Design and implementation of runoff harvesting basins for supplemental irrigation in the Burkinabe Sahel.

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Abstract

The average annual rainfall in the Burkinabe Sahel ranges between 400 and 700 mm when going from north to south. Agricultural campaigns are often quite bad in this area, because of dry spells and feeble soil fertility. To cope with this situation, more than 700 runoff harvesting basins have been built for the purpose of supplemental irrigation and close to 10,000 are foreseen by 2015. Unfortunately, some basins do not collect enough water due to their bad siting, or do not keep it long enough because of infiltration. The present study aims to propose a methodology or a technical protocol to design and implement low-cost runoff harvesting basins, with an approach based on a community mutual aid, for vulnerable farmers in the Burkinabe Sahel. The sizing of basins depend on the size of the plot to cultivate, the length and the occurrence of dry spells, the chosen speculations (maize, millet, sorghum) and their water needs, the cost of labor and materials and the farmer's motivation. Soil structure has a strong influence on the need for labour for excavation and the choice of materials for the stabilization of the walls and any waterproofing. Basins have the shape of a truncated cone or a truncated pyramid with a depth between 1.5 and 2.5 m; for a volume ranging from 50 to 300 m^3, depending on the soil texture and the longest dry spell observed in the area (22 days), for agricultural plots with surfaces from 100 to 2000 m^2. Excavation of the basin and the stabilization of its walls must be made immediately after the harvest season when the weather is relatively mild, the soil still moist enough and food not a limiting factor.

Keywords: rainfed agriculture, dry spells, runoff harvesting basins, supplemental irrigation, food security, Burkina Faso.

1. INTRODUCTION

In West Africa, future climate scenarios show an increase in the frequency of extreme weather events, higher temperatures and an increase of water resources scarcity

(IPCC, 2007). More specifically in the Sahel (Figure 1), the process of climate change will mean frequent droughts and larger dry spells between two rainy events and a high uncertainty about the starting date and the duration of the crop season (Karambiri et al., 2011).

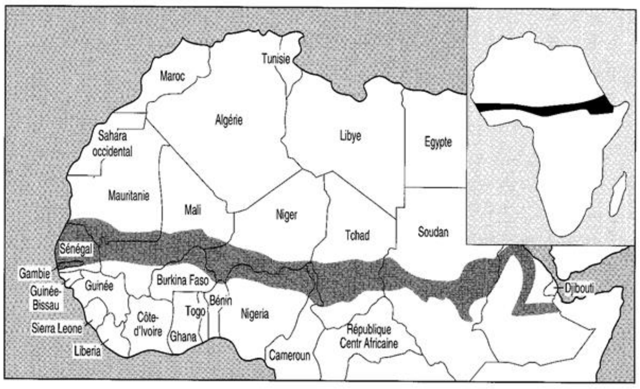

Figure 1: Geographic location of Sahel in Africa

In Sahel area, the climate is characterized by a unique rainfall season from June to September. Agriculture is mainly rain fed and therefore very dependent on climatic conditions. The duration of the rainy season varies from one year to another, but also from one site to another.

1.1. Adaptation strategies and their limits in the Sahel

To cope with rainfall variability in the Sahel, farmers use various techniques. Both traditional techniques (*zaï* and *half-moon*) and modern ones (the use of *short cycle varieties* for facing to a shorter rainy season or the implementation of *irrigated schemes*) have been developed. Construction of large and small dams and irrigation schemes has been developed with the support of governments and donors. Unfortunately, *zaï* and *half-moon* techniques become inefficient when frequent and long pockets of drought (more than 2 to 3 weeks) or intensive rains are observed (Roose, 1993). Moreover, the uncertainty about the date of onset of the rains can limit the efficiency of the use of short cycle varieties. The proportion of farmers who benefit from dams and irrigated areas is less than 2% of the total number of farmers settled in the Sahel zone (Aquastat, 2005).

1.2. Irrigation policies in Burkina Faso

Burkina Faso possesses three climatic regions (Figure 2). The northern part of the country encounters some difficulties in managing rain fed agriculture. The average annual rainfall in the Burkinabe Sahel ranges between 400 and 700 mm when going from north to south. Agricultural campaigns are often quite bad in this area, because of dry spells and feeble soil fertility.

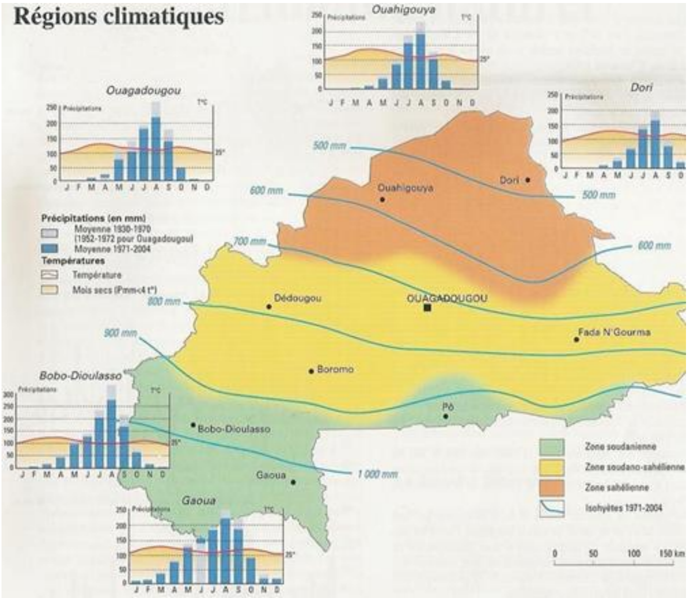

Figure 2: Climatic regions in Burkina Faso (Atlas de l'Afrique, 2005)

The strategic framework to fight poverty (CSLP, 2003) of Burkina Faso aimed to improve income growth of farmers and breeders till at least 3% per year in order to improve their living standards and reduce poverty incidence in rural areas. In the National Programme on Adaptation Strategies (PANA, 2006) of the country, supplemental irrigation appeared at the second rank of priority projects in agricultural domain. According to the 1st axis of the strategy for accelerated growth and sustainable development (SCADD), promotion of irrigated agriculture and popularization of water and soils conservation methods are preferred shares (They are part of the 5 first steps in this area) (SCADD, 2010).

1.3. The 2011-2012 crop year

According to the Ministry of Agriculture and Hydraulics (MAH), at the end of the 2011-2012 crops year, 17 of the country's 45 provinces have been unprofitable, against 08 of them in the previous year (MAH, 2012). In response to this situation, the government of Burkina Faso, on the basis of researches led by the Foundation 2iE on supplemental irrigation, has launched the "*Opération Maïs de Case*" which aims to strengthen food security by subsidizing 9800 runoff harvesting basin in 10 administrative regions of the country. Each farmer who builds a runoff harvesting basin (RHB) with a volume of 150 m^3 receives 153 € as allowance. Table 1 shows the results of the first year (MAH, 2012). RHB are realized to provide water for supplemental irrigation of maize during dry spells in farmhouses. The present study aims to propose a methodology or a technical protocol to design and implement low-cost runoff harvesting basins, with an approach based on a community mutual aid, for vulnerable farmers in the Burkinabe Sahel.

Table 1: first year results of the "Opération Maïs the Case"

REGION	Runoff harvesting basins				
	Expected	Achieved	In process of construction	Total	Received
B.MOUHOUN	1 200	139	468	607	102
CENTRE	350	150	0	150	122
C-EST	1 100	519	0	519	419
C-NORD	1 400	556	365	921	556
C-OUEST	1 250	237	181	418	237
C-SUD	700	443	-	514	95
EST	500	293	56	349	285
NORD	1 550	1149	0	1149	381
PL. CENTRAL	1 000	488	82	570	456
SAHEL	750	181	157	338	181
TOTAL	9 800	3 897	1642	5539	2 713

2. METHOD.

The method used for this study consists of three stages. The first stage was to conduct a review of the literature on cultural practices and climatic conditions in the Sahel, arid and semi-arid regions of the world. The second stage is the organization of workshop discussion with farmers to define together the best materials and the most suitable periods for the construction. Finally, we built a dozen of basins with community workforce in seven villages located in the Sahel zone. Supplemental irrigation occurs in the rainy season during dry spells, in order to prevent crops from suffering water stress (Figure 3). The characterization of dry spells is described by Sané et al. (2008). Supplemental irrigation consists in bringing additional water to crops in order to stabilize or improve yields, either qualitatively or quantitatively (Doorenbos et Kassam, 1987). The implementation of the practice differs depending on the size of the plot, the available water resources, the technical and financial resources (Dugue, 1986; Grewal et al, 1989; Dembélé et al, 1999; Fox, 2003; Somé et Ouattara, 2005; Narayan et al, 2008; CNID-B, 2009).

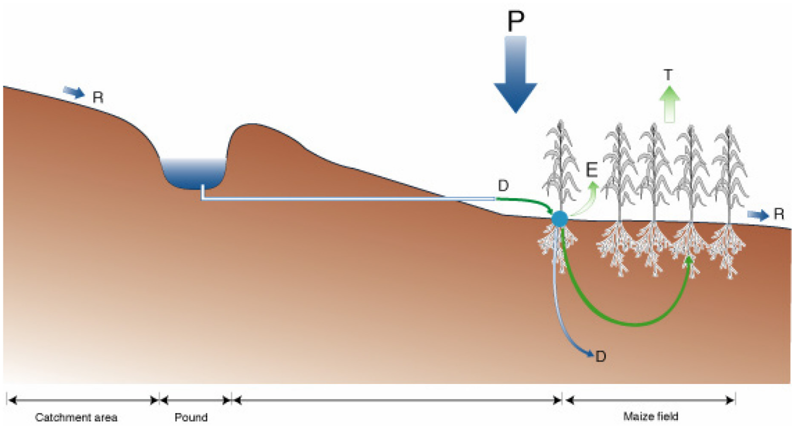

Figure 3: Principle of supplemental irrigation (Fox, 2003)

3. SITE SELECTION

The choice of the implantation site should be done with the help of farmers (Figure 3). The site for the implantation of the runoff harvesting basin (RHB) must be chosen so that the basin receives enough water. Soil structure should allow manual excavation without expending much effort. The location of the RHB in relation to the plot should not be too far and its position (either upstream or downstream of the plot) should be determined in order to collect much water and facilitate irrigation tasks.

Figure 4: Determination of the best site for supplemental irrigation from a runoff harvesting basin with farmers in the village

After the construction of RHB, will there be any reason to worry about the durability of the structure? This question lead us to avoid building near large trees (because the roots can weaken the walls), avoid areas where there's risk of collapse, avoid building a RHB on a torrential flow path and avoid rocky areas.

4. SIZING

4.1. Assessment of crop water requirements for irrigation

Sizing the runoff harvesting basin requires identification of the main agronomic parameters (Table 2) such as different speculations (special water needs based on growth stages), the rotation of crops (pure cultures or mixed cropping), the area to be sown (dose irrigation), the soil texture (soil water reserves) and rainfalls (frequency, intensity and duration of rainfall, length and recurrence of dry spells).

Table 2: Agronomic parameters

Crop	Crop coefficient Kc	Total water requirement (mm/season)	Peak needs (mm/day)	Length of the cycle (day)	Irrigated area (ha)
Maize	0.40 – 1.15	400 – 800	7	70 – 90	0.2
Millet	0.35 – 1.10	350 – 800	6	90 – 110	1 – 5
Sorghum	0.35 – 1.10	350 – 800	6	90 – 110	1 – 5

4.2. Evaluation of water supply in the RHB

The average annual rainfalls and their intensity, duration and frequency are essential to assess the emptying and the refill of the RHB. The maximum length of dry spells observed in the region is an indicator to estimate a total emptying without any refill after a certain number of days (Table 3). The topography (preferential flow paths in a watershed) governs the choice of the implantation site of the RHB. The sizes of the catchment area which collects water through runoff for the RHB and the land use during the stages of the rainy seasons (onset, middle, and end) which affect the runoff coefficient are also important to consider.

Table 3: Hydro-climatic characteristics

Rainfall (mm/year)	ETP max (mm/month)	Evaporation (mm/day)	Max length of dry spell (day)	Catchment area (ha)	Runoff coefficient (%)
400 - 800	250	10	22	3 – 10	35 – 80

2.3. Determining the shape and the optimal volume of the RHB

2.3.1. The shape (responsiveness and robustness)

The shape mostly depends on the soil structure (wall stability), the skilled labor force (some forms are more difficult to implement than others), the topography and the speed and direction of flow (water intake, upstream dissipation of the energy drained by the flow). Basins have usually the shape of a truncated cone or a truncated pyramid with a depth between 1, 5 and 2, 5 m; for a volume ranging from 50 to 300 m^3, according to the soil texture and the longest dry spell observed in the area (22 days), for agricultural plots with surfaces from 100 to 2000 m^2. In Burkina Faso, three forms are recurrent: parallelepiped, truncated pyramid with a square basis, truncated cone (Figure 4).

A: Truncated cone in the Guiè village, province of Oubritenga
B: Truncated pyramid in the Sandouré village, province of Bam
C: Parallelepiped in the Rawelgué village, province of Kadiogo
Figure 5: Some runoff harvesting basin in Burkina Faso (Photos ©2iE-CCREC)

The conservation of water in a RHB for a longer period may require relatively flatter side slopes to avoid slippage due to saturation. The area of the top and bottom for rectangular, square and inverted cone can be determined from their dimensions in case of rectangular or square and diameter in case of inverted cone (Reddy et al., 2012). According to the World Food Organisation (WFO), the suitable side slopes for different soils are given in the Table 4 (FAO, 2011 in Reddy et al., 2012).

Table 4: Suitable side slopes for different soils (FAO, 2011)

Soil type	Slope (horizontal:vertical)
Clay	1:1 to 2:1
Clay loam	1.5:1to 2:1
Sandy loam	2:1to 2.5:1
Sandy	3:1

2.3.2. The optimum volume

The optimum volume depends on selected speculations, areas to be sown, estimated water supplies and safety measures (evaporation losses, leakages). It also depends on the shape of the basin, regarding the hold of the RHB over the plot area and the potential obstacles (trees, rocks). The possibility of a faster or lower refill of the RHB after an emptying is also important to take into account. The volume should not be standardized. Table 4 presents some parameters taken into account in the northern part of Burkina Faso, by the Project on Supplemental Irrigation and Climate Information.

Table 5: Example in the Project on Supplemental Irrigation and Climate Information in the Burkinabe Sahel

Crop	Useful volume (m^3)	Total volume (m^3)	Irrigable area (ha)	Expected losses (m^3)
Maize	150	283	0.2	133

5. CONSTRUCTION

5.1. The selection of the contractor by the promoter.

A: Community workforce B: Family labour C: Building contractor

Figure 6: Contractors for the implementation of RHB.

The construction of a RHB may be done by three main actors (Figure 5) in rural area in the Burkinabe Sahel: Business Buildings and Public Works (BBPW), Community Workforce (CW) and Family Labor (FL). Considering the level of poverty in the region, it is suitable to deal with CW or FL (Table 5).

Table 6: Some considerations for the choice of the contractor.

Contractor	Working time	Skills transfer	Implementation cost	Work quality	RHB management
BBPW	+	-	-	?	-
CW	-	+	+	?	+/-
FL	-	+	+	?	+

+: Advantageous **-**: Disadvantageous **?** : Uncertain or unknown

5.2. Stages of Construction

After determining the best site and sizing the RHB, there are four main parts in building the infrastructure with a community workforce or a family labour (Figure 6). Soil structure has a strong influence on the need for labor for excavation and the choice of materials for the stabilization of the walls and any waterproofing.

Figure 7: Different stages (A to D) of construction with community workforce

5.3. Working period (excavation, stabilization, waterproofing)

Excavation of the basin and the stabilization of its walls must be made immediately after the harvest season, when the weather is relatively mild, the soil is still moist enough and food is not a limiting factor. The best working period for family labor or community workforce is between November and March of the next year (Figure 7). Regarding Business buildings and public works, the unique constraint is the rainy season, because activities are stopped.

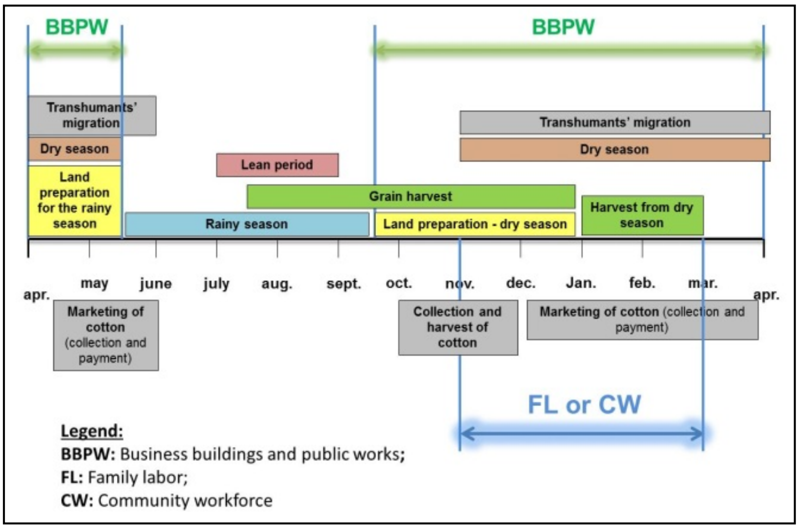

Figure 8: Working period for the construction of runoff harvesting basins (RHB).

5.4. Quality and availability of materials

The quality and the availability of materials are important to assess before the beginning of the construction. Opting in local materials supposes that they are available in sufficient quantity and acceptable quality. Sand for concrete (cleaned sand) and clay for waterproofing must be good (heavy clay or marl). Local materials sometimes avoid environmental constraints and are easily used in rural areas because of local know-how. Choosing imported materials supposes that they are adapted to the local context, they do not pose environmental constraints and they can be controlled by local technicians.

6. CONCLUSION

Supplemental irrigation is not widespread in the in Burkina Faso, though this practice would support rain fed production and secure farmers' income. However, its implementation is not an easy task, especially in areas where morphopedological and economic conditions are unfavorable. Excavation of the basin and the stabilization of its walls must be made immediately after the harvest season, when the weather is relatively mild, the soil is still moist enough and food is not a limiting factor. Farmers, researchers and decision makers must work together to jointly build a profitable and sustainable agricultural model based on the specificity of the Sahel (Fossi et al, 2012). This requires that they work together to ensure that the associated technology is inexpensive and easily replicable in rural areas, notably in promoting labor and local materials. Indeed, supplemental irrigation is compatible with the practice of zaï and half-moons; this means that local knowledge and research can greatly improve agricultural production. In Burkina Faso, some efforts are made in this direction such that more and more farmers are interested in collaboration with NGOs and research institutions.

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