Scientific Research Publishing

Agricultural Sciences, 2020, 11, 860-868
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Impact of Smart Valley on Soil Moisture Content and Rice Yield in Some Lowlands in Burkina Faso

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How to cite this paper: Delphine, B.N.A., Elliott, D.Y., Mahanat, G., Elvire, V.G., Issa, S., Ouedraogo, I. and Ouédraogo, A. (2020) Impact of Smart Valley on Soil Moisture Content and Rice Yield in Some Lowlands in Burkina Faso. *Agricultural Sciences*, **11**, 860-868.
https://doi.org/10.4236/as.2020.119055

Received: August 30, 2020
Accepted: September 26, 2020
Published: September 29, 2020

Abstract

To reduce the impact of rainfall variability on lowland rice yields, Burkina Faso state develops lowlands for small rice farmers. However, the high cost of these infrastructures makes impossible to duplicate them to satisfy the needs which are enormous. The Smart-Valley technology which is actually popularized in certain coastal countries of West Africa would therefore be a boon to increase the productivity of the Sudanese lowlands if it well regulates runoff. The object of this study was therefore to know if smart valley technology could increase soil moisture in order to mitigate the impact of drought's pockets on rice cultivation in the Sudanese lowlands. The experiment takes place in three lowlands during the rainy seasons 2018 and 2019. The climatic data comes from the meteorological stations in the study areas as well as those installed on the sites. The infiltration measurements were carried out using the double Muntz ring. The soil moisture measurement device consisted of a smart valley area of 5 ha and an undeveloped area of 5 ha per site. Sixteen tubes were installed per lowland allowing the humidity to be measured at a depth of 10, 20, 30, 40 cm using a probe. Four rice varieties, Orylux6, FKR62N, FKR19 and FKR64 were tested on plots of 0.25 ha per variety in the smart valley and undeveloped parts. The results showed that the humidity level was 12% higher in the smart-valley plots throughout the cycle compared to the unmanaged area. In addition, humidity decreases rapidly in unmanaged plots as rain becomes increasingly scarce. Finally, the smart-valley development allowed an average increase in rice yields of 21% compared to the average yield of undeveloped plots.

Keywords

Smart Valley, Soil Moisture, Lowland Development, Rice Productivity, Rain

1. Introduction

In Burkina, paddy rice production barely covers half of the needs [1]. Lowland rice is the most dominant with 67% of the total areas cultivated with rice. More than 80% of these rice-growing lowlands are undeveloped and are therefore subject to climatic variability [2] [3]. In these rainfed lowlands, yields are low, around 1.4 T/ha [4] [5]. To increase the productivity of these rainfed rice-growing lowlands, several types of development are promoted [6], and the average cost of per ha varies between $860 and $5000 [7] [8] [9]. These high costs constitute a brake on the appropriation and replication of these facilities by the beneficiaries. However, good management of runoff water in these lowlands is a prerequisite for increasing rice productivity in this ecology. Smart-valley technology, which is a low-cost, average $250 per ha in Burkina Faso [9] [10], and participatory development approach for rice cultivation in inland valleys, can be an alternative. Indeed, Smart-valley introduced in the coastal zone of West Africa during 1997 and 2001 in Ghana and Nigeria, [11] then from 2012 in Benin and Togo [12] permitted producers to manage their lowlands themselves. The national research institute of Burkina Faso in partnership with Africa Rice would like hence to introduce smart valley technology in Sudanese area in order to increase the resilience of small-scale rice producers to the effects of climate change. The object of the present study was to know if the smart valley technology made it possible to increase the soil moisture rate in order to mitigate the impact of pockets of drought on rice cultivation in the Sudanese lowlands.

2. Material and Method

2.1. Presentation of the Study Area

The experiment takes place in three lowlands including Tenseiga in the North Sudanese zone (rainfall between 600 and 900 mm), Banflagouè-fon and Sindou in the South Sudanese zone (between the 900 - 1200 mm isohyets) in Burkina. These areas are characterized by the alternation of dry and rainy seasons. In Sindou, the physical environment is characterized by a relief in three topographic units, namely the plateaus, the plains and the great cliff, and is drained by the tributaries of the Léraba river. The geological structure of Banblagouè-fon is essentially made up of sedimentary rocks. The lowland of Tenseiga is located on a peneplain dotted with lowlands and hills. Tenseiga and Banflagoè-fon are drained by many seasonal rivers (**Figure 1**).

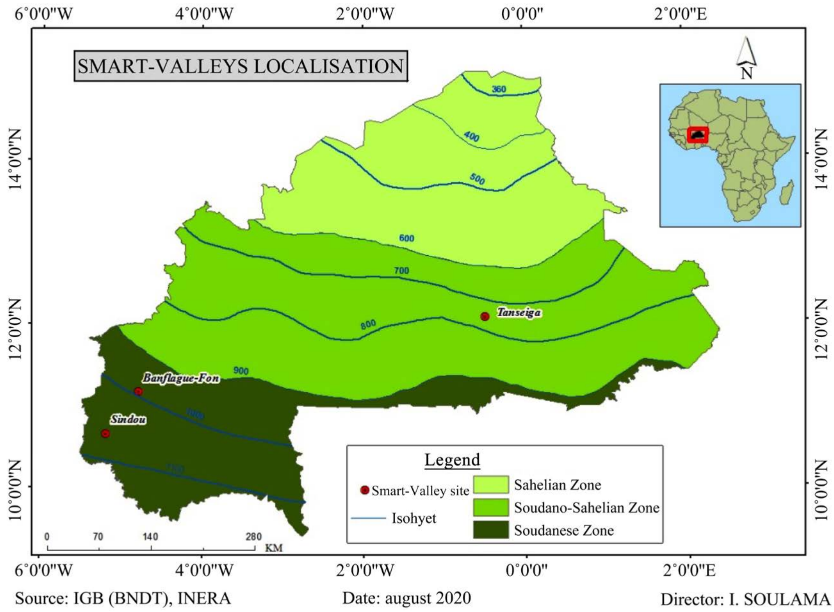

Figure 1. Location of demonstration sites in Burkina Faso.

2.2. Rainfall Data Analysis

Data from the meteorological stations of Bérégadougou (1986-2016) and Bobo-Dioulasso (1986-2016) as well as the Koupéla pluviometry (2000-2016) were used to characterize the climate on the Sindou lowlands, Banflagouè-fon and Tenseiga over the period from 2000 to 2017. However, during the experiment in 2018 and 2019, we installed an automatic climate station on each site in order to have rainfall data better reflecting the rain received.

2.3. Infiltration Measurement

These infiltration measurements were made using Muntz's double rings. More than ten measurements were carried out per site depending on the zoning of the different types of soil with the naked eye. Data was processed using GraphPad. The table of [13] allowed us to determine the types of soil according to the infiltration rates as follows (1, 2 and 3):

Cumulate the heights according to the formula:

$$h_t\left(mm\right) = \sum_{i=0}^{i=t} h_i \tag{1}$$

The average infiltration is given by:

$$I_{moy-t}\left[mm/h\right] = \frac{dh\left[mm\right]}{dt\left[h\right]} \tag{2}$$

$$I_{moy-t}\left[\frac{mm}{h}\right] = \frac{h_t - h_0}{t - t_0} \tag{3}$$

2.4. Soil Moisture Measurement Device

The measurement device consisted of an adapted smart valley part [14] of 5 ha and an undeveloped part of 5 ha as a control on each of the three lowlands. Sixteen tubes, eight of which in the smart valley area and eight in the undeveloped area, were installed in the shallows, allowing humidity to be measured at a depth of 10, 20, 30, 40 cm. The humidity measurements were carried out once a week with a type moisture meter (HH2, Moisture Meter, DELTA-T DEVICES, CAMBRIDGE-ENGLAND) during the wet seasons of 2018 and 2019. The measurements are carried out by immersing the probe in these tubes driven into the ground.

2.5. Experimentation Device

Experimentations of rice varieties have been done in the three lowlands during two rainy seasons 2018 and 2019. In the each lowland, we had taken one ha in the smart valley part and another ha in the undeveloped area. Each ha is subdivided into four subplots of 0.25 ha where four varieties of rice (Orylux6, FKR62N, FKR19 and FKR64) were tested. At harvest, the yield of the four varieties was determined in the smart valley and undeveloped area.

3. Results and Discussion

3.1. Summary about Climate Data

As annual modules, we obtain 1044 mm for Sindou, 947 mm for Banflagouè-Fon and 750 mm for Tenseiga, which is the confirmation of their location in the Sudanian zone. With the weather stations installed, the maximum daily rainfall recorded is 74 mm for Sindou, 83 mm for Banflagouè-Fon and 100.5 mm for Tenseiga during the month of August (**Table 1**).

3.2. Textural Characterization of Lowland Soils

We have 168 mm/h for Sindou, 31 mm/h for Banflagouè-Fon and 11.56 mm/h for Tansèga (**Figure 2**). We have a sandy soil for the lowland of Sindou, sandy loam soil for the lowland of Banflagouè-Fon and clayey-silty soil for Tansèga, [15] by analysis of composite samples of the soils of these lowlands, funds in the laboratory had led to the same result. According to [16] lowland soils are formed from deposits of colluvium and alluvium in the watershed. The Sindou lowland watershed is used in different places as a construction sand quarry, which strips the soil. When it rains, the sand is carried by run-off water in the shallows. This explains the strong silting of the lowland. Normally, such a type of soil is not suitable for growing rice. However, the high rainfall in the area and the saturation of the surrounding land favour the maintenance of a substantial layer of water, making the lowland suitable for rice cultivation.

3.3. Evolution of Soil Moisture

Sindou's lowland: the rainfall in 2018 seems particular compared to that of the last ten years and even more. In fact, between June 1 and September 20, 2018, we recorded 1152 mm of rain (**Figure 3**). The longest pocket of drought was seven days, and on average it rained every two days in Sindou. Contrary to what one might expect, namely the saturation of the lowland over time, given the intensity of the rains, the results of the humidity probes gave humidity levels between 25% and 40%. This is explained by the nature of the essentially sandy soil. The large volume of water which therefore arrives in the lowland is very quickly evacuated through runoff or absorbed by the soil to recharge the water table.

Banflagouè-fon's lowland: The total rainfall recorded during these three months was 906 mm. The maximum was 83 mm and the minimum, 3 mm (Figure 3). There is consistent humidity throughout the lowland with the presence of a layer of water in the rice cellars. The humidity on the finished part is between 26% and 38% while that of the unfinished part is in the range (27%; 35%). The unfinished part is therefore slightly wetter than the fitted-out part. This fact can be explained by the position of the undeveloped part in the toposequence of the lowland. It was taken downstream of the converted part. Hypodermic discharge is therefore the source of this advantage for the undeveloped part.

Table 1. Summary of climate data over the period 2000 to 2017.

	Sindou	Banflagouè-Fon	Tenseiga
Average annual rainfall (mm)	1044	947	750
Average number of rainy days per year	93	80	48
Rainfall concentration period		July-August	
Annual mean temperature (˚C)	28	27	30
Maximum daily rainfall 2018 (mm)	74	83	100.5

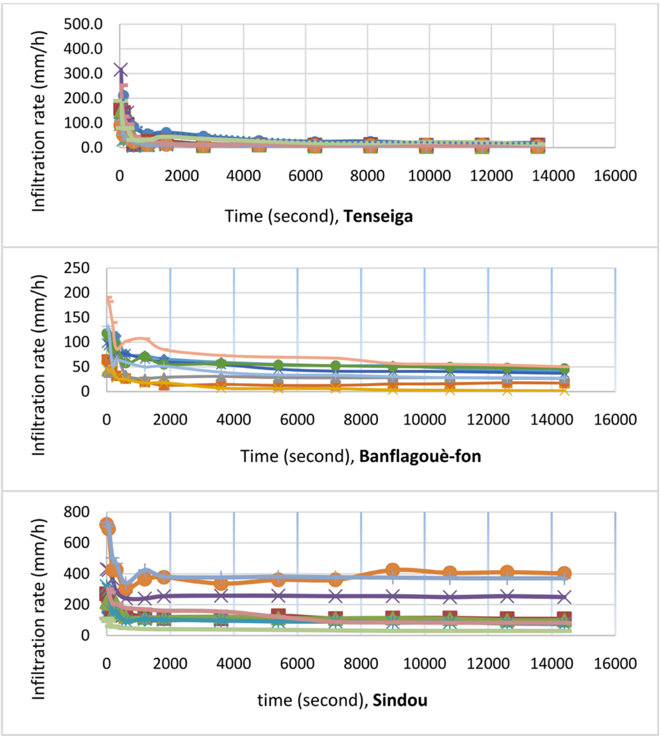

Figure 2. Evolution of the infiltration speed as a function of time on the three lowlands.

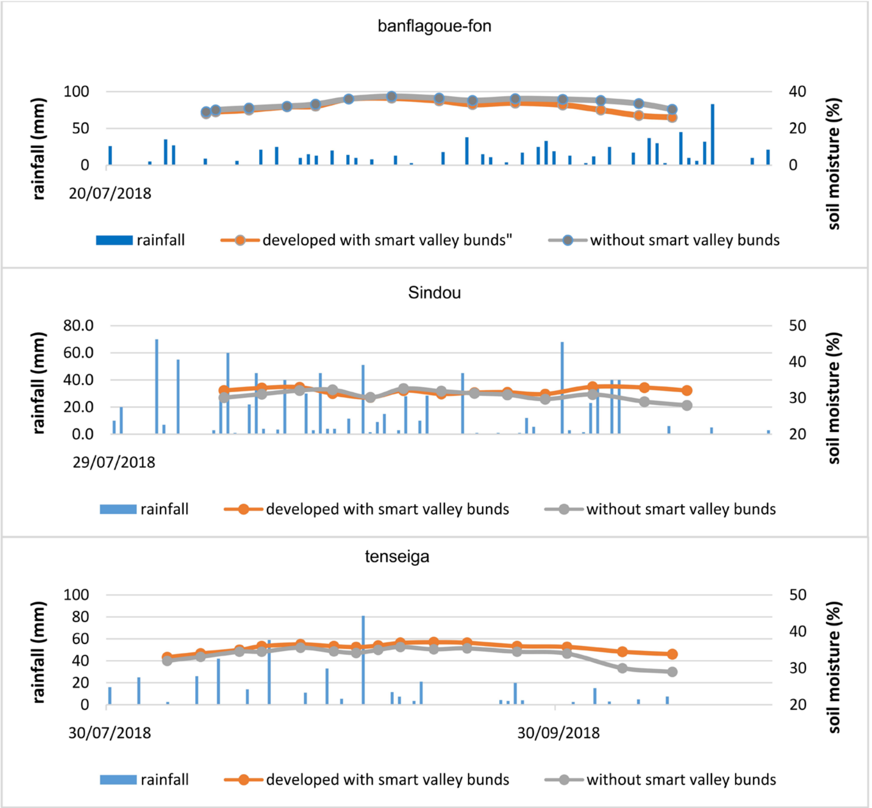

Figure 3. Change in humidity as a function of rainfall at the level of areas developed as non-developed during the rainy season 2018.

Tenseiga's lowland: The average humidity on the Smart-Valleys plots is between 25% and 40% humidity, on the other hand for the undeveloped plot, it is between 18% and 36%. In addition, after the rains stop, the soil moisture with the Smart-Valleys arrangement is preserved for an average of three weeks which allows the plant to continue growing.

With the exception of the Banflagouè-fon lowland where the downstream positioning of an undeveloped plot benefited from hypodermic runoff, the humidity rate was higher in the smart-valley plots throughout the cycle. In addition, humidity decreases rapidly in the unmanaged plots (Sindou and Tanseiga) when the rain becomes increasingly scarce. Closing the breaches in the smart'valley plots makes it possible to retain the last runoff water, thus making it possible to fight against end-of-cycle droughts. In 2019, we observed these same trends.

3.4. Yields Evolution

Yields are higher than the level of smart valley plots (**Figure 4**). The smart valley development has allowed an average yield increase of 21% compared to the average yield of unmanaged plots. In Benin, yields were doubled with smart valley approach [12] [17] [18]. In addition, this technology has transformed the yields on rice farms in Ghana and Nigeria where it was introduced in 1997 and 2001, and is estimated on average between 4.5 to 5.2 tonnes per hectare [11] [19].

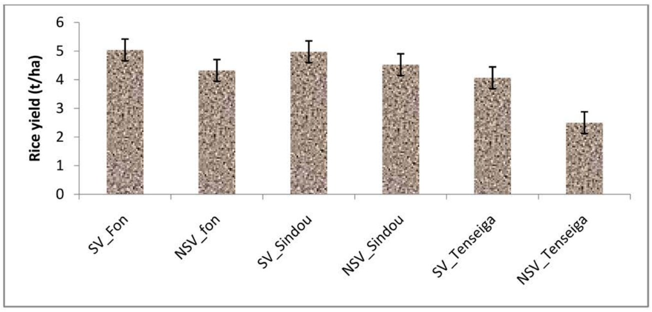

Figure 4. average yield of the four varieties of rice by site and by type of development. SV: smart valley, NSV: no smart valley.

4. Conclusion

As annual modules, we obtain 1044 mm for Sindou, 947 mm for Banflagouè-Fon and 750 mm for Tenseiga, which is the confirmation of their localisation in the Sudanese zone. The infiltration rates at the sites allowed us to conclude that the soil of the Sindou lowlands is sandy, sandy loam soil for Banflagouè-Fon and clay-loam soil for Tansèga. The sandy soil does not promote water retention even despite abundant and evenly distributed rainfall. The upstream water retention at the level of the smart valley plots feeds the hypodermic flows downstream, thus allowing the undeveloped area of Banflagouè-fon to benefit from humidity. With the exception of the Banflagouè-fon lowland, the humidity rate was 12% higher in the smart-valley plots throughout the cycle compared to the unmanaged area. In addition, humidity decreases rapidly in the unmanaged plots (Sindou and Tanseiga) when the rain becomes increasingly scarce. The closing of the breaches in the smart valley plots makes it possible to retain the last runoff water, thus making it possible to combat drought at the end of the cycle. Finally, the smart-valley development allowed an average increase in rice yields of 21% compared to the average yield of undeveloped plots.

Acknowledgements

This research was funded by the German Development Cooperation (GIZ) through the "Climate-smart rice technologies to enhance resilience of smallholder rice farmers in Burkina-Faso" (CSA-Burkina) project. Our thanks to: all the small holder farmers in Sindou, Banflagouè-Fon and Tanseiga; the technicians of CAP of Matourkou and provincial direction of ministry of agriculture which help us during these tests.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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