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Evolution of Agricultural Water Management in Rainfed Crop-Livestock Systems of the Volta Basin

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AUTHORS' ORGANIZATIONS

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IWMI International Water Management Institute

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Swiss Agency for Development and Cooperation SDC

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Acronyms

ACT	African Conservation Tillage Network
AFD	Agence Française de développement
AFDB	African Development Bank
AFDI	Agriculteurs français et développement international
AFDF	African Development Fund
AFVP	Association Française des Volontaires du Progrès
AIDA	Agricultural Innovation in Dryland Africa
AMUS	Association des mains unies du Sahel
AVV	Autorité pour l'Aménagement des Vallées des Voltas
AMB	Action Micro-Barrages
ARI	Animal Research Institute
ASTM	Action Solidarité Tiers-Monde
AWM	Agricultural Water Management
BADEA	Arab Bank for Economic Development in Africa
BMBF	Bundesministerium für Bildung und Forschung
BOAD	West African Development Bank
BPDA	Bureau de développement des Productions agricoles
CCCE	Caisse centrale de Coopération Economique
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency
CILSS	Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel/ Permanent Inter-state Committee for Drought Control in the Sahel
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CORAF	Conseil Ouest et Centre africain pour la recherche et le développement agricoles
CPWF	Challenge Program on Water end Food
CREPA	Centre Régional pour l'Eau Potable et l'Assainissement
CSIR	Council for Scientific and Industrial Research
CTA	Technical Centre for Agricultural and Rural Cooperation
DBA	Défi Belgique Afrique
DDO	Diocesan Development Office
DMP	Desert Margins Program
EC	European Commission
EEC	European Economic Community
EU	European Union
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
FARMER	Farmer Responsive Mechanisms in Extension and Research
FDR	Fonds de Développement Rural
FNGN	Fédération Nationale des Groupements Naam
GCES	Gestion conservatoire des eaux et des sols
GEF	Global Environment Facility
GERES	Groupement Européen de Restauration des Sols

GIDA	Ghana Irrigation Development Authority
GIRE	Gestion intégrée des ressources en eau
GIZ	Deutsche Gesellschaft für Internationale Zusamenarbeit
GLOWA	Globaler Wandel der Wasserkreislaufes/Global Change and the Hydrological Cycle
GWP	Global Water Partnership
ICOUR	Irrigation Company Of Upper Region
IDA	International Development Association
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
INERA	Institut de l'Environnement et de Recherches Agricoles
IRD	Institut de recherche pour le développement
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
KNUST	Kwame Nkrumah University of Science and Technology
LACOSREP	Land Conservation and Smallholder Rehabilitation Project
LWP	Livestock water productivity
MAE	Ministère des Affaires Etrangères
MAHRH	Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques
MEE	Ministère de l'Eau et de l'Environnement
MOFA	Ministry of Food and Agriculture
NARP	National Agricultural Rehabilitation Project
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organization
NRGP	Northern Rural Growth Program
ODE	Office de développement des églises
OFID	OPEC Fund for International Development
ONBI	Office National des Barrages et de l'Irrigation
OPEC	Organization of the Petroleum Exporting Countries
OPY	Operation Feed Yourself
ORD	Organismes Régionaux de développement
ORSTOM	Office de la recherche scientifique et technique outre-mer
PABSO	Projet d'aménagement des bas-fonds du Sud-Ouest
PAFASP	Projet d'appui aux filieres agro silvo pastorales
PAGEV	Projet d'Appui à la Gouvernance de l'Eau dans le bassin de la Volta
PAGIRE	Plan d'Action pour le Gestion Intégrée des Ressources en Eau
PATECORE	Projet d'aménagement des terroirs et conservation des eaux
PDA	Projet de Développement Agricole
PDRD	Programme de développement rural durable
PIGEPE	Projet d'irrigation et gestion de l'eau à petite échelle
PITDTE	Projet d'Inversion de la Tendance à la Dégradation des Terres et des Eaux
PNGTV	Programme national de gestion des terroirs villageois
PS-CES/AGF	Programme spécial de conservation des eaux et des sols et d'agroforesterie
RAIN	Rainwater Harvesting Implementation Network
RMS	Rainwater management strategies
RWH	Rainwater harvesting
RWM	Rainwater management
SARI	Savanna Agricultural Research Institute
SASSO	Sahel solidarité
SATEC	Société d'Assistance Technique pour la Coopération

SEI	Stockholm Environment Institute
SFD	Saudi Fund for Development
Six S	Savoir se servir de la saison sèche en Savanne et au Sahel
SSIDP	Small Scale Irrigation Development Project
SLaM	Sustainable Land Management
SNV	Netherlands Development Organisation
SP-PAGIRE	Secrétariat Permanent/Plan d'Action pour le Gestion Intégrée des Ressources en Eau
SRDP	Smallholder Rehabilitation and Development Program
SWC	soil and water conservation
TU Delft	Delft University of Technology
UDS	University of Development Studies
UICN	Union internationale pour la conservation de la nature
UN	United Nations
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
UWADEP	Upper West Agricultural Development Program
VBA	Volta Basin Authority
VBDC	Volta Basin Development Challenge
VIP	Village Infrastructural Project
WAHARA	Water Harvesting for Rainfed Africa
WAIPRO	West Africa Irrigation Project
WASCAL	West African Science Service Center on Climate Change and Adapted Land Use
WASH	Water, sanitation and hygiene
WB	World Bank
WFP	World Food Program
WHaTer	Water Harvesting Technologies Revisited
WHO	World Health Organization
WOCAT	World overview of conservation approaches and technologies
WP	Water productivity
WRC	Water Resources Commission
WRI	Water Research Institute
WSSCC	Water supply and sanitation collaborative council
WUA	Water users association
WUR	Wageningen University
WVBB	White Volta Basin Board
ZEF	Zentrum für Entwicklungsforschung
2iE	Institut International d'Ingénierie de l'Eau et de l'Environnement

Executive summary

Agricultural water management (AWM) is the activity of planning, developing, distributing and managing the optimum use of water resources for agricultural purposes, through a suite of strategies. This sector comprises all types of agricultural systems, from rainfed to fully irrigated, with water sources varying between rainwater, surface water or groundwater. In the dry areas of the Volta Basin, agricultural systems are mostly rainfed. AWM strategies in rainfed systems are different ways to influence rainwater flows in order to maximize infiltration in the soil, retain run-off and minimize losses, and range from field-scale techniques like stone bunds or manure application to watershed-scale structures like small reservoirs. These AWM strategies have been extensively studied and promoted in the Volta Basin during the last decades. However, economic and physical water scarcity still limits agricultural production of most of the smallholder crop-livestock farms of the basin. Numerous projects and programs are currently working on best-fit AWM identification and promotion in the basin. In this context, there is a high risk of duplication of what has been done or of reinventing the wheel. The objective of this paper is to synthesize existing knowledge, interventions, lessons, and gaps in knowledge regarding AWM in the Volta Basin. The questions that the paper addresses include (i) who did what, how, where, with which results and why, (ii) what are the lessons learned for longer term development efforts and interventions and (iii) what are the knowledge gaps, with focus on the Volta Basin. Key resource informants were interviewed and more than 250 documents were consulted, from peer-reviewed research papers to grey literature and project documents, from 1969 up to now.

In response to demographic pressure, environmental degradation, priorities of development actors and needs of smallholders, AWM strategies along with related concepts have evolved with time. First linked to erosion control in the 1960, AWM strategies were promoted for cash crop production in large scale state projects relying on technology transfer as dissemination mean. Following the first wave of droughts of the 1970s and the related food shortages, the focus moved to staple crop production and promotion of soil and water conservation techniques through large scale projects. But the approaches were too much top-down, with experts as exclusive actors, projects were too shorts with "silver bullet" solutions, there was a lack of consideration for farmers' preferences and traditions. Hence, when the second wave of droughts struck the basin in the 1980s, the smallholders were not better prepared and once again they were severely affected by loss of yields and income. Learning from these failures, researchers and development practitioners started to think in terms of participatory approach and gave increasing importance to indigenous knowledge. This emphasis on participatory approach led to improvement of indigenous technologies, development of new technologies tailored to smallholders' needs in various agroecological zones of the basin, and studies on farmers' perceptions, adoption drivers and local institutions. The concept of AWM then became more and more integrated and it evolved from "sustainable land management" to "land husbandry" which includes the socio-economic context. To address all these complex facets research-for-development projects became multidisciplinary and multi-stakeholder oriented.

Between 1970 and 2009, 195 bilateral and multilateral AWM projects were implemented in Burkina Faso, corresponding to an investment of US$ 641million. In Ghana, only 46 projects of this kind were implemented, for a total of US$ 258 million. While these projects yielded numerous technical solutions, their actual impact on livelihoods is controversial. On the one hand, impressive outcomes are reported: in Burkina Faso, an estimated 200,000 to 300,000 ha were rehabilitated, yielding an extra 80, 000 tons of food annually, i.e. enough to feed 500,000 people. On the other hand, the general consensus among researchers and policy makers is that the investments were ineffective and that the environment in fragile areas of the Basin continues to degrade, with destruction of vegetation cover, depletion of soil fertility and intense erosion. Given the quantity of AWM projects implemented and the amount of investments made in the Volta Basin over the past 40 years, the question of the return of aid investments on water availability, food security and livelihoods would be of particular interest.

The study of the evolution of AWM in the Volta Basin yielded key recommendations for research-for-development interventions and new concepts for research on water management. When promoting AWM strategies, projects should carefully study the available information on factors triggering adoption, and play on these to ensure sustainable uptake of the technology. Local capacities and agendas should be better accounted for when promoting AWM strategies or low-cost irrigation technologies. Participatory management of the water infrastructure should be carefully planned through integration of maintenance costs in project budget, capacity building of actors towards assumption of more responsibility, and ways to deal with turnovers within management committees. Farmers' capacity building is definitely a key asset for enlightened risk management and constant adaptation to new variable conditions. Scope for improvement lies in the coordination, collaboration and communication among various institutions and organisms active in the AWM sector.

Future research and development projects should concentrate on how to leverage the factors limiting adoption and enhancing system productivity while maintaining healthy ecosystem services. There is a need for a system perspective, to improve water-crop-livestock interactions, to develop off-season cultivation options and market access, and to balance distribution of gender benefits. There is a need for a multi-scale, landscape perspective, to understand ecological landscape processes and trade-offs between ecosystem services derived from and affected by AWM strategies adoption across different scales. There is a need for an institutional perspective, to facilitate management of AWM structures and to raise awareness. Finally, there is a need for a long-term perspective, to foresee the best strategies for adaptation to climate change and manage risk in the variable environment of the Volta Basin.

1. Introduction

1.1. Framework

This work was carried out within the frame of the Volta Basin Development Challenge (VBDC), funded by the Challenge Program on Water and Food (CPWF; see Annexes A1). The VBDC aims at "improving rainwater and small reservoir management to contribute to poverty reduction, and improved livelihoods resilience and people's well-being in the dry lands of Burkina Faso and Northern Ghana while taking account of implications for downstream water users including ecosystem services". Its second project (V2), which includes this paper, focuses on AWM strategies in crop-livestock systems. The project is led by the International Livestock Research Institute (ILRI) and the partners are: International Water Management Institute (IWMI), the Animal Research Institute (CSIR-ARI), INERA, the Netherlands Development Organization (SNV), and Wageningen University (WUR).

1.2. Objectives

During the last decades, much ink has been spilt on writing up AWM strategies and on the ways adoption by smallholders can be enhanced. AWM strategies have been over-studied, over-promoted, and over-funded. However, despite the efforts of numerous projects, water scarcity still limits agricultural production of most of the smallholder crop-livestock farmers of the basin and cereal yields are still lying far below their potential (Wani et al., 2009; FAO 2011b). In order to learn from the past about the underlying causes for success or failure in the implementation of AWM strategies and to identify current needs, a review of past research and development projects on AWM in the Volta Basin has been undertaken. In addition, the review will facilitate communication among key actors in water management projects.

The objective of this paper was to synthesize existing knowledge, interventions, lessons, and gaps in knowledge regarding AWM and AWM strategies adoption in the Volta basin. The questions that the paper addresses include (i) who did what, how, why, where, with which investments and which results, (ii) what are the knowledge gaps and (iii) what are the pertinent lessons for the VBDC and for decision-makers at sub- regional level.

1.3. Study area

This review has the same boundaries as the VBDC that frames it, and deals with AWM strategies practiced in rainfed crop-livestock smallholder systems of the dry areas of the Ghanaian and Burkinabe parts of the Volta Basin. Geographically, this means that the area of study for this review is the whole Burkinabe Volta Basin, and the Northern part of Ghana (Upper West, Upper East and Northern Region; Figure 1). The center and the south of Ghana are not included in the study area because they benefit from sufficient rainfall for a satisfactory production of rainfed agriculture (Lemoalle and de Condappa 2010).

1.4. Sources of information

Between 1970 and 2009, AidData, which is the most complete aid database publicly available (Tierney et al., 2011), counts 8,192 and 7,023 bilateral and multilateral aid projects (all disciplines) implemented in Burkina Faso and Ghana respectively, with important investments. While 195 projects were specifically on AWM in Burkina Faso, only 46 of this kind were implemented in Ghana, for a total investment of US$ 641 million and 258 million respectively (AidData 2010). In this context, in order to get an overview of major projects and historical trends, 25 resource informants were interviewed (see questionnaire in annexes). They had occupied or were occupying important functions in ministries, funding agencies, bilateral cooperation organisms, research organizations, NGOs or farmers organizations. Following this, more than 250 documents were consulted, from peer-reviewed research papers to grey literature and project documents, and from 1969 up to now.

1.5. Structure of the paper

Background information is given in Section 2 and 3. Section 2 presents the context of the Volta Basin, underlying the need for improvement in AWM in current smallholder crop-livestock systems. Theoretical elements of AWM are given in Section 3, as well as a short description of practices used in the area of study. An historical approach to AWM makes the object of the first core section (Section 4): how the concept of AWM has evolved from the 60s till now, which techniques were promoted when, why, through which kind of projects and programs and under which institutional and political context. Outcomes from these projects and programs are presented in Section 5, followed by reasons for limited adoption of AWM strategies (Section 6). Section 7 gives recommendations for future projects on targeting AWM strategies to agroecological zones, hot research topics and challenges in implementation.

Figure 1. Map of the Volta Basin (source: GLOWA)

2. Background: The Volta Basin

2.1. Poverty, water availability and soil degradation

The Volta Basin covers an area of around 395,000 km2 across six countries, with over 80% located in Burkina Faso and Ghana (Figure 1). The basin is inhabited by about 20 million people, of which 61% and 45% live on less than 1$ a day in Burkina Faso and Ghana, respectively (Hanjra and Gichuki 2008). In Ghana, 70% of the poor are located in the Northern region. Population is expanding at an annual growth rate of 3.4% in Burkina Faso and 2.1% in Ghana (IFAD 2009), putting growing pressure on natural resources for livelihoods and economic gains. Of this population, 90% and 76% rely on rainfed crop-livestock systems for their livelihood in Burkina Faso and in Ghana, respectively (Thornton et al., 2002).

Annual rainfall is characterized by a marked gradient between North Burkina (500 mm, unimodal distribution) and Southern Ghana (1,200 mm, bimodal distribution). While at basin scale population is a little above the water scarcity threshold of 1700 m3/yr per capita, most of the northern part of the basin suffers physical water scarcity with only about 900 m3/yr per capita in Burkina Faso (Lemoalle and de Condappa 2010). The frequency of annual droughts and of extreme seasonal hot temperatures has increased from the 1970s and is likely going to worsen in the future (Kasei et al., 2010; Battisti and Naylor 2009). Rainfall is erratic both in onset and distribution, which often constitutes a more common cause for crop failure than absolute water scarcity, i.e. low cumulative annual rainfall. The rainy season is characterized by dry spells of varying duration, which are short periods of water stress, often only a couple of weeks long, during crop growth. Such short periods of water stress can have a serious effect on crop yields if occurring during water sensitive development stages, e.g., during flowering (Rockström and deRouw 1997; Rockström 2000).

Besides being scarce and erratic, rainfall is often high intensity, which leads to rapid surface run-off, causing soil erosion and poor infiltration. That many trees and brushwood were cut to provide wood for fuel may aggravate soil degradation (Schweigman 2003; Vagen et al., 2005). More than 38% of the area of Burkina Faso has degraded soils, 30% of which can be classified as very severely degraded. In Ghana, 11% of the area can be classified as degraded soils, half of them classified as moderately severely and the other half as very severely degraded (FAO 2011a). Soil degradation induces a loss of organic matter by tillage practice, a subsequent decrease of water infiltration and soil water holding capacity, and/or a soil fertility decline due to low inputs and decrease or absence of fallow. These factors further limit agricultural production, especially in the northern part of the basin (Breman et al., 2001; Terrasson et al., 2009). Moreover, inappropriate animal management along with poor cropping practices often contributes to widespread and severe depletion, degradation and contamination of water (Peden et al., 2009). In addition to these drawbacks, global warming threatens food production, particularly in tropical countries (Ericksen et al., 2011; Eakin 2005).

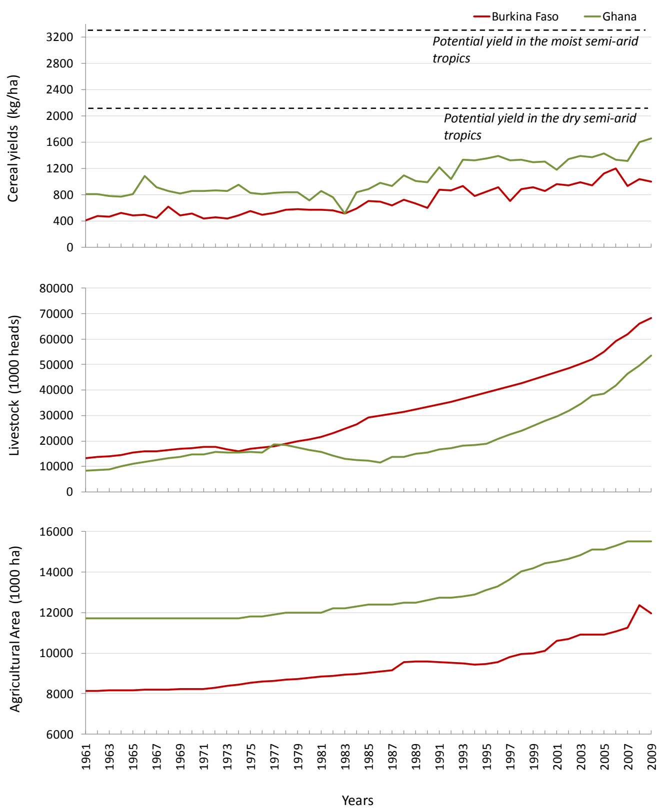
2.2. Farming systems and agricultural production

The north-south rainfall gradient defines agroecological zones with different types of farming systems and a successive north-south dominance of millet, sorghum and maize, and a decreasing dependence on livestock. The risk of within-season dry spells influences mainly cropping choices. Detailed description of the farming systems gradients and distribution of the main crops across the agro-climatic regions were given by Lemoalle and de Condappa (2010) and Hauchart (2007). Briefly, in the northernmost part of the basin, the Sahel, livestock herding is the primary activity, complemented with drought-resistant crops such as millet and cowpea. The probability of a failed growing season is 53%. In the Sahelo-Sudan, covering most of Burkina Faso, millet, sorghum and maize are the main cultivated food crops. Cotton, groundnuts and some sedentary cattle contribute to cash income. The probability of a failed growing season is 24% (Lemoalle and de Condappa 2010). The northern half of Ghana lies in the Sudan agroecological zone, a transition zone with production of both cereals and root crops. Some transhumant cattle are present seasonally and sedentary livestock keepers are widespread. The probability of a failed growing season is 17%. Finally the Guinean zone, covering the southern part of Ghana, is characterized by the cultivation of yam, cassava and plantain as main food crops. The risk of a failed growing season is only 8% (Lemoalle and de Condappa 2010). There is therefore sufficient rainfall over most of Ghana for satisfactory yields from rainfed agriculture, except in the two northern regions (van de Giesen et al., 2010).

The evolution of cereal yields, livestock population and agricultural area during the last decades is presented in Figure 2. Cereal yields are very low, ranging from 1.5 t/ha for maize to 0.9 t/ha for sorghum and 0.7 t/ha for millet (Terrasson et al., 2009). Despite a slight increase over time, they are still far from their potential (Fischer et al., 2009). The number of livestock heads has increased with time, which also corresponds to an increase in agricultural area. In 2005, the number of tropical livestock units was estimated at 1,997,200 and 451,500 in Burkina Faso and Ghana, respectively (Clanet 2008). Although livestock production is expected to continue to increase in both countries, it might still not be enough to satisfy the growing demand for livestock products (Clanet 2008).

With regard to climate change scenarios, agricultural production must increase significantly in ways that are sustainable and acceptable by rural smallholders (Lemoalle 2007). This will only be achieved through efficient water and nutrient management. Indeed, Rockström et al., (2002) showed that there are no agro-hydrological limitations to doubling on-farm crop yields even in drought prone environments, by producing “more crop per drop” of rain. In a broader perspective including grasses and shrubs, “more biomass per drop” is needed (Stroosnijder 2009). An increase in agricultural production cannot be separated from an increase in agricultural water productivity.

Figure 2. Evolution of cereal yields, livestock heads and agricultural area from 1961 to 2009 (Source: FAO) and potential yields (Fischer et al. 2009).

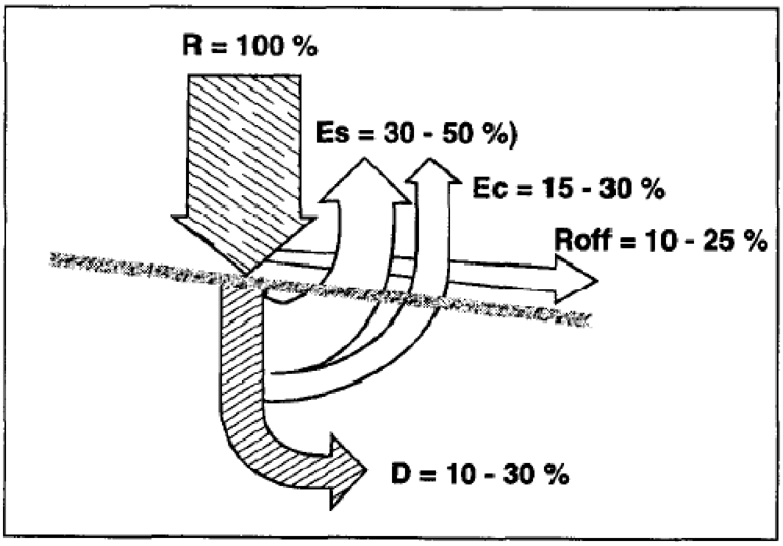


3. The basics of AWM in rainfed systems

3.1. Water balance and water productivity

The on-farm water balance is an entry point to analyze the opportunities available to improve water productivity (Rockström et al., 2002). When hitting the ground, rainfall is partitioned into various water flows, depending on rainfall intensity, topography, soil properties and land use (Figure 3). "Blue" water flow is the total run-off including the sum of surface run-off and groundwater recharge. "Green" water is the return flow of water to the atmosphere as evapotranspiration which includes a productive part as transpiration and a nonproductive part as direct evaporation from the soil, lakes, and from water intercepted by canopy surfaces (Rockström et al., 2002). In rainfed systems, AWM strategies use different ways to influence water flows in order to maximize infiltration in the soil, retain run-off and minimize losses. Ultimately, the challenge is to increase the ratio of productive to nonproductive green water flow. In the Sahel, low water use efficiency is not primarily caused by water shortage, but loss of water through run-off, soil evaporation and drainage below the root zone (Mando 1997). Following this rationale, Rockström et al., (2002) give various strategies for improved crop water productivity: maximize plant water availability (maximize infiltration of rainfall, minimize unproductive water losses (evaporation), increase soil water holding capacity, and maximize root depth), maximize plant water uptake capacity (timeliness of operations, crop management, soil fertility management), and bridge crop water deficits during dry-spells through supplemental irrigation.

Figure 3. General overview of rainfall partitioning in farming systems in the semi-arid tropics of Sub-Saharan Africa. R = seasonal rainfall, Es = evaporation from soil and interception, Ec = plant transpiration, Roff = surface run-off, and D = deep percolation (Source: Rockström, 2000).



This crop approach on water productivity was recently reviewed for a more integrated view: Molden et al., (2007) define agricultural water productivity as the ratio of the net benefits from crop, forestry, fishery, and livestock to the amount of water required to produce those benefits. In the dry areas of the Volta Basin, crop and livestock productivity are the main subsystems to take into account.

While livestock water productivity has not yet been assessed in the Volta Basin, crop water productivity generally decreases from South to North (Terrasson et al., 2009), and is below the potential. This gap is partly due to low water availability, with droughts and dry spells combined with high evaporation and poor water-holding capacity of the soil: indeed, rainfed agriculture uses only 14% of the total rainfall on the basin (Lemoalle and de Condappa 2010). Other factors for low water productivity are related to low soil fertility and little input of nutrients and organic matter, poor crop, land and water management, and risk-avoidance strategies of farmers.

Practices used to increase crop water productivity include appropriate water and soil fertility management. The interventions to increase water availability in the soils for plant uptake includes a range of strategies such as water harvesting, supplemental irrigation, precision irrigation techniques and soil and water conservation practices (Molden et al., 2010). Additional efficient efforts should capture improved crop management like input of nutrients (including fertilizer application), pest and weed control and timing of operations. Strategies to enhance livestock water productivity include improving feed sourcing of animals, enhancing animal production (milk, meat, eggs), improving health through veterinary services, grazing practices that avoid land degradation to lessen the amount of water required for grazing and reduce negative environmental impacts such as erosion (Peden et al., 2009; Descheemaeker et al., 2010). Investments in these practices can help contribute to poverty alleviation not only through increased food security and better nutrition, but also through higher and diversified income, better health, better hygiene and better education (Hanjra and Gichuki 2008).

3.2. AWM vs. rainwater management and other concepts

In the literature, various terminologies are sometimes used to designate similar or slightly different concepts in the sector of water management. This section defines the concepts behind the terminology adopted in this report.

Rainwater harvesting (RWH) refer to all activities whereby rainwater is collected artificially to make it available for cropping or domestic purposes (Vohland and Barry 2009). Generally used classification for RWH systems are rooftop catchment systems, in-situ catchment systems and runoff catchment systems (Pachpute et al., 2009). Rainwater can then be stored in underground tanks or open ponds (Vohland and Barry 2009). Due to the recent expansion in water, sanitation and hygiene (WASH) projects, many people automatically associate rainwater harvesting with rooftop catchments and drinking water.

Soil and water conservation (SWC) techniques was a terminology used mainly during the 1970s up to the 1990s to refer to all practices used in-situ to control erosion, improve soil water holding capacity and soil fertility. This corresponds roughly to the in-situ micro-catchment strategies mentioned below (in 3.3.1).

Rainwater management (RWM) implies rainwater harvesting through various types of structures and its subsequent use. From the moment various people have to share a common water source, local organisation, institutions and policies have their role to play. Therefore, the concept of RWM is an integrated view that takes into account all practices and policies that have an influence on water management, i.e. the management of the entire ecosystem and the way it is influenced by policy, institutional and social dynamics (Merrey and Gebreselassie 2011). The corresponding rainwater management strategies (RMS) include SWC techniques, in-situ and ex-situ water harvesting, conservation farming, small-scale irrigation, and crop management (Merrey and Gebreselassie 2011). However, whether small dams can be included as RMS is not clear as they depend on other hydrological processes, i.e. the management of stream flow.

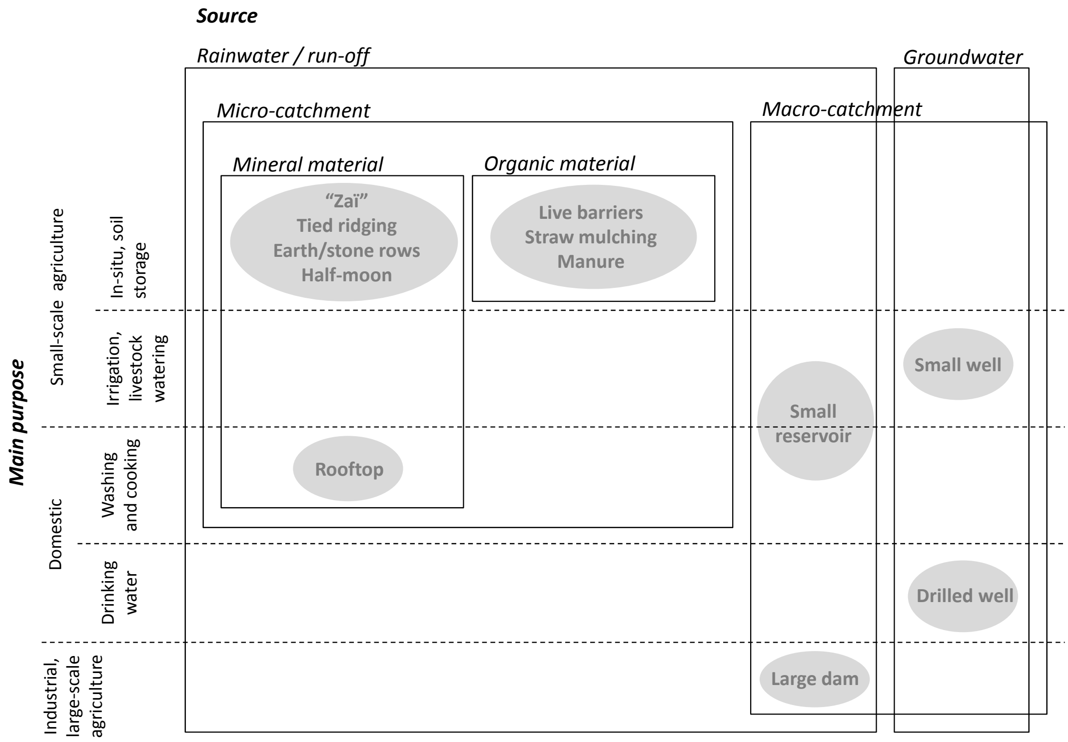
Agricultural water management (AWM) is the activity of planning, developing, distributing and managing the optimum use of water resources for agricultural purposes, through a suite of strategies. This sector comprises all types of agricultural systems, from rainfed to fully irrigated, with water sources varying between rainwater, surface water or groundwater. In the dry areas of the Volta Basin, agricultural systems are mostly rainfed, which naturally restrict the concept of AWM when applied to the study area. The related AWM strategies include all strategies of water management for agricultural purposes common in rainfed systems, i.e. in-situ micro-catchment strategies (similar to SWC techniques and RWH techniques for agricultural purpose, see 3.3.1), small reservoirs and small-scale irrigation.

3.3. Overview of AWM strategies in the Volta Basin

The AWM strategies for rainfed systems, i.e. the water management strategies addressed in this report, can be distinguished from other water management strategies according to their water source and their main purpose. Figure 4 gives a schematic classification of water management strategies used in the Volta Basin, which allows situating the AWM strategies under the scope of this report with respect to other water management strategies. Water can come from rain, run-off, or ground. It can be used for agricultural, domestic or industrial purposes. For agriculture, the type of use depends on the type of storage: if stored in the soil, it will be used essentially for in-situ crop production; if stored in small reservoirs it can be used for livestock, fishing or irrigation, but also for domestic purposes. For domestic uses, drinking water requires a certain quality, and should come ideally from groundwater through drilled wells, where available. Large dams like the Akosombo or the Bagré dam are essentially meant to provide hydropower, although it provides additional services for irrigation, livestock watering, fishing and domestic purposes. The level of coordination necessary to implement and maintain these strategies varies from individual level with the in-situ techniques, to communal level with the wells and dams, and finally the national and international level for the big dams.

This report addresses strategies with rainwater as water source and for agricultural purposes, which will hereafter be called AWM strategies, as the rainwater aspect is implicit in the frame of the Volta rainfed systems. Therefore, AWM strategies are defined here as different ways to influence rainwater flows in order to maximize infiltration in the soil, retain run-off and minimize losses, and range from field-scale techniques like stone bunds or manure application to watershed-scale structures like small reservoirs.

Figure 4. Classification of agricultural water management (AWM) strategies according to their source and their main purpose for the Volta Basin. Micro scale is field scale and macro scale is watershed scale.



Characteristics of the main AWM strategies used in the Volta are described below. Further descriptions of AWM strategies were given by other authors: see Table 2, and specially the detailed reviews from Barry et al., (2006), Hauchart (2007), Mietton (1986), and the WOCAT database (http://www.fao.org/ag/agl/agll/wocat/wocatqt.asp).

3.3.1. In-situ micro-catchment strategies

In-situ micro-catchment strategies aim at enhancing rainfall infiltration in the soil, improve soil water storage and limit top soil losses through wind and water erosion. They can be based on the construction of a physical barrier against run-off and/or on the improvement of soil water holding capacity through improved soil structure and soil fertility. Some of the in-situ micro-catchment strategies are:

- Tied ridges

  Tied ridging is traditionally practiced in Northern Ghana, and consists in planting crops on small ridges, that act as mini-dams and collects water between crop lines. Tied ridges are more effective on slopes (Fosu et al., 2008).

- Earthen contour bunds

  Earthen contour bunds were one of the first forms of field management, where small soil bunds are placed along the contour lines. It has been almost completely replaced by rock bunds or grass strips (Barry et al., 2006).

- Rock bunds/stone rows

  Constructing rock bunds/stone rows is the most widely practiced technique to combat run-off and erosion by farmers (Barry et al., 2006). The challenge was always to follow the contour lines, especially where the landscape is flat. The technique has evolved from rows placed imprecisely in the landscape to rows placed strictly along the contour lines, thanks to the introduction of a low-cost and easy to learn water spirit for measuring land levels (Steenberg et al., 2011). Advantages compared to earth contour bunds is that rocks are more solid and filtrating, so that both the bund will last longer and there is not an excess of water upstream (Dugué et al., 1993). Stones can be placed in different ways, in single row or with more stones piled up against each other. As a general rule, more stones make it more stable against time and possible disturbances like animal traffic (PATECORE 2004). Economically optimal spacing of rock bunds depends on the type of construction, materials transport cost, and how labor is organized, and is about 30 meters apart (Zougmoré et al., 2000). To make them more sustainable, they can be planted with Andropogon gayanus (andropogon, see below) and small trees (Errath et al., 1989). Stone rows are usually implemented by the community, with development projects supporting the technical, material and logistics aspects.

- Pits or "zaï"

  Zaï is an ancestral practice developed in the Yatenga (Northern Burkina) to regenerate degraded and crusted soils by breaking up the surface crust to improve water infiltration. It consists of dug holes excavated in grids, with a diameter of 15-20 cm and a depth of 10-15 cm that store rainwater for plant growth and concentrate crop nutrients (Maatman et al., 1998). The excavated soil is put on the lower side of the hole, and organic matter (manure or compost) is placed in the hole (Barry et al., 2006). This organic matter attracts termites, which play a crucial role in improving soil structure (Mando et al., 2006; Jouquet et al., 2011). This indigenous practice has fascinated many scientists and various reviews are entirely consecrated to it, among others the one of Roose et al., (1999), Mando et al., (2006), and Kaboré and Reij (2004). Zaï is not suitable for all types of soil: it is very good for crusted soils, but not for shoals. It should be always associated with bunds (Errath et al., 1989). A variation is the "zaï forestier" (Koutou et al., 2007) and the mechanized zaï using animal traction (Barro et al., 2005).

- Half-moon
  Coming from Niger in the 90s, this technique is similar to the zaï, except that the hole is less deep and in the form of a half-moon of about 4 m diameter, with the removed soil put on the downhill side (Barry et al., 2006). The technique is used on bare and crusted soils, as the zaï, and can be also used on gentle slopes (< 3%)(Zougmoré et al., 2003b). Mechanization of half-moons through the use of a special type of tractor ("Delfino" plow or "Vallerani system") is currently being developed in Northern Burkina (Conedera et al., 2010).

- Live hedges
  Live hedges have the same purpose as stone bunds. Different types of grass have been used, the more widely promoted being the andropogon, which is well known to farmers and already used for domestic purposes like roofs, mats or forage (Dugué et al., 1993; Roose 1992). Live hedges are sometimes planted upstream of stone rows ("vegetated bunds"), with the aim to allow reusing the stones to make another bund somewhere else once the grass is well established. The grass has comparable effect to the stone row in retaining water and offering a barrier to run-off. Moreover, andropogon is multi-purpose and has economic benefits (Botoni and Reij 2009). Andropogon also has the potential to improve the relationships between farmers and herders by protecting the cropping area against inadvertent animal grazing. However, as they can be consumed by termites, life barriers are less durable and therefore less widespread than stone bunds (Mietton 1986).

- Straw mulching
  This strategy consists in covering the soil with crop residues and straw to protect it against wind and water erosion (Hauchart 2007). In addition, the decomposition of this organic matter promotes soil microorganisms' activity and increases soil fertility (Mando et al., 1999).

- Crop management, manure application and paddocking
  Increasing soil fertility can improve soil structure and therefore soil water holding capacity. Strategies aiming at improved soil fertility management include the use of cover crops (Salako and Tian 2003), of reduced tillage (Payne 1999), of organic matter (Affholder 1995) and of animal manure (Korodjouma et al., 2006). In crop-livestock systems, farmers manure their fields either by corralling their animals overnight on the fields or by collecting the manure from the stalls and hand-spreading it on the fields. The amount and frequency of manure applied is influenced by rainfall, cropping and livestock densities, and the type of livestock being kept (Powell and Williams 1995).

3.3.2. Small reservoirs

Small reservoirs are structures capturing and storing run-off at macro-catchment level, with sizes ranging from 3 to 30 ha. They have multiple uses: supplementary irrigation during dry spells, dry season irrigation, fishing, livestock and household watering, and groundwater recharge through decreasing run-off. Irrigation implies the transport of the water from the reservoir to the crop, which is done either by hand from a nearby well, by means of gravity through tunnels, pipes or open channels fitted with control valves (Ofosu et al., 2010), or by mechanized irrigation systems involving pumps. These systems need a strong management structure to be efficient in terms of irrigation (Faulkner et al., 2008). While in-situ AWM strategies are practiced by individual farmers and their families, the construction, maintenance and use of small reservoirs require communal efforts and management, which in turn requires farmers' or village organizations to be in place (Schweigman 2003). With 1,053 small and medium scale reservoirs, Burkina Faso is one of the West African countries with the highest density of small reservoirs, and a continuous demand for building further reservoirs (Leemhuis et al., 2009). More than 500 small reservoirs have been identified in the Ghana Upper East Region, almost 70% of which are less than 1 ha in area (Johnston and McCartney 2010).

Small reservoirs are classified into two sub-groups namely, small dams and dugouts, according to their size, priority of water use, structural details and their management system (Namara et al., 2010). Small dams are barriers that impound permanent or temporary rivers. Depending on the topography of the watershed, small dams will be placed in the gully to retain run-off downstream. They can be made of concrete, rocks or earth, with or without spillway, permeable or not, depending on the purpose of the dam. Dugouts (or "bouli" in Burkina Faso) are artificial pools of about 3-4 m depth and 50-60 m diameter at the foot or midway up a slope where there is convergence of run-off (Barry et al., 2006). They are smaller than small dams, in terms of surface area, volume of water they impound and number of beneficiaries, and have no intake structures, canals and laterals (Namara et al., 2010). The removed soil is used to build an enclosure wall that is left open on the uphill side of the pool. The water collected can last for 2-3 months after the rains and is mainly used for livestock watering and to irrigate small market garden crops (Barry et al., 2006). Ponds are natural structures with the same functions as dugouts.

4. Evolution in technical, institutional and political aspects of AWM

From the 1960s until now, the evolution of AWM strategies promoted in Burkina Faso and Northern Ghana is summarized in Figure 5, as well as the related actors, concepts and events.

4.1. Traditional AWM strategies

Farmers in the dry areas of Burkina Faso have been practicing traditional AWM strategies for many decades. These practices were described by the ORSTOM as far back as the 1950s (Savonnet 1958). Traditionally, planting pits were used on a small scale to rehabilitate rock-hard, barren land ("zipélé"), in which rainfall could no longer infiltrate (Kabore and Reij 2004). Stone rows were laid down as semi-permeable barriers. However, as they were not built following strict contour lines, water could by-pass them, provoking small gullies elsewhere. Andropogon was sometimes planted around the plots (Roose 1992). Agronomic and biological measures for soil and water conservation were widely practiced, including fallowing, crop sequencing, and thinning (Mazzucato and Niemeijer 2000). Mulching was also traditional in large parts of Northern Burkina Faso (Slingerland and Stork 2000). As far back as 1950s, there were already small reservoirs (dugouts), mainly used for livestock watering.

In Ghana, farmers were traditionally planting on tied ridges. In addition, in the drier, hillier and more populated Upper East Region, farmers used to do terracing with bunds. As in Burkina Faso, bunds were not along contour lines and were done as erosion control measures rather than for water retention. Some farmers irrigated small gardens from shallow wells using water brought by hand, i.e. by the "bucket and calabash" method. In comparison, the Upper West and the Northern Region were not culturally used to bunds and irrigation, as lands were flat, less dry and less populated.

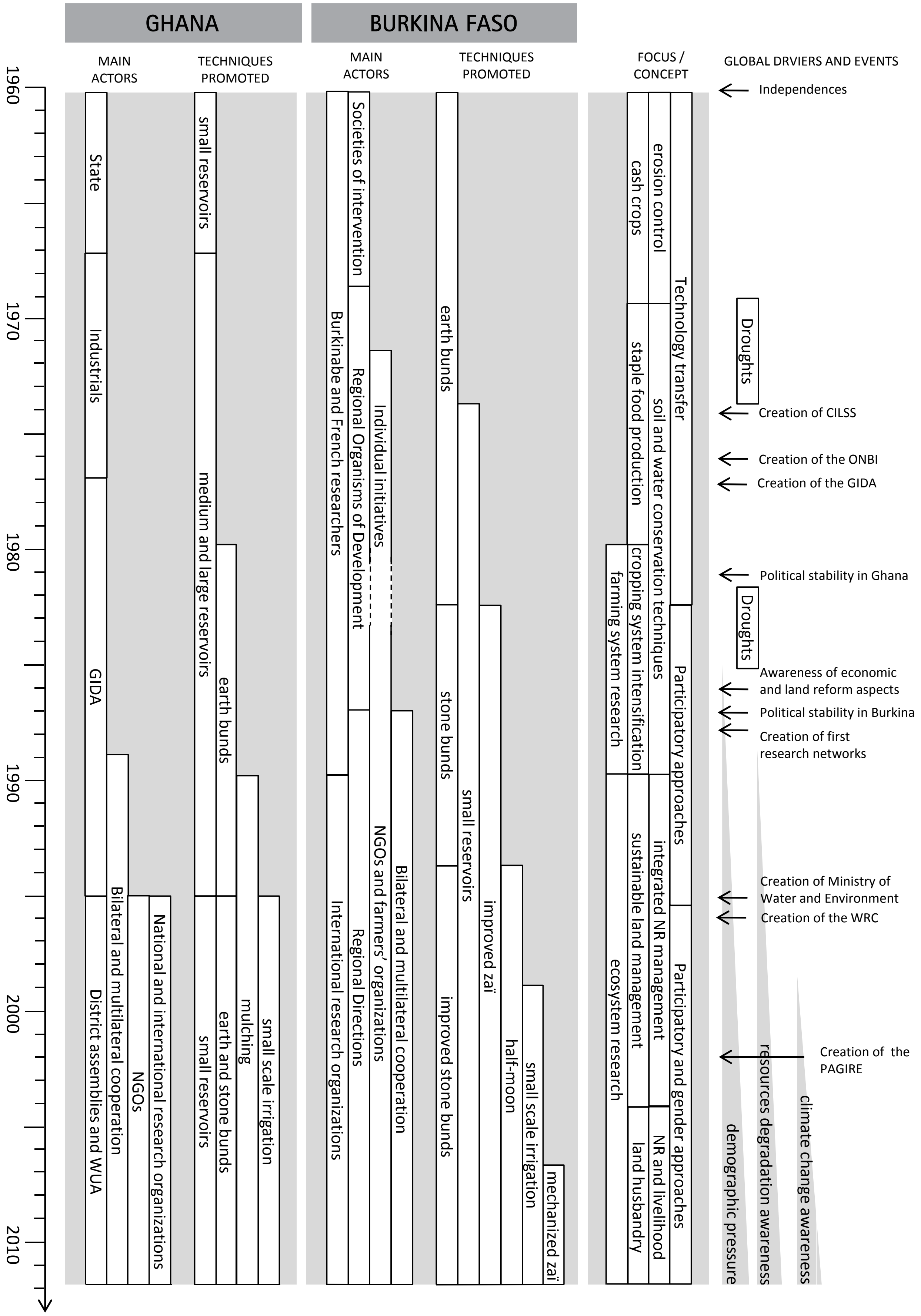
4.2. Post-colonial priorities

When Ghana became independent from the British in 1957, the South of the country was much more developed than the North. Although the British constructed some small dams to sustain year-round production in Northern Ghana, they had mainly developed the South, and deployed labor forces from Northern regions to the cocoa plantations of the South. Ghana's first President, Kwame Nkrumah (1957-66), brought a philosophy of socialization of agriculture and industry (Due 1969). Large scale government projects were created for commercial farming in the Northern Region, such as the State Farms, where large areas owned by the State were cropped with food and cash crops. Products were then sold to workers at subsidized prices. The State Farms were notoriously inefficient, due among others to diversion of funds (Girdner et al., 1980). More than a hundred small dams were constructed during the 1960s, mainly for livestock and household watering (Venot 2011).

The first water management institutions established in independent Ghana was the Volta River Authority (VRA). Created in 1961, the authority was responsible for the generation of electrical power and development and maintenance of the reservoir, and focused on water resources for public, domestic or industrial purposes (Lautze et al., 2008).

In the Burkina Faso of the 1960s (called Upper Volta at the time) after independence, the period was marked by the establishment of "Intervention Societies", which were mainly French societies with local employees, promoting new techniques for cash crops cultivation. The SATEC (Société d'Assistance Technique pour la Coopération) in Koudougou promoted the use of animal traction, the BDPA (Bureau de Développement

Figure 5. Evolution of agricultural water management (AWM) strategies promoted in the Volta Basin (Burkina Faso and Northern Ghana), and related actors, concepts and events.



des Production Agricoles) in Ouahigouya promoted earth contour bunds for groundnut cultivation. The large and expensive GERES project (European Group for Soil Restoration/Groupement Européen de Restauration des Sols), financed by the European Development Fund, designed and executed by European firms, was implemented in the Central Plateau in Burkina Faso to control erosion through the digging of ditches on a huge area of 120,000 ha using heavy machinery. As the local population was not involved in the preparation and setting up of the project, and was not willing to maintain the ditches, the project failed (Schweigman 2003; Marchal 1979). During this project, the use of andropogon for live barriers was noticed as a potentially successful AWM strategy (Marchal 1986).

Towards the end of the 1960s, the Regional Organization for Development (ORD, Organismes Régionaux de Développement), and independent structures of the state, replaced the foreign societies in order to enhance integrated rural development. They concentrated essentially on crop production and failed to integrate animal production, forestry and water. Water was not a priority for the ORDs and for research organizations at the time. As in Ghana, and in line with the rapid expansion of the Green Revolution agriculture, the focus was on intensifying cash crop production with the introduction of animal traction, improved seeds and fertilizer, and on crop yields as the main indicator of agricultural development.

4.3. The Great Droughts of the 70s and their consequences

A series of droughts struck the Sahel in the early 1970s, with devastating consequences for the entire region, namely food crisis and massive mortality among the livestock of both farmers and pastoralists (Mortimore and Adams 2001). Many farmers migrated to regions with higher rainfall in the South (McMillan et al., 1990). Unprecedented quantities of food aid were delivered to Burkina Faso. Investments in food aid were then gradually replaced by numerous programs of government and foreign aid organizations to improve the productivity of rainfed agriculture, promote food self-sufficiency, and reduce the risk of repeated famine (Painter 1995). The awareness campaigns in Europe led to individual, like the monk Brother Adrien who founded the Benedictine Monastry of Koubri and started to build small dams, in agreement with the ORDs; 83 small dams were constructed under his influence in the area of Koubri. Likewise, starting from the successful construction of a small dam in Dassa by a few Belgians, the Micro Dams Action (AMB, Action Micro-Barrage) developed in an active Burkinabe NGO that built many small reservoirs in the center region of the country. Another remarkable individual action is the foundation of the very innovative farmer organization Naam Groups National Federation (FNGN, Fédération Nationale des Groupements Naam) in Ouahigouya (Yatenga district, North of Burkina Faso) by Bernard Lédéa Ouedraogo. The FNGN aimed at promoting development while supporting traditional farmers' groups, and was really at the forefront of AWM and participatory approach in Burkina Faso.

After the droughts, the question of water for agriculture began to be included in government programs. Burkina Faso's water policies have been oriented towards ensuring a basic supply for all and mitigating vulnerability to spells of low precipitation. The National Office of Dams and Irrigation (ONBI, Office National des Barrages et de l'Irrigation) was created in 1976, with the aim of harnessing the irrigation potential of the country (Lautze et al., 2008). Half of the small reservoirs in Burkina Faso were constructed between 1974 and 1987 (Cecchi 2008).

Planners looked toward the vast, relatively fertile, well-watered, often sparsely populated and marginally used areas of river valleys as an area with the potential to address the problems of chronic food shortages and drought vulnerability through settlement and development (Painter 1995). At that time, the Volta river valleys were poorly settled due to infestation by various parasites or diseases vectors (Lahuec and Marchal 1979). In 1974, while WHO began the Onchocerciasis Control Program (OCP) to free the river valleys of this disease, the Burkina Faso government launched the Volta Valley Development Program (AVV, Aménagement des Vallées des Voltas) and gave AVV total control over 30,000 hectares of arable river valley land to organize settlements and agricultural production in the onchocerciasis controlled areas, including the development of large scale irrigated areas and buffer strip cropping. The AVV vision, like most other large scale state-led agricultural development interventions in West Africa during the 1970s, aimed to "rationalize" the use of productive resources by smallholder agriculturists (Painter 1995). The AVV planners and managers focused narrowly on increasing particular patterns of land and labor productivity, but this did not fit with the settlers who had their own perceptions of opportunities, constraints and risks. Consequently, the impact was low in relation to the degree of planning and investment made by the AVV programme (McMillan 1995). At the same time, the government of Burkina Faso launched the Rural Development Fund (FDR, Fond de développement rural) with World Bank (WB) funding, which developed earth contour bunds in the Central Plateau still considered as the most degraded zone in the country (Kabore and Reij 2004). Although lessons were learned from the 1960s and an attempt was made to involve the villagers, the approach was still basically top-down. Technically, the contour bunds were not always well designed. Moreover, their main purpose was to divert the water to prevent erosion, whereas the farmers needed the water to be retained and infiltrate to recharge groundwater, especially during poor rainfall years. Many contour bunds were therefore destroyed by the villagers (Reij 1983). Moreover, the FDR was acting at the demand of the ORDs-implemented "Groupements villageois" (Villagers groups), which were constituted only by a small part of the farmers, mostly the richer farmers, who had agreements with the ORDs (Marchal 1986). The contour bunds were built first on the land of these farmers, and those who were forced to work for their maintenance ignored their maintenance as their own lands were located elsewhere. Hence, the bunds were progressively abandoned (Marchal 1986).

The great drought of 1973-1974 led to the setting up of the Permanent Inter-state Committee for Drought Control in the Sahel (CILSS, Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel), which gathers and diffuses research work and information on desertification, natural resources management, food security and water use.

In the Ghana of the 1970s, which was much less affected by droughts, incentives for agricultural development oscillated along with the successive changes of political leadership during a period of instability. The National Redemption Council followed by the Supreme Military Council, from 1972 to 1978, was very supportive of agricultural development and more enthusiastic than its predecessors and successors. They launched the Operation Feed Yourself (OFY) to increase agricultural production to self-sufficient levels. This large campaign aimed at pushing farmers to cultivate more land more intensively, using fertilizers and mechanical traction. The OFY had poor outcome due to poor implementation (Girdner et al., 1980).

The small reservoirs built during the 60s had not been maintained well and had virtually disappeared from the national development agenda. At the beginning of the 1970s, the priority was towards an industrially-led economic development with medium and large public irrigation systems providing the foundation for a market oriented agricultural sector (Venot et al., 2011). In this regard, the government launched the construction of large dams (i.e. storing more than 3 million m3 of water) in Tono and Vea (Upper East Region). The dams were managed by companies owned by the government (the Irrigation Company Of Upper Region Ltd., ICOUR), and smallholders paid a fee to use the water. In Upper West, where no medium dams were constructed, culverts or bridges were constructed as add-on to roads for water retention. They were made of concrete, with spillway, aiming at cultivation of vegetables downstream.

With the growing importance of irrigation, the Ghana Irrigation Development Authority (GIDA) was created in 1977. The GIDA was responsible for the development of irrigation for farming, livestock improvement and fish culture. Although it undertook water diversion projects to fulfill its objectives, which may have impacted the efforts of other water management bodies, it appears that there was little cooperation between the GIDA and the VRA (Lautze et al., 2008).

In 1981, the Catholic Church created the Diocesan Development Office (DDO) in Upper East and Northern Region to train farmers in water management and construct a few dams among other activities, but the projects were not well coordinated.

4.4. Failures and reassessments

In the early 1980s, the Sahel was back to a situation of crisis and despair, stricken again by severe droughts. Average rainfall for the 1982–1985 period had fallen to 381 mm compared to 700 mm in the 1960s (Dugué 1989). Faced with general degradation of the ecosystems, some researchers observed that: "Burkina is not a developing country, it is a disappearing country" (Botoni and Reij 2009). As in the 1970s, harvest failures were common. According to a study by ICRISAT, the annual yields of sorghum and millet decreased from 570 and 490 kg DM/ha to 293 and 232 kg DM/ha, respectively (Reij et al., 2005). Drought dramatically affected food production and farmers income, especially in the Sahel and Sahelo-Sudan zones which relied heavily on rainfed agriculture, compared to the Sudan zone where people had more access to off-farm income (Reardon and Taylor 1996). Although livestock is commonly seen as a buffer to cover against fluctuations in income, households intentionally destabilized consumption in order to conserve livestock through the drought period (Kazianga and Udry 2006). Over half of the value of the income shocks was passed directly into consumption, with livestock compensating for at most between 15% and 30% of income fluctuations and stored grain for about a quarter of them (Kazianga and Udry 2006; Fafchamps et al., 1998).

The SWC projects implemented during the decade following the great droughts of the 70s did not increase farmer's yields and subsequent incomes substantially to cope with new severe climatic shocks. Indeed, an evaluation across the northern regions of Burkina showed that the lifetime of the constructed contour bunds was very short: in some villages 85% of the bunds had a lifetime of less than one year (Mietton 1986). In Ghana, development of large-scale government-controlled irrigation schemes had been a failure (Kortenhorst et al., 1989). The country was less affected by droughts, but the low water levels in Lake Volta eventually lead to power shortages in 1984, and the storage in Lake Volta did not completely recover ever since (Leemhuis et al., 2009).

The recognition of project failures initiated debates and questioning of approaches. Previously, the main problem was how to reach individual farmers in an efficient way with technology transfer as the key concept. The approach was dominated by a top-down approach and the role of experts as exclusive actors became increasingly challenged (Schweigman 2003; Ellman 1987). It was realized that indigenous knowledge should be taken as a starting point, and participatory approach became a key concept (Critchley et al., 1994; Mietton 1986; Schweigman 2003). Further reasons for failure were reported to be: too small, too short and too expensive projects; elusive pursuit of "silver bullet solutions"; neglect of marketing of inputs and outputs; farmers seen as ignorant and their practices seen as damaging to the environment; traditions and local innovations overlooked; lack of consideration of farmers' preferences; lack of partnerships and alliances; and lack of systematic analysis of measures and impact (Liniger and Critchley 2007). Reported common problems of large scale irrigation schemes were the extremely high capital costs ($10-20,000 per ha being common; Carter 1989); the over-optimistic benefit projections and development rates; the insufficient consideration of indigenous farming systems, skills and incentives; a lack of practical and management skills and the necessary attitudes on the part of national staff; and insufficient funding by governments, lending agencies and donors for the provision of operation and maintenance costs of large-scale irrigation schemes (Carter 1989).

At this point of the reassessments, Mietton (1986) had mentioned that all SWC strategies depended probably not so much on technical improvement but rather on political (land reforms) and economic measures that would stop out-migration. Marchal (1986) suggested to concentrate on planning at individual level, integrate gender aspects (as women were until now kept out of the projects despite cultivating significant areas of land), while considering the land tenure issue. In addition, for Burkina Faso, Marchal (1986) underlined that as long as migration to Cote d'Ivoire remained high (2 million Burkinabe in Cote d'Ivoire in 1983, more than 20% of the population), development projects in Burkina would attract much less Burkinabe than the salaries that they could get elsewhere.

Farmers from the Central Plateau of Burkina Faso, which is considered the most degraded area of the Volta Basin, developed various strategies to cope with the natural rainfall variability, like planting sorghum in shoals where usually pastures or rice were cultivated, favoring small ruminants which are more adapted to degraded pasture areas, or migrating to the South (Dugué et al., 1993). They started to experiment with improving SWC techniques together with technicians working for NGOs (Reij et al., 2005), like Oxfam or the Six S ("Savoir se servir de la saison sèche en Savanne et au Sahel" i.e. "to take advantage of the dry season in the Savannahs and the Sahel"), created by the FNGN, with international support. The Central Plateau was at that time a sort of laboratory for SWC techniques (Botoni and Reij 2009; Roose and Rodriguez 1990). Various innovations were introduced: the traditional zaï was improved by increasing its dimensions and by adding organic matter in it (Ouedraogo and Sawadogo 2000; Roose et al., 1999), the stone rows started to follow contour lines and became more solid with not only one row of stones but several stones placed above each other. The techniques were becoming more sustainable. Many small reservoirs were constructed between 1983 and 1987, during the "socialist revolution" of Thomas Sankara, when the political leadership of Burkina Faso undertook large infrastructure construction projects - roads, railways, small reservoirs - while promoting mass mobilization of the population (Sally et al., 2011). Sankara created the Revolutionary Defense Committee ("Comités de Défense de la Révolution") in each village, which elicited villager's participation. They retained SWC as priority in their program, beside education and health, which confirms their way of linking drought with soil water storage (Stroosnijder 2009).

Since 1987, the country entered into political stability with the regime of the new president Blaise Compaore. The ORDs were dissolved and evolved in Regional Directions which depended on the state. Still, the integration of the different services within government institutions was not resolved, as animal production and water were treated in other ministries than crop production. National programs of wide coverage started with the National Program for Terroir Management (PNGT, Programme National de Gestion des Terroirs). As experiments from farmers and NGOs had proven successful and as the country became stable, donor agencies rapidly designed SWC projects based on simple, effective techniques acceptable to farmers (Reij et al., 2005). Half of the aid investments in AWM received since the 70s was received during that period (Figure 6). Mega programs were funded through bilateral and multilateral cooperation, like the Project for land developpement and water conservation (PATECORE, Projet d'aménagement des terroirs et conservation des eaux) or the IFAD funded Special Programme of soil and water conservation - agroforestry (PS-CES/AGF, Programme Special de conservation des Eaux et des Sols et d'Agroforesterie) in the Central Plateau. These development programs were characterized by their global approach and their progressive inclusion of a natural resources dimension. Their major objective was rehabilitation of the productive capacity of the land through better control of rainfall and run-off, as well as through improved soil fertility management and reforestation. They also brought their own innovation, with for example the introduction of the half-moon technique from Niger by the PS-CES/AGF, or the stone contour bunds "3 stones" by the PATECORE, where one large stone lay on three small stones, making the construction much more resistant. Beside the big programs, many other projects intensified the promotion of SWC techniques (OXFAM's Agroforestry Project/Projet Agro-Forestier, Caritas, Six S, AFVP, Plan de Parrainage International de Kaya, etc.) (Rochette 1989). After a short decline between the droughts of the 70s and the 80s, AWM was again in the research agenda with the Yatenga region research and development project (ORSTOM, INERA, CIRAD), this time with a landscape perspective and in relation to organic matter management and labour (Dugué et al., 1993). All actors were gathered through the Provincial Framework of Technical Consultation (Cadre de Concertation Technique Provincial), which started in 1989-1990 on the initiative of the PATECORE. People were discussing approaches and techniques regularly, trying to avoid overlapping work and to harmonize strategies. Today, it is still functioning and is monitored by the government.

In Ghana, agricultural development also aimed at intensification of cropping system because international markets had recently opened and local products could not compete with foreign subsidized products. Intensification started with promotion of contour bunds for rice and vegetables. A group of ex-Silsoe College students founded the local NGO TRAX, which was the first to improve the traditional bunds of the Upper East by following contour lines. The IFAD-funded Smallholder Rehabilitation and Development Program (SRDP) was implemented in Northern Ghana. The WB Low Risk Rice Program also promoted contour bunds, followed by the Farmer Responsive Mechanisms in Extension and Research (FARMER) project funded by Canadian International Development Agency (CIDA) and some NGOs. From here on, Volta Basin governments' development programs gave more and more importance to water management over time, through varying institutions and policies (Lautze et al., 2008). Still, priorities for water use were not the same in Burkina Faso as in Ghana: with most rivers in Burkina Faso drying up during the dry season, Burkina Faso prioritized AWM while Ghana aimed primarily at producing energy through Lake Volta and the Akosombo-Kpong hydropower scheme (Lemoalle and de Condappa 2010; Lautze et al., 2008).

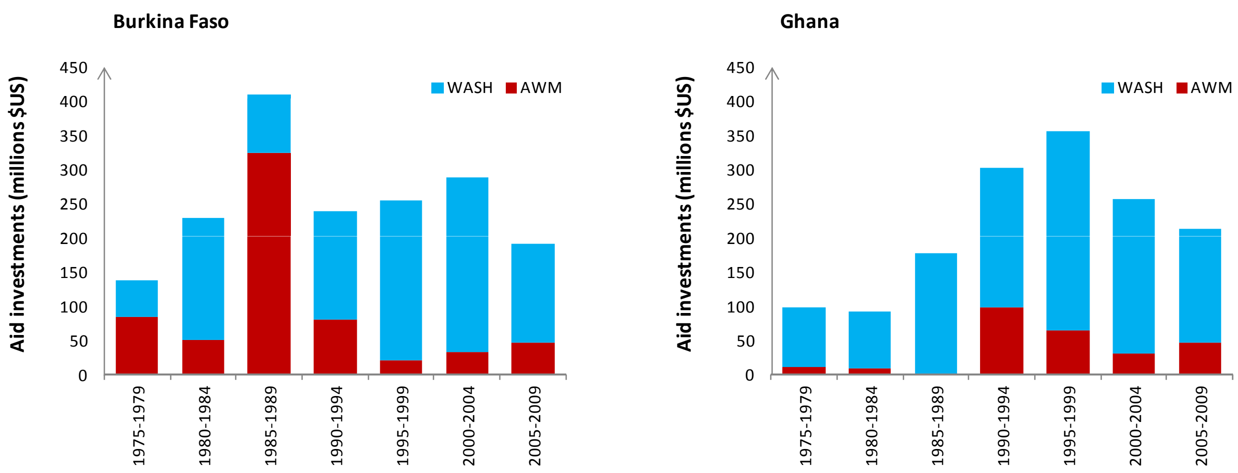
Increasing concern about ecological degradation and the recognition of the vital role that natural resources have in rural livelihood systems stimulated funding for natural resources management, including water (Batterbury and Warren 2001). The concepts of "sustainable land management" and "conservation agriculture" were introduced in the 90s, and became progressively essential aspects of research and development projects (Roose 1989; Gordon and Amatekpor 1999). Concerns about natural resources degradation also stimulated better coordination of water institutions, with the creation of the Water and Environment Ministry (MEE) in Burkina Faso in 1995 and Water Resources Commission (WRC) in Ghana in 1996 (Lautze et al., 2008).

4.5. The rise of small scale irrigation

After failures of large schemes in Ghana, small-scale irrigation started to gain the favor of large donor-driven investments, and boosted a renewed interest in small reservoirs, where they had been long neglected. Between 1995 and 2009, 82 small reservoirs were constructed in the three northern regions, mainly by IFAD and NGOs like Plan Ghana, the Red Cross, or Action Aid. This is approximately twice the number built between 1970 and 1995. At least, another 80 small reservoirs in the Upper East and Upper West regions were rehabilitated during the same period (Venot et al., 2011). The shift of the main purpose of small reservoirs from livestock watering to small scale irrigation let the door open to a bunch of technical and conceptual innovations: new techniques tailored for small scale irrigation emerged, with the progressive inclusion of treadle pumps, motor pumps, and drip irrigation. In Burkina Faso, this was supported by various projects and associations like the WB-funded private irrigation development and joint activities project (DIPAC, Projet de développement de l'irrigation privée et des activités connexes) or the Association of irrigation professionals (APIPAC, Association des Professionnels de l'Irrigation privée et des activités connexes) created in 1997. The rise of small scale irrigation contributed to the increase in cropping area and to changes in the landscape around small reservoirs and wells, which rendered livestock management difficult in areas with strong pastoralist traditions like the Sahel. To minimize the risks of damage on crops and to ensure water for herds, pastoralists had to move away from the cropping area and cover longer distances to reach pastoral units (Diallo and Vall 2010; Zongo et al., 2006). People started studying how to best combine farmers and pastoralists in this changing environment (d'Aquino 1998) and to develop adaptation strategies like for example the use of live hedges to keep livestock out of vegetables gardens (Ayuk 1997). Today, the question of the sustainability of pastoral systems is still in the research agenda (Ayantunde et al., 2011).

In Ghana, small scale irrigation projects started in the Upper East, where people were culturally used to irrigation and where the dry season cropping was utilized for cash crops. The IFAD-funded Land Conservation and Soil Rehabilitation Program (LACOSREP) developed irrigation with gravity systems and canals, and introduced Water Users Associations (WUA) in the mid 2000s. The WUA represented an important movement towards participatory management, which pushed farmers to take over and manage reservoirs themselves. For each dam, people were trained to supervise the use of the dam, collect taxes, and pass information. Another IFAD project started later on in the Upper West, the Upper West Agricultural Development Project (UWADEP) with similar activities. IFAD portfolio was continued with LACOSREP II, which introduced closed channel irrigation method, which wasted much less water than the open channel methods used until this time (Namara et al., 2010). Altogether, a lot of efforts were placed in small dam construction or rehabilitation. However, when considering the intended irrigation use of small dams, many of them are not functioning efficiently today and numerous institutional drawbacks do not allow WUAs to fully contribute to their sustainable governance (Venot 2011). In the Northern Region, pumps were introduced by the AfDB-funded Small Scale Irrigation Development Project (SSIDP) to extract water from the White Volta. Water was brought into storages, and then mainly used for gravity irrigation during the dry season, sometimes also for supplemental irrigation. Farmers were trained to control water distribution. Unfortunately problems emerged, related to the competence of contractors, or the failure of machinery or techniques used. Although the project was largely unsuccessful (AfDB 2010), it marked the start of pump integration in irrigation systems in Northern Ghana. The Lowland Rice Development Project (LRDP), funded by the French Development Agency (AFD, Agence Française de development), introduced smaller water regulation structures, i.e. small dykes (order of magnitude: about 15 meters length) made of concrete and equipped with steel gates that allowed famers to regulate water supply to downstream areas, mainly for use at the end of the rainy season. The water regulation structures were used for irrigation during the first dry season months and for livestock watering. They improved

Figure 6. Evolution of aid investments for agricultural water management (AWM) projects and water, sanitation and hygiene (WASH) projects in (a) Burkina Faso and (b) Ghana (Source: AidData).



roads as well, as vehicles could pass over the structure. However, there were technical problems, among others a lot of leakages provoking structure breakdown, and corrosion, which hampered the opening of the gates. As farmers were trained only to open and close the gates and not to repair the structure, most of these water regulation structures degraded and are no longer functional today.

While small reservoirs and small-scale irrigation were heavily promoted, in-situ AWM strategies were not completely out of the agenda. Ghana's Ministry of Food and Agriculture (MOFA) implemented the Land and Water Management Project in 1995, followed by the National Soil and Water Conservation Working Group to focus on SWC technologies mainly in the three regions of Northern Ghana. Between 1996 and 2000, the National Agricultural Rehabilitation Project (NARP) was implemented to promote indigenous practices like earth bunds, terracing and tied ridges, followed by the Savanna Resources Management Project on rehabilitation of degraded land. Various land conservation projects promoting earth or stones bunds and mulching were implemented such as Sustainable Land Management (SLaM) project of the University of Development Studies (UDS), the AFD-funded Rice Sector Support Project, and Care International project on conservation agriculture.

4.6. Towards an integrated view of AWM

Meanwhile, scientists and developers progressively realized that support to natural resource management alone does little to improve 'livelihood viability' (Batterbury and Warren 2001) and that the socio-economic context had to be better integrated with natural resources management. The concept of conservation agriculture was not enough and was replaced by the concept of "land husbandry" or "village land-use management" (Roose et al., 2008), which involves an integrated set of land management practices intended to increase or maintain land productivity, including proper soil and water conservation (Stroosnijder 2009) and socio-economic aspects. Towards this end, farmers' perception of soil fertility, erosion and environmental issues begin to attract scientific attention (Critchley et al., 1994), for example the study of Roncoli et al., (2001) on farmers' understanding of climate-crop interactions and ways to cope with drought, or the study of Mazzucato and Niemeijer (2000) on local social institutions and cultural economy. Research for development projects turned multidisciplinary and multi-stakeholder to address all these facets and get better chances of sustainable achievements, although with increased risk of scattered outcomes. Some examples are the first phase of CPWF (2004-2008), the GEF-funded ICRISAT-led Desert Margins Program (2003-2009), or the EU-funded CIRAD-led Agricultural Innovation in Dryland Africa (AIDA) project (2007-2009).

4.7. Current trends in research and development projects

The evolution in technical, institutional and political aspects of AWM has led to a set of trends which can be observed in the characteristics of current projects and programs (Table 1).

- Supplementary irrigation, dry season crops and market access
  Whether based on rainwater harvesting from small dams or dugouts, promoting motor pumps, treadle pumps or drip irrigation, various projects are now focused on small scale irrigation systems. Production of off-season valuable crops for market, decrease of crop failure risk associated with dry-spells through supplementary irrigation, and better linkages with markets, can increase smallholders' income, food security and crops diversification. Examples are the IFAD Small Scale Irrigation and Water Management Project (PIGEPE, Projet irrigation et gestion de l'eau à petite échelle), 2iE project on supplementary irrigation and climate information, AgWater Solutions Project from IWMI, or USAID-CILSS West Africa Irrigation Project (WAIPRO). The sector attracted also commercial interests with social enterprises like iDE, who develops low cost treadle pumps and drip irrigation toolkits, and trains small-scale enterprises to manufacture and distribute them at a fair market price.

In Northern Ghana, where lack of demand for cereal products and lack of incentives for producing more are a major barrier for rural development, market development is of particular interest. This forms the main objective of IFAD/MOFA Northern Rural Growth Program (NRGP), along with value chain approaches. A similar project in Burkina Faso is the Support project for agro-silvo-pastoral value chains (PAFASP, projet d'appui aux filieres agro silvo pastorales) of the government.

- Integrated solutions, landscape and livelihoods

  Another set of current projects concentrates on improving livelihoods and farming systems resilience and adaptation through the development and the promotion of integrated and locally adapted solutions studied at farm and catchment level. This is the natural evolution of some of the mega programs implemented in the past: the GIZ Agricultural Development Project (PDA, Projet de développement Agricole) following the PATECORE, or the IFAD Sustainable Rural Development Project (PDRD, Projet de Développement rural durable) following the PS-CES/AGF.

  Research projects often complement this by studies on ecosystem services and analyses of biophysical and socio-economic trade-offs between water uses. Examples are the EU-funded project Water Harvesting for Rainfed Africa (WAHARA), the other EU-funded project Water Harvesting Technologies Revisited (WHaTer), the VBDC, and partially the Ausaid-CSIRO-CORAF/WECARD projects on farming systems.

- Adoption and governance

  The study of governance processes and other factors influencing successful adoption and upscaling of AWM strategies is an important topic in research projects, as in the AgWater Solutions Project and in the VBDC. Land tenure studies, decentralization support and cooperation at basin level are the key activities of various developments projects like the Water governance support project in the Volta Basin (PAGEV Projet d'Appui à la Gouvernance de l'Eau dans le bassin de la Volta).

- Global drivers

  Sustainability of AWM strategies in a climate change perspective can be assessed through various models. The GLOWA project (Globaler Wandel des Wasserkreislaufes/Global Change and the Hydrological Cycle) was designed to provide a comprehensive, integrated analysis of the physical and socioeconomic determinants of the hydrologic cycle within the Volta Basin, with a specific focus on the impacts of global environmental change (Rodgers et al., 2007).

  The new West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) plans to enhance the resilience of human and environmental systems to climate change and increased variability, and will thereby develop studies on water resources in the Volta among other activities.

Finally, it can be mentioned that AWM is currently not the first priority for the Burkinabe and Ghanaian government, compared to other sectors like education or health which are on top of the list. This is in line with what communities mentioned as their priorities for development during the communal development plans. As from Figure 6 and 7, the focus is now much more on drinking water, resulting in a growth of water and sanitation (WASH) projects and institutions like WSSCC, RAIN, IRHA, WaterAid, CREPA, or Akvo. Within the agricultural sector though, water management is a priority and gets a good share of the investments. Figure 7 also shows that during the last decade, aid investments in the water sector were higher in Burkina Faso than in Ghana. Further differences in aid priorities between both countries are that in Ghana, more was invested in agricultural policy, fishing, and extension, while in Burkina more was invested in livestock and in research.

Figure 7. Repartition of aid investments in the area of agriculture and water, for the timeframe 2000-2009, in (a) Burkina Faso and (b) Ghana (Source: AidData). The category "Agric development" account for all projects that are not part of another category (e.g. linked to post harvest, crop management, industrial crops, or financial services).

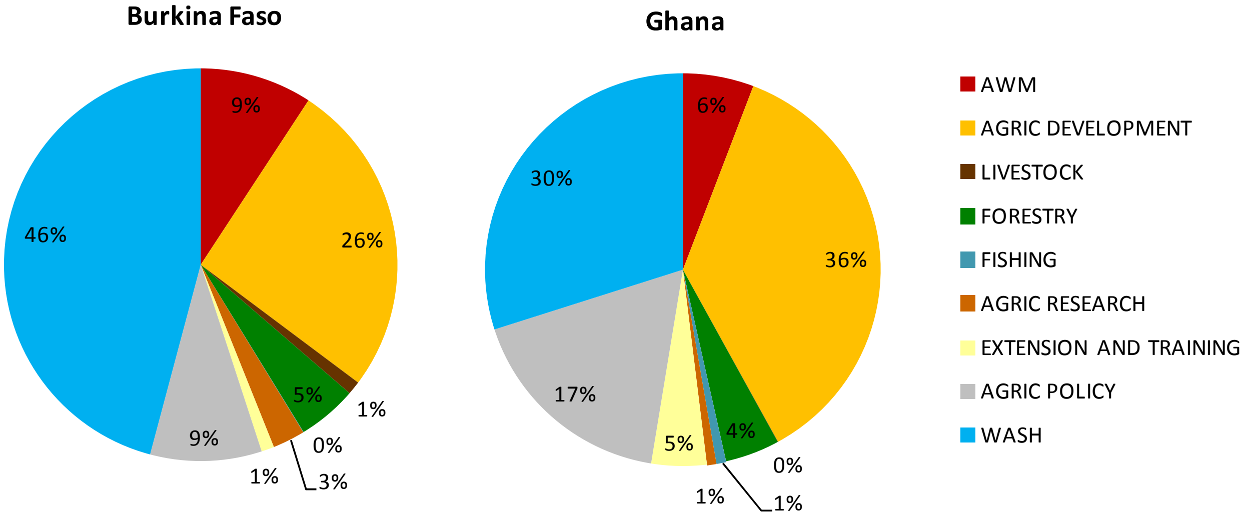


Table 1. Examples of research and/or development projects illustrating current trends in the Volta Basin

Topic	Organization	Project acronym	Project name
Supplementary irrigation and dry season crops	IFAD	PIGEPE	Small Scale Irrigation and Water Management Project
	IWMI	AgWaterSolutions	Agricultural Water Management Solutions
	USAID - CILSS	WAIPRO	West Africa Irrigation Project
Market development	IFAD/MOFA	NRGP	Northern Rural Growth Program
	WB/MAHRH	PAFASP	Support project for agro-silvo-pastoral value chains
Integrated solutions, landscape and livelihood	GIZ	PDA	Agricultural Development Project
	IFAD	PDRD	Sustainable Rural Development Project
	CPWF	VBDC	Volta Basin Development Challenge
	EU	WAHARA	Water Harvesting Technologies Revisited
	EU	WHaTer	Water Harvesting for Rainfed Africa
Adoption and governance	IUCN	PAGEF	Water Governance Support Project in the Volta Basin
	CPWF	VBDC	Volta Basin Development Challenge
	IWMI	AgWaterSolutions	Agricultural Water Management Solutions
Global drivers	BMBF	GLOWA	Global Change and the Hydrological Cycle
	ZEF	WASCAL	West African Science Service Center on Climate Change and Adapted Land Use

5. Outcomes of major AWM research and development projects and programs

5.1. From research projects

Research results on AWM strategies in Burkina Faso and Ghana have been widely documented, especially the work of IRD and INERA. Reviews on different aspects of AWM strategies are also available. A non-extensive list of publications on AWM strategies used in the Volta Basin is given in Table 2, underlying also the aspects treated by the publications. Technical recommendations have been documented elsewhere (e.g. Technical sheets of INERA and PS-CES/AGF, and PATECORE technical handbook).

Vohland and Barry (2009) reported recently that in-situ AWM strategies improve hydrological indicators such as infiltration and groundwater recharge, that soil nutrients are enriched, and that biomass production increases, with subsequent higher yields. It has been argued that more residues are produced and vegetation regenerates quicker, which increases livestock production and allows a shift from extensive management to semi-intensive methods (Reij et al., 2005), although a systematic review is yet to be done on this topic. By lowering the risk for crop failure, AWM strategies can function as an entry point for farmers to increase investments in soil fertility through the use of more fertilizer (Rockström 2000). Indeed, one reason for low fertilizer use in the Sahel is that farmers avoid investing in inputs due to high risks of crop failure as a result of droughts and dry spells (Brouwer and Bouma 1997; Rockström 2000; Rockström et al., 2002). Stone bunds improve yields up to 80%, decrease run-off significantly (Lamachère and Serpantié 1990), and increase soil water storage and crop water use efficiency (Zougmoré et al., 2004). Impact is much higher (up to 140% increase) when combined with organic matter management (Zougmoré et al., 2003a; Zougmoré et al., 2004). Modifying organic matter management practice can increase crop water use efficiency by 15 to 25%, or more depending on the actual soil nutrient deficiencies (Hatfield et al., 2001; Breman et al., 2001). Effect on yields may not be immediate, and be perceived only in the long term (de Graaff 1996). Likewise, run-off decreases about 10% the first year and up to 70% after 5 to 6 years of filling up (Hauchart 2007). Effects of grass strips are similar (Zougmoré et al., 2003a; Zougmoré et al., 2004; van Loon and Stroosnijder 2000).

Zaï practice has the potential to increase cereal yields by a factor of 10 (Roose et al., 1999), and yields increase further with the application of organic amendments (Fatondji et al., 2006). Zaï allows collecting 25% of a run-off coming from 5 times its area (Roose et al., 1999) and decreases water evaporation, which maintains soil humidity longer and allows mitigating dry spells. Zaï improves crop water use efficiency by a factor of about 2 and improves nutrient uptake (Fatondji et al., 2006). The concentration of run-off water, organic manure, and a complement of mineral nutrients in the pits increase biomass production and re-vegetation by numerous weeds and forage species, which rehabilitate crusted soils on longer term (Roose et al., 1999). The zaï technique is particularly promising when soils are very poor, but not when soils are fertile as it hampers the introduction of animal traction for ploughing and weeding (Maatman et al., 1998).

As for the zaï, half-moons allow cereal cultivation in soils where nothing else could otherwise be grown. Soil water content increases, and cereal yields increase up to 4 times, reaching 1,600 kg/ha when combined with nutrient management (Zougmoré et al., 2003b).

Tied ridging increased yield by up to 20% as well as crop water productivity (Fosu et al., 2008), and has a significant effect on run-off and sediment transport limitation (Fosu 2007).

Table 2. Review of research on the main agricultural water management (AWM) strategies for rainfed systems in the Volta Basin.

AWM strategy	Where studied	Effects reported and aspects reviewed					Reference
		Erosion control/water balance parameters	Yields/ biomass production	Water and nutrient use efficiency	Technical/ practical aspects	Other	
Zaï	Burkina Faso		+		x	Potential/impact on HH level	Maatman, 1998
	Burkina Faso	++	+++			Biodiversity	Roose, 1999
	Burkina Faso					Economy and adoption	Kinane, 2002
	Burkina Faso		+++		x	History and farming system perspective	Kaboré and Reij, 2004
	Niger		+++	+++			Fatondji, 2006
	Burkina Faso	++	+++			Review	Mando, 2006
	Burkina Faso					Potential	Ouedraogo, 2008
Zaï forestier	Burkina Faso					Adoption	Koutou et al., 2007
Half moon	Burkina Faso	++	++				Zougmoré, 2003b
Stone bunds	Burkina Faso	++	+++				Lamachère and Serpantié, 1990
	Burkina Faso		+		x	Potential/impact on HH level	Maatman, 1998
	Burkina Faso				x		Zougmoré, 2000
	Burkina Faso					Economy and adoption	Kinane, 2002
	Burkina Faso	+++	+++	++			Zougmoré et al., 2003a; Zougmoré et al., 2003b; Zougmoré et al., 2004
	Burkina Faso		++				PATECORE, 2005
Tied ridges	Ghana	+	+	+			Fosu, 2007; Fosu et al., 2008
Andropogon Life barriers Hedgerows	Burkina Faso				x		Dugué et al., 1993
	Burkina Faso	++			x		van Loon, 2000
	Burkina Faso	+++	+++	++			Zougmoré et al., 2003a; Zougmoré et al., 2004
Straw mulching	Niger	++					Bielders et al., 1995
	Burkina Faso		+			Termites	Mando, 1997; Mando et al., 1999
Small reservoirs and irrigation	Burkina Faso	+	+++				Van Driel and Vlaar, 1991
	Burkina Faso		+++				Fox, 2000
	SSA		+++	+		Conceptual	Rockström, 2002
	Burkina Faso					Risk analysis, economics	Fox, 2005
	Ghana				x		Liebe, 2005
	Ghana		+			Economics	Faulkner, 2008
	Ghana			+			Mdemu, 2009
	Ghana					Economics	Agyare et al., 2009
	Ghana				x	Institutions, economics	Namara et al., 2010
	Volta Basin		++	++	x	Review	Ofosu, 2010
	Burkina Faso					Institutions, management	Sally et al., 2011
	Ghana					Institutions, management	Venot et al., 2011
Transversal reviews, Various techniques	Burkina Faso		+/-		x		Mietton, 1986
	West Africa		+/-		x		Roose, 1989
	Burkina Faso				x	History	Dugué et al., 1993
	Burkina Faso		+			Economics	de Graaf, 1996
	Burkina Faso					Institutions, economics	Mazzucato, 2000
	Burkina Faso		++	++		Farming system	Reij et al., 2005
	West Africa		x		x	Potential for outscaling	Barry et al., 2006; Barry et al., 2008
	Volta Basin	++	++		x		Hauchart, 2007
	Sahel		+++			Adoption + farming system + economy	Bottoni et Reij, 2009
	African drylands	++	++			Economy and farming systems	Vohland, 2009

+, maximum increase of up to 30%
++: maximum increase between 30 and 75%
+++: maximum increase of more than 75%
- : no significant effect

With mulching, 2 tons of straw will cover only 7 to 10% of the soil surface, but can reduce run-off and sedimentation flows by up to 40 to 60% (Bielders et al., 1995). On crusted soils, a key role in mulching effectiveness is played by termites, without which soil water content does not significantly increase (Mando 1997; Mando et al., 1999).

Permeable dykes increase cereal yields upstream due to a higher water and nutrient availability with the sedimentation process. However, with small dykes, infiltration increase is not high enough to make an impact on groundwater recharge (van Driel and Vlaar 1991).

With AWM strategies, natural pastures increase in quantity and quality, making it possible to raise more livestock and help maintaining herders longer away from cultivated zones, which can help decrease the conflicts between farmers and herders (Botoni and Reij 2009), provided the local conventions governing the management of grazing areas and the natural resources are strong. However, when crops replace native vegetation, conflicts might be strengthened (Vohland and Barry 2009). Although livestock trampling decreases water infiltration in grazing areas (Savadogo et al., 2007), animal manure increases soil water holding capacity through improved soil structure (Korodjouma et al., 2006).

Supplemental irrigation from small ponds during dry spells increased cereal yields by 41%, and by 180% in combination with nutrient management (Fox and Rockström 2000). As for in-situ AWM strategies, adequate fertilizer application is the major contributor to water productivity improvements (Ofosu et al., 2010). Water productivity of small reservoirs has been reported as low, with losses of more than 60% of the water supply at farm scale (Mdemu et al., 2009). The reasons for this can be technical, like when the amount of water stored is reduced by siltation from upstream land (de Graaff 1996), and/or linked to management (Sally et al., 2011). Indeed, two very comparable small reservoirs of similar size, set in the same socio-economic and physical environments can have large differences in water and land profitability, due to social and institutional reasons (Faulkner et al., 2008). Technologies characterized by relatively small farm sizes are better managed because they are able to provide adequate water and crop nutrients thus resulting in higher productivity, and high profit margins (Ofosu et al., 2010). On the other side, the expansion of small-scale irrigation contributes to the fragility of river and reservoir banks, and reduces the capacity of storage reservoirs through silting (Abric et al., 2011). It should be noted that the efficiency of small reservoirs often focuses on the benefits derived from the water use for irrigation, such as the resulting crop yield, whereas the value of reservoirs from a multiple use perspective, linked to the range of livelihood, economic and ecosystems services or to the water storage investment in view of climate adaptation strategies, is often poorly recognized.

Improvements in water and soil management allowed many farmers to diversify their production and to grow vegetables for sale (Schweigman 2003). Farmers practicing AWM strategies profit in most cases from higher food security and higher income (Vohland and Barry 2009), but the increase in crop production is not always sufficient to feed all members of the household, especially in years with low rainfall (Maatman et al., 1998). They are able to save some income for other purposes, but impact on farm-level food security is more limited than what is sometimes supposed on the basis of a simple extrapolation of plot-level results (Maatman et al., 1998). Additional income from new agricultural technologies is in most cases unequally distributed between genders, although the technologies can benefit women if bargaining prevails as behavior for decision-making in the household (Lawrence et al., 1999).

5.2. From development projects

Studies have been reporting contradictory views of the impact of AWM strategies-based development projects on livelihoods. On one side, the general consensus among researchers and policy makers is that the environment on the Central Plateau continues to degrade, with decreasing rainfall, endemic drought, destruction of vegetation cover, depletion of soil fertility and intense erosion (Reij et al., 2005; CONAGESE 1999). On the other side, developers argue that the intense promotion of AWM strategies initiated in the 80s finally helped trigger a process of agricultural intensification and allowed achievement of higher levels of food security, reduced land degradation and out-migrations, and improved material wellbeing, despite an unfavorable climatic, demographic and socio economic context (Botoni and Reij 2009; IFAD 2006a).

The positive results from case studies recorded by CILSS and GTZ in the 80s (Rochette 1989) were confirmed by CILSS' recent impact evaluation of all investments done in natural resources management in the Sahel, which stressed that the positive impact of the projects and programs is often underestimated. Traditional practices have been improved, and hundreds of thousands of ha of land were restored by projects and programs (Botoni and Reij 2009). In Burkina Faso an estimated 200,000 to 300,000 ha were re-invigorated by farmers developing zaï and stone bunds, yielding an extra 80,000 tons of food annually: enough to feed 500,000 people (Steenberg et al., 2011). Impacts on grain yields was indeed high, with 39% increase for stone rows, 69% for zaï, 112% for half moon and 118% for zaï and stone rows together (Botoni and Reij 2009). Impact assessment studies from individual projects are also optimistic. Among others, the PATECORE project reports very positive results of AWM strategies on land rehabilitation in the Central Plateau and an increase in cereal yields of 20-50% (Neubert et al., 2000; PATECORE 2004); the PS CES/AGF project has realized stone rows on close to 89,600 ha, zaï on 32,500 ha, half-moon on 324 ha, 748 irrigation dikes, 201 functional wells, an increase in food security for hundreds of thousands of households and numerous capacity building, training and institution building efforts (IFAD 2004; Reij et al., 2001); OXFAM's Agroforestry Project trained 4,542 farmers from 406 villages in various AWM strategies techniques between 1983 and 1991, which resulted in an increase in crop yields by 40-100% with improved land management, and the rehabilitation of about 8,000 ha of degraded land; during the DIPAC, 1,547 treadle pumps were sold, 329 producers received technical and feasibility advice for the acquisition of irrigation equipment, and more than 50 artisans were trained in equipment manufacturing and maintenance (Abric et al., 2011); LACOSREP I, UWADEP and LACOSREP II constructed and put into operation a total of 90 small dams and reservoirs, thereby developing about 1,000 ha of irrigated land (although 132 ha out of the 1,000 ha are new developments and the rest are rehabilitations of existing dams), and brought together about 50,000 households into WUA (Namara et al., 2010). However, this was less than what was planned due to delays in contracting and construction of dams and irrigation infrastructure (Johnston and McCartney 2010).

These outcomes are impressive, but would still need more detailed impact evaluations. Indeed, central government officers in Accra have argued that development investments in Northern Ghana have been ineffective (IFAD 2006a). Many of the hundreds of small dams constructed are not functional anymore due to poor maintenance, engineering problems, and lack of institutional support (IFAD 2006a; IFAD 2006b). A study done in 1998 in the Central Plateau showed that the source of farmers' knowledge about zaï for 72% of the respondents came from parents and neighbors, 11% from agriculture extension agents, and none from the projects (Slingerland and Stork 2000). These findings call into question the overly positive impression sometimes given by development actors, and show that it would be good to relate project benefits more closely to the amount of investments involved in producing them, to verify their sustainability and to quantify their actual impact on livelihoods.

6. Adoption of AWM strategies

6.1. Farmers' perceptions of AWM strategies

In a study carried out with 60 farmers in Northern Burkina in 2001, 90% of the farmers interviewed reported the lack of rain as their major problem in relation to cultivation (Visser et al., 2003). They had a good knowledge of wind erosion processes, but did not report the effects of water erosion processes: only 32% of the farmers interviewed observed run-off, and 15% observed erosion and deposition during periods of high intense rainfall (Visser et al., 2003). A study carried out in Ghana in 1999 showed that more than one fourth of the farmers interviewed were applying animal manure on their fields, associating soil organic matter with soil moisture conservation (Quansah et al., 2001). Reij et al., (2005) report that farmers see a positive impact of AWM strategies on crop yields, on trees survival and productivity, and on the water level in wells located within or immediately downstream of AWM strategies implementations. This was confirmed by a participatory rural appraisal carried out in 2011 in 16 villages of the basin, where farmers also recognized that AWM strategies increase soil fertility, decrease run-off, provide water for livestock, and, in the case of dry season vegetable growers, are a direct source of income (Karbo and Ouattara, unpublished results). Some farmers were pioneers in creating "AWM strategies schools" or "market days" to train their fellow farmers (Ouedraogo and Sawadogo 2000; Steenberg et al., 2011). In some areas, AWM strategies are entirely integrated in agricultural practices, and their usefulness is not even questioned: "Without zaï, you harvest nothing here", summarized a farmer of the Yatenga region, Northern Burkina Faso in July 2011.

6.2. Factors limiting sustainable adoption

Adoption is taken here in a broad sense and includes adoption of in-situ individually managed AWM strategies as well as maintenance and use of communal infrastructures.

Surveys on 700 production units in Burkina Faso showed that the rate of AWM strategies adoption was about 53%, mostly a combination of zaï and stone rows (Botoni and Reij 2009), while another study on 1500 production units reported that the rate of adoption was about 33%, mostly in the Sahel and Sahelo-Soudan zones (Ouedraogo et al., 2010). In Ghana, the adoption rate of the majority of technologies has been minimal and most often unproductive or short lived (Bediako 2009). The rate of adoption was in general below expectations, in view of the amount of efforts undertaken in the AWM sector since the 80s. While farmers perceive the positive effects of AWM strategies on their natural capital and on agricultural production in particular, there are still a number of factors limiting sustainable adoption. These factors range from material scarcity to lack of institutional support.

- Material

  The main difficulty for stone rows is the availability of stones. While at the beginning, stones were easy to find no further than 2-3 km, people need now to get them from sites located 10 to 15 km away from their fields. As about 40 tons of stone are required to treat 1 ha of land with stone bunds (Reij et al., 2005), farmers need to have or lend a vehicle (truck or a cart). Back in the 1990s, this problem of availability and transportation of stones was already known and people were already looking at an alternative to stone rows (Dugué et al., 1993). However, stone rows are still promoted today through projects providing trucks for transportation.

  Zaï is manure limited: farmers need to have a minimum of 2-3 livestock heads to produce enough manure to fill their pits (Botoni and Reij 2009; Maatman et al., 1998). For the zaï "forestier", Koutou et al., (2007) add that the number of hoes, the source of care and acceptance to lend work material to their neighbors affected adoption. For live barriers, seeds may not be available.

- Work load and costs

  Availability of farm labor for AWM strategies implementation is usually low, as activities are conducted between January and June, which correspond to a period of intensive vegetable cultivation and harvesting as well as migration of the most able-bodied villagers from rural areas to urban centers (Barry et al., 2008).

  The number of zaï pits per ha is generally about 12,000 to 15,000, depending on the crop chosen (Barry et al., 2006), and more than 300 man-hours are necessary to build them (Barro et al., 2005). This implies not only availability of a familiar working force, but also a lot of motivation as the work is realized during the dry and hot season (Botoni and Reij 2009). An alternative using animal traction to reduce work load has been developed (Clavel et al., 2008; Barro et al., 2005), but it is yet to become widespread. Stone bunds require 97 man-days per ha (Barry et al., 2008). For one ha of combined zaï and contour bunds, the cost lies between US$ 75- 175, with an additional $30/year/ha for the maintenance (Steenberg et al., 2011). Half-moon and mulching are also work extensive, and the gain in cereal productivity may not always compensate for the investment in time requested by such AWM practices (Hauchart 2007). New types of irrigation from small reservoirs involve high input costs for pumps and accessories (Agyare et al., 2009). Given these costs associated with AWM strategies, it is not surprising that access to credit is reported as a major factor for adoption (Faltermeier 2007; Agyare et al., 2009).

- Land tenure

  There is a strong link between land tenure and AWM strategies adoption in the Volta Basin (Niasse 2008). Land is historically distributed between different lineages. Lent plots cannot be easily constructed with stone rows or planted with trees, which are seen as signs of appropriation by the owner (Dugué et al., 1993). Moreover, farmers are reluctant to invest work and money in long-term soil rehabilitation practices on someone else's land. In the case of women's groups, access to some natural resource management technologies is equally problematic due to the difficulties they face regarding land ownership or acquisition for farming (Barry et al., 2008).

- Maintenance and use of communal infrastructures

  With time, siltation and breaches of dam walls request maintenance works can induce costs and technical know-how. Usually, a villager had been capacitated as technician, and the whole village contributes to a cash box through taxes. However, communal infrastructure is often difficult to manage in practice. Everybody wants to use the infrastructure but nobody feels responsible, and once it breaks there is often no money, no capacity, or no will to repair. For example it can happen that the technician migrates to Côte d'Ivoire or South Ghana without transferring his knowledge or that villagers do not contribute to the cash box. Turnovers within management committees do not help: projects frequently need to reinstruct a completely new committee just a year after construction. Improved construction and maintenance of small dams, as well as maintenance of irrigation infrastructures, were reported as determinants (IFAD 2008).

  When it comes to the use of a communal infrastructure, similar management problems can hinder its good functioning and integration within the community. Dams are multipurpose, but some uses may be neglected by the decision-makers. If there is not enough water for all usages or if one usage hinders another, conflict situations may arise, for example between farmers and pastoralists or upstream and downstream users (Labbé 2007). For example, livestock manure may contaminate water, hindering its use for the household due to risks of zoonotic diseases. And if the infrastructure is shared between two or more villages, management and collaboration becomes even more difficult.

- Traditional customs and ways of thinking
  Beliefs and customs may hinder adoption of new techniques. For example, some farmers think that God is supposed to provide rainwater, and that irrigation would be a bad omen. Traditional authorities and customary rights and tenure have been shown to play significant roles in land and water management in northern Ghana (Laube 2009; Lund 2008). Due to different customs, differential behaviors are observed when it comes to adaptation to climate change. For example, yields in Northern Burkina are somehow more secure than yields in the center region. Farmers in the Sahel are expecting more drought hazards and dig zaï systematically, whereas farmers in the center are less prepared and can potentially lose much more if a dry spell happens at a critical moment. In the center, it is said that soil is rich, so farmers do not prepare themselves and go with the flow as their parents have always done. This is fine as long as rainfall is adequate, but with climate change risks, zaï may become more necessary in the center as well.

  Enhancing the security of property and responsibility of farmers could also help in getting them more involved in community development. Indeed, "all across Africa, people look after the things they own but ignore or destroy what is controlled by the state" (Reij and Pearce 2008).

- Institutional support and project design
  Technology promoters themselves are reported to be the cause for non-adoption of technologies, through poorly designed and executed strategies that do not fit the needs of farmers, their circumstances and their diversity (Bediako 2009). Indeed, successful outscaling of AWM strategies strongly depends on the participatory methodologies used, which include farmer field schools, farmer-driven experimentation, rural radios, and choice of best-fit AWM strategies for each agroecological zone (Barry et al., 2008; Sturdy et al., 2008). It has also been reported that poor performance of small reservoirs was due among others to uncoordinated institutional arrangements for decision making, complicated administrative and contractual setbacks and lack of managerial and organization capacities (Venot et al., 2011). The large number of NGOs controlling technology dissemination with different strategies, negative competition, and ineffective government supervision creates confusion and makes technology adoption more evasive for farmers (Bediako 2009). A better collaboration with local NGOs is deemed necessary (IFAD 2008).

In relation to these limiting factors, adoption drivers for in-situ AWM strategies in West Africa have been summarized by Drechsel et al., (2005) and are mainly accessibility to information, yield increase, soil conservation, improved nutrient availability, secure land tenure, low labor demand, low capital requirement, and low risk perception (Figure 8). In addition, adoption of zaï and stone bunds in Northern Burkina Faso is also related to small ruminants holdings and perception of soil degradation (Sidibe 2005).

7. Recommendations and challenges for future projects

7.1. Geographical suitability

Each of the AWM strategies can be targeted to definite agroecological zones. Maps of the geographical repartition of AWM strategies are available (Hauchart 2007; Barry et al., 2008; Venot et al., 2011; Liebe et al., 2005; Cecchi 2008). Zaï and half-moons are destined to crusted soils and arid areas of the basin, i.e. mainly the Sahel and Sahelo-Sudan zones. The optimum climatic condition for zaï is between the isohyets of 300 and 800 mm rainfall (Roose et al., 1999). It becomes ineffective when there are frequent and long pockets of drought (more than 2 to 3 weeks) and inappropriate when the rains are more abundant like in the Sudan zone (Roose, 1993). While dugouts require only a small depression and are found in the whole basin, dams request a shoal with enough difference in elevation (Liebe et al., 2005), which is not a common topographic feature in the Sahel or in the Upper Western region of Ghana. Stone rows are fine in most of the places, with potential for more combination with live barriers. In the Sahel they are found often in combination with zaï, and in the Sudan zone with dams in order to stabilize the sides of the catchment and limit siltation in the reservoir. In the future, the zaï geographical limit may move south as rains become more and more erratic. The potential for the irrigated area is very high in Ghana: 1,200,000 ha can be potentially irrigated while only 6,400 ha were developed with irrigation. In Burkina, the potential is lower, with 142,000 ha of potential irrigated area vs. 24,300 developed (Hussain et al., 2007). In addition, informal irrigation is sometimes 3 to 4 times the official data on irrigation area.

7.2. Lessons learned from research and development projects

The recognition of projects failures in the 80s gave rise to a number of recommendations on best practices in development projects that have become the norm today. Most of these recommendations are directed towards general project approaches and implementation, and therefore applicable to all kind of disciplines. In addition, lessons from AWM research and development projects generated the elements of a new global concept of water management, with some specific applications for the Volta Basin.

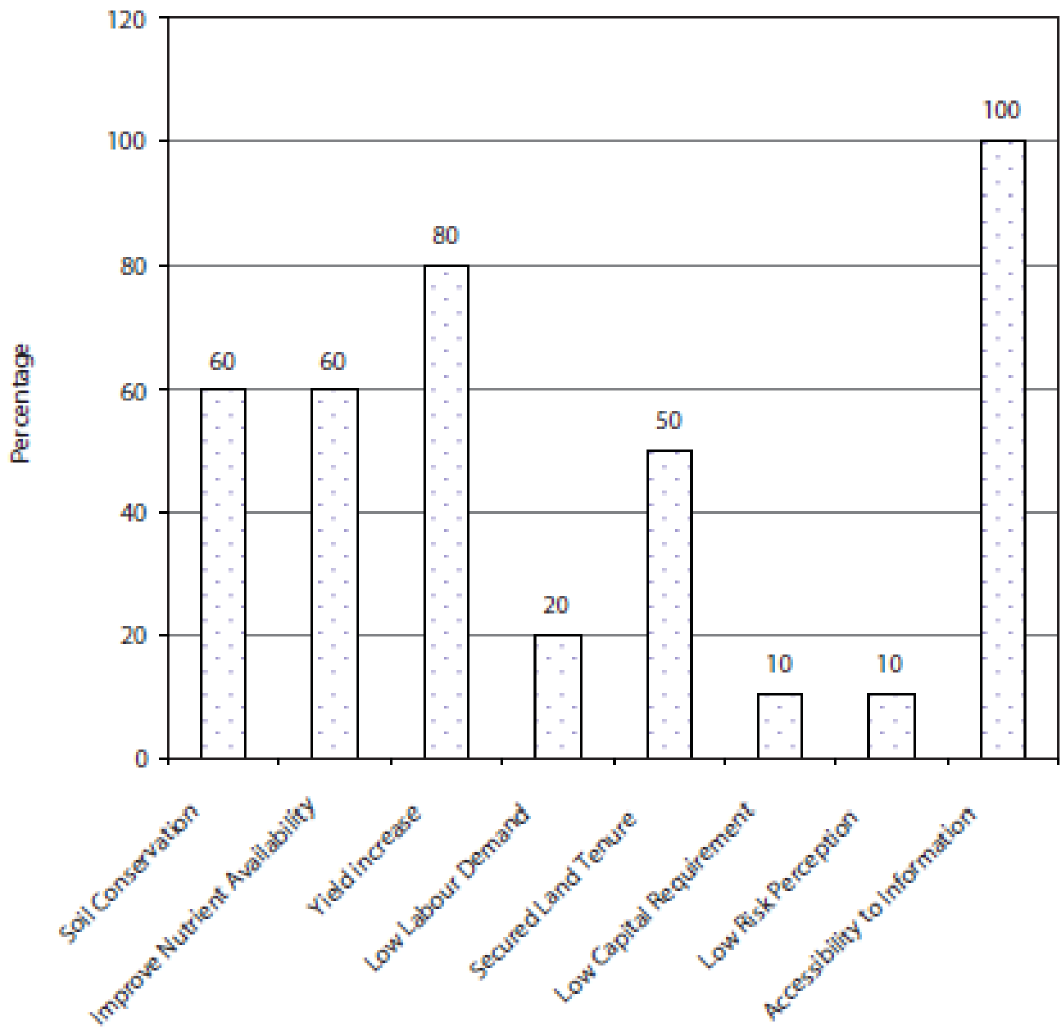
7.2.1. General project approaches

Best-practices in projects to help guaranteeing the sustainable impact on livelihoods were debated and proposed by various authors and organizations (Critchley et al., 1994; Schweigman 2003; Liniger and Critchley 2007; GTZ 1996). The initiative must fit into national or regional development agendas and priorities to ensure that stakeholders are interested and take ownership. Local knowledge and skills must be taken into account, and where necessary, national staff must be provided with appropriate capacity building elements. Farmers' preferences must be considered, and nowadays project funding is almost always conditioned to the inclusion of one form or another of participation, including gender. However, practically, it can sometimes be difficult to conciliate the outcomes of a participatory process with the predefined objectives of a project, which then leaves space for methodological improvements. Developers should approach farmers with a range of suggestions, rather than with one single best-fit option, and link up closely with national development programs.

7.2.2. Specific recommendations for AWM projects...

- ... on resources management
  In general, water management should always be combined with improved soil fertility management

Figure 8. Adoption drivers for agricultural water management (AWM) strategies in West Africa (Source: Drechsel et al., 2005).



practices, as well as improved cultivars to obtain significant yield increases and maximize benefits of better water management in the crop system, as soil fertility constraints often constitute the primary limiting factor to crop growth (Fox and Rockström 2000; Zougmoré et al., 2003a; Maatman et al., 1998). Interactions between water, crop and livestock management should be improved and combined with conservation agriculture (use of fences, nutrient recycling, plot rotations, dry season feed, etc.).

- ... on local capacities

  When promoting RMS, projects should carefully study the available information on factors triggering adoption, and use these to help guarantee the sustainable uptake of the technology. This would include gathering of information on current government incentives and measures with regard to the project topic. For example, in-situ RMS must be promoted in full knowledge of on-going land reforms. Local capacities have to be better taken into account when promoting RMS or low-cost irrigation technologies: no stone rows should be promoted where stones are not easily available, no mechanized systems where there is no well functioning microcredit system to sustain it, no irrigation for vegetables where there is no market, no low-cost irrigation technologies where there is no simultaneous development of supply chains (Abric et al., 2011), etc. While this type of recommendation will sound obvious for most actors in the sector, it is interesting to note that in practice people actually writing proposals may be sitting far away from project locations, with limited time and information, resulting in the development of disconnected plans of activities.

- ... on infrastructures management
  Although people start to speak about a "blue revolution" i.e. the development of small-scale irrigation systems for dry season production (IRIN 2011), this still need improvements in infrastructure management, beside the development of supply-chain for irrigation technologies. Participatory management of the infrastructures should be carefully studied and planned, through integration of maintenance costs in project budget, capacity building of actors towards assumption of more responsibility, and ways to deal with turnovers within management committees. Water productivity of small reservoirs could be improved through better irrigation water management and agronomic practices (Mdemu et al., 2009), or by simply maximizing the multiple benefits generated by small water storage in landscapes (Cecchi 2007).

- ... on capacity building
  Building the technical and financial capacity of farmers remains critical in various domains, as for example in the development of smallholder private irrigation (Abric et al., 2011). In another sense, since one of the consequences of climate change is to challenge agricultural production in water scarce areas, a particularly important investment sector is the capacity building of farmers to think ahead for several years, whereas the older generation did not have to worry for much more than the immediate season to come. Farmers' capacity building is definitely a key asset for enlightened risk management and constant adaptation to new and variable conditions. And still, when building capacities, farmers' own knowledge and traditions should never be overlooked (Francis and Carter 2001).

7.2.3. The new global concept of AWM

During the last 25 years, our theoretical work landscape has progressively included notions like managing variability, adapting technologies, allocating labor, using markets etc., causing significant shifts in the paradigms used to understand water scarce environments (Mortimore and Adams 2001). A detailed description of the elements of the new paradigm for AWM research is given by Merrey and Gebreselassie (2011). Briefly, it states that single-factor interventions may not by themselves lead to optimal outcomes, and that they have to be combined in a landscape approach, integrating not only various technologies but also institutions, policies, ecosystem services and socio-economic aspects. This is in line with the evolution in AWM concepts described in Section 4, where people, livelihood and natural resources are more and more taken as inter-related elements of a landscape.

7.3. Knowledge gaps and research topics

Technically, AWM strategies do not offer much scope for improvement. A whole catalogue of solutions is available, pushing the research questions further to topics like system integration, feasibility, impacts on livelihood, or political incentives. Based on the outcomes, lessons learned and on the new concept for AWM, the following knowledge gaps have been identified:

- Integrated management and system perspective
  There is a need for a system perspective, where the viability of AWM strategies is assessed within

the context of farming systems, and where they are seen as catalysts to improve and modernize them (Rockström 2000). The livestock component is often left aside in AWM strategies - and especially in SWC - research although it is a major component of farming systems, particularly in the Sahel. In this view, the interactions between the different components of the systems should be evaluated, reconciling water and nutrient management, as well as crop and livestock production, through detailed trade-off analyses when allocating a specific natural resource for one or the other element of the system. Efficiency in the use of these resources, including especially livestock water productivity, should be assessed for various environmental and livelihood conditions in order to provide adequate long-term management recommendations to farmers and extension agencies.

- Landscape approaches and ecosystem services
  From the new paradigm for AWM research, it is clear that water cycle and land management are inextricably linked (Bossio et al., 2010) and that large scale studies should assess the impact of AWM strategies on landscape functions (Vohland and Barry 2009). One step further, various authors recommended integrating land, water, crop and livestock management with livelihoods (Stroosnijder 2009; Roose and Rodriguez 1990; Lemoalle and de Condappa 2010), and include not only the interests of present farmers, but also the ones of other stakeholders, e.g. future farmers and downstream communities (de Graaff 1996). If an increase in water productivity results in reduced drainage in arid regions, then reduced groundwater recharge may influence the availability of drinking water (Gregory et al., 2000), or decrease the use of run-off collection for irrigation downstream (Rockström 2000). Still, there is inadequate knowledge on hydrological impacts and limits of up-scaling rainwater harvesting at a river basin scale (Ngigi 2003). In general, ecological landscape processes and trade-offs between ecosystem services derived from AWM strategies need to be better understood (Gordon et al., 2010).

- Economic aspects
  Mechanization of labor demanding practices may be promising (mechanized zaï or half-moons with Vallerani system), but need to be promoted jointly with appropriate micro-credit or renting systems as farmers would need to purchase or rent small equipments or machines. The economic viability of these mechanized techniques needs to be assessed.

  More investment should be targeted to market development studies (Lemoalle and de Condappa 2010).

- Climate change and risk management
  As stated above, AWM strategies' potential and impact with respect to future climate change must be assessed (Vohland and Barry 2009): What are the possible strategies for adaptation? How can male and female farmers manage risks and variability? How do they perceive risk? How much can unstable Sahelian ecosystems bear, and how can their resilience be increased? As proposed by Mortimore and Adams (2001), we need to search for a paradigm that is more sensitive to the internal adaptive resources of farming households, the constraints they face, their autonomous capabilities and the external forces acting upon them.

- Governance and adoption
  Implementation, adoption and upscaling of existing AWM strategies remains limited because of institutional, social, cultural and economic reasons (Lemoalle and de Condappa 2010). These reasons need to be better understood in order to ensure successful acquisition of AWM strategies by individuals. Decision-making processes and mental models in this sense offer many topics for further research.

- Development aid and impact assessment

  Passionate debates on the effectiveness of development aid are on-going (Tierney et al., 2011). Given the quantity of AWM projects implemented and the amount of investments made in the Volta over the past 40 years, the question of the return of aid investments on water availability, food security and livelihoods would be of particular interest. Indeed, evaluating impact is particularly critical in developing countries where resources are scarce and every dollar spent should aim to maximize its impact on poverty reduction (Baker 2000). Various approaches are available to monitor and assess the impact of investments in AWM, but there is still a need to combine them in multi-scale approaches, making use of common indicators and a variety of information sources including scientific data and local knowledge through participatory methods (Schwilch et al., 2011). Until now, these approaches have not been applied to AWM in the Volta Basin.

7.4. Effectiveness of projects and programs

Rigorous evaluation can be very powerful in assessing the appropriateness and effectiveness of projects and programs (Baker 2000). It allows detecting weaknesses in project design, reasons for delay, failure to reach the intended beneficiaries, and the extent of internal and external constraints. However, the best impact evaluation study will only be useful for future projects and programs if properly communicated. The importance of information management is more and more recognized (World Bank 2004), and could be improved through a series of factors, to be addressed at both institutional and individual levels.

- Communication

  Differences in priorities between international donors and government have been reported as problematic (Morardet et al., 2005). The lack of communication between current projects, between institutions, and even inside institutions is striking. Failure to communicate and document efficiently project results, failure to take into account recommendations from projects evaluations, failure to look for more information when writing up new projects often lead to repetitions of what had been previously done. It is interesting to note that reasons for project failures mentioned in the 1990s (Hudson 1991) are the same reasons cited for failures today. For example, the difficulties in finding stones for rows and the suitability of Andropogon for replacing them step by step was already mentioned in the 1980s, but today many projects still build exclusively on stone rows and face the same problems of lack of adoption due to stone scarcity.

  Although various databases gather information on AWM strategies, for example WOCAT, interactions between research and development actors should be improved through participative learning (Schweigman 2003).

- Coordination

  Despite institutional efforts for more coordination among donors and projects notably embodied in the Paris declaration of 2005 calling for direct budget support to governments (rather than project based support), the scene of rural development with AWM strategies is still characterized by a set of scattered projects and programs that are little related. It can happen that projects are funded by the same organism, implemented in the same region, but still are completely disconnected if not hampering each other's successful implementation (de Fraiture 2011, personal communication). It is not uncommon to see international and national organizations alike seeking funding from different donors to conduct the same activities on the ground. This might signal a tendency to devise truly integrated strategies but could also be seen as "double funding" and lack of accountability. Different institutions (sometimes funded by the same organism) may start at the same time in the same place with the same type of activity, leading to double and concurrent work, and a waste of resources.

- Collaboration and commitment
  For reporting reasons and attribution of outcomes to their activities, projects have a tendency to delineate their area of work and not to seek interactions with others in the same sector with the same objectives. For instance, in Burkina Faso, no less than 4 different projects are separately conducting baseline/literature reviews on past AWM initiatives in the country. This is partly due to challenges regarding the sharing of information and data, but it also stems from a willingness to secure one's activities and presence in the sector as well as due to the researcher's ambitions towards publication. Breaking the deadlock and achieving more sustainable impact require a change in donor and actor strategies and their acceptance of uncertainty as well as a less traceable link between their activities and outcomes in the field. There are also cases of absence of collaboration among local farmers' organizations undertaking similar projects in the same village. One of the main reasons may be that village organizations in sub-Saharan Africa are often seen as "ready for a project to come in" (Bernard et al., 2008). Further, this lack of interaction can also be explained because both local farmers organizations and outside partners are seeking some sort of 'exclusivity' (Donnelly-Roark et al., 2001). According to Schweigman (2003), it is not nature which is the main reason for the stagnation of food production in Africa but "the illusion of the exclusive actor".

8. Conclusion

In response to continuous changes in global drivers, institutional priorities, and needs of smallholders, AWM strategies have evolved over time, along with the concepts related to them. While different climatic and topographic characteristics have triggered a differential promotion of AWM strategies in the various agroecological zones of the Burkinabe and Ghanaian parts of the Volta Basin, adoption of AWM strategies was mainly due to the type of approach used by projects and programs. Along with the oscillating level of success of projects and programs, the approaches have been continuously adapted, in a dynamic way. From top-down approaches to participatory development, from focus on crop productivity to landscape approach, projects implemented today have not much in common with the projects of the past, and are expected to have much more sustainable impact.

The evolution of AWM in the Volta Basin yielded a number of lessons, ranging from recommendations on project design and implementation to new concepts and topics for AWM research. While numerous technical solutions have been developed and are available, adoption and adaptation of AWM strategies remains limited. Future research and development projects should concentrate on levering the factors limiting adoption and enhancing system productivity while ensuring healthy ecosystem services for long term sustainability. There is a need for a system-wide perspective, to improve water-crop-livestock interactions, to develop off-season cultivation options and market access, and to balance gender benefits. There is a need for a landscape perspective, to understand ecological landscape processes and trade-offs between ecosystem services derived from AWM strategies. There is a need for an institutional perspective, to facilitate management of AWM structures and to raise awareness. There is a need for a long-term perspective, to foresee the best strategies for adaptation to climate change and manage risk in the variable environment of the Volta Basin. Finally, there is a need for an impact perspective, with a continued assessment of actual benefits and effectiveness of large-scale international research for development programs.

References

Abric, S., M. Sonou, B. Augeard, F. Onimus, D. Durlin, A. Soumaila and F. Gadelle 2011. Lessons learned in the development of smallholder private irrigation for high-value crops in West Africa. Joint organizational Discussion Paper—issue 4, pp 76. Washington D.C.: World Bank.

AfDB 2010. Agricultural Water Management - An evaluation of the African Development Bank's assistance in Ghana and Mali. High Level Evaluations Division (OPEV.2).

Affholder, F. 1995. Effect of organic-matter input on the water-balance and yield of millet under tropical dryland condition. Field Crops Research 41 (2), 109-121.

Agyare, W.A., N. Kyei-Baffour, R. Ayariga, K.O. Gyasi, B. Barry and E. Ofori 2009. Irrigation options in the upper east region of Ghana. In: Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008, eds. E. Humphrey and R.S. Bayot; Colombo, Sri Lanka: The CGIAR Challenge Program on Water and Food (CPWF).

AidData 2010. Tracking development finance. http://www.aiddata.org/search/index. Last accessed: October 2011.

Ayantunde, A.A., J. de Leeuw, M.D. Turner and M. Said 2011. Challenges of assessing the sustainability of (agro)-pastoral systems. Livestock Science 139 (1-2), 30-43.

Ayuk, E.T. 1997. Adoption of agroforestry technology: The case of live hedges in the central plateau of Burkina Faso. Agricultural Systems 54 (2), 189-206.

Baker, J. 2000. Evaluating the impact of development projects on poverty : a handbook for practitioners. Washington D.C.: World Bank.

Barro, A., R. Zougmore and S.J.B. Taonda 2005. Mécanisation de la technique du zaï manuel en zone semi-aride. Cahiers Agricultures 14 (6), 549 -559.

Barry, B., A.O. Olaleye, R. Zougmore and D. Fatondji 2006. Assessment of indigenous rainwater harvesting and soil water conservation technologies in the Sudan and Sahelian ones of West Africa. Accra, Ghana: International Water Management Institute (IWMI).

Barry, B., A.O. Olaleye, R. Zougmoré and D. Fatondji 2008. Rainwater harvesting technologies in the Sahelian zone of West Africa and the potential for outscaling. IWMI Working Paper 126, pp 40. Colombo, Sri Lanka: International Water Management Institute (IWMI)

Batterbury, S. and A. Warren 2001. The African Sahel 25 years after the great drought: assessing progress and moving towards new agendas and approaches. Global Environmental Change-Human and Policy Dimensions 11 (1), 1-8.

Battisti, D.S. and R.L. Naylor 2009. Historical warnings of future food insecurity with unprecedented seasonal heat. Science 323 (5911), 240-244.

Bediako, J.A. 2009. Agricultural technology adoption successes and failures in Ghana and Kenya. In: Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008., eds. E. Humphrey and R.S. Bayot; Colombo, Sri Lanka: The CGIAR Challenge Program on Water and Food (CPWF).

Bernard, T., M.-H. Collion, P. Rondot, E. Sadoulet and A. De Janvry 2008. Do Village Organizations Make a Difference in African Rural Development? A Study for Senegal and Burkina Faso. World Development 36 (11), 2188-2204.

Bielders, C., K. Michels, E. Schlecht and F. Mahler 1995. Intérêt de la fumure organique et du paillage pour l'intensification de la production agricole sur terres dégradées. Colloque international sur l'intensification agricole au Sahel : mythe ou réalité ?, pp 40. Bamako, 28 Nov - 02 Dec 1995.

Bossio, D., K. Geheb and W. Critchley 2010. Managing water by managing land: Addressing land degradation to improve water productivity and rural livelihoods. Agricultural Water Management 97 (4), 536-542.

Botoni, E. and C. Reij 2009. La transformation silencieuse de l'environnement et des systèmes de production au Sahel : Impacts des investissements publics et privés dans la gestion des ressources naturelles. Amsterdam: Center for International Cooperation (CIP), Free University, and Ouagadougou: Comité permanent Inter-Etats de Lutte contre la Sécheresse dans Sahel (CILSS).

Breman, H., J.J.R. Groot and H. van Keulen 2001. Resource limitations in Sahelian agriculture. Global Environmental Change-Human and Policy Dimensions 11 (1), 59-68.

Brouwer, J. and J. Bouma 1997. Soil and crop growth variability in the Sahel: Highlights of research (1990-95). ICRISAT Sahelian Center, Information Bulletin No 49. Patancheru, Andra Pradesh: ICRISAT.
Carter, R.C. 1989. The development of small-scale irrigation in sub-Saharan Africa. Public administration and development 9, 543-555.

Cecchi, P. 2007. L'eau en partage - Les petits barrages en Côte d'Ivoire. Paris: Institut de recherche pour le développement (IRD).

Cecchi, P. 2008. Towards an Atlas of Lakes and Reservoirs in Burkina Faso. SRP Tool Kit Working Paper.

Clanet, J.C. 2008. Elevages et pastoralisme dans le bassin de la Volta. Volta Basin Focal Project Report No 11, pp 120. Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF).

Clavel, N., A. Barro, T. Belay, R. Lahmar and F. Maraux 2008. Changements techniques et dynamique d'innovation agricole en Afrique Sahelienne: le cas du Zaï mécanisé au Burkina Faso et de l'introduction d'une cactée en Ethiopie. Vertigo 8 (3).

CONAGESE 1999. Plan d'Action National de Lutte contre la Désertification. Ouagadougou, Burkina Faso.

Conedera, M., N. Bomio-Pacciorini, P. Bomio-Pacciorini, S. Sciacca, L. Grandi, A. Boureima and A.M. Vettraino 2010. Restoring degraded ecosystems in the Sahel Bois Et Forets Des Tropiques (304), 61-71.
Critchley, W.R.S., C. Reij and T.J. Willcocks 1994. Indigenous soil and water conservation - a review of the state of knowledge and prospects for building on traditions. Land Degradation and Rehabilitation 5 (4), 293-314.

d'Aquino, P. 1998. Sahelian agropastoral options and patterns in northern Burkina Faso. Cahiers Agricultures 7 (2), 93-103.

de Graaff, J. 1996. The price of soil erosion: an economic evaluation of soil conservation and watershed development. PhD thesis, Wageningen University.

Descheemaeker, K., T. Amede and A. Haileslassie 2010. Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa. Agricultural Water Management 97 (5), 579-586.

Diallo, M.A. and E. Vall 2010. Landscape changes and pastoral practices evolution in Western Burkina Faso. Rencontres Autour des Recherches sur les Ruminants 17, 175-178.

Donnelly-Roark, P., K. Ouédraogo and X. Ye 2001. Can local institutions reduce poverty? Rural decentralization in Burkina Faso. Policy Research Paper No. 2677. World Bank.

Drechsel, P., A.O. Olaleye, A. Adeoti, L. Thiombiano, B. Barry and K. Vohland 2005. Adoption driver and constraints of resource conservation technologies in Sub-Saharan Africa. pp 21. Available at http://www.lk.iwmi.org/africa/West/projects/Adoption%20Technology/Technology_Adoption.htm.
Due, J.M. 1969. What has happened to the Ghanaian State Farms? Illinois Agriculural Economics 9 (2), 25-35.

Dugué, P. 1989. Possibilités et limites de l'intensification des systèmes de cultures vivriers en zone Soudano-Sahelienne: le cas du Yatenga (Burkina Faso). Montpellier: DSA/CIRAD.

Dugué, P., E. Roose and L. Rodriguez 1993. L'aménagement de terroirs villageois et l'amélioration de la production agricole au Yatenga (Burkina Faso) - Une expérience de recherche-développement. Cah. ORSTOM, sér. Pédol. 28 (2), 385-402.

Eakin, H. 2005. Climate change and tropical agriculture: Implications for social vulnerability and food security. Climate Change and Global Food Security, 293-320.

Ellman, A. 1987. Technology-transfer in smallholder farming systems - A program of promotion in Africa and the South-Pacific. Agricultural Administration and Extension 25 (3), 143-160.

Ericksen, P.J., P.K. Thornton, A.M. Notenbaert, L. Cramer, P. Jones and M. Herrero 2011. Mapping hotspots of climate change and food insecurity in the global tropics. CCFAS Report no. 5. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Errath, C., J.-L. Somé, L. Rodriguez and Y. Véquaud 1989. Technique traditionnelle du zai associee aux diguettes anti-erosives. Exemple de restauration des sols au Yatenga. Filmstrip. FAO, Rome.

Fafchamps, M., C. Udry and K. Czukas 1998. Drought and saving in West Africa: are livestock a buffer stock? Journal of Development Economics 55 (2), 273-305.

Faltermeier, L. 2007. Adoption of water conservation and intensification technologies in the lowland rice production systems of Northern Ghana. MEIDE conference Maastricht, Netherlands, May 30- June1, 2007.

FAO 2011a. GLASOD maps, http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp. Rome.

FAO 2011b. http://faostat.fao.org/site/339/default.aspx. Last accessed: October 2011. Rome, Italy.
Fatondji, D., C. Martius, C.L. Bielders, P.L.G. Vlek, A. Bationo and B. Gerard 2006. Effect of planting technique and amendment type on pearl millet yield, nutrient uptake, and water use on degraded land in Niger. Nutrient Cycling In Agroecosystems 76 (2-3), 203-217.

Faulkner, J.W., T. Steenhuis, N.V. De Giesen, M. Andreini and J.R. Liebe 2008. Water use and productivity of two small reservoir irrigation schemes in Ghana's Upper East Region. Irrigation And Drainage 57 (2), 151-163.

Fischer, G., H. Van Velthuizen, E. Hizsnyik and D. Wiberg 2009. Potentially obtainable yields in the semi-arid tropics. Global Theme on Agroecosystems. Report no. 54. pp 68. Patancheru, Andrah Pradesh, India: ICRISAT.

Fosu, M. 2007. Effect of run off on sediment and nutrient transport at Tono, Ghana. PES Annual report. Tamale, Ghana: Savanna Agricultural Research Institute (SARI).

Fosu, M., S. Sawadogo-Kabore, A. Bationo, R. Tabo, S.S. Buah, R. Kanton, M. Bonzi, D. Fatondji, O. Hassane and A. Abdou 2008. Efficient rainwater harvesting and nutrient management for high crop productivity in Volta Basin. In: Fighting poverty through sustainable water use. Proceedings of the CGIAR Challemge Program on Water and Food, 2nd Internation Forum on Water and Food, Addis Abeba, Ethiopia, November 10-14, 2008., eds. E. Humphrey, et al.; CPWF, Colombo, Sri Lanka.

Fox, P. and J. Rockström 2000. Water-harvesting for supplementary irrigation of cereal crops to overcome intra-seasonal dry-spells in the Sahel. Physics And Chemistry Of The Earth Part B-Hydrology Oceans And Atmosphere 25 (3), 289-296.

Francis, C.A. and H.C. Carter 2001. Participatory education for sustainable agriculture: Everyone a teacher, everyone a learner. Journal of Sustainable Agriculture 18 (1), 71-83.

Girdner, J., V. Olorunsola, M. Froning and E. Hansen 1980. Ghanas agricultural food policy - Operation Feed Yourself. Food Policy 5 (1), 14-25.

Gordon, C. and J.A. Amatekpor 1999. The sustainable integrated development of the Volta Basin in Ghana. Accra: Volta Basin Research Project.

Gordon, L.J., C.M. Finlayson and M. Falkenmark 2010. Managing water in agriculture for food production and other ecosystem services. Agricultural Water Management 97 (4, Sp. Iss. SI).

Gregory, P.J., L.P. Simmonds and C.J. Pilbeam 2000. Soil type, climatic regime, and the response of water use efficiency to crop management. Agronomy Journal 92 (5), 814-820.

GTZ 1996. Project Cycle Management (PCM) and Objectives-Oriented Project Planning (ZOPP) - Guidelines.

Hanjra, M.A. and F. Gichuki 2008. Investments in agricultural water management for poverty reduction in Africa: Case studies of Limpopo, Nile, and Volta river basins. Natural Resources Forum 32 (3), 185-202.

Hatfield, J.L., T.J. Sauer and J.H. Prueger 2001. Managing soils to achieve greater water use efficiency: A review. Agronomy Journal 93 (2), 271-280.

Hauchart, V. 2007. Durabilité de l'agriculture en fonction des pratiques culturales actuelles et conseillées (Burkina Faso et Nord Ghana). Volta Basin Focal Project Report No 2, pp 109. Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF).

Hudson, N.W. 1991. A study of the reasons for success or failure of soil conservation projects. FAO soils bulletin 64. Rome: Food and Agriculture Organisation (FAO).

Hussain, I., F. Gichuki, M.A. Louw, W. Andah and M. Moustafa 2007. Agricultural water management pathways to breaking the poverty trap: Case studies of the Limpopo, Nile and Volta river basins. Irrigation And Drainage 56 (2), 277-288.

IFAD 2004. Burkina Faso - Programme spécial Conservation des eaux et des sols – agroforesterie (PS CES/AGF) Rapport d'évaluation intermédiaire. Rapport N°1471-BF. Rome: IFAD.

IFAD 2006a. Upper East Region Land Conservation and Smallholder Rehabilitation Project (LACOSREP) – Phase II Interim Evaluation. . Report No. 1757-GH. Rome: IFAD.

IFAD 2006b. Upper West Agricultural Development Project - Interim Evaluation Report No. 1758-GH. Rome: IFAD.

IFAD 2008. NRGP Design document. Report No. 1975. Rome: IFAD.

IFAD 2009. http://www.ruralpovertyportal.org/web/guest/country/statistics/tags/. Rome.

IRIN 2011. Burkina Faso: "Blue revolution" needed to boost dry-season harvest. http://www.irinnews.org/printreport.aspx?reportid=94223, date accessed: 21.11.2011.

Johnston, R. and M. McCartney 2010. Inventory of water storage types in the Blue Nile and Volta river basins. IWMI Working Papers 140, pp 48. Colombo: International Water Management Institute (IWMI)

Jouquet, P., S. Traoré, C. Choosai, C. Hartmann and D. Bignell 2011. Influence of termites on ecosystem functioning. Ecosystem services provided by termites. European Journal of Soil Biology, in press.

Kabore, D. and C. Reij 2004. The emergence and spreading of an improved traditional soil and water conservation practice in Burkina Faso. EPTD Discussion Paper No. 114. Washington: IFPRI.

Kasei, R., B. Diekkrueger and C. Leemhuis 2010. Drought frequency in the Volta Basin of West Africa. Sustainability Science 5 (1), 89-97.

Kazianga, H. and C. Udry 2006. Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. Journal of Development Economics 79 (2), 413-446.

Korodjouma, O., O. Badiori, A. Ayemou and S.P. Michel 2006. Long-term effect of ploughing, and organic matter input on soil moisture characteristics of a Ferric Lixisol in Burkina Faso. Soil & Tillage Research 88 (1-2), 217-224.

Kortenhorst, L.F., V.S.P.N. G. and L.H. Sprey 1989. Prospects and problems of irrigation development in Sahelian and sub-Saharan Africa. Irrigation and Drainage Systems 3, 13-45.

Koutou, M., A. Ouedraogo, H.B. Nacro and M. Lepage 2007. Déterminants de l'adoption du zaï forestier et perspectives de valorisation de la technique (province du Yatenga, Burkina Faso). Actes des JSIRAUF. Hanoi, 6-9 november 2007.

Labbé, O. 2007. Analyse institutionnelle de la gestion et des usages de l'eau en Afrique de l'ouest. Bassins du Niger et de la Volta. Volta Basin Focal Project Report No 8, pp 121. Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF).

Lahuec, J.P. and J.Y. Marchal 1979. Mobilité du peuplement Bissa et Mossi. Travaux et documents de l'ORSTOM n°103. Paris: ORSTOM.

Lamachère, J.-M. and G. Serpantié 1990. Valorisation agricole des eaux de ruissellement et lutte contre l'érosion sur champs cultivés en mil en zone soudano-sahélienne (Burkina Faso, région de Bidi). Journées scientifiques. Utilisation rationnelle de l'eau des petits bassins versants en zone aride. Ouagadougou: Aupelf-Uref.

Laube, W. 2009. Creative bureaucracy: Balancing power in irrigation administration in northern Ghana. ZEF Working Papers series 41. Bonn: Center for Development Research, University of Bonn.

Lautze, J., B. Barry and E. Youkhana 2008. Changing paradigms in volta basin water management: customary, national and transboundary. Water Policy 10 (6), 577-594.

Lawrence, P.C., J.H. Sanders and S. Ramaswamy 1999. The impact of agricultural and household technologies on women: a conceptual and quantitative analysis in Burkina Faso. Agricultural Economics 20 (3), 203-214.

Leemhuis, C., G. Jung, R. Kasei and J. Liebe 2009. The Volta Basin Water Allocation System: assessing the impact of small-scale reservoir development on the water resources of the Volta basin, West Africa. Adv. Geosci. 21, 57-62.

Lemoalle, J. 2007. Global trends in the Volta basin. Volta Basin Focal Project Report No 3, pp 26. Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF).

Lemoalle, J. and D. de Condappa 2010. Farming systems and food production in the Volta Basin. Water International 35 (5), 655-680.

Liebe, J., N. van de Giesen and M. Andreini 2005. Estimation of small reservoir storage capacities in a semi-arid environment - A case study in the Upper East Region of Ghana. Physics And Chemistry Of The Earth 30 (6-7), 448-454.

Liniger, H.P. and W. Critchley 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. World Overview of Conservation Approaches and Technologies. CTA, FAO, UNEP, CDE.

Lund, C. 2008. Small dams and fluid tenure. In: Local politics and the dynamics of property in Africa, 156-173. Cambridge University Press.

Maatman, A., H. Sawadogo, C. Schweigman and A. Ouedraogo 1998. Application of zai and rock bunds in the northwest region of Burkina Faso: Study of its impact on household level by using a stochastic linear programming model. Netherlands Journal Of Agricultural Science 46 (1), 123-136.

Mando, A. 1997. The impact of termites and mulch on the water balance of crusted Sahelian soil. Soil Technology 11 (2), 121-138.

Mando, A., L. Brussaard and L. Stroosnijder 1999. Termite- and mulch-mediated rehabilitation of vegetation on crusted soil in West Africa. Restoration Ecology 7 (1), 33-41.

Mando, A., D. Fatondji, R. Zougmore, L. Brussaard, C.L. Bielders and C. Martius 2006. Restoring soil fertility in semi-arid west Africa: Assessment of an indigenous technology. Biological Approaches To Sustainable Soil Systems 113, 391-399.

Marchal, J.Y. 1979. L' espace des technicians et celui des paysans; histoire d'un perimètre anti-érosif en Haute-Volta. In: Maîtrise de l'espace agraire et développement en Afrique tropicale, ed ORSTOM; 245-252. Paris.

Marchal, J.Y. 1986. Vingt ans de lutte antiérosive au nord du Burkina Faso. Cah. ORSTOM, sér. Pédol 22 (2), 173-180.

Mazzucato, V. and D. Niemeijer 2000. The cultural economy of soil and water conservation: Market principles and social networks in eastern Burkina Faso. Development and Change 31 (4), 831-855.

McMillan, D.E. 1995. Sahel visions: planned settlement and river blindness control in Burkina Faso. pp 223. Phoenix: University of Arizona Press.

McMillan, D.E., J.B. Nana and K. Sawadogo 1990. Settlement and development in river basin control zones: Case study Burkina Faso. WB Technical Paper No.200. Washington D.C.: World Bank

Mdemu, M.V., C. Rodgers, P.L.G. Vlek and J.J. Borgadi 2009. Water productivity (WP) in reservoir irrigated schemes in the upper east region (UER) of Ghana. Physics And Chemistry Of The Earth 34 (4-5), 324-328.

Merrey, D.J. and T. Gebreselassie 2011. Promoting improved rainwater and land management in the Blue Nile (Abay) basin of Ethiopia. NBDC Technical Report 1. Nairobi: International Livestock Research Institute (ILRI).

Mietton, M. 1986. Méthodes et efficacité de la lutte contre l'érosion hydrique au Burkina Faso. Cah. ORSTOM, sér. Pédol 22 (2), 181-196.

Molden, D., T. Oweis, P. Steduto, P. Bindraban, M.A. Hanjra and J. Kijne 2010. Improving agricultural water productivity: Between optimism and caution. Agricultural Water Management 97 (4), Sp. Iss.

Molden, D., T.Y. Oweis, P. Steduto, J.W. Kijne, M.A. Hanjra and P.S. Bindraban 2007. Pathways for increasing agricultural water productivity. In: Water for Food. Water for Life: A Comprehensive Assessment of WatervManagement in Agriculture, ed D. Molden; 279-310. London: Earthscan, and Colombo: International Water Management Institute (IWMI).

Morardet, S., D.J. Merrey, J. Seshoka and H. Sally 2005. Improving irrigation project planning and implementation processes in sub-Saharan Africa: Diagnosis and recommendations. pp 91. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Mortimore, M.J. and W.M. Adams 2001. Farmer adaptation, change and 'crisis' in the Sahel. Global Environmental Change-Human and Policy Dimensions 11 (1), 49-57.

Namara, R.E., L. Horowitz, S. Kolavalli, G. Kranjac-Berisavljevic, B.N. Dawuni and B. Barry 2010. Typology of irrigation systems in Ghana. IWMI Working Paper 142, pp 35. Colombo: International Water Management Institute (IWMI)

Neubert, S., E. Dick, F. Höllinger, R. Palm, G. Swamy and C. de Valon 2000. Analyse d'impact du projet de gestion des ressources naturelles PATECORE au Burkina Faso. Bonn: Deutsches Institut für Entwicklungspolitik (DIE).

Ngigi, S.N. 2003. What is the limit of up-scaling rainwater harvesting in a river basin? Physics and Chemistry of the Earth, Parts A/B/C 28 (20-27), 943.

Niasse, M. 2008. Analyse Institutionnelle. Volta Basin Focal Project Report No 15, pp 51. Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF).

Ofosu, E.A., P. van der Zaag, N.C. van de Giesen and S.N. Odai 2010. Productivity of irrigation technologies in the White Volta basin. Physics And Chemistry Of The Earth 35 (13-14), 706-716.

Ouedraogo, A. and H. Sawadogo 2000. Three models of extension by farmer innovators in Burkina Faso LEISA Magazine 16.2. (July 2000).

Ouedraogo, M., Y. Dembele and L. Some 2010. Farmer perceptions and adaptation options to rainfall change: Evidence from Burkina Faso. Sécheresse 21 (2), 87-96.

Pachpute, J.S., S.D. Tumbo, H. Sally and M.L. Mul 2009. Sustainability of Rainwater Harvesting Systems in Rural Catchment of Sub-Saharan Africa. Water Resources Management 23 (13), 2815-2839.

Painter, T.M. 1995. Sahel visions - Planned settlement and river-blindness control in Burkina Faso - McMillan, D.E. Human Ecology 23 (4), 510-517.

PATECORE 2004. Les expériences du PATECORE dans le Plateau Central au Burkina Faso - 17 années au côté des producteurs dans la lutte contre la désertification du Bam, de l'Oubritenga et du Kourweogo - Document de Capitalisation. pp 54. Bonn: GTZ - DED - KFW.

Payne, W.A. 1999. Shallow tillage with a traditional West African hoe to conserve soil water. Soil Science Society Of America Journal 63 (4), 972-976.

Peden, D., G. Taddesse and A. Haileslassie 2009. Livestock water productivity: implications for sub-Saharan Africa. Rangeland Journal 31 (2), 187-193.

Powell, J.M. and T.O. Williams 1995. An overview of mixed farming systems in Sub-Saharan Africa. In: Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa. Volume II: Technical papers. Conference Proceedings, eds. J.M. Powell, S. Fernandez-Rivera, T.O. Williams and C. Renard; 21-36. Addis Ababa: ILCA.

Quansah, C., P. Drechsel, B.B. Yirenkyi and S. Asante-Mensah 2001. Farmers' perceptions and management of soil organic matter - a case study from West Africa. Nutrient Cycling In Agroecosystems 61 (1-2), 205-213.

Reardon, T. and J.E. Taylor 1996. Agroclimatic shock, income inequality, and poverty: Evidence from Burkina Faso. World Development 24 (5), 901-914.

Reij, C. 1983. L'évolution de la lutte anti-érosive en Haute Volta depuis l' indépendance vers une plus grande participation de la population. Amsterdam: Institute of Environmental Studies, Free University.
Reij, C., M. Ouedraogo, A. Ouedraogo, D. Kabore, A. Belemvire and C. Zida 2001. Etude d'impact des actions de CES, d'agroforesterie et d'intensification agricole au Plateau Central, Burkina Faso. IFAD/ Vrije Universiteit Amsterdam.

Reij, C. and F. Pearce 2008. Can't see the desert for the trees. New Scientist 197 (2649), 42-43.

Reij, C., G. Tappan and A. Belemvire 2005. Changing land management practices and vegetation on the Central Plateau of Burkina Faso (1968-2002). Journal of Arid Environments 63 (3), 642-659.

Rochette, R.M. 1989. Le Sahel en lutte contre la désertification: leçons d'expériences. Eschborn: CILSS, PAC, GTZ

Rockström, J. 2000. Water resources management in smallholder farms in Eastern and Southern Africa: An overview. Physics And Chemistry Of The Earth Part B-Hydrology Oceans And Atmosphere 25 (3), 275-283.

Rockström, J., J. Barron and P. Fox 2002. Rainwater management for increased productivity among small-holder farmers in drought prone environments. Physics And Chemistry Of The Earth 27 (11-22), 949-959.

Rockström, J. and A. deRouw 1997. Water, nutrients and slope position in on-farm pearl millet cultivation in the Sahel. Plant And Soil 195 (2), 311-327.

Rodgers, C., N.V. de Giesen, W. Laube, P.L.G. Vlek and E. Youkhana 2007. The GLOWA Volta Project: A framework for water resources decision-making and scientific capacity building in a transnational West African Basin. Water Resources Management 21 (1), 295-313.

Roncoli, C., K. Ingram and P. Kirshen 2001. The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. Climate Research 19 (2), 119-132.

Roose, E. 1989. Diversité des stratégies traditionnelles et modernes de conservation de l'eau et des sols - influence du milieu physique et humain en région Soudano-Sahélienne d'Afrique Occidentale. Réseau zones arides - La diversité dans l'aridité. 31. ORSTOM

Roose, E. 1992. Diversité des stratégies de conservation de l'eau et des sols. In: L'aridité, une contrainte au développement, eds. E. Le Floc'h, M. Grouzis, A. Cornet and J.-C. Bille; Montpellier: ORSTOM, coll. Didactiques.

Roose, E., J. Albergel, G. De Noni, M. Sabir and A. Laouina 2008. Efficacité de la GCES en milieu semiaride. Paris: AUF, EAC et IRD.

Roose, E., V. Kabore and C. Guenat 1999. Zai practice: A west African traditional rehabilitation system for semiarid degraded lands, a case study in Burkina Faso. Arid Soil Research and Rehabilitation 13 (4), 343-355.

Roose, E. and L. Rodriguez 1990. Aménagement de terroirs au Yatenga. Quatre années de GCES : bilan et perspectives. Rapport CRPA - INERA - ClRAD - ORSTOM, pp 57. Montpellier.

Salako, F.K. and G. Tian 2003. Soil water depletion under various leguminous cover crops in the derived savanna of West Africa. Agriculture Ecosystems & Environment 100 (2-3), 173-180.

Sally, H., H. Lévite and J. Cour 2011. Local Water Management of Small Reservoirs: Lessons from Two Case Studies in Burkina Faso. Water alternatives 4 (3).

Savadogo, P., L. Sawadogo and D. Tiveau 2007. Effects of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna woodlands of Burkina Faso. Agriculture Ecosystems & Environment 118 (1-4), 80-92.

Savonnet, G. 1958. Méthodes employees par certaines populations de la Haute-Volta pour lutter contre I'érosion. Notes Africaines 78, 38-40.

Schweigman, C. 2003. Food security: opportunities and responsibilities, or: the illusion of the exclusive actor. CDS Research report No. 19 Groningen: University of Groningen, Centre for Development Studies.

Schwilch, G., B. Bestelmeyer, S. Bunning, W. Critchley, J. Herrick, K. Kellner, H.P. Liniger, F. Nachtergaele, C.J. Ritsema, B. Schuster, R. Tabo, G. van Lynden and M. Winslow 2011. Experiences in monitoring and assessment of sustainable land management Land Degradation & Development 22 (2), 214-225.

Sidibe, A. 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. Agricultural Water Management 71 (3), 211-224.

Slingerland, M.A. and V.E. Stork 2000. Determinants of the practice of Zai and mulching in North Burkina Faso. Journal of Sustainable Agriculture 16 (2), 53-76.

Steenberg, F., A. van Tuinhof and L. Knoop 2011. Transforming Lives Transforming Landscapes. The Business of Sustainable Water Buffer Management. Wageningen, The Netherlands: 3R Water Secretariat.

Stroosnijder, L. 2009. Modifying land management in order to improve efficiency of rainwater use in the African highlands. Soil & Tillage Research 103 (2), 247-256.

Sturdy, J.D., G.P.W. Jewitt and S.A. Lorentz 2008. Building an understanding of water use innovation adoption processes through farmer-driven experimentation. Physics And Chemistry Of The Earth 33 (8-13), 859-872.

Terrasson, I., M.J. Fisher, W. Andah and J. Lemoalle 2009. Yields and water productivity of rainfed grain crops in the Volta Basin, West Africa. Water International 34 (1), 104-118.

Thornton, P.K., R.L. Kruska, N. Henninger, P.M. Kristjanson, R.S. Reid, A.N. Atieno and T. Ndegwa 2002. Mapping poverty and livestock in the developing world. pp 124. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Tierney, M.J., D.L. Nielson, D.G. Hawkins, J. Timmons Roberts, M.G. Findley, R.M. Powers, B. Parks, S.E. Wilson and R.L. Hicks 2011. More dollars than sense: Refining our knowledge of development finance using AidData. World Development 39 (11), 1891-1906.

Vagen, T.G., R. Lal and B.R. Singh 2005. Soil carbon sequestration in sub-Saharan Africa: A review. Land Degradation & Development 16 (1), 53-71.

van de Giesen, N., J. Liebe and G. Jung 2010. Adapting to climate change in the Volta Basin, West Africa. Current Science 98 (8), 1033-1037.

van Driel, W.F. and J.C. Vlaar 1991. Impact des digues filtrantes sur le bilan hydrique et sur les rendements agricoles dans la région de Rissiam, Burkina Faso. In: Soil Water Balance in the Sudano-Sahelian Zone. Proceedings of the Int. Workshop, Niamey, Niger, eds. M.V.K. Sivakumar, J.S. Wallace, C. Renard and C. Giroux; Wallingford, UK: IAHS Press, Institute of Hydrology.

van Loon, E. and L. Stroosnijder 2000. A modelling strategy to design hedgerow barrier systems for water conservation in the Sahel. Physics And Chemistry Of The Earth Part B-Hydrology Oceans And Atmosphere 25 (3), 297-302.

Venot, J.P. 2011. What commons? Rethinking participation in the sub-Saharan African water sector. Paper presented at the 13th Biennial Conference of the International Association for the Study of the Commons (IASC). Hyderabad, India, 10-14 January, 2011.

Venot, J.P., M. Andreini and C.B. Pinkstaff 2011. Planning and corrupting water resources development: The case of small reservoirs in Ghana. Water alternatives 4 (3).

Visser, S.M., J.K. Leenders and M. Leeuwis 2003. Farmers' perceptions of erosion by wind and water in northern Burkina Faso. Land Degradation & Development 14 (1), 123-132.

Vohland, K. and B. Barry 2009. A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands. Agriculture Ecosystems & Environment 131 (3-4), 119-127.
Wani, S.P., J. Rockström and T.Y. Oweis 2009. Rainfed agriculture: Unlocking the potential. Wallingford, UK: CABI.

WorldBank 2004. What is development communication? http://go.worldbank.org/5CHGCEWM70. Washington D.C.: World Bank. Last accessed: January 2012.

Zongo, B.I.N., R. De Deken, P. Lefevre and E. Thys 2006. Decisional factors in the water resources management by the livestock keepers and the agro-pastoralist in a semi-arid zone of Burkina Faso. Tropicultura 24 (3), 147-152.

Zougmoré, R., D. Kabore and J. Lowenberg-DeBoer 2000. Optimal spacing of soil conservation barriers: Example of rock bunds in Burkina Faso. Agronomy Journal 92 (2), 361-368.

Zougmoré, R., A. Mando, J. Ringersma and L. Stroosnijder 2003a. Effect of combined water and nutrient management on runoff and sorghum yield in semiarid Burkina Faso. Soil Use and Management 19 (3), 257-264.

Zougmoré, R., A. Mando and L. Stroosnijder 2004. Effect of soil and water conservation and nutrient management on the soil-plant water balance in semi-arid Burkina Faso. Agricultural Water Management 65 (2), 103-120.

Zougmoré, R., Z. Zida and N.F. Kambou 2003b. Role of nutrient amendments in the success of half-moon soil and water conservation practice in semiarid Burkina Faso. Soil & Tillage Research 71 (2), 143-149.

Annexes

A1. The Volta Basin Development Challenge: Projects description

The Challenge Program on Water and Food (CPWF) was launched in 2002 as one of the reform initiatives of the Consultative Group on International Agricultural Research (CGIAR). Phase 1 ran from 2004–2008 and Phase 2 runs from 2009–2013. CPWF aims to increase the resilience of social and ecological systems through better water management for food production (crops, fisheries and livestock). CPWF operates an innovative research and development approach that brings together a broad range of scientists, development specialists, policy makers and communities, in six river basins, to address the challenges of food security, poverty and water scarcity (CPWF 2011). One of these river basins is the Volta.

The Volta Basin Development Challenge (VBDC) aims at "improving rainwater and small reservoir management to contribute to poverty reduction, and improved livelihoods resilience and people's well-being in the dry lands of Burkina Faso and Northern Ghana while taking account of implications for downstream water users including ecosystem services".
To achieve this, a set of five separate but interdependent research-for-development projects is being implemented:

- Project V1, "Targeting and scaling out", will develop a web-based decision-support tool that will identify likely sites to introduce AWM interventions for smallholder farming systems based on assessments of social, economic and biophysical conditions, and basin-scale water management realities. This project is led by the Stockholm Environment Institute (SEI), partners are the Institut National de l'Environnement et de Recherches Agricoles (INERA), the Kwame Nkrumah University of Science and Technology (KNUST), the Savanna Agricultural Research Institute (CSIR-SARI) and the University of Ouagadougou.

- Project V2 (which includes this paper), "Integrated management of rainwater for crop-livestock agroecosystems", will identify, evaluate, adapt, and disseminate best-fit integrated rainwater management strategies (RMS), comprising of technological solutions, directed at different domains of the agroecosystems, strengthened by enabling institutional and policy environments and linked to market incentives that can drive adoption. This project is led by the International Livestock Research Institute (ILRI) and the partners are: International Water Management Institute (IWMI), the Animal Research Institute (CSIR-ARI), INERA, the Netherlands Development Organisation (SNV), and Wageningen University (WUR).

- Project V3, "Management of small reservoirs", focuses on integrated management options at local scale for small reservoirs, in a multiple use context. These include perpetuating infrastructures, protecting and where necessary improving the water quality for the various uses; enhancing water productivity potentials; and seeking equity in generated benefits. This project is led by Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the partners are: INERA, the Water Research Institute (CSIR-WRI), CSIR-SARI, 2iE Foundation, SEI, and Delft University of Technology (TU Delft).

- Project V4, "Governance of rainwater and small reservoirs", will provide better understanding of the processes that govern integrated water management policy-making, practice and research in the basin and identify demand-driven opportunities for the management and the governance of rainwater and small reservoirs at the watershed (sub-basin) level. This will enhance impacts of on-going policy initiatives in the Volta basin. This project is led by IWMI, partners are CIRAD, CSIR-WRI, the Water Resources Commission-White Volta Basin Board (WRC-WVBB), the Secrétariat Permanent/ Plan d'Action pour le Gestion Intégrée des Ressources en Eau (SP-PAGIRE), and University of Development Studies (UDS).

- Project V5, “Coordination and enabling change”, will ensure coherence amongst the VBDC Projects and manage their interdependences such that the research is well integrated and aligned to stakeholders needs so as to contribute to poverty reduction and improved livelihood resilience in the Basin. This project is led by the Volta Basin Authority (VBA) and the partners are the Global Water Partnership (GWP), INERA and IWMI.

A2. Questionnaire for the key informants interview (S. Douxchamps and J.-P. Venot)

Aim: to get an idea of the evolution (since the 60s) and the actual trends in technical, institutional and political aspects of rainwater management for agricultural development in the Volta Basin (Burkina Faso and Northern Ghana).

Techniques considered :

- In situ: Zai, Half-moon, Stone rows, life barriers, contour bunds, mulching, tied ridging, etc.
- Combined with irrigation: small reservoirs, dugouts, dykes.

Note: Questions are cross-cutting and depending on the interviewee, queries start from the context or from the techniques.

Context: Agriculture and rainwater management in Burkina Faso/Ghana

- What is the importance of rainwater management in the context of agricultural development in Burkina Faso/Ghana? When are the first efforts in this area reported?
- Can you identify particular time periods during which efforts were important/limited? What were the causes for these changes, and why? What justifications where used?
- According to the time period, which practice/technique was privileged? Particularly, what was the relative importance given to the water aspect in relation to the soil fertility aspect?
- What are the central actors in the area? How did that evolve with time, i.e. did some actors disappear or emerge, and if yes, when and why?
- Are there mechanisms for coordination between NGO development projects and government actions? Is it documented? Are the results and impact of the projects reported somewhere?

Rainwater management techniques

- Which techniques were mainly promoted?
- How did these techniques start, by whom, where, how?
- How did these techniques evolve? What/who has pushed or slowed down their adoption?
- What impact did they have? What were their limits? What did not work?
- According to you, which of these techniques seems to have the best future? Why?

Initiatives and projects that promoted rainwater management for agricultural development

- What are the main initiatives/projects that promoted rainwater management?
- Which techniques were promoted by these projects, with whom, where, how and why?
- What was the impact of these projects? What were their limits? What did not work?
- Which political initiatives do you remember particularly? What were the reasons for their success or failure?

Documents

- Is there any documentation of this information, even partially?

Message

- What would be your take-home message regarding rainwater management for agriculture in Burkina Faso/Ghana?

Contacts

- Who else could you indicate us as key informant for these problematic?

A3. List of AWM projects carried on in Burkina Faso and in Ghana from 1970 (source: AidData, 2011)

Year of commitment	Donor	Umbrella / Financing agency + Cofinancer	Implementing agency	Investment (US$ constant)	Project title	Short description
BURKINA FASO						
1973	IDA	WB		7,756,757	Regional Drought Relieve	
1975	Canada	CIDA		629,448		Bambakari dam
1976	France	MAE		1,723,905		Bagre irrigation
1976	Canada	CIDA		46,045		Bambakari dam
1976	Netherlands	NIO/FMO		3,204,316		Dams
1976	France	MAE		175,366		Bagre irrigation
1976	EC	EDF		6,016,180		Irrigation
1977	AFDF	AFDB + Switzerland, WB (IDA)		17,258,503	Integrated Rural Development	To enable 46,500 small-scale farmers to increase their cotton and cereals production with the construction of a ginning factory, storage facilities and an irrigation system, and through the provision of an improved extension service.
1977	EC	EIB		16,862,076		Shore Protection
1977	Netherlands	NIO/FMO		2,083,612		Dams
1977	France	MAE		2,544,616		Dam for irrigation
1978	France	MAE		175,613		Sluice-Valve
1978	France	MAE		1,756,131		Irrigation
1978	France	MAE		2,926,885		Puits
1978	France	MAE		1,319,440		Volta Valley development
1978	France	MAE		3,129,426		Volta Valley development
1979	France	MAE		1,193,031		Volta River development
1979	France	MAE		3,266,897		Volta River development
1979	AFDF	AFDB		18,122,541	Water Control and Integrated Rural Development Project	The project is to control the water in the Thion and Kongny Sahel areas so as to provide water for human consumption and animal use. It would also provide water for irrigation. The project involves the construction of two earth dams one each at Thiou and Kongny to provide water supply, watering of livestock and irrigation of small areas downstream covering about 70 ha at Thiou and 120 ha at Kongny. A total of about 7,400 inhabitants and 35,000 heads of livestock in south locations would benefit from the water supply. About 380 families would each be allocated 0.50 ha of irrigated land for intensive cultivation.
1979	France	MAE		367,944		Drought control
1979	France	MAE		1,315,679		Drought control
1980	IDA	WB		13,583,738	Niena Dionkele Rice Development Project	The main objectives of this first four-year pilot phase will be to test key assumptions regarding future development of swamp areas, in order to convert swampland to more productive use.
1980	France	MAE		543,950		River development Study
1980	France	MAE		939,550		Dam study
1980	France	MAE		1,236,250		Dam repair
1980	France	MAE		296,700		Dams
1980	France	AFD		1,681,299		Volta Valley development
1980	France	AFD		4,668,079		Bagre irrigation pilot project
1981	France	MAE		418,311		Volta River development study
1982	France	MAE		86,886		Water ressources studies program
1982	France	AFD		3,801,279		Dam and sugar cane irrigation
1982	France	MAE		2,117,855		Bagre Dam studies
1982	EC	EDF		3,213,314		Dakiri dam
1982	France	MAE		418,141		Water ressources studies program
1983	France	MAE		408,336		Land rehabilitation
1983	Sweden	SIDA		481,432		Soil preservation
1983	France	MAE		176,945		Agricultural water study
1983	France	MAE		186,020		Agricultural water study
1983	EC	EDF		16,930,537		Hydro agricultural development, Douna Plain
1985	AFDF	AFDB		2,496,190	Feasibility Study for 35 Hydro-Agricultural Earth Dams	The feasibility study aims at identifying the potentials of the project area with a view to enhancing their rational exploitation. It involves carrying out socioeconomic and topographic surveys
1985	France	MAE		356,264		Land development and reclamation
1985	France	MAE		213,758		Irrigation
1986	France	MAE		712,219		Dams
1986	France	MAE		13,609		Dams
1986	BADEA	AFDB + AFDF, CCCE, Kuweit Fund		23,567,518	Bagre Dam (Hydroelectric & Agricultural Production)	Building of a 30m high earth-filled dam and a reservoir with a capacity of 1.7 billion cubic metres on the river Volta. Construction of a 16 MW hydroelectric power station. Providing an area of 2100 hectares for irrigated agriculture and 4200 hectares for rainfed agriculture. Achieving self sufficiency in food production by producing 55,000 tons of rice annually in the first phase and 90,000 in the second phase. Providing 28,000 seasonal and permanent agricultural job opportunities and resettle 9,250 families.
1987	OPEC	Kuwait Fund + SFD, BADEA		6,518,134	Bagre Dam	The aim of the project is to help alleviate the problem of food shortages in Burkina Faso by developing agricultural production in the Bagre region of the White Volta River Valley. The project will develop a total of 7,400 ha of land and is expected to yield 55000 tons of rice annually. In addition, a total of 4,425 ha of rain-fed land will also be reclaimed and is expected to yield 6,550 tons of vegetables and 4,800 tons of grain each year. The project includes: (i) construction of a dam, a reservoir, and two supply canals
1987	Italy	DGCS		51,462,765		Irrigation
1987	Japan	MOFA		4,256,107		Hydro-agriculture
1988	Netherlands	MFA		216,488		Land development and reclamation

1988	EC	EDF	3,614,526	Plaine Douna Aménagements hydro-agricoles	Hydro agricultural development, Douna Plain
1988	Netherlands	MFA	444,757		Dams
1989	OPEC	Kuwait Fund + SFD, BADEA	16,081,258	Bagre Dam	
1989	France	AFD	10,882,964		Dams
1989	France	AFD	8,706,371		Dams
1989	AFDF	AFDB + EEC, BOAD	65,736,021	Bagre Dam	The project aims at guaranteeing food self-sufficiency of farmers
1989	OPEC	Kuwait Fund + Burkina Faso	3,055,161	Regional Village and Pastoral Water Supply	The project aims at meeting the basic drinking water requirements of 220,000 people and their livestock in 332 villages in the Poni and Bougouriba regions, located in the south-west. It is part of the second phase of the regional water supply program launched by the CEAO. The project consists of: (i) construction of 306 dugwells with screens, protective walls, troughs and drainage
1989	OPEC	Kuwait Fund + SFD, BADEA, AFDB	16,081,258	Bagre Dam	
1989	AFDF	AFDB + BOAD	65,736,021	Bagre Dam	The project aims at guaranteeing food self-sufficiency of farmers
1989	Saudi Arabia	Kuwait Fund + BADEA, BOAD, OFID	18,886,475	Bajaria Dam	The project mainly aims at the construction of 30 meters high earthfill storage dam with related works and installations of necessary equipment on the Nakanbe River for the irrigation of 7,500 ha, production of about 16 MW of electric power and possible water supply to the capital. The irrigation will be limited in the first state to an area of 2,000 ha. The project consists of civil works for spillway, irrigation water intake, power station and construction of staff housing.
1989	Kuwait	Kuwait Fund + Burkina Faso, SFD, CCCE, BOAD	19,153,084	Bagre Dam Project for Agriculture and Power Generation	The aim of the Project is to increase food production, create new job opportunities and to increase farmers income and improve their standard of living, in addition to the participation of Bagre Generation Station in meeting the demand for electricity in the Capital Ouagadougou and surrounding areas. The Project consists of the construction of an earth dam on White Volta River, with a storage capacity of about 1.7 billion m3, and the construction of a 16 MEGW generation station, in addition to a transmission line, substations, irrigation and drainage works and field distribution networks, rain-fed land reform, and the provision of the necessary infrastructure in the Project area.
1989	Netherlands	MFA	168,924		Soil degradation control
1989	Netherlands	MFA	3,722,868		Irrigation project
1989	Netherlands	MFA	1,064,612		Irrigation
1990	AFDF	AFDB	4,573,498	Ministry of Water Resources Institutional Support for Irrigation Management Research Development (Grant)	The project seeks mainly to improve the performance of irrigation schemes by introducing appropriate management methods and techniques, and defining development methods that would make for optimum utilisation of available resources and ensure the long life of the irrigation facilities. Achievement of this objective would involve research development and training activities.
1990	Denmark	DANIDA	8,987,357		Erosion control
1990	Netherlands	MFA	407,384		Earth dam
1990	EC	EDF	526,875	Plaine Douna Aménagements hydro-agricoles	
1991	BADEA		3,512,273	Rural Water Supply	PROJECT - Digging 190 boreholes, in addition to engineering work which comprises platforms and reservoirs
1992	Japan	MOFA	5,628,271		Underground Water exploitation
1993	AFDF	AFDB	13,946,092	Rural Water Supply Project	The project's objectives are threefold: (i) to cover the drinking water supply needs of the inhabitants of the provinces of Bougouriba (south-western region), Comoe, Houet, Kenedougou (Haut-Bassins region) and Mouhoun (Mouhoun Belt region), by establishing 500 permanent equipped water points, capable of meeting the potable water requirements of nearly 250,000 persons by the year 1997, at the rate of 20 litres per person per day
1993	OPEC		4,588,028	Water Resources Development	The objective of the project is to clean and rehabilitate around 820 dug wells and 2,050 tube wells, including the masonry and concrete surface infrastructure, casings and water catchment systems. In addition, filtering systems will be installed. Over 200 old hand pumps will be repaired or replaced. I"early 80 new tube wells will be drilled to replace ones that have gone dry. The project area includes over 1,000 villages in six provinces, Bazega, Ganzourgou, Kadiogo, Naouri, Oubretinaga and Zoundweogo, and has a population of 1.5 million inhabitants and 1 million head of livestock. The project is expected to have positive effects not only on health conditions and water security, but also on agricultural productivity. When work on the wells is completed, less time and energy will have to be spent carrying water from distant wells. The project also aims to sensitize the population to the dangers of unsafe water and to introduce better water resource management practices.
1993	Italy	DGCS	399,582	Water and Soil Comservation Program	
1993	France	AFD	1,683,691	Bagré Dam	
1993	France	AFD	7,155,687	Bagré Dam	
1993	EC	EDF	83,755	Etude topographique périmètres irrigués	
1993	EC	EDF	2,791,837	Appui à l'aménagement hydro-agricole	
1993	EC	EDF	15,840	Aménagement hydro-agricole	
1993	EC	EDF	125,633	Etude pédologique périmètres irrigués	
1994	IFAD	UN + BOAD, UNICEF, Burkina Faso, Beneficiaries	20,368,866	Special Programme for Soil and Water Phase II	This seven-year IFAD-initiated intervention is a follow-up to a previous programme which was designed to restore the agricultural potential of the Central Plateau, an area which faces severe environmenta[degradation and population pressure with resulting food shortage. Based on the previous phase, the objective of Phase II is to consolidate activities initiated in four provinces and expand them to three additional provinces, with the aim of raising production, incomes and living standards of the rural population in the area, thereby reducing out-migration
1994	BADEA		4,337,534	Sono Agricultural Project in Sourou Area	Irrigation and reclamation of land

1994	France	AFD	Monastère de Koubri	20,928		Dam
1994	Belgium	AGCD	Oxfam	68,062	Conservation des eaux et des sols et agroforesterie	
1994	EC	EDF		1,037,202	Consolidation et mise en valeur	
1995	Canada	IDRC		41,163	Séminaire sur la désertification	
1996	Austria	BMA	ODE	325,710	Intergrierte Ressourcenbewirtschaft in der Region Boromo (PDIZB)	Integrated management of resources
1996	Belgium	AGCD		69,446	Conservation des eaux et des sols - Ouahigouya, Yatenga	
1996	Netherlands	MFA		97,638	Séminaire national sur la fertilité des sols	
1996	Canada	CIDA	MEE	201,187	Appui au processus d'élaboration du PAN	Desertification control
1996	Canada	IDRC		245,239	Désertification Programme d'Action	Désertification: élaboration du programme d'action
1996	Canada	IDRC + Burkina Faso		100,497	Désertification Programme d'Action	Désertification: élaboration du programme d'action
1997	AFDF	AFDB		2,200,362	Agricultural Development and Hydro Rehabilitation Study	The objective of the study is to evaluate the feasibility of irrigated agricultural development of the area. This will involve preparation of an improvement and development plan for a scheme of 2,000 ha of cultivated land situated in the northern part of the village, on the east bank of the Sourou River, in the Sourou Province. The study will be carried out in two phases. The first phase entails detailed review of all existing documents relating to the studies, and collection of additional data, to be used to prepare analytical review of agricultural development problems and a proposal of an action plan for each selected site. The second phase will focus on the preparation of feasibility studies on agricultural development projects for each site. The agricultural development program to be proposed under the studies would give consideration to projects which will increase the income of farmers
1997	Belgium	AGCD		56,708	Programme de conservation des sols - FNGN	
1997	Netherlands	MFA	Ambassade de Ouagadougou	192,482		Desertification control
1998	Italy	DGCS		5,860	1891/CISV/HVO	Water and soil conservation programme, through NGOs
1998	Austria	BMA	FNGN	299,088	Integrierte Ressoucenbewirtschaftung und Aufforstung Yatenga und Sourou Zondoma - GENYSZ	
1998	Belgium	AGCD		55,300	Programme de conservation des sols - FNGN	
1999	IDA	WB	Ministère de l'Agriculture/APIPAC	5,374,790	Pilot Private Irrigation Development Project	The Pilot Private Irrigation Development Project seeks to test and evaluate an approach for the provision of demand-driven support services necessary to develop an efficient, sustainable small irrigation sub-sector in Burkina Faso. There are four project components. 1) The first component will finance the project technical executing agency and its capacity building. 2) The second component will promote new technologies through on-farm and off-farm support services including technical feasibility studies for micro irrigation and related investments. This component focuses on providing target beneficiaries (small irrigation farmers, private operators involved in the marketing and processing of irrigation products, and providers of farm inputs and services to irrigation activities) support services aimed at increasing their incomes and employment. 3) The third component will help the target beneficiaries establish a record in the formal credit system, thereby gaining access in the future to the formal banking sector. 4) The fourth component will support the establishment of a strong monitoring and evaluation capacity. 5) The fifth component will set up a financial coordination unit, which is
1999	Canada	IDRC		26,844	Gestion des usages conflictuels de l'eau dans le bassin du Nakambé	
1999	UNDP	UN		230	Eau et développement régional	
1999	Italy	DGCS		915	1891/CISV/HVO	Water and soil conservation programme, volunteers and cooperants
1999	Austria	BMA	FNGN	332,936	Integrierte Ressoucenbewirtschaftung und Aufforstung Yatenga und Sourou Zondoma - GENYSZ	
1999	France	AFD		6,277,674	Barrage de Ziga	
1999	Belgium	AGCD	Oxfam	99,098	Conservation des eaux et des sols et agroforesterie	
1999	Germany	GTZ		563,062	Integrated rural development	
1999	Germany	GTZ		2,533,780	Programme Sahel-Burkinabe (PSB)	
1999	Germany	GTZ		2,252,249	Agricultural Development, Poni and Noum Porvinces	
1999	Italy	DGCS		276,988	Land reclamation and improvement of agricultural production in Passore Province (2421/CISV/HVO)	

1999	Canada	IDRC		78,973	Participatory communication to support community action against desertification in the Sahel	
2000	Austria	BMA	FNGN, AIUO	263,622	Sustainable natural resources management in South West Burkina Faso	
2000	Belgium	DGCD	Oxfam	35,182	Conservation des eaux et des sols et agroforesterie	
2000	Belgium	DGCD		67,851	Vulgarisation de la technique du zaï pour réhabiliter les sols	
2000	Denmark	DANIDA	FKN	429,896	Prévention de la désertification	Soil, water and agroforestry conservation works.
2000	France	AFD		3,409,824		Low land developpement
2000	Germany	Found		163,643		Agricultural land resources
2000	Italy	DGCS		8,868	1891/CISV/HVO Soil and water conservation Program	
2000	United Kingdom	DFID		106,876	Water resources JFS 1535	To improve the management capabilities of waterpoint committees.
2000	Italy	DGCS		107,235	Land reclamation and improvement of agricultural production in Passore Province (2421/CISV/HVO)	
2000	EC	CEC		217,432	PVD/2000/291	Agricultural land ressources
2000	Germany	Found		186,354		Agricultural water resources
2000	EC	CEC		278,648	PVD/2000/196 Programme hydro-agricole de Zogoungou en appui à l'union Naam de Gomponsom Province du Passore	
2001	Belgium	DGCD	ONG	36,830	Vulgarisation de la technique du zaï pour réhabiliter les sols	
2001	Belgium	DGCD	Oxfam/FBS	219,166	Conservation des Eaux et des Sols - Gestion des ressources	
2001	Germany	KFW	Ministère de l'économie et des finances	890,455	Transport services in Bam region phase II	Provision of transport services for erosion protecting measures
2001	Germany	GTZ		2,048,062	Ressourcenerhaltende Bewirtschaftung auf dem Zentralplateau (ALT: 1994.2002.7)	Resources management in the Central Plateau
2001	Germany	GTZ		1,780,928	Agricultural developpement, Poni and Noumb provinces	
2001	Italy	DGCS		78,362	Land reclamation and improvement of agricultural production in Passore Province (2421/CISV/HVO)	
2001	Netherlands	MFA	MEE	128,878	Land use study Central Plateau	Comparison of land use and environmental impact of measures and projects/programs of land developpement between 1980 and
2001	Germany	GTZ		1,780,928	Small farms irrigation program	
2002	AFDF	AFDB + Burkina Faso		13,013,304	Small Dams Rehabilitation Project	Sustain improvement of agriculture production by the rehabilitation of 40 dams and protection of 2,150 ha of associated perimeters, and the construction of additional infrastructure. The project will be implemented over a period of 6 years and will be financed by the ADF and the Government of Burkina Faso. The ADF contribution represents 88.0 percent of the total project cost.
2002	Belgium	DGCD	ONG	82,929	Vulgarisation de la technique du zaï pour réhabiliter les sols	
2002	Italy	DGCS		6,722	Land reclamation and improvement of agricultural production in Passore Province (2421/CISV/HVO)	
2002	Netherlands	MFA	Direction générale de coopération internationale	36,985	Mid Term evaluation review Fasepe	results evaluation and reorientation of the FASEPE project (RF013505) (2002-2004)
2002	Belgium	DGCD	FBS/ Iles de Paix	437,780	Agropastoral development Yamba	
2002	Germany	Found		76,677		Government contributions via NGOs
2002	Netherlands	MFA	IWMI	483,516	Comprehensive Assessment of Water Management in Agriculture	
2002	Korea			3,228	Irrigation Development and Water Management	Invitation of Trainees

2003	Kuwait			3,638,174	Small Irrigation Development Project	The Project aims at strengthening food security, improving living standards and reducing poverty of the population in different rural areas of the country through rehabilitation and construction of dug wells and small cofferdams to irrigate small farms. Construction and/or rehabilitation of about 210 small water schemes and ancillaries for small farms irrigation of about 1000 ha at different areas of the country.
2003	Belgium	DGCD	ONG	8,578	Vulgarisation de la technique du zaï pour réhabiliter les sols	
2003	Belgium	DGCD	Iles de Paix	292,783	Agropastoral development Yamba	
2003	Germany	Found		243,193		Government contributions via NGOs
2004	Germany	BMZ		513,047	Weiterführung des wasser und Landbewirtschaftungsprogramms in Ouahigouya	Agricultural land ressources
2004	Germany	BMZ		90,604	Förderung des Kleinbauerlichen Bewasserungslandwirtschaft in Koudougou	Agricultural land ressources
2004	Japan	JICA		21,717		
2004	Germany	GTZ		35,256	Stone rows in the South West (ALT: 8920951)	Agricultural water resources
2004	Sweden	Sida	Country public administration	2,097,186	Support to PAGIRE	PAGIRE - Plan d'action pour la gestion intégrée des ressources en eau
2004	Italy	LA		8,356	Contribution for wells in Burkina Faso villages	
2005	Germany	BMZ	NGOs and civil society	482,174	Fortsetzung der Förderung des Kleinbauerlichen Bewasserungslandwirtschaft in Koudougou	Agricultural land ressources
2005	Belgium	DGCD	AMB	85,636	Hydraulique villageaoise et culture maraîchaire	
2005	Belgium	DGCD		63,527		Contruction of 2 small reservoirs
2005	Belgium	DGCD		18,720		Valorisation of 2 small reservoirs
2005	Belgium	DGCD	EMESEA	42,061	Hydraulique villageoise et culture maraîchaire	
2005	Germany	KFW	Public sector	4,164,228	Low land developement	
2005	Netherlands	MFA	MEFBF	6,027,159	OUA PDRD FDL EAU 2005	Water investments 2005-2006
2005	Germany	GTZ	Public sector	12,646	PEBASO	PEBASO
2006	Kuwait			10,641,899	Samendeni Dam for Agricultural Development Project	The Project aims at developing the agricultural production by irrigation of 1500 ha, through the construction of a dam at the source of the upper Mouhoun River, with an ultimate goal of about 23000 ha. Construction of a 2,9 km long, 24,9 m high zoned earth dam across the Mouhoun river with a reservoir capacity of about 1050 million m3
2006	Germany	BMZ	NGOs and civil society	589,674	Integrated support to protect agricultural land resources	
2006	Luxembourg	MFA	ASTM	13,412	Accord-Cadre ASTM 2005-2009	Agricultural land resources
2006	Luxembourg	MFA	ASTM	1,135	Accord-Cadre ASTM 2005-2009	Agricultural land resources
2006	Belgium	DGCD	NGO DBA	18,312		Valorisation of 2 small reservoirs
2006	Belgium	DGCD	NGO DBA	62,151		Contruction of 2 small reservoirs
2006	Japan	MAFF		1,076,437		
2006	Japan	JICA		27,122		
2006	Japan	JICA		10,993		
2006	Austria	Reg	VEZ	16,082		Rehabilitation of an embankment dam in Toolo
2006	Belgium	DGCD	NGO Iles de Paix	107,213	Agropastoral development Yamba	
2006	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	41,148	AMB - Hydraulique villageoise et culture maraîchaire	
2006	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	83,787	EMESA - Hydraulique villageoise et culture maraîchaire	
2006	Germany	BMZ	NGOs and civil society	268,029	Watershed development in rural areas, Diocese Fada N'Gorma	
2006	Germany	BMZ	NGOs and civil society	396,692		Further support for water management programs of the Catholic Church of Burkina Faso
2006	Germany	BMZ	NGOs and civil society	686,161	Watershed development for rural communities, Diocese Fada N'Gourma	
2006	Luxembourg	MFA	Fondation Chreschte Mam Sahel	20,570	AC CMS 2005	Ministry participation - Agricultural water resources
2006	Luxembourg	MFA	Fondation Chreschte Mam Sahel	3,327	AC CMS 2006	Ministry participation - Agricultural water resources

2006	Luxembourg	MFA	Fondation Chreschte Mam Sahel	44,686	AC CMS 2007	Ministry participation - Agricultural water resources
2006	Luxembourg	MFA	Fondation Chreschte Mam Sahel	25,998	AC CMS 2008	Ministry participation - Agricultural water resources
2006	Luxembourg	MFA	Fondation Chreschte Mam Sahel	30,444	AC CMS 2009	Ministry participation - Agricultural water resources
2006	Luxembourg	MFA	Frères des Hommes ASBL	12,866	Accord - Cadre 2005-2008 - Frères des Hommes A.S.B.L.	Agricultural Water resources
2006	Luxembourg	MFA	Frères des Hommes ASBL	13,265	Accord - Cadre 2005-2008 - Frères des Hommes A.S.B.L.	Agricultural Water resources
2007	IFAD	UN + IFAD, OFID, Beneficiaries, Burkina Faso		9,135,631	Small-scale Irrigation and Water Management Project	The project will help 20,000 poor rural households intensify and diversify their agricultural production. It will support new and newly refurbished small-scale irrigation schemes, including innovative micro-irrigation technologies. The project will promote local negotiation processes to enhance participantsâ€™ access to land and water. It will also support marketing activities.
2007	Luxembourg	MFA	ASTM	1,296	Accord-cadre ASTM 2005-2009	
2007	Luxembourg	MFA	ASTM	11,663	Accord-cadre ASTM 2005-2009	
2007	Austria	Reg	CARITAS Innsbruck	51,161	Construction of an agricultural water reservoir	
2007	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	32,579	EMESA - Hydraulique villageoise et culture maraîchaire	
2007	Belgium	DGCD	NGO Iles de Paix	123,241	Agropastoral development Yamba	
2007	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	101,974	AMB - Hydraulique villageoise et culture maraîchaire	
2007	Germany	BMZ	NGOs and civil society	575,276	Integrated support for sustainable care of hydraulic structures and soil improvement	Integrated support for sustainable care of hydraulic structures and soil improvement
2007	Spain	MFA	FAO	958,298	Water in Africa	To improve the food and nutrition situation of the population and reduce poverty in rural areas while increasing and diversifying agricultural production through the dissemination and application of improved techniques and economically viable management and use of water. Specifically: To improve the control of river water, to strenghten national capacities in the field of small-scale irrigation production agricultural water infrastructure management and the management of natural resources.
2007	Korea			8,105	Groundwater Resources Development and Management for ASEAN Member Countries	Invitation of Trainees
2008	Germany	BMZ	National NGOs	442,989	Agricultural water ressources and environment protection at Nouna and Dedougou	
2008	Italy	LA		36,916	Contrast the desertification using jatropha curcas	Project to contrast the desertification through the cultivation of jatropha curcas in the municipality of Dori using new technologies
2008	Luxembourg	MFA	National NGOs	32,934	AMB - Construction of small dams in the Koudougou region	
2008	France	MISC		20,137	Research - Protection of water resources	
2008	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	77,500	AMB - Hydraulique villageoise et culture maraîchaire	
2008	Belgium	DGCD	NGO Sos Layettes Solidarité et Développement	62,092	EMESEA - Hydraulique villageoise et culture maraîchaire	
2008	Germany	BMZ	KfW	6,921,705	Low land developement - phase II	
2008	Germany	BMZ	National NGOs	246,874	Groundwater exploitation for agricultural use for small farmer self-help groups, Diocese of Koudougou	
2008	Spain	MUNIC		23,072		Aggregated information - municipalities
2008	United States	MCC		3,070,319	Agriculture Project (Compact Activity) for Water Management and Irrigation Activity.	

GHANA

1977	EC	EIB		10,133,459		Irrigation
1979	Australia	AusAID		34,468		Irrigation equipment

1980	EC	EDF		4,873,886		Irigation, Weija
1983	EC	EDF		346,306		Irrigation rehabilitation
1983	EC	EDF		894,240		Irigation, Weija
1983	AFDF	AFDB		2,896,141	Kpong Irrigation Study Project	The study involves identification, design and scheduling of construction of the elements of the irrigation and drainage system and other associated engineering facilities in the farming complex including the social and physical infrastructures. It also incorporates the determination of engineering quantities and associated costs, preparation of guidelines for the eventual operation, management of the irrigation system, provision of tender documents for the construction works, and management consultancy required for establishing the agricultural output of the project.
1990	IFAD	UN		16,469,013	Upper-East Region Land Conservation and Smallholder Rehabilitation	The goal of this seven-year, [FAD-initiated project is to raise the incomes of farming families in the impoverished Upper-East Region of Ghana and to stem the environmental degradation to which the region is prone. The predominantly rural population, with a per capita income of less than US$ 110, is afflicted by high child mortality rates, inadequate health facilities, [ow levels of education and poor inherent soil fertility, which is further exhausted by drought and erosion. The target group comprises 70000 beneficiary families averaging seven persons, each fami[y cultivating an average of 2.5 ha. Twenty percent of this group are households headed by women and one of the prime objectives of the project is to improve the economic status of women beneficiaries through the provIsion of credit and support for income-generating activities. To increase food pmduction and the incomes offami[ies living be[owthe poverty line, mechanisms for environmental protection will be established, as will formal and informal beneficiary organizations to provide technical and social services to smallho[ders on a sustainable basis. The princlpa[components are: (i) agricultural development
1990	BADEA			10,540,168	Kpong Irrigation	Project Components The project consists of tbe following : - rehabilitation and reclamation of about 3220 hectares of cultivable land for growing rice on the right bank of river Volta behind Kpong dam
1990	AFDF	AFDB + BADEA		51,526,829	Kpong Irrigation	The aim of the projectisto increase food produc-tion under sustainable rice-based cultivation systems.Itconsists of the provision of gravity irrigation sup-pliesfrom the existing Kpong reservoir, and the reha-bilitation of the existing irrigation system with a view to the cultivation of paddy rice by smallholder ricefarmers
1990	IFAD	UN		16,469,013	Upper-East Region Land Conservation and Smallholder Rehabilitation	The goal of this seven-year, [FAD-initiated project is to raise the incomes of farming families in the impoverished Upper-East Region of Ghana and to stem the environmental degradation to which the region is prone. The predominantly rural population, with a per capita income of less than US$ 110, is afflicted by high child mortality rates, inadequate health facilities, [ow levels of education and poor inherent soil fertility, which is further exhausted by drought and erosion. The target group comprises 70000 beneficiary families averaging seven persons, each fami[y cultivating an average of 2.5 ha. Twenty percent of this group are households headed by women and one of the prime objectives of the project is to improve the economic status of women beneficiaries through the provIsion of credit and support for income-generating activities. To increase food pmduction and the incomes offami[ies living be[owthe poverty line, mechanisms for environmental protection will be established, as will formal and informal beneficiary organizations to provide technical and social services to smallho[ders on a sustainable basis. The princlpa[components are: (i) agricultural development
1991	EC	EDF		82,282	Weija irrigation project diagnostic	
1992	EC	EDF		3,733	Weija irrigation project diagnostic	
1992	AFDF	AFDB		3,375,267	Feasibility Study of Small-Scale Irrigation Projects (Grant)	The study aims at supporting the efforts of the Ghanaian Government in its quest to attain food self-sufficiency, especially in cereals production. The principle objective is to prepare general feasibility studies on a series of small-scale irrigation sub-projects in the southern regions (Ashanti, Brong Ahafo, Central, Volta, Eastern, Western, Upper Accra), and on another series of small-scale water conservation sub-projects in the country's northern regions (Northern, Far Western and Far Eastern). The ADF/TAF grant will be used in financing the entire foreign exchange cost of the study.
1995	IFAD	UN + Beneficiaries		11,367,008	Upper West Agricultural Development Project	The Upper West Region is one of the poorest regions of Ghana and this seven-year IFAD-initiated project will lead to an increased level of food security for smallholders on a sustainable basis. Its immediate objectives are to boost agricultural (crop and livestock) production and promote non-farm income-generating activities. The corresponding strategy would consist of: (i) raising food production and incomes of the population living in poverty
1995	Denmark	DANIDA	MOFA	4,153,752		Land and water resources development
1995	OPEC	Kuwait Fund + BADEA, Ghana		6,779,528	Korle Lagoon Ecological Restoration	The loan will help finance improvements in environmental health conditions in an ecologically sensitive area in the capital Accra. Plans call for dredging the Korle Lagoon and Odaw River and landscaping the surrounding area, which is designated as park land. Korle Lagoon is the principal drainage basin into which the greater portion of the floodwaters of the capital flow before entering the sea. The lagoon receives discharges from a number of rivers and has consequently become heavily polluted and silted, creating a serious health hazard for nearby residents, particularly during flooding. The project aims at removing all vegetation on the surface of the lagoon and obstructions in the areas to be dredged. The drainage work will include the establishment of two new treatment stations for waste water from the residential and commercial areas to the north of the lagoon.
1996	United States	EXIM			Water pumps, drilling rigs and accessories	
1997	AFDF	AFDB + Ghana, NGOs, WFP		21,714,098	Small-scale Irrigation Development Project	The objective of the project is to contribute to improved food security in the country. It will also seek to improve nutrition, boost farmers' incomes, reduce food imports through increased agricultural outputs, and contribute to increased employment opportunities. The project will expand irrigable land in Ghana by developing 15 small-scale irrigation schemes, covering 2,142 ha. In addition, 4 water conservation schemes of 359 ha and 12 micro schemes of 89 ha will be constructed. Cropping intensity will thereby increase by 200 per cent and crop production by 16,000 tons per year. The project will provide farmers with the opportunity to adopt improved farming practices. Since the crops commonly grown under irrigation are rice and vegetables, irrigation developments would also boost women's earnings, through direct sales of vegetables and by increased opportunities for processing. The project will also ensure that women participate in all the activities by providing them with training, organizational support and credit facilities. Measures have been taken to enhance the environmental sustainability of the project through the setting up of irrigation farmers associations. These
1998	Japan	MOFA	MOFA	6,165,939	Rehabilitation of irrigation facilities	

1998	IFC	WB		528,221	Plantation Resources Limited will rehabilitate and modernize 3 coffee plantations acquired through privatization. Plans include a new irrigation system. This project will transfer coffee management know-how and generate foreign exchange (AEF).	
1999	Germany	GTZ		1,689,187	KV-Wasserversorgung in der Volta und Eastern Regionen	
1999	IFAD	UN + IFAD, Ghana, Beneficiaries, NGOs		11,886,555	Upper-East Region Land Conservation and Smallholder Rehabilitation Project â€“ Phase II	This five-year IFAD-initiated project is designed to extend the benefits of dam rehabilitation and strengthen the capacity of WUAs, improve access of women to land and build on existing credit experience to improve household food security. As part of its objectives for this second phase, the project seeks to: â€¢ resolve technical issues relating to irrigated agriculture and crop production
2000	Denmark	DANIDA	MOFA	1,458,952	Soil and Water resources: locations vulnerable to erosion	The objective is to improve conditions of cultivating on locations vulnevable to erosion.
2000	Germany	Found		193,187		
2000	BADEA			9,500,000	Small Farms Irrigation Project (Phase II)	Objectives of the Project: The project aims at supporting the Government's objectives in the agricultural sector to increase the agricultural intensity by using water resources to expand the agricultural area for food crops and ensure food security, improvement of nutrition standards in addition to enhancing the production of cash crops. The project aims also at creating employment opportunities and saving a large portion of foreign currency through the reduction of food imports. Description of the Project: The project involves the civil works for the irrigation and drainage networks, supply of equipment for different irrigation methods, farmers support services in the field of training and agricultural information, establishment and support of the project implementation unit in addition to the consultancy services.
2001	IFAD	UN + Ghana, Beneficiaries, NGOs		11,959,684	Northern Region Poverty Reduction Programme	The goal of this six-year, IFAD-initiated programme is to improve the livelihoods of rural poor communities, with emphasis on women and other vulnerable groups, by improving rural development services and community and individual self-help capacities. Specific objectives are to: (i) build the capacity of decentralized local government, civil-society and community organizations to better respond to the needs of the poorest strata of the rural population
2002	France	MAE		7,911	Agriculture and food security	
2002	Netherlands	MFA	IWMI	483,516	Comprehensive Assessment of Water Management in Agriculture	
2002	Korea			7,316	Irrigation Development and Water Management	Invitation of Trainees
2003	Italy	DGCS		272,986	Integrate rural development and environmental protection in Afram plain district	
2003	Japan	JICA		27,012		
2003	Japan	JICA		11,515		
2004	Germany	L G		28,314		Federal states contributions
2004	Germany	BMZ		121,444	Nachhaltge Land und Forstwirtschaft in Aburi	
2004	Canada	CIDA		5,605,063	Environment management - Environment Protection Agency Land and Water	To develop effective policies, institutions and practices that support improvements in land and water management in rural communities
2004	Japan	JICA		75,890		
2004	Germany	GTZ		33,558	Improvement of agricultural water management in Upper west	
2004	GEF		University of Ghana and Consortium of Partners	861,456	Sustainable Land Management for Mitigating Land Degradation, Enhancing Agricultural Biodiversity and Reducing Poverty (SLaM)	To contribute to sustainable ecosystem-based integrated land management in globally, nationally and locally significant land resources in agricultural areas under threat of land degradation, for greater ecosystem stability, enhanced food security and improved rural livelihoods. Immediate Objectives: 1. Ecosystem recovery demonstrated and upscaled in priority degraded lands, using best practices in sustainable land management (SLM) to enhance ecosystem stability and functions, agricultural productive capacity, food security and rural livelihoods 2. Enhanced capacity for mitigation of land degradation and for sustainable land management through greater awareness, mainstreaming, and policy reform
2005	Japan	JICA		31,828		
2006	Japan	JICA		84,225		
2006	Korea			5,304		
2007	Japan	JICA		93,911		
2007	United States	MCC		22,928,773	Agricultural water resources Compact activity	Agricultural water resources. Millennium Challenge Corporation Country Compact. The Millennium Challenge Account (MCA) is a Presidential initiative to reduce poverty through economic growth in poor countries. The MCA provides assistance only to countries that have already created the conditions for growth by ruling justly investing in their people and encouraging economic freedom with a particular emphasis on anti-corruption.
2007	Korea			6,097	Groundwater Resources Development and Management for ASEAN Member Countries	Invitation of Trainees

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About CPWF

The Challenge Program on Water and Food was launched in 2002 as a reform initiative of the CGIAR, the Consultative Group on International Agricultural Research. CPWF aims to increase the resilience of social and ecological systems through better water management for food production (crops, fisheries and livestock). CPWF does this through an innovative research and development approach that brings together a broad range of scientists, development specialists, policy makers and communities to address the challenges of food security, poverty and water scarcity. CPWF is currently working in six river basins globally: Andes, Ganges, Limpopo, Mekong, Nile and Volta.

About this R4D Paper

Agriculture Water Management strategies (AWM) have been extensively studied and promoted in the Volta basin during the last decades. However, water scarcity still limits agricultural production of most of the small-holder crop-livestock farms in the basin. In the dry areas of the Volta Basin, agricultural systems are mostly rainfed. AWM strategies in rainfed systems are different ways to influence rainwater flows in order to maximize infiltration in the soil, retain run-off and minimize losses, and range from field-scale techniques like stone bunds or manure application to watershed-scale structures like small reservoirs. The study of the evolution of AWM in the Volta Basin yielded key recommendations for research-for- development interventions and new concepts for research on water management. When promoting AWM strategies, projects should carefully study the available information on factors triggering adoption, and play on these to ensure sustainable uptake of the technology.

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