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Small Scale Irrigation in Mali: Constraints and Opportunities

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Abstract

The economy of Mali is based essentially on agriculture (agriculture, livestock, fishery and forestry) with a contribution of about 36 % to the national gross product (NGP) and 40% to export earnings. Agriculture employs 80% of the labor force. Agricultural production is mainly rainfall dependent which varies on average between less than 100 mm in the North and 1200 in the South-West. Total production and productivity are heavily impacted by rainfall variation and one easy solution for people is to migrate towards more secure zones. However, the country benefits from two rivers enabling at least two cropping seasons through irrigation, thus increasing production and settle population. Large irrigation systems (through dams) are very expensive to implement, while small scale irrigation systems can be implemented at relatively low costs to benefit communities. Adopting and scaling up such technologies could help increase agricultural land capacity and reduce rural poverty. For irrigation to be highly productive improved agronomic management practices should be adopted. The main constraints are farmers' organization for inputs supply, water management and stocks storage. Farmers choose irrigation systems based on cost, management and revenues; for vegetable production they prefer Californian irrigation system, while for rice the preference is motor-pump. The study is conducted in Sikasso, Koulikoro and Mopti regions on small scale irrigation systems for providing information and proposing solutions to decision makers. The expected outputs/outcomes of the project include: (i) Documentation of water resources available in Mali, (ii) identification of small scale irrigation technologies available in Mali, (iii) selection of technologies suitable for different regions in the country, (iv) Assessment of social and economic profitability of selected technologies.

Key words:

Water Sources, Irrigation System, Rainfall Variability, Gross Margin

Introduction

The economy of Mali is based on the primary sector (agriculture, livestock, fishery and forestry) which contributes up to 36 % of national gross product (NGP) and 40% of the export incomes. It also constitutes the main source of incomes for 80% of the country's population.

The population is estimated at about 16 million (update of the 2009 census) with average density of 11.7 inhabitants/square kilometer varying from 20 inhabitants/km² in the south regions (Koulikoro, Kayes, Ségou, Sikasso, Mopti) to less than 1 inhabitants/km² in the North regions (Gao, Tombouctou and Kidal).

The average growth rate of gross domestic product (GDP) for the past ten years is about 5% and the demographic grow rate in the same period is 3.6%. Increase in agricultural productivity is estimated around 4% which close to the population growth rate. The GDP per inhabitant is now estimated to US\$1200.

In Mali, the most agricultural production depends on rainfall. Average rainfall varies between less than 100 mm in the North and 1200 in the South-West. Climate variability has a huge impact on production with years of failure; at that time populations have to migrate towards more secure zones. Mali has only one rainy season; during that season, the country gets considerable water and land resources are used for the development of agriculture through irrigation.

An integrated farming system(s) is the key factor in improving the capacity of agricultural land and reducing the poverty of rural communities in Sub-Saharan African (SSA) countries. This can be achieved through appropriate irrigation technologies and improved agronomic management practices to increase agricultural productivity taking into consideration environmental constraints and the prevalent social and economic factors.

Large dams are huge currency sinks and their achievement takes long time before populations start to get benefit from them. Their management requires human resources and equipments for their functioning. Small scale irrigation systems cost less and are relatively easier to manage by the community.

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Water Resources in Mali

Surface Water

Perennial surface water resource

The hydrographic system in Mali, comprises the basins of Senegal River and Niger River (DNH, 2006). The capacities of the rivers are:

- 70 billion m³ of water in average year
- 110 billion m³ of water in humid year
- 30 billion m³ of water in dry year.

The South and the Centre of the country have the majority of watersheds; the Northern part is characterized by the presence of numerous fossil valleys. Surface water is mainly from the rivers and their dependents (Senegal and Niger rivers). Underground water is estimated to be 2 to 5 times lesser. It is also important to know that surface water contributes about 10 to 15% of the total volume of water consumed by populations, the balance of the demand is covered by underground water (DNH, 2006)

Non-perennial surface water resource

Non-perennial water is the volume collected in water reservoirs by constructing infrastructures or natural ponds and kept for few months. This type of collected water exists all over Mali and is estimated to be about 15 billion m³ yearly. Usually, non-perennial water is used by populations living in remote areas from the river bank (DNHE, 2006).

Underground Water Resource

Volume of underground water resource

The volume of static underground water reserve in Mali is estimated at 2700 billion m³ with an annual renewable rate of 66 billion m³ representing the main source of water consumed by populations. The level of mobilization of this water resource is very low. Its mining is made possible through 15100 drills and 9400 modern wells with large diameter (DNH, 2003).

Underground water pollution and contamination

Generally, underground water tables are not polluted by human activities. Only few cases of poor contamination are observed in urban areas where agriculture occurs using fertilizers and pesticides. For example, water controls in Bamako city revealed that nitrate content was higher than indicated norms for pure water (ENI, 1991). It has been proved that the contamination of underground water in Bamako city is chemical and bacterial.

Underground water availability in Mali

Table1 shows precipitation and renewable water sources in Mali. The total renewable water resource is found to be 137 billion m³ corresponding to 11 417 m³ per inhabitant and per year. Today, annual water needs are evaluated to about 6 billion m³ distributed as followed:

- 1 % of pure water for drinking
- 1 % for livestock
- 98 % agricultural and others usages.

Table 1: Precipitation and renewable water in Mali

Precipitation and renewable water resource	Volume (billion m ³)
Volume of precipitation	415
Perennial water of surface	56
Non-perennial water of surface	15
Renewable underground water	66
Total renewable water resource	137
Average per person per year	11417

Characteristics of household farms

In 2012, the results of the survey revealed that farm characteristics vary from one region to another. A Koulikoro region, 97.6% of the farms is in rural areas against 2.4% near the urban areas. However, in the Mopti region, 75% of the investigated farms are in rural areas against 25% in urban areas.

Land and land use

The typology of the farms based on size of owned land is presented in the table below.

Table2: Percentage of farm type in Koulikoro and Mopti regions

Typologie of Farms	Koulikoro	Mopti
Large farms (> 10 ha)	22.0	8.3
Average farms (5 to 10 ha)	26.8	22.2
Small farms (<5 ha)	51.2	69.4
Total	100	100

The results show that the size varies according to the region. Koulikoro has more large and medium farm sizes while in Mopti, small farm size are more than 5 ha (about 69.4% of the total farms in the region) predominant.

Literacy of farm members

The number of farm members who are illiterate is more important in Mopti (86.8%) than in Koulikoro (39%). The main activities of the households are crop and livestock production. The following table shows the level of literacy of household heads in the study area.

Table3: Level of education of the household heads

Level education	Number	%
Illiterate	81	55,1
Read and write only	32	21,8
primary school	22	15,0
secondary school	8	5,4
technical	3	2,0
university	1	,7
Total	147	100,0

Source: PARI survey 2016

Former studies found that household heads are predominantly male (83%). Their average age is 48 years. The average number of people by household is 18. More than half are illiterate (55%), only 22% are literate, 15% received primary level education and 5% secondary level of study.

Main occupation of surveyed household heads

Crop production is the main occupation of household heads (more than 70%) in both regions. Agro farmers (crop and livestock producers) represent 8 in Mopti and 27% in Koulikoro. Main and secondary occupations of farm household heads are presented in the graphic below.

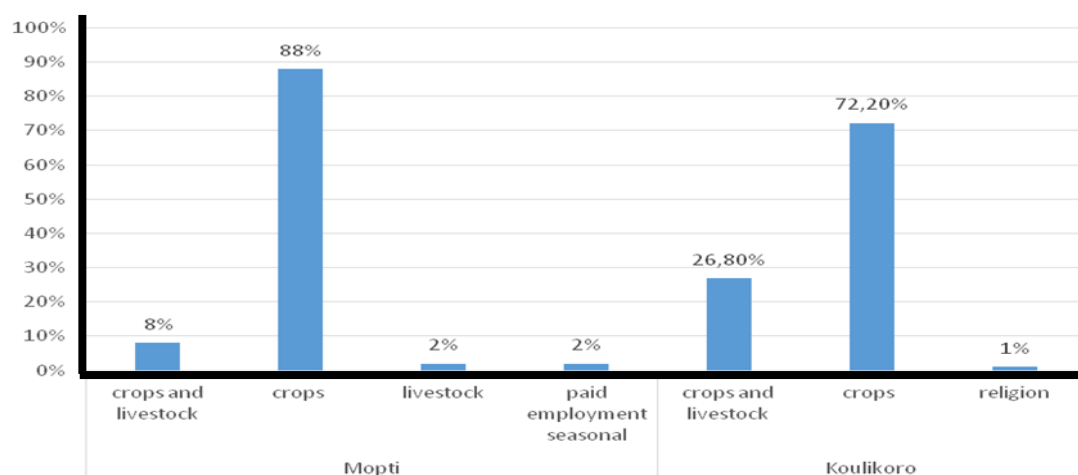


Figure 1: Main occupation of surveyed household heads

Irrigated crops

The most important crops under small scale irrigation in the region of Koulikoro are onion (11.4%), tomato (10.9%), maize (10.4%) and rice (10%). In Mopti region, rice and shallot are mainly cultivated. The following graphic represents the distribution of major crops in the two regions.

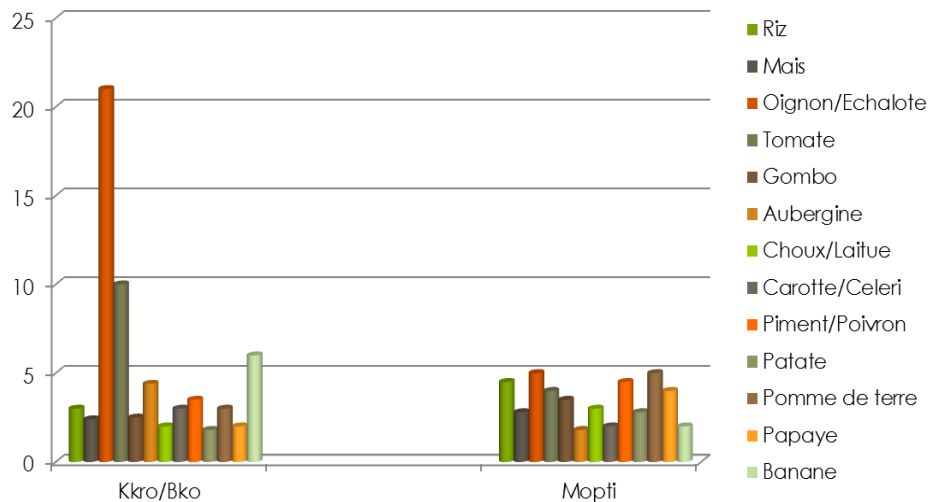


Figure 2: Distribution of major crops

Identification of Appropriate Irrigation Technologies

Small scale irrigation technologies

Many small scale irrigation technologies are used in Mali. These technologies comprise manual watering and mechanical watering including pedal pump (Nafasoro), Aeolian pump, electric pump and motor pump. For the manual watering, water is lifted from wells, rivers or other surface water sources by human force using rope and a container (Photo 1). This technology is mainly used by poor resource farmers.

For mechanical watering, water is lifted by pumping systems (Photo 2). This method is used for small and large irrigation systems by average and wealthy farmers. Water is distributed to plots through the gravity irrigation, Californian system, sprinkling system, drip irrigation and manual watering.



Photo1. Manual watering system for home gardens



Photo 2: Motor-pump for small scale rice irrigation

Gravity irrigation technology

Irrigation by gravity is used on small scale irrigated areas for cereals (rice, wheat, maize) and vegetables production. It is mainly practiced in the northern zones of Mali (Gao, Tombouctou and Mopti). In this system, water is lifted from the river, pond, lake; using motor-pumps and distributed to plots through primary and secondary irrigation canals (Photo 3).



Photo 3: Gravity irrigation on small scale system

Californian irrigation system

This irrigation method is used for vegetable crops production. Water is lifted from the surface or the underground and distributed to plants into furrows. With this system, crops are arranged on ridges. This system is mainly used for vegetables in urban areas.



Photo 4: Californian irrigation system for onion cropping

Sprinkling Irrigation system



Photo 5: Sprinkling irrigation system on shallot cropping

It is practiced on commercial farms for high value crops such as fruit trees and currently on sugar cane in the Office du Niger. Irrigation operations are also simplified with an irrigation management optimized specifically tailored to the areas and speculation.

Drip irrigation technology

The drip irrigation practice is taking off in Mali. Development programs and services such as the PCDA (Compactivity and Diversification of Agricultural Program), NGOs and research institute (IER) have contributed greatly to the awareness of this technology. The drip low pressure system is the most popular. The technology is mainly used for fruits and vegetables cropping in the urban areas by wealthy farmers (Photo 6)



Photo 6: Drip irrigation systems on banana.

Manual watering practice.

This system is commonly used in rural areas of Mali by the low-resource farmers. Buckets, calabashes, watering cans are used to distribute irrigation water to crops (Photo 7). Water sources for this practice are wells, rivers, lakes, etc. Crops irrigated by this system are mainly vegetables.



Photo 7: Manual watering practice in onion cropping in Mopti region

Results of Irrigation Technologies in the Different Regions Studied

Sprinkling irrigation on potatoes at Kati

Comparing sprinkling and farmers' irrigation practices in Koulikoro region for potato production yielded to the results in the table below.

Table4: Characteristics of potato tubers

Treatments	Caliber >45mm	Caliber 35-45mm	Caliber 25-35mm	Depreciated	Yield kg/ha
Famer practice	177,63	124,90	92,98	96.45	9839,2
Sprinkling	647,99	296,22	148,11	155.52	24956,8

Drip irrigation on Tomato

Results of drip irrigation compared to famers' irrigation practice (irrigation by gravity) are presented in the table below.

Table5: Tomato production from the two types of irrigation

Treatments	Yields (kg /ha)
Famers' practice	30304
Drip irrigation	48811

Californian irrigation on the shallot

Farmers' practice compared to Californian system for shallot production as it could be seen in the graphics below.

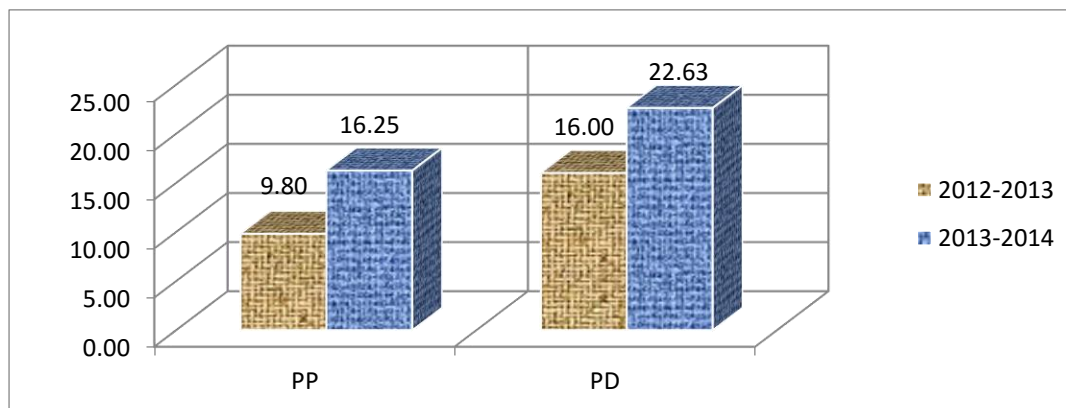


Figure 3: Farmers' practice compared to Californian system for shallot production

On average farmers' practice requires more time for irrigation than Californian system as it could be seen in the figure below.

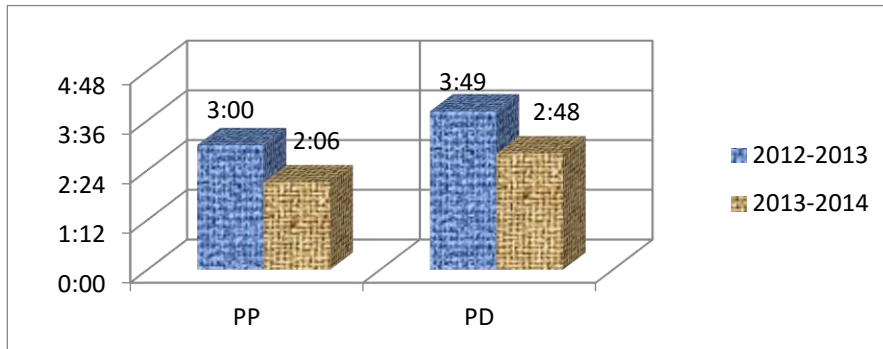


Figure 4: Average farmers practice for Irrigation

Comparing irrigation systems

All three irrigation systems provide better production than farmers' practice. Productivity and water volumes applied in the different system are better than farmers' practice in all cases as it could be seen in the following table.

Table 6: Comparing production of three irrigation systems to farmers' practice

Parameters	crops					
	Shallot		Potato		Tomato	
	Californian	Farmer practice (furrow irrigation)	Sprinkler	Farmer practice (Manual aspersion)	Drip irrigation	Farmer practice (furrow irrigation)
Water consumption (m3)	205,2	312	212,63	434,64	315	396
Production (Kg)	800	490	1303,38	516,94	1000	500
Crop Productivity (Kg/m3 water)	3,89	1,6	6,13	1,69	3,2	1,26
Water productivity (FCFA/m3)	585	235,6	1226	238	952	378

Gross Margin Analysis of the Three Irrigation Systems

Californian System.

Calculations provided positive gross and net margins. With an average yield of shallot ranges between 15 and 17 t/ha, products are sufficient enough to support total production costs under Californian system. Net profit is estimated at 123 082 FCFA.

Sprinkling irrigation

Gross and net margins under sprinkler system are negative. Return to investment shows that the traditional practice of irrigation is not profitable and a farmer could lose up to 1,22% of his investment.

Drip Irrigation System

Results show negative gross and net margins. Production is insufficient to support total costs; a farmer can lose up to 20% of investment.

Preferred irrigation system by farmers

The most preferred irrigation system by farmers are Californian (28%), followed by the sprinkler (26%), then the drip irrigation system (24%) for vegetable production. For cereal production such as rice and wheat farmers prefer motor pump.

Also 75% of producers said they had no difficulty to adopt drip irrigation, 78% for sprinkling and 100% for the Californian. However, some problems were revealed by farmers in relation to the use of the drip irrigation system such as the high cost (6%) the maintenance and the adverse effects of climate (sun) on kits (6%), lack of knowledge of the technique (3%) by producers and the need for training (3%), the slow and insufficient amount of water for watering (3%). For spraying, farmers report that the technique is not very suitable for crops (3%), insufficient training on technique (3%), the cost of energy, (3%), the cost of sprinklers (3%), and irrigation failure (3%).

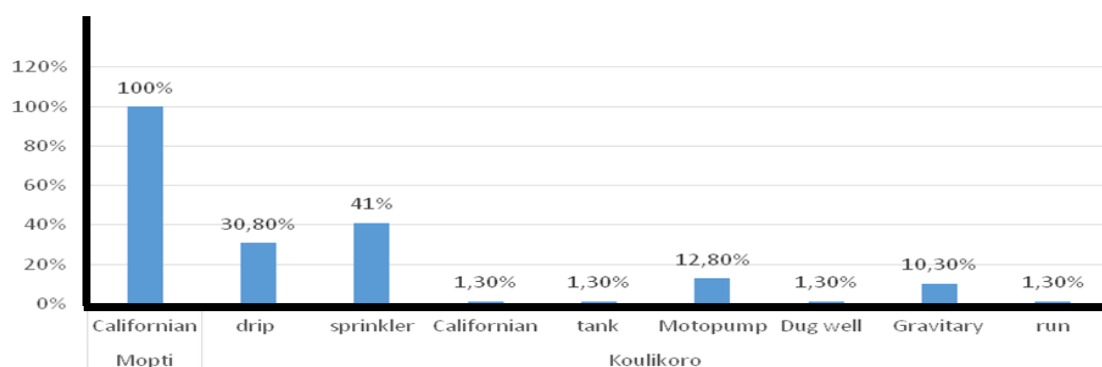


Figure 5: Preferred irrigation system by farmers

Conclusion

Agriculture in Mali is based on rainfall; however, Mali has a lot of water resources. The Senegal and Niger rivers produce by themselves 70 billion m³ of water on average by year. The estimated non-perennial water resource is about 15 billion m³. This water fraction is particularly interesting for people far from rivers (DNHE, 2006). Underground water resource in Mali is estimated to 2700 billion m³ of static reserve with annual renewable rate of 66 billion m³ representing the main source of consumption water for the population. The level of mobilization of this water resource is very low. Generally, the water table of Mali's underground water is not/or less affected by pollution mainly due to human activities.

The total renewable water resource is found to be 137 billion m³ corresponding to 11 417 m³ per inhabitant and per year. Nowadays, annual water needs are evaluated to about 6 billion m³ distributed as 1 % for pure water supply for the population, 1 % for livestock and 98 % agricultural and others uses.

There are many technologies used for small scale irrigation in Mali. These technologies include manual and mechanical lifting of water. Pedal pump (Nafasoro), Aeolian pump, electric pump and motor pump are used. For the manual, water is lifted from wells, rivers or other water source at the surface by human force using rope and a container. This is mainly used by poor resource farmers. For the mechanical, water is lifted by a pumping system. This method is used for small and medium irrigation by average and wealthy farmers. In both methods water is distributed to plots through gravity to cultivate vegetables and cereal crops (maize, rice and wheat).

Californian system mainly used for vegetable crops in urban areas; Sprinkling system practiced on commercial farms for high value crops such as fruit trees; drip irrigation mainly used in vegetables cropping in the urban areas by wealthy farmers.

For vegetable production farmers prefer Californian system in Koulikoro and Mopti; while for cereal production, they prefer motor pumps. But region wise, farmers in Koulikoro like the sprinkler system more than the others.

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