techniques, rehabilitation of small-scale irrigation schemes, as well as wetland development.

Other countries limited the scope of technologies to one or two types of water control technologies:

- Guinea, Togo and Burundi, with exclusive wetland development;

- Lesotho and Cape Verde, with a focus on water savings and localized irrigation techniques; and

- Niger, with an excellent and successful focus on micro-irrigation technologies.

3.2.2 Selection of regions

The number of regions selected greatly varied per country, since a choice had to be made based on available financial and human resources, which restricted the number of regions and districts. Most countries selected different regions in order to allow testing of different technologies under various agro-ecological and social conditions, and to allow upscaling on a national scale. In some countries (Ethiopia), specific regions were selected to address development potential of remote regions.

The SPFS criteria for selecting high potential regions in order to achieve rapid results in increased food production sometimes contradicted national priorities in food security for food-insecure regions were the need is more urgent. Food-insecure regions, typically lack infrastructure and human resource capacity. Access to reliable water resources often proved problematic, and successful irrigated crop production a much more difficult challenge to overcome, even though the justification for intervention in such areas was greater. Water harvesting and expensive deep well construction in the dry remote areas (Ethiopia and Sudan) were often the only options for technology selection, with often limited results in increased crop production and very high investment costs.

3.2.3 Selection of and consultations with target groups

The main target groups of the SPFS were smallholder farmers. In many ways, this group determined the selection and process of demonstration and introduction of technologies, as well their sustainability.

There are still large differences among smallholders in terms of social, educational and economic condition, as elaborated in the following categories of smallholders:

- **Experienced smallholder farmers** and small-scale landowners who are already familiar with irrigation constitute the group who are best able to readily adapt new water control technologies and demonstrate capabilities for investing in low-cost irrigation technologies, such as small pumps and well development, as shown in Niger and Nigeria.

- **Vulnerable, landless farmers** with no experience in irrigated agriculture, most of whom are in need of food security, require a much longer process of introduction, assistance and financial assistance to succeed in adopting new water technologies, as shown in a number of cases in Congo, Chad and Angola. Intensive training programmes such as the FFSs were effective in some cases (Sierra Leone).

- **Women farmers and women's groups** have frequently been targeted for the introduction of new water control technologies, and in several projects, there was a clear majority of women's groups. Women farmers are traditionally involved in rice production and in particular, also the marketing of vegetable produce. They have shown to cooperate more readily and efficiently as a group (Guinea) and adopt new technologies than do mixed groups where men maintain leadership, as traditionally established. Land ownership has proved a constraint for women's groups, as in most cases, they only have access to small garden plots. In Mali, one of the pump schemes was abandoned by women farmers because of the complex parcellation. The educational level has been another constraint, which was effectively addressed in Guinea by a large literacy programme for all women members. The introduction of treadle pump technology has been limited in some cases by women's discomfort in mounting and working the treadles.

- **Water users groups,** sharing a common water resource and cooperating in a small-scale irrigation scheme, constitute the logical target group for introducing improved water control technologies and increasing crop production. Smallholder farmers already cultivating wetland areas have shown willingness to work together in bunding fields, erecting flood protection works and improving drainage systems, as in Guinea, Burkina Faso and Ghana. In most cases, their inputs are restricted to labour inputs, while more advanced individual farmers invest in well development and small pumps for dry season irrigation. Greater difficulties have been found among smallholder farmers in small-scale irrigation schemes to effectively work together in operating and maintaining the irrigation system and in contributing to the costs of scheme operation. Despite sustained efforts in training and motivation building, this has been the greatest obstacle in the rehabilitation of smallholder irrigation systems, undertaken in the WCC programmes of the SPFSs.

Consultation with farmers is an essential phase in the planning process in order to select the target groups that are truly motivated and capable of adopting new technologies and defining their own preference and priorities. A procedure

FIGURE 42.
Participatory diagnostic and solution finding with target groups – FAO Manual and guidelines on Participatory Training and extension in farmers water management

Problem observed *First solution found* *Solution proposed* for a participatory diagnostic approach needs to be adopted in order that farmers recognize their problems and define their own solutions and means to improve their water control system (Figure 42).

Project design needs sufficient flexibility to allow a proper process of consultation with potential target groups, based on which suitable technologies can be selected, adopted, tested and adjusted over time.

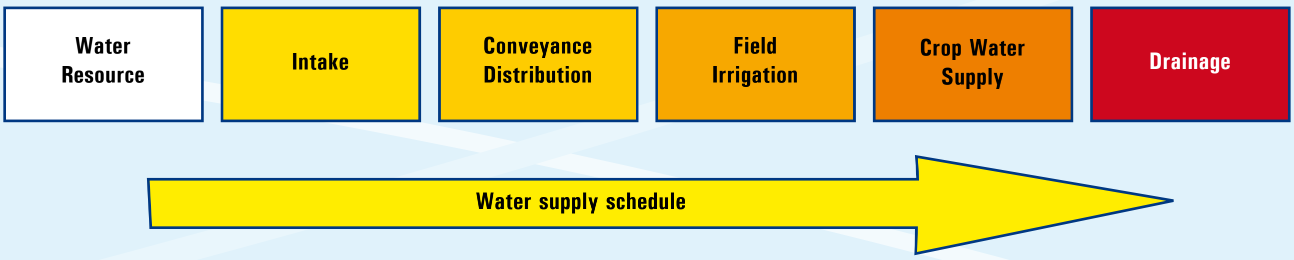
In Sudan, where implementation was to a large extent entrusted to the regional agencies, project design showed considerable deviation from the original project provisions. Technologies considered too expensive were abandoned (e.g. spate irrigation) or expanded with additional resources from state governments, as in the highly successful chiselling operations, which were expanded to 35 000 ha with funds made available by state governments and farmers' own resources.

3.2.4 Integration of water control component technologies into one effective water control system

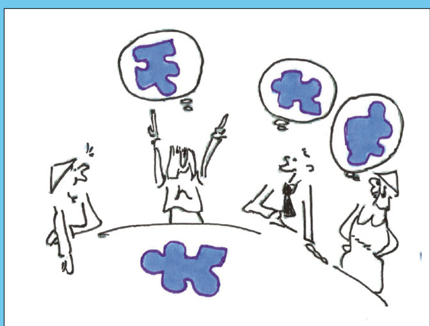
The selection of improved water technologies was often focused on one single technology only. The full supply cycle of water control from the source to the crop needs to be taken into consideration since removing one constraint in the cycle will have little impact when other bottlenecks continue to limit good water control. The water supply cycle is schematically indicated in Figure 43.

A typical example is the treadle pump or motorized pump introduced in most countries under the WCC-SPFS. The pump can significantly improve water supply for irrigation. However, water still needs to be supplied from a water source, which may be a readily available from a stream or pond, but in the case of ground water, it should be linked to well development technologies. Moreover, water from the pump needs to be conveyed to the field. The small discharge of the treadle pump carried through small field channels result in considerable losses; while in the case of motorized pumps, an extensive field channel lay-out is required.

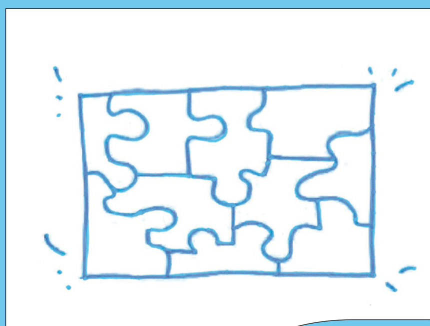
FIGURE 43.
Schematic analysis of the irrigation water supply system



Group discussion



Contribution from the group



Final solution

Where farmers are provided with a treadle pump only, as was often the case, without giving adequate attention to how water will be pumped from the source to the crops, the technology will duly fail.

Introducing the low-pressure pipe system for conveying water from the pumps to the field has been successful in Niger, Madagascar, Ghana and Chad. Success have been particularly impressive in Niger, where the combination of well development, motorized pumps and the low pressure pipe system has been applied in over 1 000 systems. Considerable water savings and expansion of irrigated areas are reported there.

In Mauritania, the introduction of a pipe system from the pump at the river to the irrigation system was reported as the most important technology contribution from the SPFS.

Similarly, in the rehabilitation of smallholder irrigation schemes, often only one aspect of the irrigation system was addressed: a new pump installed (Mozambique), an intake structure improved, or a piece of canal lining (Malawi) provided. Little consideration seems to have been given to the importance of water distribution and regulating structures, and the irrigation supply schedules. Improvement of drainage and flood protection works of smallholder schemes have been mentioned only in a very few cases (Nigeria, Mozambique).

Wetland development has shown much better integration; adaptation of various WCC technologies, such as bunding, drainage and flood protection for rice production, were combined with well development, water retention and water lifting devices. In some cases (Guinea), watershed management, erosion control and tree planting were also included.

Pakistan provides another interesting example for an integrated approach in on-farm water development, where watercourse improvements include lining of channels, installation of division boxes and field outlet structures (Figure 31). Moreover, an intensive programme for precision land levelling has been promoted under the OFWM-SPFS, which was highly successful (Figure 44).

Very few projects report on the promotion of improved surface irrigation methods, such as furrowing and land levelling. Scheduling of irrigation, providing water at the right time and right quantity, are other important technologies to reduce water losses and increase productivity and expand irrigated areas. Few of the reports make any mention of these technologies, which are very important to increase yields and reduce water losses. FAO's Water Service has published an extensive range of field guidelines and manuals on irrigation scheduling, which seem rarely used in the water control programme of the SPFS (see Bibliography in Annex 2).

There is a need to systematically analyse the opportunities to optimize water supply, reviewing the appropriate technologies for each of the different components of the water supply system.

The six components of the water supply system include:

- the water resource component;
- the intake component;

FIGURE 44.
Precision field leveling in the OFWM Programme in Pakistan – Government of Punjab

- the conveyance and distribution component;
- the field water component;
- the crop water supply and water management component;
- the drainage component.

3.3 EVALUATION OF PERFORMANCE

3.3.1 Performance indicators

The available reports of the SPFS provide only scattered information on the performance of the different technologies with respect to the technical and agricultural performance, the investment and operating costs, the social adaptation and constraints encountered. When available, these have been reported in the evaluation of the different technologies.

The information reported is not systematic, and there is room for further improvement for a better analysis of constraints and conditions for successful introduction of water control technologies.

Performance of the technology can be measured according to various indicators related to the technical, agricultural, environmental, economical and social conditions, as outlined below:

- **Technical performance** relates to the complexity of the installation of the technologies and equipment, the availability of local skills and tools to introduce them, requirements for operation and maintenance, and efficiency in terms of outputs (discharge) and input (labour, fuel, maintenance).

- **Agricultural performance** relates to the increase of productivity due to better water availability, but also, in particular, to the use of appropriate inputs (fertilizers, seeds), the intensification of the cropping calendar for dry season irrigation, and the effectiveness of the technology to save water and increase the areas that can be effectively irrigated for agricultural production.

- **Financial and economic performance** relates to the investment cost for equipment installation, the costs for O&M including fuel, labour and materials, and the lifespan of the equipment. For most technologies, a first estimate is given on investment costs, depreciation and operation and maintenance costs, expressed in costs per ha per season, which can be related directly to production and revenues according market prices.

- **Environmental performance** relates to the impact of the technologies on the environment in terms of excessive water use, flooding, salinity, water quality, and in particular, on available surface and groundwater resources and on biodiversity.

- **Social performance** relates to the adaptability of the new technologies by smallholder farmers, their acceptance, appreciation and interest in the technology, and requirements in training and capacity building and technical support. A specific aspect to be considered, as reported in several cases, is the conflicting interests of different WUGs; water is contested by smallholders for irrigation, by pastoralists for cattle watering and/or by fishers for fishing.

- **Institutional performance** relates to the requirements of institutional support and technical assistance required for the successful introduction and sustainability of the technologies. This includes support from government organizations and NGOs, and in particular, the private sector in providing services and assistance, as discussed below.

3.3.2 Cost assessment and profitability

A vital element in the evaluation of performance of the water technologies and its upscaling is an assessment of investment and operating costs of the different water control technologies. Several programmes report on investment costs, which show large variations for the different countries and technologies, and create considerable gaps, but allow a very global and approximate estimate of average costs, as summarized in Table 6.

There is much less information on operating costs related to fuel consumption and labour costs.

It is clear, however, that this plays a major role in the sustainability of the technologies, and several cases have been reported where farmers' groups abandon pumping because they consider costs too high (Malawi, Mali). Table 6 gives some indicative figures, based on separate analyses, assuming US$ 1 per day for labour costs and US$ 1 for 1 litre of fuel. Actual costs may vary considerably for different countries and under different conditions (remoteness of the area and transportation problems).

Profitability is clearly directly linked to agricultural productivity achieved under the various water technology systems and the price obtained for agricultural products. In many reports, optimistic information is provided on yields; these are obtained under pilot conditions and may prove difficult to sustain on a larger scale, and depend in many ways on the provision and availability of inputs such as quality seeds, fertilizers and pesticides.

Profitability ultimately depends on the prices obtained for agricultural products, even in the case of auto-consumption. With a yield of 2.5 tonnes/ha and a price of US$ 0.30 per kg for a cereal crop (rice, maize), as is common in many countries. A gross income of only US$ 750 per ha is achieved, which in general is insufficient to cover inputs such as fertilizers, seeds, labour and irrigation investment and operation costs. Higher yields and better prices can quickly make a difference, however, in particular for high value irrigated crops.

TABLE 6. Investment and operation cost estimates in water control technologies

	UNIT COSTS (USD)	INVESTMENT COSTS PER ha (USD)	OPERATING COSTS PER ha (USD)
Micro-irrigation technologies		500	400
Shallow well development	300	800	
Treadle pump	150	400	400
Small motorized pumps	250–1 000	400	500
Low pressure pipes	1 200	1 000	
Drip irrigation kit (500 m2)	165	3 300	300
Small-scale scheme rehabilitation		1 000– 3 000	
Gravity intake and head canal		3 000	250
Pump scheme		2 000	500
Small dam		4 000	200
Deep well development	10 000	1 200	1 000
Wetland development			
Bunding and drainage		600	300
Dry season irrigation		500	500
Water harvesting			
Contour bunding		600	300
Spate irrigation		4 000	200

4. IMPROVED CROP PRODUCTION, MARKETING AND ACCESS TO CREDIT

A unique feature of the SPFS is the integration of improved water control technologies with the introduction of improved cultural practices through the *intensification component*. This has proved very important, because investments in improved water availability will remain futile if not combined with better production methods including agricultural inputs such as improved seeds and fertilizers to increase substantially yields. Moreover, appropriate market outlets, storage facilities and credit for agricultural inputs, including irrigation, have proved essential to ensure sustainability and have specifically been addressed through the *constraint analysis component* of the SPFS.

The demonstrations of WCC technologies can only be successful in improving food security and smallholder farmers' income if they are set in a favourable framework that will ensure that the new technologies are economical viable and lead to an increase in agricultural production and marketable produce.

In a range of countries, the SPFS has demonstrated the benefits of this integrated approach. In countries where this has been neglected or where the WCC has been operating separately from the other components, as occurred in some of the early WCC TCP projects (Egypt, Zambia), this has been clearly less productive.

In the cases where no clear water component was included in the SPFS (Sierra Leone, Kenya, Mozambique, PAN II), the impact of water control techniques has been limited.

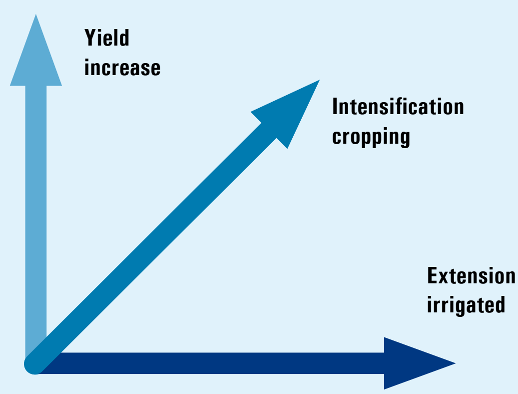
Information on crops, yields and production increase are provided in most SPFS project reports. However, the reported production and yield increases are not recorded systematically, are inconsistent and often incidental, and are not sustainable over larger areas. As a result, it proved impossible to make reliable estimates on average yield and production increases. A review of the information, as far as available, is summarized in Table 6.

4.1 OPTIMIZING CROP PRODUCTION THROUGH WATER CONTROL

Crop production is optimized through improved water control and water availability in three different ways, as schematically indicated in Figure 45:

- by increased productivity through the maximizing of yields with optimal water supply and improved agricultural practices and inputs (seeds, fertilizers);
- by extending the irrigated area through a more efficient irrigation system, and water savings;
- by intensifying the cropping calendar through the introduction of second and even third cropping seasons.

FIGURE 45.
Three dimensional increase in crop production by water control technologies



BENEFITS OF INCREASED CROP PRODUCTION UNDER THE WATER CONTROL COMPONENT, AS REPORTED BY THE VARIOUS SPFSS

- BURKINA FASO reported yields of 3.65 tonnes/ha from wetlands, while rice yields amounted to 5 tonnes/ha for small-scale irrigation schemes.
- Vegetable production in CAPE VERDE increased from 15 to 20 tonnes/ha, and drip irrigation systems increased water savings from 25 to 40 percent, resulting in an increase in areas irrigated.
- CHAD achieved double cropping on some small-scale irrigation schemes and promoted the expansion of rice cultivation in 60 ha of wetlands and 7 ha of vegetables.
- In GHANA, vegetable production from shallow wells provided a significant increase in income, while through wetland development paddy yields were reported to increase from 2.1 to 7 tonnes/ha.
- GUINEA reported an increase from 0.4 to 1.5 tonnes/ha on the wetland schemes.
- In MALI, small village irrigation schemes are reported to have increased rice yields from 3 to 7 tonnes/ha.
- In MOZAMBIQUE, treadle pumps provided to FFS groups allowed vegetable production and extended maize growing in small-scale irrigation schemes
- NIGER introduced vegetable production in the dry season and supplemental irrigation for rice production through micro-irrigation schemes in 925 villages on a total area of 758 ha.
- In NIGERIA, cropping intensity under the pump irrigation reach 200 percent, with 10 000 tonnes of vegetables produced on approximately 1 200 ha.
- SENEGAL reported that rice production in small pump schemes increased from 5 to 7 tonnes/ha, while micro-schemes were applied to 100 vegetable production units.
- SUDAN successfully increased groundnut and sorghum production on 35 000 ha through the chiselling of hard soils.
- In its small irrigation schemes, SOUTH AFRICA reported yield increases for maize from 1 tonne to 3 tonnes/ha and for paddy from 1.1 to 3 tonnes/ha.
- In SIERRA LEONE, vegetable production was promoted in wetlands through the provision of treadle pumps to FFS groups.
- In the UNITED REPUBLIC OF TANZANIA, rice yield in the small irrigation schemes increased from 1.1 to 3 tonnes/ha.
- In ZAMBIA, vegetable production was promoted by treadle pump irrigation and small earth dams, and along small streams in the wetlands (dambos)
- In LIBERIA, TOGO, BURUNDI, CAMEROON, rice and vegetable cultivation was promoted in wetland areas.

Increasing productivity of irrigated crop production has been successfully achieved through the **intensification component**, as reported in many of the SPFS programmes, and has typically been accomplished by:

- improvement of soil fertility through the provision of inputs of chemical fertilizers or the promotion of organic through composting and farm manure;
- introduction of improved seeds of high-yielding varieties responding to a greater water availability;
- effective pest and disease control, in particular through integrated pest management (IPM), as promoted in the FFSs;
- appropriate land cultivation methods and equipment in line with available labour and farming system.

Extension of the irrigated areas is an important means to increase crop production, often with the same amount of water supply. It can be achieved by a more efficient operation and water distribution system, in particular in the smallholder and micro-irrigation schemes, since irrigation efficiency is often as low as 20 to 40 percent.

Improving water efficiency can be achieved by:

- improving the irrigation system by rehabilitation and improving operations and maintenance, as reported in the smallholder irrigation schemes in United Republic of Tanzania, where irrigation efficiency improved from 15 percent to 40 percent;
- reducing conveyance losses by installing low-pressure pipe system, as successfully introduced in a range of SPFSs (Niger, Madagascar, Mauritania, Senegal) or lining of canals (Malawi, Nepal);
- introducing localized irrigation methods with pressurized water conveyance up to crop level, as introduced in Lesotho and Cape Verde, and reporting on water savings up to 40 percent;
- improved surface irrigation methods by land levelling, as very successfully promoted in Pakistan, or through the introduction of furrow irrigation;
- the introduction of appropriate water regulation structures were reported in only a few cases (Pakistan, Malawi) and few specifics were provided on the different types of water regulation structures (field outlets, division boxes, drop structures). There have been some good examples in Asia (e.g. Pakistan's water course improvement programme, the SPIN programme in Nepal);
- the introduction of rotational water supply and irrigation scheduling, is an important tool to ensure water supply to the crop at the right time and in the right quantity. Although the FAO Water Service has extensive training material on the subject, there are no records showing that rotational supply and irrigation scheduling has been effectively introduced in the WCC-SPFS;

Intensification of the cropping calendar can be achieved through irrigation in a second and occasionally even a third cropping period, provided water resources are adequate. In most SPFSs, the WCC has allowed a further intensification of the cropping season, by dry season irrigation at least for part of the irrigated area, as introduced and reported in several countries:

- Nigeria reports that an almost 200 percent cropping intensity can be achieved under the pump schemes there where a continuous water supply can be assured;
- many of the wetland development programmes, such as in Guinea and Burkina Faso, have successfully promoted vegetable production in the dry season for at least part of the area (10 to 30 percent) after rice has been harvested, which provided an important means of income and has benefitted many women farmers. However, in certain cases, a serious drop in water level in the dry season has prevented a further intensification (Burkina Faso);
- smallholder irrigation schemes typically consist of 30 to 60 percent double-cropping in the dry season, irrigating vegetables, maize and other field crops. Water supplies are a constraint in the dry season, however, since operating river schemes has low discharges and irrigation requirements are often much higher. Pumping costs can be a further constraint on dry season irrigation, as reported in some cases.

An overview of production increases that can be expected in the different water control systems are provided in Table 7.

Access to rural credit, providing advice to farmers on the use of credit, group savings and collective purchase of inputs, and encouraging the private sector to open up new sales points are essential to make farm inputs available to farmers.

Full integration of the crop intensification and diversification component into the water control component is of paramount importance in order to achieve indeed the potential increase in food production and food security, through investments in improved water control.

TABLE 7. Benefits of increased crop production and irrigated area under different water control systems

WATER CONTROL TYPE	PRODUCTIVITY INCREASE	INTENSIFICATION CROPPING CALENDAR	AREA EXTENSION (%)
Wetland development	Wet season Rice production 0.5 → 1.5–2 tonnes/ha	Dry season vegetable production 10–15 tonnes/ha	20–60
Small-scale irrigation schemes	Wet season Rice, maize, sorghum 2.0 → 3–5 tonnes/ha Dry season 2.0 → 4–6 tonnes/ha	Dry season production (maize, vegetables) on 30–100 % of irrigated area	30–50
Micro-irrigation	Wet season Supplementary irrigation of rice, maize, groundnuts 2 → 3–5 tonnes	Dry season vegetable production 10–20 tonnes/ha	20
Water harvesting	Wet season 0.2 → 0.8–1.2 tonnes/ha		50–100

4.2 CROP SELECTION, MARKETING AND PROCESSING

Most crops under irrigation in the SPFSs include rice and maize as food crops, and vegetables as cash crops. Rice (Figure 46) and maize are typically grown in the rainy season with supplemental irrigation and water control by drainage in the wetlands. Irrigation for vegetable production (Figure 47) is carried out in particular during the dry season periods, which are the most suitable for vegetable production. This provides important, additional income for smallholder farmers, provided they have access to markets.

Opportunities to optimize income from crop production have been included in several SPFSs and include:

- intensifying the crop calendar by introducing second season crops in addition to vegetables such as beans and green fodder, which can be cultivated on residual moisture after harvest of the rice crop;
- introducing short-cycle crops, allowing a second crop to be grown when water is limited.

Profitability of irrigated crop production is linked to obtaining good prices for produce, but in many

FIGURE 46.
Rice - main irrigated crop in wetland development – SPFS in Liberia

FIGURE 47.
Vegetables – principal sah crop in irrigated agriculture – drip irrigation – SPFS Ghana

programmes, marketing of produce has been reported as a serious constraint. The success of peri-urban schemes in the SPFSs (Guinea, Burkina Faso, Cameroon, Congo) is largely due to the ready access to nearby market outlets.

Exploring opportunities for better market access has been raised in many constraint analyses and has been a topic in several training programmes (Nigeria, Niger, Cape Verde, Sierra Leone). These programmes have included the introduction of market information systems such as those promoted in the NPFS in Nigeria and the United Republic of Tanzania to allow farmers better insight into market opportunities for their crops

Processing produce for its incremental value addition has been included in certain cases, as well as, in particular, the promotion of communal storage systems (Cameroon) and collective sales of produce.

Promotion of aquaculture and rice-fish production with the introduction of irrigation can significantly improve the value chain and increase income and protein intake (Figure 48).

4.3 RURAL CREDIT, REVOLVING FUNDS AND COMMUNITY CONTRIBUTIONS

Financing agricultural inputs and irrigation equipment is a key element for sustainability. Several SPFSs have addressed the issue and tried to find solutions. Input supplies have often been provided as a starting point for a revolving fund and a group savings activity. Success has been limited and only in rare cases has groups saving evolved into a sustained credit activity, as in Guinea (Figure 49).

Several of the evaluation reports strongly suggest to pay more attention to this point and to involve rural financing institutions in programme implementation (Nigeria, United Republic of Tanzania). Niger has provided a good example where input supplies were made available as a seasonal credit to be reimbursed in kind (seeds) at 30 percent interest, and fertilizers in cash at 10 percent interest.

The establishment of rural stores to facilitate access to agricultural inputs was promoted in several SPFSs (United Republic of Tanzania, Ghana, Niger).

Most smallholder farmers are not in a position to access the necessary funds for advanced irrigation technologies and equipment, which are often substantial. Public funding is required for the larger irrigation development. Private irrigation development and investment in micro-irrigation systems have been possible, however, with financing by the farmers themselves. This has been successful under the SPFS in Niger and Cape Verde, where local credit institutes were successfully involved in providing the necessary credit to farmers for the purchase of irrigation equipment — to be repaid in three years with 15 percent interest in Niger and by a subsidized credit (10–15 percent) in Cape Verde.

For successful involvement of local credit institutes, training and capacity building of the credit institutes is needed to familiarize them with costs and procedures of irrigation investments and to define the conditions and

FIGURE 48.
Rice – fish cultivation – SPFS in Madagascar

FIGURE 49.
A Rural Credit Association – SPFS in Guinea

criteria for loan assessment with possible government guarantees and/or subsidies, such as the World Bank supported private irrigation development programmes in Nigeria, Niger, Burkina Faso and Mali.

Financing larger irrigation and water control works is often partly or fully supported by public investments, international donors and financial institutes. In most irrigation development programmes, the principle has been established that farmers should substantially contribute to part of the construction cost (15 to 50 percent) through a combination of cash, labour and/or construction materials. The contributions from communities and WUA contributions have proved difficult, however, and often below expectations, as reported in several cases (Chad). Nevertheless, in a few cases, contributions were also positive, as reported from the SPFS in Swaziland, where 30 ha smallholder irrigation schemes were implemented with the full participation of the WUA of 180 households.

Wetland development has in general shown a much better farmer participation in the implementation of improvement works, which proved simpler and were well within the capacity of the local communities. SPFS reports from Guinea, Burkina, Togo, Liberia and Burundi report all positive contributions from the communities.

5. TECHNICAL SUPPORT, TRAINING AND CAPACITY BUILDING

The technical support in the SPFS implementation has been a critical aspect for its success. The holistic approach in irrigation development requires specialized technical expertise in the concept, design and implementation of the civil structures and water control technologies, as well support in the agricultural, social and economical aspects of introducing and demonstrating the technologies. The availability of adequate technical expertise has been essential.

With an emphasis **on national execution**, national agencies and institutes have played a leading role in the implementation of the WCCs and SPFSs.

FAO's technical assistance played an important role in programme implementation by providing specialized technical support through the South-South Cooperation Programme and through technical support missions of the Organization's technical staff, in particular, the water specialists in the regional and subregional offices.

Further technical and social support was obtained through involvement and close cooperation with international NGOs, specialized in the development of appropriate water control technologies.

Capacity building of local technical staff and service providers (NGOs and the private sector) has been given special attention in most SPFSs in order to build up and strengthen the local capacity to provide effective technical and extension support to farmers and assist in the implementation of the demonstration programme.

Training of farmers has been the main focus of the SPFS. In each country, numerous demonstrations on sample plots and extension sessions have been held. Emphasis has been placed on a participatory approach and the establishment of participatory farmer groups as target groups for the demonstrations and diagnostic appraisals. The FFS approach has been successfully promoted in a range of countries as an effective tool to introduce improved cultural practices and technologies.

Special efforts were made in the WCC programmes to strengthen the capacities of the WUAs to effectively operate and maintain smallholder irrigation schemes.

FIGURE 50.
Technical assisance South South expert from Viet Nam – SPFS Madagascar

FIGURE 51.
Institutional support in the implementation of the demonstration programme – 1 hectare tubewell pump module – NPFS in Nigeria

5.1 TECHNICAL SUPPORT SERVICES

The results and quality of the WCC were to a large extent dependent on the capacity of the national institutes and agencies entrusted with the implementation of the SPFS programme. In countries with a weak institutional structure, results have clearly been more difficult to achieve (Chad, Democratic Republic of the Congo, Liberia).

Good results in many countries could be directly attributed to a good institutional set-up and effective support services, as shown in following examples:

- Nigeria has profited from extensive South-South assistance, as did Senegal and Burkina Faso.
- Niger and Madagascar were able to profit from good support services provided by international NGOs and to involve the private sector in the supply, installation and manufacturing of irrigation equipment
- Guinea and Mozambique were supported by community support services provided by NGOs.

In Asia, institutional support is often more developed, and the SPFSs were able to directly profit from the institutional arrangements in place, such as in Pakistan with its OFWM Programme, which has been ongoing for many years, and in Indonesia and Sri Lanka, with good staffing arrangements and competent water management staff at the district level. The SPFSs in the Lao People's Democratic Republic and Cambodia, on the other hand, were constrained by weak staffing, despite an intensive training programmes set up by the SPFS.

Certain evaluation reports reported weak or lack of technical supervision as specific causes of serious flaws in implementation (Chad, Ethiopia, Guinea Bissau).

A vital element in the WCC technology demonstration programme was to define responsibilities and tasks of the different institutes, their capacity and their commitment to implementing the water control programmes and provide the technical support services related to:

- the selection, conception, design and implementation the WCC technologies;
- the appropriate cultural practices to optimize irrigated crop production;
- demonstrations and farmers' training and extension programmes;
- the formation and strengthening of WUAs.

5.1.1 National Support Services

Depending on the institutional arrangement in each country for SPFS implementation, several national agencies and organizations were involved in the implementation of the SPFS and WCC programme (Figure 50, Nigeria). They would typically include:

- **the irrigation agency,** responsible for irrigation and water resource policies, selection, conception and implementation of the water control technologies and the technical designs, construction, operation and maintenance of the irrigation infrastructure (Figure 52);
- **the agricultural agency,** responsible for technical advice and services related to appropriate agricultural practices and inputs for irrigated crops, and is linked to agricultural research and extension;
- **Extension departments or units,** directly responsible for maintaining direct contacts with the farmers for the transfer of knowledge.

An appraisal of the institutions and agencies to involve and their capacity for implementing the programme as well as their specific tasks in introducing the WCC technologies should have been an essential element in the project design, but was often only superficially carried out and entrusted to the national SPFS coordination unit.

A further complication arose in the coordination between the different technical agencies. Where responsibilities and coordination of SPFS activities were entrusted to the department responsible for food security or agriculture, the technical department responsible for irrigation was often insufficiently involved in WCC activities. On the other hand, where WCC activities were entrusted to the irrigation department, involvement of agricultural department and extension units were sometimes disappointing.

Technical support to the implementation of the SPFS and WCC was provided in most countries at different levels.

- **At the farm and the community level:** Technical staff and extension workers provided support and relevant advice to farmers and farmer groups in the installation, demonstration and use of the new technologies (Figure 52).

- **At the district and, at times, the provincial level:** A multi-disciplinary team of subject- matter specialists and technicians from different agencies and organizations, including NGOs and private sectors responsible for the selection and planning of the demonstration programme, provided direct support to field and extension staff in the implementation of the demonstration programme.

- **At the national level:** The national SPFS team, representing the concerned ministry and line agencies (irrigation departments, extension departments, research organizations), was responsible for the overall planning of the SPFS and the integration of the WCC in national policies and strategies and to integrate the SPFS into the various ongoing and planned development programmes in food security and irrigation. The national team provided overall guidance and support to the district teams and assist in the implementation of the programme and coordinate reporting and follow-up.

The effectiveness of implementation of support services, in particular at the field level, was often hampered by a lack of adequate resources for transport and communications. This should have been a government obligation, but resources were often insufficient or unavailable.

In several countries, the extension services have been severely restricted in funds and human resources, putting a severe strain on an essential part of the WCC demonstration programme. In some cases (Niger), NGOs have effectively and successfully assumed part of the tasks and functions of the extension services.

Defining the appropriate support structure to ensure an adequate capacity to implement the often ambitious WCC programmes has been a weak point in many SPFSs. Although provisions for staff training were included in most SPFSs, there have been few cases with a systematic analysis of the institutional framework to implement the programme or an assessment of the capacity to do so, based on which a meaningful training programme and a foreign assistance programme could be defined. In-service staff training should be continuous in order to ensure that staff reports on constraints encountered and receives continuous technical training.

FIGURE 52. Farmers' training in water management – FAO Manual and guidelines on Participatory Training and extension in farmers water management

FIGURE 53. Technical advice on the installation of an outlet pipe – SPFS in Guinea

5.1.2 FAO technical assistance

In order to assist the national and district teams in the implementation of the programme, FAO has provided extensive technical support through the South-South Cooperation (SSC) programme and through a range of technical support missions.

Under the SSC agreements, a total of 241 water control experts and technicians from 12 different countries were assigned to 39 SPFS countries, of which 22 in Africa. The NPFS in Nigeria was the largest beneficiary of SSC programme, where 105 WCC experts and technicians from China were assigned (Figure 54). Table 8 shows the distribution and origin of the South–South experts.

The impact of the South-South experts has been mixed, with good outputs reported in several countries, including Senegal and Ghana, where respectively six and nine experts/technicians from China were assigned, in Burkina Faso, with six experts/technicians from Morocco, and in Cape Verde with six specialists from Cuba.

South-South experts were assigned in the district offices and worked directly with farmers and technicians in the field. In Madagascar, the Government assigned a national counterpart to each of the 30 South-South experts in order to ensure that, through in-service training, the competences of the foreign specialists would be transferred effectively to the national staff.

In some countries, the impact of the South-South experts and technicians was limited due to the delays in construction works or to conflict, as occurred in Eritrea (15 Indian specialists) and Ethiopia (six Chinese specialists). In other cases, South-South cooperation was flawed by difficulties in communication and lack of facilities made available for South-South experts. Planning and reporting by South-South experts was mostly sporadic, which makes a proper evaluation of their efforts and impact difficult.

Valuable FAO technical assistance was provided in particular from the FAO water specialists in the regional and sub-regional offices. They carried out numerous technical support missions and provided valuable background information on the WCC implementation in their BTO reports

FAO's Investment Centre played an important role in the formulation of many of the larger water control investment programmes, such as those financed for the AfDB and the Libyan trust fund.

The **FAO Evaluation Service** (PBE) has been instrumental in the implementation and coordination of several evaluations of the SPFS programmes, which provide valuable information on results and constraints and occasionally depressive reading.

5.1.3 Non-governmental organizations

In several countries, NGOs have played an important role in the introduction and development of innovative technologies. Several international NGOs have specialized in the development of innovative water control technologies adopted to conditions in developing

FIGURE 54.
South South Expert in NPFS Nigeria

FIGURE 55.
A demonstration of the concrete treadle pump - FAO-W3W in the United Republic of Tanzania

TABLE 8. Specialization and country of origin of South-South

COUNTRY OF ORIGIN	TOTAL	WATER CC	FISHERY	LIVESTOCK	OTHER DIV	CROP INTENS	INTERPRET	OTHER
China	588	148	60	100	7	219	18	36
Viet Nam	187	11	21	33	3	86		33
Cuba	117	25	4	25		58		5
Morocco	65	10		12	5	22		16
India	39	18		8		13		
Philippines	35	7	5	9		14		
Myanmar	27	12	2	5		2		6
Bangladesh	16	3		5		8		
Chile	15			2		12		1
Egypt	14	6	2			6		
Pakistan	4	1		1		2		
Jordan	3			1		2		
Total	1 110	241	94	201	15	444	18	97
	100%	22%	8%	18%	1%	40%	2%	9%

countries and have provided valuable assistance to the SPFS programmes in a number of countries, including:

- **International Development Enterprise (IDE) (USA)** provided support in the introduction of treadle pumps and drip irrigation kits in the SPFSs in Zambia, Nepal and Cambodia.
- **Water for the Third World (W3W), (Switzerland)** provided support in the introduction of the concrete treadle pump in SPFS programmes in United Republic of Tanzania (Figure 55), Lesotho and Madagascar.
- **Practica Foundation (Netherlands)** provided support in the introduction of metal treadle pumps, small motorized pumps, low-pressure pipe systems and well drilling techniques for the SPFSs in Madagascar.
- **Entreprise Works (USA)** provided support in the introduction of treadle pumps in Niger and Senegal.
- **Approtec** (Kenya) ensured sales of money-making treadle pumps to several SPFS projects, among others, in Mozambique, Malawi and Uganda.

In a number of countries (Guinea, Mozambique, Angola), NGOs were engaged within the SPFS programme for groups training and community support.

5.2 TRAINING AND CAPACITY BUILDING

Capacity building and training of all actors involved were essential elements in the entire process of introduction of the water control technologies. Information, demonstration, advice, training, extension and follow-up support have been provided to ensure that smallholder farmers are adequately informed on the proper management and use of the technologies. Technical staff and extension workers assisted in the introduction, installation and use of the new technologies, providing the necessary information, demonstration and advice to farmers.

5.2.1 Staff training

Most SPFS programmes made provisions for training of national staff on the procedures and conditions for the introduction of the WCC technologies.

Several reports mention staff training being implemented, although often with few details.

Through a programme of training of trainers (TOT) (Figure 56) technical staff and extension workers received training and instructions to implement the SPFS programme and to report back on success and failures. The TOT training in WCC technologies have often been lacking or insufficiently implemented in many SPFS programmes.

Little information is available on the cost of staff training, except for the training programmes in Zambia, Nepal and Cambodia where a detailed analysis was given for the training costs at the national, district and field levels.

The three-month TOT for FFS moderators was reported to cost approximately US$ 50 000. The training of 20 district offers and technical staff including national and district seminars, as provided in Zambia, Nepal and Cambodia, cost approximately US$ 35 000 annually.

5.2.2 Farmers' training and demonstrations

Demonstrations and farmers' training were included in all WCC programmes, although at various intensities. No systematic information could be collected on how farmers' training and demonstrations were implemented and few details in the form of manuals and guidelines used could be identified. The list below provides summarized information on training collected from different reports. It gives an idea of the training and demonstrations provided in the different countries:

- **BENIN**: training of 287 farmers in rice production in wetlands;
- **BURKINA FASO**: demonstrations on 92 sites, involving 12 883 farmers through FFSs on improved crop production technologies, including water control;
- **BURUNDI**: demonstrations on treadle pumps on 20 sites;
- **CAMEROON**: training of 200 groups in wetland vegetable production involving 2 000 farmers, mainly women;
- **CAPE VERDE**: intensive farmers training on improved cultural practices and the use of drip irrigation systems;
- **THE DEMOCRATIC REPUBLIC OF THE CONGO**: on 15 sites wetland development, eight groups, 1 684 farmers trained in improved production techniques, including vegetable production;
- **GHANA**: 32 FFS groups for 1 000 households;
- **GUINEA**: on seven sites, 247 women's groups, involving 7 061 farmers (70 percent of whom were women);
- **KENYA**: on ten sites, training of farmers in water management (drainage, flood protection, moisture conservation) through FFS training;

FIGURE 56.
Training of trainers: SSC technicians from Vietnam providing training to national technicians and extension staff – SPFS in Madagascar

NIGER

In NIGER, massive efforts has been devoted to the demonstration and training of farmers in micro-irrigation technologies:

- **on 1 553 sites, micro-irrigation equipment was installed and demonstrated, including tube wells, motorized pumps and low pressure pipe systems;**
- **close cooperation was established with NGOs in the installation and training of farmers;**
- **demonstrations led to strong interest from other farmers and a rapidly developing private sector.**

- **LESOTHO:** 62 farmers trained on nine sites on gravity sprinkler irrigation and ten extension staff and 13 irrigation technicians; continuous follow-up by extension workers;
- **LIBERIA:** training of 100 farmers in improved WCC practices for wetland cultivation;
- **MADAGASCAR:** demonstration of micro-irrigation systems on 53 sites with assistance from NGOs;
- **MALAWI:** on 22 sites in irrigation schemes, 400 FFSs were set up;
- **MALI:** 480 FFSs in village irrigation schemes;
- **MAURITANIA:** 13 sites, four schemes, two cooperatives, 598 farmers and members of the WUA involved in training and demonstrations;
- **MOZAMBIQUE:** a total of 468 FFS were trained under the AfDB and PAN I project;
- **NIGER:** massive efforts in micro-irrigation demonstrations, with 1 553 sites established where irrigation equipment was installed with assistance from NGOs;
- **NIGERIA:** demonstrations carried out on more than 2000 irrigation plots on 109 sites, mainly for vegetable production;
- **SIERRA LEONE:** 1 465 FFSs implemented for 19 500 households and 510 schools, treadle pump demonstrations through 70 FFSs;
- **SOUTH AFRICA:** FFS training of 109 participatory farmer groups for 5 200 households;
- **SWAZILAND:** FFS and WUA training for 180 households;
- **UGANDA:** in-service farmers training on irrigation of vegetables and coffee;
- **THE UNITED REPUBLIC OF TANZANIA:** For seven irrigation schemes, 69 FFSs were implemented;
- **ZAMBIA:** An intensive farmers' training programme with FFS training in water management and micro-irrigation systems.

5.2.3 The Farmers' Field School approach

The FFS approach has been successfully introduced in several SPFS programmes and constitutes an excellent tool to involve, consult and inform farmers in a participatory manner on improved cultural practices and new technologies. It allows to follow the different stages of crop production, over at least one growing season, and assess and resolve problems.

Developed originally in the IPM Programme in Asia, the concept of the FFS approach has been widely followed in the SPFS crop intensification component to introduce improved cultural practices, and in some cases, water control technologies.

The FFS was introduced in the SPFS in West Africa through the regional IPM programme. Mozambique, Kenya and Sierra Leone (Figures 56 and 57) have been the countries where the FFS has been used as exclusive tool for SPFS. Table 9 provides the list of countries where the FFS was introduced in the SPFS

TABLE 9. Farmers' field schools introduced in the SPFS programmes

COUNTRIES	SITES	FARMERS' FIELD SCHOOLS (FFSS)	HOUSEHOLDS
Burkina Faso	92 sites		12 883 farmers
Ghana:		32 FFS groups	1 000 households
Kenya	10 sites		
Malawi	22 sites	400 FFS groups	
Mali		480 FFSs	
Mozambique		468 FFSs	
Niger		FFS in vegetable production (no numbers reported)	
Sierra Leone		1 465 FFSs	19 500 households, 510 schools
South Africa		109 participatory farmers groups (PFGs)	5 200 households
Swaziland		FFSs and WUAs	180 households
United Republic of Tanzania	7 schemes	69 FFSs	
Zambia:		FFS in on-farm Watermanagemet	

programmes, with further details on sites, number of schools and households involved as reported.

The approach has evolved in various ways for improved crop production, soil fertility (Kenya) and soil conservation practices and also for improved farm water management (Zambia).

Several SPFS programmes mentioned introduction of the treadle pump through the FFS school.

Costs of the FFS amounted to US$ 15 to 40 per farmer or US$ 300 to 500 per FFS, not including the costs of the training of trainers (TOT). The original IPM FFS School includes an intensive three-month, TOT in the field, which cost US$ 50 000 for 20 to 24 trainers (Figure 57). Although very effective, this TOT training has proved expensive and has often been replaced by shorter and more frequent training events.

FIGURE 57.
A farmers' field school trainer – SPFS in Sierra Leone

FIGURE 58.
Farmers' field school training – SPFS in Sierra Leone

There is a tendency in the implementation of the FFS to focus more on IPM, social issues and group interactions and there is a lack innovative technologies, as reported specifically in the PAN programme in Mozambique.

The FFS approach could be very instrumental in the introduction of micro-irrigation technologies and for the strengthening of WUAs. The early SPFS programmes in Zambia, Cambodia, Nepal, introduced the FFS approach in a participatory training and extension programme for farm water management, based on which an extensive manual and guidelines were prepared and published by the FAO Water Service (NRLW) in the Land and Water CD-Rom series No 14: *Participatory training and extension in farmers' water management*. The guidelines apparently have not have found further applications under the WCC-SPFS.

5.2.4 Training of women

Many of the WCCs in the SPFPs have had a specific **focus on the promotion of women's groups,** in particular, for the irrigation of horticultural crops.

Guinea and many other SPFS countries extensively report on this aspect (Figure 59).

The Women in Irrigation (WIN) project implemented in Zambia, Nepal and Cambodia within the framework of the food security programmes provided a specific focus on gender issues in irrigation schemes and the promotion of women's groups and training in vegetable farming and processing of agricultural produce.

GUINEA

Under the wetland development programme in GUINEA, 5 000 women farmers were trained in improved rice and vegetable production and targeted in:

- **literacy programmes;**
- **cooperative development;**
- **marketing.**

5.2.5 Training of local manufacturers and the private sector

The private sector can play a vital role in providing irrigation equipment and technical services, and in ensuring sustainability and rapid expansion of technologies demonstrated in the WCC programmes. This was very clearly and successfully demonstrated in a number of countries.

In the framework of the WCC of the SPFS, a range of activities were undertaken in several countries, as summarized below:

- **NIGER** and **NIGERIA** provide excellent examples where the sales and after-sale services of private sector traders played an important role in the distribution of pumps, PVC pipes and flexible and inflatable hoses.

- In **SUDAN**, private tractor services have implemented chiselling services for 35 000 ha of hard soils.

FIGURE 59.
Women farmers' training – SPFS in Sierra Leone

FIGURE 60.
Women farmers' training – SPFS in Guinea

- In **PAKISTAN**, private tractor services provided precision levelling of fields for more efficient water control and irrigation of field crops.

- **NIGERIA** reported an increasing shortage of qualified drillers, plumbers, welders and mechanics for well development in the rapid expansion of micro-irrigation schemes.

- In **CAPE VERDE**, private sector became increasingly involved in the sales of drip irrigation equipment.

- In **LESOTHO**, local craftspersons were trained and participated in the installation of the piped distribution systems and storage reservoirs and gravity sprinkler systems.

- In the **UNITED REPUBLIC OF TANZANIA, MADAGASCAR** and **LESOTHO**, in a number of training workshops conducted by the Swiss NGO W3W trained several dozens of local craftspersons on concrete treadle techniques; in **MADAGASCAR**, Practica Foundation provided training to local workshops in the manufacturing of the metal pressure pump (Figure 61), the preferred treadle pump type, popular among farmers.

- In **MADAGASCAR** and **NIGER**, teams of local drillers were trained in low-cost well drilling techniques with the assistance of the specialized international NGOs.

- In **MADAGASCAR**, private sector traders were assisted in the importation of low-cost motorized pumps.

FIGURE 61.
Training of local craftspersons in manufacturing of the metal pressure treadle pump – SPFS in Madagascar

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ANNEX 1

LIST OF FAO ASSISTED FOOD SECURITY PROJECTS WITH WATER CONTROL COMPONENT 1995-2009

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Angola	No specific WCC, irrigation of horticultural crops, drinking watersupply			• GCP /ANG/039/SPA-Access to quality water for irrigated urban and periurban agriculture in Luanda	$999 930
Benin	wetland development (128 ha), well development and small reservoirs for vegetables irrigation, farmers training, 443)	1	VIE	• TCP/BEN/8921 + TCP/BEN/2901: maîtrise de l'eau	$410 000
Burkina Faso	Small scale irrigation rehabilitation (47 sites, 70 ha) with shallow well development and at low cost by water users, wetland development (drainage and dikes), water conservation and water harvesting (cordons pierreux (100ha), casierage (35 ha))	6	Mor	• GCP /BKF/042/LIB-Programme spécial de sécurité alimentaire au Burkina Faso -Phase I-(1 999 876), • GCP /BKF/048/ VEN-Projet d`intensification agricole par la maîtrise de l'eau dans les régions du Plateau Central, du Nord et du Sahel-(2 300 000) • GCP/BKF/049/ SPA-Projet d`intensification agricole par la maîtrise de l'eau dans les Régions du Centre-Sud et du Centre-Ouest-(2 160 000) • GCSP/ BKF/044/AND-Accès à l'eau pour la promotion des cultures maraîchère autour du barrage de Vy-(48 685) • GDCP/ BKF/001/ SPA-Projet de gestion de l'eau pour l'intensification agricole-(155 528)	$6 664 089
Burundi	Wetland development (5 sites) with low cost construction by local farmers, Waster users association development and training, 20 treadle pumps for vegetable farming (5 sites)			• TCP/ BDI/3001: Appui à la diversification de la production agricole dans le cadre du PSSA – ($ 334 483) Phase II of TCP/BDI/0168 ($ 65 235), Aménagement des petits marais et bas-fonds», • TCP/BDI/8926 ($ 268,048	$667 766
Cameroun	Wetland development (19 sites, 2 peri-urbain sites), Soil and water conservation (s sites) Well development (14 wells)	1	EGY	• PCT/CMR/0065 «Assistance à la composante maîtrise de l'eau»	$335 000
Cape Verde	Small scale irrigation rehabilitation (5 schemes, 100ha)(canal lining, water measurements, water distribution, irrigation scheduling), water users management, Drip irrigation introduction for fruit and vegetables (with credit arrangements)	6	CUB	• PCT/CVI/8926 ; Maitrise de l'eau ($ 255 572) • UTF/CVI/038/CVI : Programme Spécial de Sécurité Alimentaire -Phase 1, ($ 984 145), Cape Verde¬ • GCP/CVI/ 039/SPA-Contribution à l'amélioration et diversification des systèmes de production des producteurs au Cap Vert, (1 575 992)	$2 815 709
Central Africa	No water control				$0

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUNTRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Chad	Wetland development (2 sites, 43 ha) (dikes and 20 treadle pumps) (TCP) ---Small scale irrigation (3 sites, 168 ha), development plans, 50 micro and mini schemes, pipe distribution systems, moto-pumps, terrassing tools, 912 farmers.			• TCP/CHD/8923 ($180 809) + TCP/CHD/0065 ($ 104,926) Maîtrise de l'eau dans le cadre du Programme spécial pour la sécurité alimentaire de • GCP /CHD/026/LIB-Programme spécial de sécurité alimentaire au Tchad -Phase I--(1 699 991)	$1 985 726
Congo DRC	Small scale irrigation rehabilitation works at low costs by water users, strengthening water users association for better management and maintenance			• GCP /DRC/028/BEL-Projet dappui au développement de l'horticulture urbaine et périurbaine (Phase I et Phase II)-($ 8 563 069) • TCP/ DRC/2906-Appui a la Maitrise et a la Gestion de l'Eau dans le Cadre du PSSA, Bas-fond de Tshuenge et de Loma($380 377)	$8 943 446
Congo Rep	Small scale irrigation (15 sites) development with small reservoirs, distribution works, fish pond development, rice irrigation	3	VIE	• TCP/ PRC/2903: Appui a la Maitrise de l'Eau dans le Cadre du Programme Special pour la Securite Alimentaire (PSSA), ($399 704) • UTF/PRC/001/PRC : Programme spécial de sécurité alimentaire ($ 3 216 231)	$3 615 935
Cote dÍvoire	Micro irrigation development (2 sites, 13 ha, 100 farmers) for vegetable irrigation, development plans for rice irrigation (411 ha) vegetable (137 ha) and plantain (45 ha)			• SPFP/IVC/8801-Appui à la production de l'horticulture urbaine et périurbaine (projet HUP	$238 196
Djibouti	Rehabilitation of water harvesting schemes, watershed management, introduction of treadle pumps (6 sites, 50 farmers), vegetable irrigation development.	3	MOR	• TCP/DJI/8821 + TCP/DJI/0065 : Maitrise et Developpement des Techniques d'Irrigation et de Conservation des Eaux dans Le Cadre du PSSA (Phase I & II) : ($ 176 000 + $ 122 096) - • GCP /DJI/002/IDB (401.715 $EU comme don de la BID en appui à la CSS).	$699 811
Egypte	Water use efficient farm irrigation			• TCP/EGY/8924 + 2802: Water Control Component of the SPFS in the New Valley (Phase I & II) ($375 000 + $112,000)	$487 000
Equatorial Guinea	No water control				$0
Eritrea	Small scale irrigation improvements with small dams and well development, demonstration of efficient on-farm water management techniques	15	Ind	• TCP/ERI/0170, TCP/ERI/3002 Conservation Agriculture, Phase I & II) $ 225 194, $88 347, • GCSP/ERI/003/ITA : SPFS -Pilot Phase in Eritrea : Emphasis on Water Control, Intensification, Diversification and Constraints Analysis (1 077 876)	$1 391 417
Ethiopia	Small dam development and Water harvesting, demonstration of efficeinet on-farm irrigation practices and techniques, staff training and development plans	6	CPR	• GCSP/ ETH/057/ ITA-Special Programme for Food Security in Ethiopia-Irrigation Component-Pilot Phase--1,866,124	$1 866 124

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Gabon	Wetland development for irrigation (150 ha) and rainfed water management (235 ha), training of 27 rural engineers (SSC), Peri-urbaine development, including micro-irrigation	8	CPR	• UTF /GAB/010/GAB, Appui au démarrage du Programme spécial pour la securité alimentaire (PSSA) $ 4 140 000 dollars, • TCP/GAB/3002 (D) sur « promotion des technologies de micro-jardins, de l'agriculture urbaine et périurbaine » $ 356 000	$4 496 000
Gambia	Low-cost water lifting devices for horticulture (11 sites, 1500 farmers)	3	BGD	• TCP/GAM/2801 : Water Control Component of the Special Programme for Food Security $45 857, • GCSP/ GAM/021/ITA	$650 857
Ghana	Small scale irrigation development and rehabilitation with water harvesting and flood protection (bunding and ditches), dam rehabilitation. On-farm irrigation improvements, (treadle pumps, well developments (tubewells), PVC water conveyance systems, training of staff (30) FFS	8	CPR	• SPFP/ GHA/6701 -SPFP -Food Security in Ghana,--537,300, • UTF /GHA/027/GHA-Special Programme for Food Security Phase I-932,745	$1 469 745
Guinea Bissau	Wetland (Mangrove) development and rehabilitation (690 ha, 1800 farmers) for rice with improved soil and water management, farmer and staff training	2	CUB	• TCP/GBS/0067 : Appui a la Maitrise de l'Eau : $88 554 • GTFS/ GBS/028/ ITA-Diversification, intensification et valorisation des produits agricoles locaux (DIVA) dans les régions de Oio et de Bafata-1 500 000	$1 588 554
Guinea	Wetland development and rehabilitation for rice, horticulture (7 sites, 260 ha, 7061 farmers), improved water management and maintenance, water control structures, training of staff (73) and groups formation and training of farmers (7061).			• UTF/GUI/014/GUI : Programme Special pour la Securité Alimentaire (Phase I) $960 334 GCP / GUI/018/ • SPA-Projet et réalisation et mise en valuer d`aménagements hydro-agricoles dans les préfectures de Tougué et Dabola-2 160 002 • GCSP/GUI/015/ITA -Programme Spécial pour la Sécurité Alimentaire -Projet pilote d'appui au PSSA dans la région administrative de Kindia (Préfectures de Kindia et de Forecariah)-999 964, • TCP/GUI/014 : Evaluation du potentiel en bas-fonds en Guinée forestière $360 000	$4 480 300
Kenya	Wetland rehabilitation and improvements (drainage, water conservation in dry season) (9 sites). Farmers field schools			• TCP/KEN/6716 : Demonstration of Low Cost Irrigation, $ 248 903	$248 903
Lesotho	On-farm irrigation technologies (treadle pump,) on surface (dams) and groundwater resources) and appropriate water use for vege table irrigation, training of technicians and manufacturers	3	Ind	• GCPS/LES/043/AUS-Support to the Special Programme for Food Security (SPFS) Water Control Component: Pro-Poor Small-Farm Irrigation with Pedal Pump Technology $35 067, • OSRO/ LES/501/ EC-Provision of drip irrigation kits to enhance agricultural production $ 211 832 • TCP/ LES/ 8922+2801+ 3001-Water Control Component of the Special Programme for Food Security + Phase II and III – (310 444)	$557 343

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Liberia	Wetland development (water control techniques: small weirs, drainage channels, wcc structures) (50 ha), soil and water conservation techniques, low cost on-farm irrigation techniques (pumps) (10 ha) and effective water management practices and maintenance			• TCP/LIR/8923 ($355,000) + TCP/LIR/2802 (150 000): "Water Control Component of the SPFS	$505 000
Madagascar	Small scale irrigation rehabilitation for rice and offseason crops, water users association training, introduction of on-farm irrigation techniques (treadle pumps, motopumps, PVC distribution systems, drip irrigation), introduction of low-cost well development, training of water users associations (FFS) and treadle pump manufacturers			• GCP /MAG/075/SWI-Appui à l'introduction des technologies appropriées de l'exhaure-43 166, • GDCP/ MAG/001/NET-Amélioration de l'accès à l'eau pour la consommation humaine et pour l'irrigation dans la Commune d'Alasora-$ 20 114, • TCP/ MAG/ 2905-Renforcement des capacités de maîtrise de l'eau des populations affectées par la sécheresse dans le sud de Madagascar-$ 267 075, • TCP/ MAG/ 3003-Appui à la valorisation des bassins versants et des périmètres irrigués--$317 496	$647 851
Malawi	Small scale irrigation development, (8 schemes), micro schemes with small pumps (6 sites) and treadle pumps (30), staff training (irrigation & extension) water users association training though FFS.	12	MYA	• TCP/MLW/8921 : Water Contro Component SPFS (Phase I & II) : $353 000 • UTF/MLW/025/UTF : AfDB: Special Programme for Food Security -Phase I $931,401, • GCPS/ MLW/030/ NOR-Enhancing Food Security and Developing Sustainable Rural Livelihoods-5 290 257 • GDCP/ MLW/001/FLA -Improving Food Security and Nutrition Policies and Programme Outreach--5 510 274, • OSRO/ MLW/601/SPA-Promoción de pequeños sistemas de regadío y diversificación de cultivos en los distritos de Machinga, Kasungu y Lilongwe en Malawi--$296 625	$12 381 557

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Mali	small scale irrigation rehabilitation (100ha), flood protection and regulating structures with low cost water users participation, well development (28) and treadle pump installation (65), valley bottom and flood plain irrigation of rice, water users training through FFS for vegetable production (789 farmers)	2	VIE/CPR	• GCP /MLI/018/WFP-Suivi technique de l'aménagement des bas-fonds dans le cadre du projet PAM/PBF/Mali -Bilatéral Japonais (10 000) • GCP /MLI/024/LIB-Programme spécial de sécurité alimentaire au Mali -Phase I(1 999 989) • GCP /MLI/028/ VEN-Projet d`intensification agricole par la maîtrise de l'eau dans le Sahel occidental—($ 2 300 000) • GCP /MLI/030/ SPA-Projet de petite irrigation villageoise dans les régions de Mopti et de Gao-$-1 940 000, • GCPS/ MLI/029/ SPA-Programme Spéciale de Sécurité Alimentaire (PSSA) dans la région de Koulikoro (Mali)—($ 2 560 384) • GTFS/ MLI/030/ ITA -Projet d'appui aux organisations paysannes du Plateau Dogon pour une meilleure valorisation de leurs productions maraîchères-$ 2 000 000 • TCP/ MLI/2908-Formulation de projects d`appui à la sécurité alimentaire pour financement par la BOAD $ 276 137 • UTF /MLI/025/MLI-Assistance technique au Programme de formation de la sous-composante -Petite Irrigation -du projet PNIR/IDA—($565 727)	$11 652 237
Mauritania	Small scale irrigation rehabilitation (13 sites SPFS), on-farm irrigation techniques (drip irrigation), rehabilitation procedures, salinity control, strengthening water user associations, 3 schemes (150 ha, 5122 water users) rehabilitated (BAD), 2 schemes (110 ha, 166 menages) by SPA	5	CPR	• GCPS/ MAU/026/ SPA Programme Special de Securite Alimentaire en Mauritanie -Projet de Rehabilitation des Perimetres Irrigues de Belinabe et de Djowol IV ($ 1 579 566), • GCPS/ MAU/030/SPA Programme Spécial de Sécurité Alimentaire en Mauritan e -Projet pilote de renforcement économique et d`aménagement du périmètre de Djéwol IVL 926 995 $EU) • UTF /MAU/024/MAU Programme spécial pour la sécurité alimentaire -Phase I $ 992 486 • GCSP/MAU/027/MNC appui au SSC (150 000 $EU)	$3 649 047
Morocco	Rehabilitation of 2 water reservoirs plus irrigation outlets, introduction of growing vegetables, soil conservation practices (terracing)			• TCP/MOR/8924 et TCP/MOR/9166, Maroc ($ 355 500 + $ 66 500) Appui aux Programme de Développement Rural en Zone Bour	$422 000

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Mozambique	Small scale irrigation rehabilitation and development with improved O&M, farm water management, shallow well development (wetlands), 135 treadle pumps distribution, water policy development, staff training and water users training through FFS			• GCPS/ MOZ/033/ SWI-Support to SPFS Water Control Component: Rehabilitation of Small-scale Irrigation Schemes that have been Damaged by Floods and Droughts -$234 723. • GCP /MOZ/084/EC-Strategic Planning for Irrigation in Mozambique: Consolidation of the National Irrigation Policy and Strategy ($416 581) • OSRO/ MOZ/302/BEL-Improvement of food security in Inhambane province through family gardening with irrigation-$ 360 405 • TCP/ MOZ/ 2901-Rehabilitation of Small-scale Irrigation Schemes -$385 210	$1 396 919
Niger	Small scale irrigation development and rehabilitation at low costs (700 ha 6840 farmers), (dams and low land irrigation), micro irrigation through 1 050 well development and 1 150 PVC distribution systems, 1 268 motopumps	1	Mor	• GCP /NER/040/LIB : Programme spécial de sécurité alimentaire Phase I au Niger $1 699 622, • GCP /NER/048/SPA :Projet de petite hydraulique pour la sécurité alimentaire dans les régions de Zinder et de Tahoua $ 2 160 000	$3 859 622
Nigeria	Improved irrigation management for irrigation schemes, development of micro irrigation systems through small dams, well development, small irrigation pumps and low cost irrigation techniques, participatory construction of irrigation and drainage works, staff training and formation and training of water users groups	105	CPR	• TCP/NIR/8923: SPFS: Pilot Phase in Kano State-Water Control Component $340 500, • UTF /NIR/047/NIR National Special Food Security Programme, Nigeria (South South Cooperation) 48 196 697, • UTF /NIR/046/NIR-Review of the Public Irrigation Sub-sector, Nigeria--$ 1 310 086,¬	$49 847 283
Rwanda	intensification of rice irrigation by improved management and maintenance, waterharvestisting and conservation agriculture			• TCP/ RWA/ 2905-Support to the Programme on Intensification of Rice Production for Food Security--352 051 • TCP/ RWA/ 3102-Appui à l'introduction des techniques de collecte et utilisation des eaux de pluie pour usage agricole au Rwanda--$244 000	$596 051
Senegal	Small scale irrigation rehabilitation (7), wetland development (dike construction for erosion and salinity control) (50 sites), small dam construction, well development (50) and small reservoir construction (200), 7 km pipe lines, 100 vegetable site developped, participatory farmers planning of irrigation projects	6	SEN	• GCP/ SEN/059/ SPA-Projet de petite hydraulique villageoise dans le Bassin Arachidier-$ 1 940 000 • TCP/ SEN/2906-Promotion des Techniques des Micro-Irrigation a Tres Basse Pression--$208 722 • TCP/SEN/3202-Appui à la relance de la riziculture--$487 000, • GCP/SEN/052/BEL: Projet de promotion paysanne dans le cadre de la gestion des terroirs pour la Sécurité Alimentaire au Sénégal (PPSA-Sénégal) $ 764 984	$3 400 706

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUNTRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Sierra Leone	rice irrigation development, school gardens	3	CPR	• SPFP/SIL/0101 "Community-based Extension and Capacitybuilding Programme (CECP)", $ 160 163 • GCP/SIL/024/GER field support to farmer groups, school gardens and right to food mass communications are being carried out, (US$924 255)	$1 084 418
South Africa	small scale irrigation scheme management and micro irrigation development through pedal and small irrigation pumps and equipment; farmers training through FFS and Participatory Farmers Groups (PFG) (109)			• no specific project on WCC executed by FAO	$0
Sudan	water harvesting schemes and small dam development			• TCP/SUD/0170 Water Control Component of the Special Programme for Food Security $206 983 • TCP/SUD/0066 : Advance allocation WCC Component SPFS $ $23 500, • GCP /SUD/051/LIB-Special Programme for Food Security Phase I in Sudan--$1 927 130 • GCP /SUD/053/OPF-Special Programme for Food Security in North Kordofan-$ 200 010 • GCP /SUD/055/SPA-Special Programme for Food Security Phase I: Support to Traditional Farmers and Agro-Pastoral Livelihoods in Western Parts of White Nile State--$ 1 630 000	$3 987 623
Swaziland	small scale irrigation (30 Ha0 and wetland (5) development, treadle pump introduction, low cost efficient irrigation technologies, technical and extension staff and WUA training	1	PAK	• OSRO/ SWA/702/USA-Rehabilitation of water supply facilities and promotion of water harvesting technology in Swaziland--$ 334 400, • TCP/ SWA/2803+3001+ 8921 Water Control Component of the Special Programme for Food Security $ 99 103 + 78 869 +$ 344 000-, • TCP/ SWA/2908-Formulation of National Irrigation Policy and Strategy--$ 184 769	$1 041 141
Tanzania	Small scale waterharvesting schemes (SPFS), small scale irrigation rehabilitation works (AfDB), introduction of treadle pumps, well development and water users association training	5	EGY	• SPFP/URT/4501 : dryland and wet land development in Dodoma and Morogoro $ 1 514 726 • GCP /URT/117+8/SWI Support to SPFS Extension Phase I: Vegetables Gardens Irrigating from Shallow Wells Using Pedal Pump Technology $ 396 283 • TCP/URT/9066 Zanzibar WCC $ 181 047 • UTF/URT/117/UTF : AfDB WCC small irrigation development $ 976 910 • GCP /URT/123/JPN-Small-Scale Farmer`s Irrigation Development in Drought Affected Areas in Tanzania-1 303 650 • TCP/ URT/3101-National irrigation policy and transitional strategy-$ 200 066, • UTF /URT/121/URT-Farmer Training Support Programme for Smallholder Irrigation Schemes in the Rufiji and Pangani Basins -Tanzania--$ 128,385	$4 701 067

COUNTRY	WCC MAIN ACTIVITIES	NO SSC	COUN TRY SSC	WCC RELATED PROJECTS	TOTAL BUDGET WCC PROJECTS
Togo	small scale irrigation rehabilitation and wetland development for rice and vegetables, improved management and simple regulating structures, floodprotection works, training of farmers and water users through FFS			• TCP/ TOG/8923+2901-Appui à la maîtrise et à la gestion de l'eau dans le cadre du PSSA + Phase I & II $ 498 361	$498 361
Uganda	micro irrigation development with small pumps (treadle, motopumps) and piped distribution, supplementary irrigation of coffee			• TCP/UGA/8821 + TCP/UGA/8924 + TCP/UGA/2802 Small-Scale Irrigation Development in Support of SPFS: $ 162 118, + $ 194 000 + $ 77 703	$433 821
Zambia	Small dam development and rehabilitation (IFAD), well development and treadle pump introduction, staff and water users training (FFS)			• SPFP/ZAM/4501 : SPFS programme $ 791 788, • UTF/ZAM/068/ZAM Small Holder Irrigation and Water Use project $ 1 056 555 • GCP/INT/750/FIP Empowerment of Women in irrigation and water resources management, household nutrition and health (Zambia, Nepal, Cambodia) $ 1 691 025	$2 412 018
Zimbabawe	micro irrigation development around dams and wetlands with low irrigation equipment (treadle pumps, moto pumps, well development, drip irrigation) for vegetable production, technical and extension staff training, water users association training			• TCP/ZIM/8924 : Water Control Component of the SPFS : $318 000	$318 000
Total	43	205			$147 446 573

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