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FARMERS' PRACTICES AND WILLINGNESS TO ADOPT SUPPLEMENTAL IRRIGATION IN BURKINA FASO

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Abstract

This study analyzes farmers' practices and willingness to adopt supplemental irrigation on rainfed crops in the Sahelian and Sudano-Sahelian areas of Burkina Faso. A survey of 629 farmers revealed a diversity of farming practices within and between two agro-climatic zones. Over 65% of farmers believe that supplemental irrigation is a good way to mitigate the adverse effects of dry spells on crop yields. Determining factors of farmers' willingness to adopt supplemental irrigation were identified using a logistic model. Lack of information is the major obstacle to promoting this innovation. Farmers' training and information dissemination are the best ways to increase the acceptance of this promising technology.

Keys words: *Innovation, dry spell, rainfed crop, farmers, willingness to adopt.*

1. Introduction

The West African economy is built predominantly on rainfed agriculture, which is highly influenced by climate variability and change (GIEC, 2007). Limited and erratic precipitation results in low crop yields because the currently techniques adopted by farmers are not effective in stabilizing agricultural production during a 2 to 3 weeks dry spells (Roose, 1993). Supplemental irrigation is one possible way of overcoming the water deficit of rainfed crops in semi-arid areas (Dialla, 2002; Pathak *et al.* 2009; Rockström *et al.* 2010).

In Burkina Faso, Some (1989) conducted several tests of supplemental irrigation on sorghum in the Sahelian and Sudano-Sahelian agro-climatic zones and reported that this practice can increase yields by 10% to 85% depending on the agricultural season. Dembele *et* *al.* (1999) showed that supplemental irrigation can increase yields of upland rice by more than 90% in sandy soil packed with organic material in Karfiguela and Farako-Ba respectively in the regions of "Cascades and Hauts-Bassins" in the sudanian zone. Several experiments and theoretical calculations demonstrated the ability of supplemental irrigation to increase the productivity of rainfed crops (Sivakumar, 1992; Rockström *et al.* 2004; Adekalu *et al.* 2009).

Supplemental irrigation of rainfed crops has been tested but not promoted in rural areas of Burkina Faso. However, most farmers are in favor of adopting innovations to mitigate the risks of drought (Ouédraogo *et al.* 2010). The farmers' commitment to adopt agricultural innovations prompted the International Institute for Water Engineering and Environment to promote supplemental irrigation via basins that collect run-off water in the provinces of Bam and Yatenga in a project for supplemental irrigation and climate information since the 2012-2013 rainy season campaign. The Ministry of Agriculture and Water Resources disseminated the practice in 10 of the 13 regions of Burkina Faso, mainly in the Sahelian and Sudano-Sahelian agro-climatic zones through "garden maize". At this point, although we can consider that supplemental irrigation has been promoted in Burkina Faso, its acceptance by farmers has not been determined.

This paper aims to determine the likelihood of farmers adopting supplemental irrigation by examining its position with respect to their practices and agricultural technologies used in farms. Our study was specifically designed to examine the practices of farmers on the one hand, and to identify the determining factors of the farmers' willingness to adopt supplemental irrigation on the other and draw conclusions that might help in developing institutional interventions to encourage adoption.

2. Methodology

2.1 Study Area

Burkina Faso is a landlocked country in the heart of West Africa which borders Mali to the west and north, Niger to the east and Côte d'Ivoire, Ghana, Togo and Benin to the south. The population is mainly rural (80%) and primarily employed in agriculture rainfed (86% of the workforce). Three climatic zones can be defined: the Sahel, the Sudan-Sahelian, and the Sudan-Guinea. In the Sahelian zone, annual rainfall ranges between 300 and 600 mm and is characterized by a very irregular spatial and temporal distribution. The rainy season lasts less than three months. The Sudano-Sahelian zone is characterized between 600 and 900 mm annual rainfall and a rainy season lasting from four to five months. In the Sudan-Guinea, annual rainfall is above 900 mm and the rainy season is than five months.

The study was conducted in the Sahelian and Sudano-Sahelian areas. With less than 70 days of rainfall, the Sahelian and Sudano-Sahelian zones are more subject to rainfall deficit because of dry spell during the rainy season than the South-Sudanian zone (SP/CONEDD, 2007). Many consider irrigation a necessity to boost agricultural production and improve food security. The supplemental irrigation of rainfed crops is already practiced at a small scale in several tropical countries (Oweis *et al.* 2004; Merabeta & Boutiba, 2005; He *et al.* 2007). However supplemental irrigation is still a rare innovation among West African farmers on family farms not located in irrigation schemes especially as the practice has not progressed beyond the experimental stage (Some, 1989; Fox & Rockström, 2003).

2.2 Description of Supplemental Irrigation

Supplemental irrigation supplies crops with water during the long dry spell that can occur during the rainy season. The water comes from small man-made basins that collect and store run-off water from neighboring farm micro-watersheds. This strategy makes it possible to irrigate a portion of land under more intensive cultivation. It is based on four principles: (i) the construction of the basin, (ii) the collection of run-off water, (iii) the selection and implementation of crops, and (iv) the use of irrigation. The ponds are dug by members of the household, usually with the support of the community. Producers may use paid labor for pond construction. Information concerning the difference between a trapezoidal and rectangular pond is disseminated to farmers. The recommended volume is 150 m^3 for 0.25 ha of irrigated maize. The choice of the volume and shape of the basin are left up to the farmer. The basin is dug in a location as far as possible upstream from the irrigated plot to collect run-off. Adjustments are made in the ground to facilitate run-off pouring into the basin. Water is brought to rainfed crops that would normally produce yields without irrigation. A treadle pump is generally used, but farmers can use other methods of extraction such as motor pumps, hand pumps or watering cans.

2.3 Theoretical Frameworks

Methods to analyze the farmers' willingness to adopt agricultural innovations were originally based on models of human behavior borrowed from neo-classical economics. These models can be grouped in three categories. The Theory of Reasoned Action (TAR) states that an individual's intention to adopt a technology is determined by two factors, one reflecting his personal interests and the other his social influence (Ajzen & Madden, 1986). Stemming from TAR, a model of technology acceptance states that adoption is mainly determined by two types of perceptions: the perceived usefulness of the system and its perceived ease of use (Davis, 1989). The diffusion of innovation theory states that the perceived value of an innovation depends on its relative advantage, compatibility, complexity, trial ability and the way it is observed (Rogers, 2003). This theory can be likened to the spread of an epidemic (Richefort & Fusillier, 2010).

Alternative behavior models were based on economic theory which predicts that, faced with a problem of choice, a rational economic agent chooses the option that maximizes his utility (Gourieroux, 1989). For a farmer, the expression of the utility function for U_{ij} for j alternatives is:

$$U_{ij} = \alpha_j X_i + \varepsilon_{ij} \quad (1)$$

Farmers' decisions are assumed to provide the use of U_{i1} and U_{i0} respectively for acceptance or rejection of supplemental irrigation. A farmer selects alternative $j=1$ if the value of U_{i1} is greater than U_{i0} provided by the alternative $j=0$:

$$U_{i1} = \alpha_1 X_i + \varepsilon_{i1} > U_{i0} = \alpha_0 X_i + \varepsilon_{i0} \quad (2)$$

In this expression, X_i is a vector of characteristics of household j, α_j is a vector of the parameters to be estimated and ε_{ij} is a random error term. The presence of ε_{ij} in the use of function leads to solutions as a probability to choose between each alternative. The probability of choosing alternative $j=1$ is:

$$P = P(j=1) = P(U_{i1} > U_{i0}) = P\,(\alpha_1 X_i + \varepsilon_{i1} > \alpha_0 X_i + \varepsilon_{i0}) \quad (3)$$

$$= P(\varepsilon_{i1} - \varepsilon_{i0} > \alpha_0 X_i - \alpha_1 X_i\,) = P(\varepsilon_{i1} - \varepsilon_{i0} > (\alpha_0 - \alpha_1\,)X_i) \quad (4)$$

$$= P\left(\mu_i > \beta X_i\right) = \Phi(\beta X_i) \quad (5)$$

This equation indicates that the probability that a household i will adopt supplemental irrigation is the probability that the utility provided by the latter is greater than the utility derived from the non-adoption to the cumulative distribution $\Phi(\beta X_i)$.

$\mu_i = \varepsilon_{i1} - \varepsilon_{i0}$ is independently distributed disturbances and $\Phi(\beta X_i)$ is the distribution function associated with μ_i. The law of μ_i determines the distribution of the distribution function $\Phi(\beta X_i)$ and associated model type. In the literature, there are several models to analyze decisions to adopt agricultural innovations based on the law of μ_i including probit models (Benin *et al.* 2004; Akinola & Owombo, 2012), logit models (Sidibe, 2005; He *et al.* 2007) and tobit models (Adesina *et al.* 2008; Mbetid-Bessane, 2010). The logit model has the advantage of greater simplicity (Greene, 2011). Model structure representing farmer i's decision to adopt or reject supplemental irrigation is given by the following expression:

$$P = \Phi(\beta X_i) = \frac{Exp\,(\beta X_i)}{1 + Exp\,(\beta X_i)} \tag{6}$$

P is the dependent variable that takes 1 if adopted and otherwise 0, β is the vector of the parameters to be estimated, X_i is the explanatory variables of farmers and $\Phi(\beta X_i)$ is the probability that the farmer will adopt supplemental irrigation.

2.4 Model Specification

For an economic agent, adoption of innovation refers to a binary variable that takes 1 if he adopts the innovation and otherwise 0 (Greene, 2011). In this study, the binary variable defines the willingness to adopt supplemental irrigation (ASI). The dependent variable ASI_i is treated as 1 if the farmer i will adopt supplemental irrigation and otherwise 0. Explanatory variables are related to the socio-economic characteristics of the farmers, their perception of drought and interest in supplemental irrigation (Table 1). Assumptions were made on the influence of each on the farmers' willingness to adopt supplemental irrigation.

The socioeconomic characteristics are age, education, marital status, household size, being an active laborer, equipment, membership of a farmers' organization, ways to access land, farm income and off-farm income. Previous studies have shown that young farmers (Rogers, 2003; Paxton *et al.* 2011; Akinola & Owombo, 2012), married heads of households (Nkamleu & Coulibaly, 2000) and organized groups of farmers (Asfaw *et al.* 2011) are more likely to adopt agricultural innovations. Similarly, household size, being an active laborer, education, access to agricultural services, agricultural equipment and farm income favor the adoption of new agricultural techniques by farmers (Neupane *et al.* 2002; Asrat *et al.* 2004; Muzari *et al.* 2012). According to Nkamleu and Coulibaly (2000), off-farm income did not. Farmers who receive high off-farm income compared to their income from agricultural activities invest less in agriculture, particularly in agricultural innovations. Based on the results of previous studies, young farmers (< 45 years old) and married heads of households and / or educated farmers are likely to adopt supplemental irrigation. Household size, household members' access to agricultural services, membership of a farmers' organization, being an active laborer, equipment, and farm income are also expected to positively influence farmers' willingness to adopt supplemental irrigation. On the other hand, the expected effect of off-farm income is negative. In addition, land status plays an important role in the adoption of agricultural innovations (Alavalapati *et al.* 1995). Land tenure also influences the use sustainable farm management strategies. In rural areas, farmers generally access land through inheritance (Nkamleu & Coulibaly, 2000). The mode of access to land by inheritance is assumed to positively impact farmers' willingness to adopt supplemental irrigation.

Table 1. Description of the Variables Specified in the Empirical Binary Logistic Model

Variables	Description of the variables	Expected effects
Provinces		
Yatenga (reference)	Membership Yatenga (0=no; 1=yes)	+
Bam	Membership Bam (0=no; 1=yes)	-
Kadiogo	Membership Kadiogo (0=no; 1=yes)	-
Bazega	Membership Bazega (0=no; 1=yes)	-
Socio-economic characteristics		
Marital	Marital status (0 = single; 1 = married)	+
Education	Level of education (0 = illiterate; 1= literate)	+
Age	Age of household head (0= old ; 1 = young (age < 45)	+
Size	Size of the farm household	+
Labor	Family labor	+
Organization	Membership of a farmers’ organization	+
Land	Mode of access to land (0=other; 1=heritage)	+
Transport	Owns transport equipment (0=no; 1=yes)	+
Access	Access to technical services (0=no; 1=yes)	+
Income	Farm income	+
Off-farm income	Off-farm income	+
Farmers' perceptions of dry spells		
Stable	Dry spells continue unchanged (0=no; 1=yes)	-
Decrease	Decrease in the number of dry spells (0=no; 1=yes)	-
Increase (reference)	Increase in the number of dry spells (0=no; 1=yes)	+
Alternating	Change in chisel dry spells (0=no; 1=yes)	
No response	No answer concerning future dry spells (0=no; 1=yes)	-
Adoption of agricultural technologies		
Bunds	Use of stone bunds (0=no; 1=yes)	+
Mulching	Practice of mulching (0=no; 1=yes)	+
Moons	Practice half-moons (0=no; 1=yes)	+
Dikes	Use of small dikes (0=no; 1=yes)	+
Diversification	Diversification of crops (0=no; 1=yes)	+
Manure	Use of organic manure (0=no; 1=yes)	+
Rotation	Practice crop rotation (0=no; 1=yes)	+
Seeds	Use of improved seeds (0=no; 1=yes)	+
Zaï	Practice of zaï (0=no; 1=yes)	+
Farmers’ perceptions of supplemental irrigation based on runoff basins		
Intention	Seen or heard of supplemental irrigation since 2012 (0=no; 1=yes)	+
Maize (reference)	Useful for the cultivation of maize (0=no; 1=yes)	+
Sorghum	Useful for the cultivation of sorghum (0=no; 1=yes)	+
Millet	Useful for the cultivation of millet (0=no; 1=yes)	+
Rice	Useful for the cultivation of rice (0=no; 1=yes)	+
Vegetables	Useful for the cultivation of vegetables (0=no; 1=yes)	+
Don’t know	No response for appropriate crops	+
Cost	Construction cost of the basin	-

Source: Own elaboration
Note: + expected positive effect; - expected

Farmers have different perceptions of changes in the frequency of dry spell over time. These perceptions vary from no change, to a decrease or an increase in the frequency of dry spell or drought (Roncoli *et al.* 2002). Farmers may also have no opinion about these trends. To take all these perceptions into account in the model, it was assumed that the majority of farmers have been affected by a higher dry spell within and between agro-climatic zones. This assumption allows us to compare the farmers' willingness to adopt supplemental irrigation based on their perception of dry spells.

Agricultural technologies adopted by farmers to increase agricultural productivity are organic manure, crop diversification, rotation, improved seeds, techniques and water conservation. Improved maize, sorghum and rice seeds are the main ones. Zaï, half-moons, filtering dykes and bunds are the main techniques for conserving soil and water (Zougmore *et al.* 2004). In the context of adaptation to dry spell, the expected effect of the adoption of agricultural technologies is assumed to be positive with respect farmers' willingness to adopt supplemental irrigation.

Farmers' assessments of supplemental irrigation based on runoff basins are linked with their expected impact on rainfed crops, the cost of building the basin and access to information. The International Institute for Water Engineering and Environment and Ministry of Agriculture and Water Resources has promoted supplemental irrigation on maize production. Maize cultivation should have a positive impact on farmers' willingness to adopt supplemental irrigation comparatively to others farmers' choices. The cost of construction of the basin consists of expenses related to the excavation and annual maintenance and was estimated at CFA 652,150 Francs for a household that uses only a paid workforce. It is equivalent to six times the poverty line estimated at CFA 108,454 Francs per year in 2009 in Burkina Faso (INSD, 2010). Compared to the poverty line, the construction cost is assumed to affect farmers' willingness to adopt supplemental irrigation. Agricultural innovations are subject to moral hazard and objectives whose existence delays their adoption (Nkamleu & Adesina, 2008). Access to information reduces these risks and facilitates the adoption of new technologies (Kpad & Rom, 2013). Similarly, access to information is expected to positively impact farmers' willingness to adopt supplemental irrigation.

In the study area, low rainfall is observed in Yatenga located in the extreme north of the Sahelian zone. This province is dryer than the other study area. Farmers in Yatenga should thus be more inclined to adopt supplemental irrigation compared to farmers in the other study areas.

2.5 Data Collection and Processing

Data was collected on the basis of stratified sampling at three levels chosen in collaboration with the team of the project for supplemental irrigation and climate information and the provincial direction of the Ministry of Agriculture and Water Resources. The different levels are provinces, villages and farmers. Updated data on the number of farmers per village were obtained from the permanent agricultural survey of the Ministry of Agriculture and Water Resources. According to this data base, 629 farmers located in 11 villages were surveyed from January to February 2014 in the provinces of Yatenga, Bam, Kadiogo and Bazega. In each village, a third of the farmers were randomly selected for the survey.

CSPRO 3.3 software was used for data entry. These data were forwarded to SPSS 20 software to produce descriptive statistics. Analysis of variance (ANOVA) was used to compare the continuous variables with normal distribution at the significance threshold p = 5%. Kruskal-Wallis test and Chi-square were used as an alternative to ANOVA when the assumption of normality of the variables was not accepted. The econometric model was assessed based on the likelihood ratio tests and the adequacy level at a threshold of 1% with

Stata.12 software. Regression parameters were tested by the Wald statistic which is distributed according to the Chi-square law with one degree of freedom.

3. Results

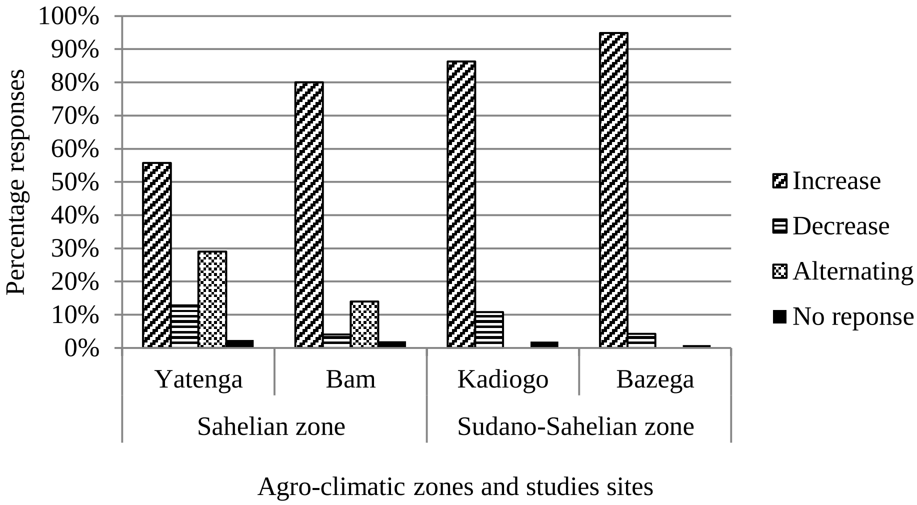
3.1 Current Farmers' Practices in the Agro-Climatic Zones

Table 2 presents the socio- economic characteristics of the farmers in our sample. In the province of Bam, the heads of households were educated (48.5%), organized (41.5%), young (71.9%) and earned more income from agriculture (CFA 99685.60 ± 9984.17 Francs) than those in other provinces. The proportion of married men among farmers was higher in Kadiogo (98%). Farm size (16) and the number of assets (6) were higher in Yatenga. Therefore these farmers have good access (9.70%) to supervision by agricultural services. Low levels of equipment (35.0%) and off-income (CFA 76,285.71 ± 14,536.02 Francs) were observed in Bazega. In general, socio-economic characteristics differed significantly within and between agro-climatic zones ($p < 5\%$). Only off-farm incomes were similar ($p > 10\%$).

Table 2. Socio-economic Characteristics of Farm Households

Agro-climatic zones	Sahelian		Sudano-Sahelian		p-value
Provinces	Yatenga	Bam	Kadiogo	Bazega	
Age of household head					0.000
Young (%)	51.4	71.9	62.4	47.0	
Old (%)	48.6	28.1	37.6	53.0	
Marital Status					0.037
Single (%)	4.3	9.5	2.0	6.8	
Married (%)	95.7	90.5	98.0	93.2	
Education					0.001
Illiterate (%)	61.4	51.5	59.8	74.4	
Literate (%)	38.6	48.5	40.2	25.6	
Organization					0.000
No (%)	62.4	58.5	91.2	88.0	
Yes (%)	37.6	41.5	8.8	12.0	
Land					0.000
No (%)	20.0	1.0	2.90	0.9	
Yes (%)	80.0	99.0	97.1	99.1	
Access					0.000
No (%)	90.3	96.5	95.6	98.8	
Yes (%)	9.7	3.5	4.4	1.2	
Transport					0.000
No (%)	61.0	63.8	46.4	65.0	
Yes (%)	39.0	36.2	43.6	35.0	
Size	16.12±0.84	10.81±0.41	8.43±0.37	9.74±0.54	0.000
Labor	6.21±0.54	4.21±0.23	3.44±0.16	4.62±0.30	0.000
Income (CFA Francs)	62,090.90± 3,151.98	99,685.60± 9,984.17	59,562.06± 2,735.96	41,341.60± 4,257.28	0.000
Off-farm income (CFA Francs)	198,992.01± 31,039.34	247,112.50± 34,176.83	153,719.30± 33,677.51	762,85.71± 14,536.02	0.214

Source: Own Survey Result, 2014



Source: Own Survey Result, 2014

Figure 1. Farmers' Evaluation of Dry Spells in The Past Two Decades

Most farmers perceived an increase in dry spell in the last two decades (Figure 1). This increase was perceived by 55.7% of the farmers in Yatenga, 80% in Bam, and 86% and 94.9% in Kadiogo and Bazega, respectively. The proportions of farmers who perceive an increase in dry spell is growing throughout the provinces in the Sahelian zone (Yatenga, Bam) compared to those of the Sudano-Sahelian zone (Kadiogo, Bazega) but the differences were not significant ($p > 10\%$).

Table 3. Adoption of Agricultural Innovations

Agro-climatic zones	Sahelian		Sudano-Sahelian		p-value
Provinces	Yatenga	Bam	Kadiogo	Bazega	
Zaï (%)	53.3	94.5	6.9	0.9	0.000
Bunds (%)	72.9	88.5	80.4	17.1	0.000
Moons (%)	1.4	1.0	0.0	0.0	0.402
Dikes (%)	1.0	1.0	0.0	30.8	0.000
Diversification (%)	51.4	11.0	96.1	96.6	0.000
Mulching (%)	7.1	2.5	20.6	1.7	0.000
Rotation (%)	33.3	6.0	97.1	93.2	0.000
Seeds (%)	42.9	28.5	71.6	22.2	0.000
Manure (%)	96.7	94.5	68.6	97.4	0.000

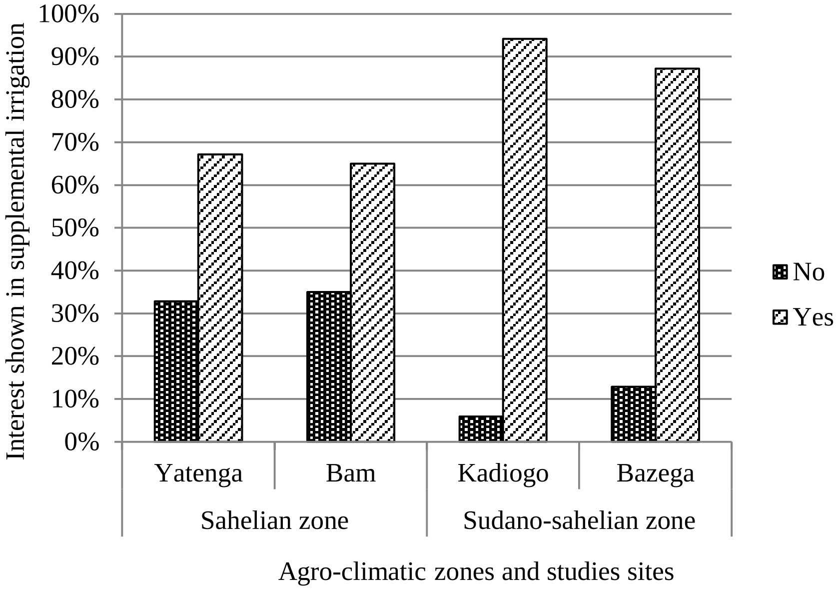
Source: Own Survey Result, 2014

Several agricultural innovations have been adopted by farmers to mitigate the impact of dry spell (Table 3). More than 50% of farmers in all provinces have started using organic fertilizer. In Yatenga and Bam provinces, which are located in the Sahelian zone, zaï has been adopted by 53.3% and 94.5% compared to 6.9% and 0.9% of farmers in the Kadiogo and Bazega provinces located in the Sudano-Sahelian zone. However crop rotation is now practiced by 97.1% of farmers in Kadiogo and 93.2% in Bazega compared to 33.3% in

Yatenga and 6% in Bam. Over 80% of farmers are using stone bunds in all provinces except Bazega (17.1%). The adoption of half-moons was low in all provinces. The rate of tillage and crop diversification is greater than 50% in Kadiogo, Bazega and Yatenga versus less than 12% in Bam. The use of improved seeds ranges between 22% and 71.6% in all provinces. Less than 2% of farmers adopted filter bunds in all provinces except in Bazega where they were adopted by 30.8%. Except for half-moons, the adoption of innovations varied significantly among provinces ($p < 0.001$).

3.2 Farmers' Assessments of Supplemental Irrigation

The majority of farmers planned to introduce supplemental irrigation in their farming systems during the next agricultural campaign (Figure 2). However the potential acceptance rate varied significantly with the province and agro-climatic zone ($p < 0.001$), it was 94.1% and 87.2% respectively in Kadiogo and Bazega and 67.1% and 65% in Yatenga and Bam. The interest shown by producers was linked to the possible increase in agricultural productivity.



Source: Own Survey Result, 2014

Figure 2. Distribution of Farms According to Their Degree of Motivation to Use Supplemental Irrigation

Asymmetric information ($p < 0.001$) on the use of supplemental irrigation appeared between the provinces (Table 4). The proportion of farmers who were aware of supplemental irrigation was estimated at 85% and 64.5% respectively at Yatenga and Bam in the Sahelian zone. However the rate of the information dissemination only reached 30.4% and 24.8% in Kadiogo and Bazega in the Sudano-Sahelian zone. For 95.5% of farmers in Kadiogo and 52.4% in Bazega and 83.3% and 76.2% of farmers in respectively Bam and Yatenga, the main sources of information were other farmers (word of mouth).

Table 4. Farmers' Access to Information on Supplemental Irrigation

Agro-climatic zones	Sahelian		Sudano-Sahelian		p-value
Provinces	Yatenga	Bam	Kadiogo	Bazega	
Information (heard or observed)					0.000
Yes (%)	85.7	64.5	30.4	24.8	
No (%)	14.3	35.5	69.6	75.2	
Information sources					0.000
Radio (%)	23.8	16.7	4.8	47.6	
Farmers (%)	76.2	83.3	95.5	52.4	

Source: Own Survey Result, 2014

The majority of farmers said that maize is the most appropriate crop for supplemental irrigation (Table 5). However the acceptance rates of maize varied significantly between provinces ($p < 0.001$). Kadiogo had the highest rate (98%) of farmers who cultivated maize. Maize cultivation will help fill the food gap experienced by some farmers. In addition to supplemental irrigation for maize, farmers considered that the water collected in small basins could also be used to water livestock but fewer approve its use for building houses or for drinking water but with significant differences among the provinces ($p < 0.001$). In areas located farther from their homes, some farmers drink the water in the basins.

Table 5. Expected Interest Supplemental Irrigation

Agro-climatic zones	Sahelian		Sudano-Sahelian		p-value
Provinces	Yatenga	Bam	Kadiogo	Bazega	
Appropriate crops					0.000
Maize (%)	77.1	76.5	98.0	91.1	
Millet (%)	14.4	3.7	1.0	1.8	
Sorghum (%)	2.6	19.8	0	5.4	
Rice (%)	2.6	0.0	0.0	0.0	
Vegetables (%)	3.3	0.0	1.0	1.7	
Other uses					0.000
Watering livestock (%)	95.3	87.8	100	54.5	
Building houses (%)	2.3	9.6	0	27.3	
Drinking water (%)	2.3	2.6	0	18.2	

Source: Own Survey Result, 2014

The farmers' preferences refer to the choice of shape of the basin and the types of field where the basin should be dug (Table 6). The rectangular basin was chosen by 59.3%, 80% and 89.2% respectively in Yatenga, Bam and Bazega. Nearly 79.2% of farmers Kadiogo did not choose a particular shape for the basin. The other basins were poorly adopted. Approximately 73% of farmers selected the home farm for the location of their basin in Yatenga and Bam in the Sahelian zone. Respectively 68% and 81% of farmers in Kadiogo and Bazega in the Sudano-Sahelian zone owned bush fields where a basin could be dug. Overall, the choice of the shape of the basin and the type of field varied significantly within and between agro-climatic zones ($p < 0.001$).

Table 6. Farmers' Preferences with Respect to Runoff Basins

Agro-climatic zones	Sahelian		Sudano-Sahelian		p-value
Provinces	Yatenga	Bam	Kadiogo	Bazega	
Type of farm appropriate for a basin					0.000
Home farm (%)	27.2	27.7	68.4	81.4	
Bush farm (%)	72.8	72.3	31.6	18.6	
Shape of basin					0.000
Circular (%)	6.4	16.9	7.3	10.8	
Rectangular (%)	58.9	80.0	13.5	89.2	
Trapezoidal (%)	0.7	3.1	0.0	0.0	
No response (%)	34.3	0.0	79.2	0.0	

Source: Own Survey Result, 2014

3.3 Factors Affecting Farmers' Willingness to Adopt Supplemental Irrigation

Socio-economic variables such as marital status, age of the head of household, household size, and the number of active laborers, equipment, and farm income significantly affected ASI (Table 7). Variables that positively impacted ASI were household size, 1%, farm income, 5% but also transport and marital status, 10%. In contrast, the variables age and assets affected the respective ASI threshold of 5% and 1%. These results show that supplemental irrigation is likely to be accepted based on the size of the household, by married men, by farmers with a cart, and by farmers for whom agriculture is the main source of income. But the young heads of households and the majority of active peasants do not intend to include it in their farming systems.

Among the variables related to farmers' perceptions of dry spell, the lack of perception of possible future changes in dry spell negatively influenced ASI at a threshold of 5%. This result shows that farmers who are not aware of changes in the frequency of dry spell are less likely to adopt supplemental irrigation than farmers who perceived an increase, decrease, stability or alternation of dry spell.

Among the variables related to agricultural innovations already adopted by the farmers, stone bunds, mulching, crop diversification, seeds, half-moons and zaï significantly affected ASI. Stone bunds and seeds positively impacted ASI at a risk threshold of 1% versus mulching at 5%. But half-moons and zaï are variables that affect ASI at a threshold of 10%. The adoption of bunds, mulching and use of improved seeds encourage farmers to practice supplemental irrigation in contrast to the practice of zaï, half-moons and crop diversification, which do not.

Access to information on irrigation and lack of knowledge on the most suitable crop were variables that affected ASI. Access to information promotes ASI at a risk threshold of 1% while ignorance of the appropriate crop affects the risk by 1%. Farmers who were aware of the practice of supplemental irrigation on maize have a tendency to adopt it whereas farmers who were unable to identify suitable crops did not.

Variables in Kadiogo and Bazega positively influenced the ASI threshold by 1%. In contrast the variable in Bam affected the threshold by 1%. These results show that the propensity of farmers to practice supplemental irrigation is similar in the provinces of Yatenga, Kadiogo and Bazega but low in Bam.

Table 7. Summary of Explanatory Variables

Variables	Coefficients	Standard errors	z	P>|z|
Provinces				
Bam	-1.070	0.367	-2.920	0.004**
Kadiogo	1.425	0.532	2.680	0.007**
Bazega	1.660	0.527	3.150	0.002**
Socio-economic characteristics				
Marital status	0.582	0.342	1.701	0.088*
Education	0.095	0.185	0.516	0.609
Age	-0.561	0.194	-2.903	0.004**
Size	0.089	0.023	3.854	0.000***
Labor	-0.109	0.030	-3.611	0.000***
Organization	0.288	0.208	1.386	0.166
Land	0.557	0.426	1.319	0.191
Transport	0.348	0.191	1.820	0.069*
Access	0.627	0.559	1.127	0.262
Income	0.000	0.000	2.761	0.006**
Off-farm income	0.063	0.044	1.433	0.154
Farmers' perceptions of dry spells				
Stable	-0.181	0.319	-0.731	0.374
Decrease	-0.277	0.324	-0.868	0.392
Alternative	0.277	0.254	1.095	0.277
No response	-1.216	0.590	-2.062	0.039*
Adoption of agricultural technologies				
Bunds	0.929	0.253	3.679	0.000***
Mulching	1.145	0.572	2.001	0.045**
Moons	-1.598	0.931	-1.725	0.086***
Dikes	0.410	0.456	0.906	0.368
Diversification	-0.776	0.284	-2.730	0.006**
Manure	-0.276	0.416	-0.664	0.508
Rotation	-0.270	0.283	-0.956	0.341
Seeds	1.305	0.247	5.298	0.000***
Zaï	-0.573	0.313	-1.832	0.067*
Farmers' perceptions of supplemental irrigation				
Intention	1.108	0.221	5.021	0.000***
Sorghum	0.489	0.315	1.550	0.120
Millet	0.356	0.398	-1.454	0.371
Rice	-	-	-	-
Vegetables	-0.908	0.627	0.899	0.148
Don't know	-2.017	0.294	-6.867	0.000***
Cost	-	-	-	-
Constant	-7.828	4.246	-1.841	0.065
Number of observations: 629; Percent correct= 80.89%; LR chi2(32) = 360.651; Prob > chi2 =0.000 ; Pseudo R^2 = 0.295; Log likelihood = -431.550;				

Source: Own Estimation Result, 2014

Note: asterisks * significant at 10%; ** significant at 5%; *** significant at 1%

4. Discussion

4.1 Current Farmers’ Practices Within and Between Climatic Zones

Our analysis of farmers' practices showed that the adoption of agricultural innovations varied within and between the Sahelian and Sudano-Sahelian climatic zones in Burkina Faso. These results are in agreement with the results of several previous studies indicating that heterogeneity is due to the combination of several socio-economic factors (Kebede *et al.* 1990; Ashok & Sasikala, 2012). According to Sidibe (2005), farmers’ education and their perception of land degradation facilitate the adoption of the zaï technique while belonging to a peasant organization facilitates the adoption of bunds in the Sahelian zone. According to Ouedraogo *et al.* (2010), household access to agricultural services explains the use of improved seeds.

In the present study, the heterogeneous adoption of agricultural innovations could also be explained by the farmers’ different perceptions of dry spell within and between the Sahelian and Sudano-Sahelian zones. This result is in agreement with that of Brou *et al.* (2005) who found that the adoption of some practices in the agro-climatic regions of Côte d’Ivoire was prompted by their perceptions of climate hazards. Other studies in Benin also indicate that the use of agricultural practices depends on the farmers’ perceptions of climate change (Smit *et al.* 1996; Deressa *et al.* 2008; Baudoin, 2010). Despite farmers' strategies, yields of rainfed crops are still undergoing drastic declines linked to dry spell (MAH, 2012). Faced with this situation, more than 65% of the farmers believe that supplemental irrigation is an effective strategy.

4.2 Willingness to Adopt Supplemental Irrigation

The results showed that acceptance of supplemental irrigation by farmers differ. The size of the farms, married heads of households and farmers who mainly rely on agricultural income were willing to adopt supplemental irrigation. They were unanimous that this new innovation would not only help stabilize yields of rainfed crops during dry spell but also diversify their sources of income by enabling the cultivation of vegetable crops during the rainy season. In contrast, young heads of households and most active farmers were not interested in supplemental irrigation. They were more interested in non-agricultural activities including gold mining which can provide a substantially higher cash income than agriculture in some northern regions of Burkina Faso (Thune, 2011).

Unlike the adoption of zaï and crop diversification, the adoption of bunds and the use of improved seeds encouraged farmers to irrigate rainfed crops. Producers believed that zaï and crop diversification would minimize the adverse effects of dry spell on yield as well as supplemental irrigation. They thought that if zaï and crop diversification are practiced, there is no need for supplemental irrigation. However they recognized the need for supplemental irrigation if they chose the use of improved varieties of seeds to increase agricultural yields. However, improved varieties can improve crop yields only if water is available for the crops (Brocke *et al.* 2013). Farmers believe that irrigation is still useful in fields where mulching is practiced and where farm bunds are located, since these innovations do not enable the soil to retain soil moisture for a long time. According to Zougmore *et al.* (2004), bunds are recommended to reduce erosion rather than to maintain soil moisture.

Farmers who perceived an increase, decrease, alternation or stability of dry spell are more likely to adopt supplemental irrigation than other farmers. They believe supplemental irrigation will increase crop yields. But farmers who do not perceive possible a future increase in dry spell are not interested in supplemental irrigation. The attitude of these farmers could be because they are not aware of the importance of supplemental irrigation in stabilizing or increasing agricultural yields. This is due to the lack of knowledge and lack of training. Indeed the majority of farmers were only informed about supplemental irrigation by word of mouth. The inaccessibility of the media and agricultural services explains this situation. According to Munshi (2004), acquiring information from neighbors does not facilitate the adoption of new agricultural innovations.

In addition, more farmers in Yatenga, Kadiogo and Bazega used more supplemental irrigation than farmers in Bam. The difference in the likelihood of farmers to practice supplemental irrigation within and between agro-climatic zones could be explained not only by their socio-economic characteristics and the types of innovation they have already adopted but also by their perception of dry spell and especially information asymmetry.

5. Conclusion and Policy Implications

This study analyzed the link between farmers' practices, characteristics and their willingness to adopt supplemental irrigation in farming systems that are subject to long dry spell during the rainy season. We showed that farmers have different socio-economic characteristics, rates of adoption of agricultural innovations and heterogeneous perceptions of the future of dry spell within and between the Sahelian and Sudano-Sahelian regions of Burkina Faso. Most farmers believe that supplemental irrigation is an alternative way to mitigate these dry spell. Over 65% of farmers are planning to use rainfed irrigation from a basin that collects run-off water. Large households, married heads of households, farmers who mainly rely on agricultural income are willing to use supplemental irrigation. Farmers who are able to appreciate the variability of dry spell are also more likely to adopt supplemental irrigation. But young and the most active heads of households are not interested because they are more geared towards non-agricultural activities. The use of bunds and improved seeds encourages farmers to irrigate rainfed crops while the practice of zaï and crop diversification does not. Lack of awareness is a major constraint to the promotion of supplemental irrigation. Most farmers are only aware of the practice by word of mouth. Measures oriented towards training and awareness raising of farmers are needed to facilitate the adoption of supplemental irrigation in farming systems but the specificities of the agro-climatic zones need to be taken into account.

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