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Farmers' Behavior and Innovations' Adoption Processes in Rural Sahel: Case of Supplemental Irrigation from Farm Ponds in Burkina Faso

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Abstract

Since 2012, development actors have promoted supplemental irrigation from farm ponds to cope with rainfall variability in Burkina Faso, but few farmers have adopted the innovation. Although harvesting runoff water in ponds is an old practice in Sahelian Burkina Faso, farmers were not accustomed to irrigating crops with stored rainwater. In the context of low adoption rates of innovation, it is useful to understand the behavior and profile of those who do adopt innovations. This article analyzes farmers' adoption processes by focusing on their socio-economic characteristics and on stakeholders' social representations of the innovation. We conducted field surveys of 18 institutional actors and 33 adopters. Our results showed that farmers have favorable attitudes towards adoption and that institutional actors help strengthen these intentions by influencing farmers' social norms and capacities to act, but that the farmers' perceptions of difficulties, risk, and social norms prevent them from adopting. As supplemental irrigation from farm ponds is a labor-intensive innovation, farmers who cannot call on community labor or hire seasonal workers are limited in their adoption of the innovation. In addition, the fear of being subjected to mockery by members of the community or the fear of losing social prestige is a social norm that may limit the adoption of the innovation. We characterized the profile of adopters, who mainly have a low income but a high social status that allows them to receive support from policy-makers. Farmers have a preference for growing cash crops rather than subsistence crops the latter being the goal of most institutional actors. Our study showed that farmers' preferences and perceptions of social norms, as well as the characteristics of innovations, are important as socio-economic and technical factors in farmers' adoption processes.

Keywords: adoption processes, farmers, innovation adoption, institutions, social representation

Comportement des agriculteurs et processus d'adoption d'innovations dans le Sahel : cas de l'irrigation de complément à partir d'étangs agricoles au Burkina Faso

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Résumé

Depuis 2012, les acteurs du développement ont encouragé l'irrigation de complément à partir des étangs agricoles pour faire face à la variabilité des précipitations au Burkina Faso, mais peu d'agriculteurs ont adopté cette innovation. Bien que la récupération des eaux de ruissellement dans des étangs soit une pratique ancienne dans la région sahélienne du Burkina Faso, les agriculteurs n'étaient pas habitués à irriguer les cultures avec l'eau de pluie stockée. Dans ce contexte de faibles taux d'adoption de l'innovation, il est utile de comprendre le comportement et le profil de ceux qui adoptent. Cet article analyse les processus d'adoption des agriculteurs en se concentrant sur leurs caractéristiques socio-économiques et sur les représentations sociales de l'innovation des acteurs. Nous avons mené des enquêtes de terrain auprès de 18 acteurs institutionnels et 33 adoptants. Nos résultats ont montré que les agriculteurs ont des attitudes favorables à l'adoption et que les acteurs institutionnels contribuent à renforcer ces intentions en influençant les normes sociales et les capacités d'action des agriculteurs, mais que les perceptions des agriculteurs quant aux difficultés, aux risques et aux normes sociales les empêchent d'adopter. L'irrigation de complément à partir des étangs agricoles étant une innovation à forte intensité de main d'oeuvre, les agriculteurs qui ne peuvent pas faire appel à la main d'oeuvre communautaire ou embaucher des travailleurs saisonniers sont limités dans leur adoption de l'innovation. De plus, la peur de faire face à la raillerie des membres de la communauté ou la peur de perdre son prestige social est une norme sociale qui peut limiter l'adoption de l'innovation. Nous avons caractérisé le profil des adoptants, qui ont pour la plupart de faibles revenus mais un statut social élevé leur permettant de bénéficier du soutien des décideurs politiques. Les agriculteurs préfèrent cultiver des cultures de rente plutôt que des cultures de subsistance, ces dernières étant l'objectif de la plupart des acteurs institutionnels. Notre étude a montré que les préférences des agriculteurs et leurs perceptions des normes sociales, ainsi que des caractéristiques des innovations, sont aussi importantes que les facteurs socio-économiques et techniques dans leurs processus d'adoption.

Mots-clés : adoption d'innovations, agriculteurs, institutions, processus d'adoption, représentation sociale

1.0 Introduction

Rainfed agriculture accounts for more than 95% of cultivated land in Sahelian countries. Droughts thus have a marked negative impact on agricultural production (Girard et al., 2021), particularly dry spells caused by rainfall variability during the rainy season. As with many factors, such as financial constraints, availability and credit issues, the risk of dry spells is too high to justify the purchase of inputs, so farmers apply very little fertilizer to their crops. Yields remain low, resulting in food insecurity and impoverishment in rural areas (Barbier, 2010). Many farmers are already adopting some water and soil conservation techniques, such as *zaï*[1], half-moons and stone barriers. However, these techniques are not enough to guarantee good yields when dry spells last two to three weeks. In this context, supplemental irrigation is presented as the best technique to cope with the water deficit in the case of rainfed crops (Fox & Rockström, 2003).

Rainwater harvesting in ponds is an old practice in Burkina Faso (Guillaud, 1993), and traditional ponds are commonly called *boulis* in the Mooré language. The collected water was mainly used for watering livestock or other purposes, such as manufacturing bricks, but not to irrigate crops. Irrigating rainfed crops in the rainy season has never been done before. It appears to be incompatible with existing social practices (e.g., the boulis are for collective use) and not cost-effective. The innovation considered here consists of digging farm ponds with a capacity of about three hundred cubic meters to collect runoff water from the surrounding landscape. In Burkina Faso, researchers tested the use of supplemental irrigation for rainfed crops during dry spells using farm ponds (Araya et al., 2024; Sanfo et al., 2017; Zongo et al., 2015). Before the intervention of institutional actors, farmers did not irrigate traditional rainfed crops (maize or beans), even when water and irrigation equipment were available. Institutional actors may have influenced farmers' social norms or practices, as found by Rodriguez-Sickert et al. (2008) in a game experiment.

Since 2012, the Burkinabe government and local and international organizations have been trying to promote this innovation. Some institutional actors provide advice and financial and technical support for farmers, but the rate of adoption remains low. This situation resembles others in Burkina Faso and, more broadly, in sub-Saharan Africa, where several development projects to promote agricultural innovations have had poor results (Venot et al., 2017). To improve their interventions in rural areas, it is thus important for development actors to better understand farmers' behavior.

The aim of the present study was to analyze the farmers' process of adopting the innovation by focusing on their socio-economic characteristics and on the stakeholders' social representations of the innovation, using economic and psychosocial approaches. We combined economic analysis and social sciences to improve our understanding of the decision-making processes of individuals (Simon, 1986; Kahneman, 2012).

2.0 Theoretical Framework

Here we present the economic and psychosocial approaches we used to analyze the farmers' process of adopting the innovation (see Table 1). To analyze the farmers' decision, we built a model based on the foundations of microeconomic equilibrium (supply and demand for innovation) and the evolutionary model. We then combined this economic dimension with a psychosocial approach based on the theory of planned behavior and social representation.

[1] Zaï is a technique whereby small holes are dug to sow seeds and contain water and fertilizer in each poquet.

Table 1. *Summary of the Theoretical Approaches Used in this Study*

Approaches	Models / theories	Main foundations of analysis	Principal investigators
Economic	Microeconomic equilibrium	New consumer theory Rational behavior of individuals	Lancaster, 1966; Simon, 1986
	Evolutionary model and innovation system	Non-linearity of innovation Appropriation & learning Interactions between actors	Nelson, 1985; Dosi & Nelson, 1994
Psychosocial	Theory of planned behavior	Attitude Subjective norms Perceived behavioral control Intention & behavior	Ajzen, 1991; 2005
	Theory of social representation	Common innovation representation Central core & peripheral elements	Abric, 2001; Jodelet, 2003; Moscovici, 1961

Source: Authors.

2.1 Economic Approach

2.1.1. Microeconomic equilibrium. We consider farmers as agents who maximize their utility by optimizing their innovation adoption choices (Faure et al., 2018). Most economic studies of the adoption of agricultural innovations are based on consumer theory, which helps identify the combination of individuals' preferences and budgetary constraints that maximize utility. Based on the new consumer theory (Lancaster, 1966), the utility of an innovation can be determined by farmers' preferences for its characteristics. For example, authors, including Adesina and Baidu-Forson (1995) and Asrat et al. (2010), showed that farmers' decisions to adopt an innovation mainly depend on the characteristics of the innovation.

A microeconomic equilibrium model analyzes the adoption of innovation as an interaction between adopters and the object to be adopted (adopters are consumers, and the object of potential adoption is defined as a good). This model relies on two basic assumptions: (i) information plays a negligible role in the diffusion of an innovation and (ii) the economic agents behave rationally. In this approach, a low rate of diffusion implies that for at least some potential adopters, the proposed innovation is no better than existing practices (Rahm & Huffman, 1984). This means that those who have not yet adopted the innovation do not necessarily lack information but rather expect the ideal opportunity to adopt it (Ruttan, 1996). This interpretation may also stem from the fact that potential adopters are involved in a relatively slow learning process, i.e. learning by doing, as they acquire information about the innovation progressively (e.g., the Bayesian model) (Ghadim & Pannell, 1999).

However, the linearity of the innovation, which excludes any interaction in the process of adoption, is one limitation of this neoclassical model (Silverberg et al., 1988): the innovation is presented as the result of the culmination of

scientific knowledge, thus disregarding learning (especially learning by adopters). Contrary to this reasoning, which can be an obstacle to a real understanding of the farmers' behavior, our study accounts for the different interactions that may occur between farmers and institutional actors.

2.1.2. Evolutionary model and innovation system. According to Faure et al. (2018), the evolutionary model describes the adoption of an innovation as a process leading to the choice of the most suitable technology. This approach challenges the diffusionist paradigm of innovation (i.e., the linearity of innovation), as well as the standard maximization and equilibrium models (Dosi & Nelson, 1994). According to Silverberg et al. (1988), an evolutionary model must account for the characteristics of the innovation, namely the complexity of its implementation and the degrees of appropriation and learning. The model must be able to incorporate the diversity of economic agents, including their ability to adopt the proposed technology, their level of education and their behavior. Finally, the model must also account for the technical and profitability elements specific to each agent, such as the size of the farm, the relative advantages of the innovation, and the market shares. Following these evolutionary approaches, research based on the notion of innovation systems started to emerge in the late 1980s (Touzard et al., 2014). An innovation system can be defined as a set of actors, institutions, organizations and networks interacting to enable innovation at the scale of a technology, sector, region, or nation (Carlsson et al., 2002).

The dual approach combining the equilibrium model and the evolutionary model (from which the innovation system derived), allowed us to analyze both farmers' adoption decisions and the different interactions between the actors concerned (farmers, researchers and development actors). We chose an economic approach that accounts for individual decisions plus for all the external factors that culminate in these decisions. Based on the work of Simon (1986), the psychosocial approach complemented and strengthened our economic analysis of the farmers' adoption process.

2.2 Psychosocial Approach

2.2.1. Theory of planned behavior. To analyze the behavior of farmers in adopting an innovation, we followed the theory of planned behavior (Ajzen, 1991; 2005) and incorporated institutional actors in Ajzen's model, as we hypothesized they play an important role in farmers' decision-making (Rodriguez-Sickert et al., 2008). This model is the second main approach used in economics to analyze decisions on whether to adopt; the first approach is based on utility maximization theory. Ajzen distinguishes two steps in a decision process: before behaving (then adopting), the first step is to be well-intentioned towards acting, which is explained by three elements (attitude, subjective norms and perceived behavioral control).

Attitude corresponds to the utility related to self-interests. It includes elements such as self-esteem, preferences, perceptions and prestige that influence the individuals' choices and are non-directly observable. These elements can be verbal or non-verbal (e.g., facial expressions) and are obtained from the individuals themselves or from people around them (e.g., neighbors). Neuro-economics can also help identify attitudes (Sanfey et al., 2003). However, in our study, we were only interested in verbal answers, which is the case in most research (Ajzen, 2005).

Subjective norms correspond to collective interests and represent the social dimension of individuals, who may feel social pressure to make decisions, or not. For example, as irrigating rainfed crops during the rainy season may appear

incompatible with prevailing social norms in certain rural areas of Burkina Faso, it is interesting to analyze the compatibility of the adoption of the innovation and existing subjective norms. Some socially shared religious beliefs that favor an innovation allow farmers to be willing to adopt it (Van den Bergh & Gowdy, 2009). Subjective norms also include the opinion of others, which plays a significant role in decisions to adopt (Bonavia & Brox-Ponce, 2018; Dana et al., 2006), especially in rural Africa.

Perceived behavioral control corresponds to factors over which the individual has control, such as willingness and freedom to act, level of education, and financial capabilities. We assumed that farmers would only adopt an innovation if they had confidence in their ability to implement it and that institutional actors can strengthen this capacity to act.

2.2.2. Theory of social representation. To judge if an individual is well intentioned requires addressing elements that are not easily observable (e.g., beliefs, social norms, perceptions). To characterize them, it is possible to call on a concept proposed by psychosociologists: social representation, which was first theorized by Moscovici, is "a form of knowledge, socially elaborated and shared, with a practical focus that contributes to the creation of a common reality for a social unit" (Moscovici, 1961, as cited in Jodelet, 2003, p. 43). A way to identify a social representation consists of following the theory of the central core, proposed by Abric (2001), who distinguished (1) the central elements or "central core" of the social representation of the object concerned from (2) the peripheral elements. The central elements organize and stabilize the content of the representation, allowing it to resist change, in contrast to the peripheral elements, which are not rigid and refer to more personal aspects of the representation.

3.0 Methods

3.1 Study Area

The study area is located between 50 to 100 kilometers from the capital Ouagadougou. It covered 16 villages belonging to five different regions, among thirteen, of Burkina Faso: Centre, Centre-Nord, Centre-Ouest, Centre-Sud and Plateau Central (see Figure 1). Agriculture in Burkina Faso is mainly manual and almost entirely rainfed, oriented towards grain production, including millet, maize, sorghum, beans and groundnuts, and some vegetables. The average annual rainfall in the study area is 750 mm, and the soil is mainly ferruginous (see Figure 1). Ferruginous soils are constraining for agriculture because they are comparatively poor in organic matter, nitrogen, phosphorus and potassium (Pallo et al., 2009). In addition, soil fertility is gradually degrading because of the disappearance of fallows due to rapid population growth (estimated at 3% per year). Traditional soil fertility methods, such as agroforestry, applying manure or compost and rotation with legumes, do little to compensate for the decrease in soil organic matter and mineral elements in the soils. More mineral and organic nutrients are needed, but even when they are added, their impact on yields is very often reduced by dry spells. Because of their financial constraints, availability and credit issues, and the high risk of drought during the rainy season, farmers only apply very small amounts of fertilizers. Supplemental irrigation using farm ponds could make fertilization economically more attractive.

This geographical delimitation formed the basis on which empirical analyses were carried out, such as the analysis of farmers' socio-economic and cultural characteristics. Indeed, small family farms (on average less than 5 hectares in size) characterize the study area, which is mainly populated by the Mossi ethnic group, which accounts for about 50% of the population of Burkina Faso. In general, farmers have traditional ownership rights to their land holdings. Land is

transferred from one generation to another, and a traditional land chief guarantees land ownership. Most farmers obtained land tenure through their lineage or through lending.

3.2 Interviews

Between May and July 2019, we conducted semi-structured interviews with the main institutional actors of this innovation, as well as with farmers who had dug a farm pond. Each interview lasted about one hour. The data were collected in writing following an interview guide, supported by audio recordings that enabled the transcription of the farmers' statements. The main topics discussed were the role of institutional actors, the adoption of supplemental irrigation based on farm ponds, farmers' preferences and perceptions of the characteristics of the technique, and the social norms. Interviews were conducted either in the local language or in French, as appropriate.

3.2.1 Institutional actors interviewed. Institutional actors were either professional or traditional actors:

1. The 16 professional actors belonged to local and international organizations, such as public office, research organizations, and NGOs[2]. They were selected in a reasoned way, by taking their experience and their role in the implementation of the innovation into account. These are the main actors who promote supplemental irrigation in Burkina Faso, either by piloting or financing its implementation.
2. The two traditional actors[3] are among the proponents of traditional habits and customs in Burkina Faso. They were selected in a reasoned way based on their availability and knowledge about the adoption of innovations in rural areas.

3.2.2 Farmers interviewed. We interviewed 33 farmers who were chosen in two separate ways for optimal representativeness:

1. The first group comprised 25 farmers randomly selected from the official list of adopters provided by the Government Department of Agriculture and Hydro-agricultural Development.
2. The second group comprised eight adopters who were not on the official list but had a farm pond. They were identified through interviews with institutional actors. They often presented different characteristics than the other adopters, e.g., were organized as a group of farmers, or received technical and financial support from other organizations.

The two selection criteria helped us meet farmers who differed, either in socio-economic aspects, or in geographical, organizational and financial aspects. The farmers we interviewed represent about 4.5% of all the farm pond adopters in Burkina Faso, and 37.5% of the villages we surveyed had only one adopter.

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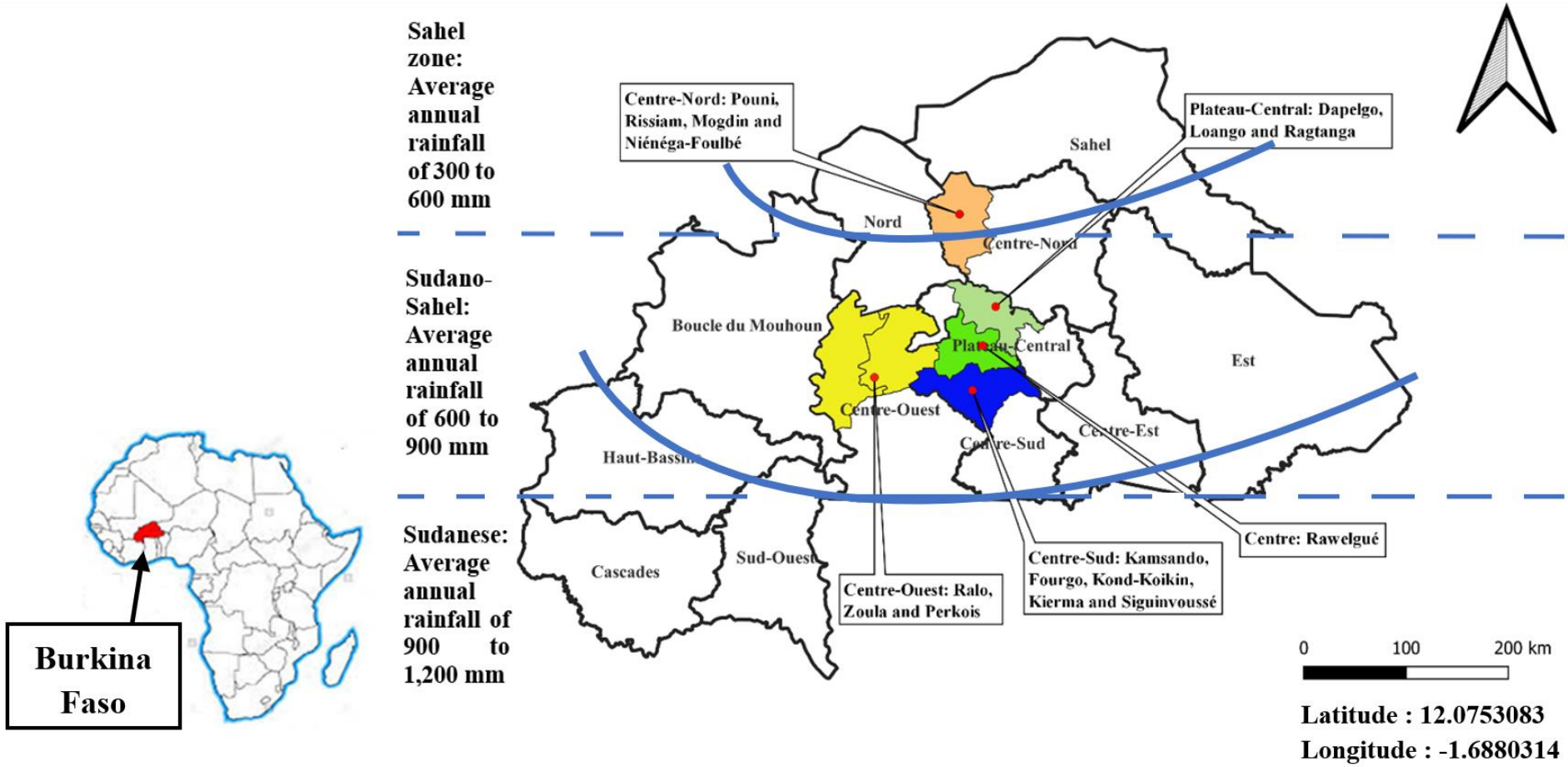
[2] Government office of Hydraulic Installations and Irrigation Development; Institute of Environment and Agricultural Research; International Institute for Water and Environmental Engineering; Center for International Cooperation in Agricultural Research for Development; Inter-State Committee for Drought Control in the Sahel; West African Economic and Monetary Union; NGO – SEVE Africa (Supporting the Emergence and Development of the Local Economy in Africa) and NGO – Zood-Nooma.

[3] Traditional chief inducted by "Mogho Naaba," the king of the Mossi (majority ethnic group), in Burkina Faso; Alternative Nobel Prize 2018 in Sweden. Awarded for his fight against the desert advance in Northern Burkina Faso.

Figure 1: Map of the study areas.



Source: Authors, adapted from the meteorological department of Burkina Faso.

3.3 Social Representation Using the Hierarchical Evocation Method

We used the hierarchical evocation method to identify the central core of the representation of supplemental irrigation (Vergès, 1992) as this method provides easy access to the representational scope and its structure (Lo Monaco et al., 2017). To this end, the interviewees were asked to say the three words or expressions that spontaneously came to mind when they heard the words "supplemental irrigation." They were then asked to rank them in order of importance. Finally, following Montginoul and Vestier (2018), they had to score each word or expression on a five-point satisfaction scale, from -2 (not good at all) to +2 (very good). This process ranked their words in order of importance and satisfaction, thereby avoiding any subjective interpretation of the interviewees' responses.

The hierarchical evocation method consists of crossing the indicators of the frequency of appearance of the word, and the degree of importance accorded to it. When indicators of high frequency and degree of importance are met, hypotheses can be formulated concerning the quantitative centrality (thresholds) and qualitative centrality (average importance of words) of the word concerned, following the work of Vergès (1992) and Abric (2001). First, a word or expression was considered to be of quantitative centrality if more than 10% of the farmers we interviewed mentioned it. Second, words whose average importance tended towards 1 were considered to be of qualitative centrality.

Using these two hypotheses, three types of elements were distinguished (see Table 2): the words mentioned by a large proportion of the interviewees and ranked higher were the "central elements," while the "contrasting elements" were those mentioned by a small proportion of interviewees, but still ranked high; the "peripheral elements" are words mentioned by a large proportion of the interviewees, but ranked low.

Table 2. *Analysis of Hierarchical Evocations*

		Importance	
		Strong (average rank <2)[4]	**Low (average rank ≥ 2)**
Frequency of occurrence	**High (≥ 10%)**[5]	Core: area of quantitative and qualitative centrality	First periphery
	Low (<10%)	Contrasting elements	Second periphery

Source: Authors.

4.0 Results and Discussion

The results are presented and discussed in three steps: the social representation of the innovation for farmers and institutional actors (step 1); analysis of the farmers' innovation adoption process using the case of supplemental irrigation from farm ponds (step 2); and the characterization of a standard profile of adopters (step 3).

[4] The importance of a word or an expression is considered strong when its average rank is less than 2. The threshold 2 was determined by the overall average rank as each interviewee had to provide 3 words or expressions.

[5] The frequency of occurrence was considered high when it accounted for more than 10% of all the terms mentioned.

4.1 The Social representation of the Innovation for Farmers and Institutional Actors

4.1.1. A precise social representation for farmers as opposed to that of institutional actors. The data collected from the surveys showed that the farmers had a more precise social representation of the innovation than the institutional actors. Identifying the words used by interviewees to evoke "supplemental irrigation" made it possible to decide whether or not a social representation existed. Calculating indexes (rarity and diversity) on non-lemmatized answers (i.e., before reducing the number of words mentioned, by grouping words or expressions with the same meaning) made it possible to place them between 0 and 1: the more they tend towards 0, the stronger the consensus, and the more precise the social representation (see Table 2).

Our results showed that the term "supplemental irrigation" did not have a precise social representation for the institutional actors, in contrast to the farmers who had taken ownership of the innovation. Although many institutional actors are working on this new technology and even if they have the same goal (improving farmers' livelihood conditions), they have different approaches to implementing the innovation. This diversity means they do not have the same representation of supplemental irrigation. Table 2 shows that farmers spontaneously produced more similar words and expressions (low rarity index), with low diversity between them (low diversity index), than institutional actors.

Table 2. *Rarity and Diversity Indexes for the Term "Supplemental Irrigation" for Institutions and Farmers*

	Rarity index	**Diversity index**
Method of calculation	Number of terms with frequency "1" / Total number of answers obtained	Number of different answers between them / Total number of answers obtained
Institutional actors (18)	0.64	0.79
Farmers (33)	0.33	0.46

Source: Authors.

4.1.2. An innovation perceived as positive by institutional actors as helping achieve food security. For institutional actors "supplemental irrigation" is more particularly associated with three positively connoted expressions ("water supply," "food security" and "support for agricultural production") (see Table 3): the farm pond innovation supports agricultural production by irrigating rainfed crops, and helping to reach food security goals. The negatively connoted expression "dry spell" was also often mentioned but ranked lower (first periphery). The second periphery elements detail the social representation of the farm pond technique, with more positive expressions (e.g., "beneficial" and "solidarity and social cohesion") than negative ("difficult" and "maintenance issues"). Finally, a few institutional actors did not associate the innovation with anything specific: the contrasted elements identified the term rather than giving a contrasting view of it.

Two statements made by institutional actors are given below:

> Farm ponds are small structures that can store 200 to 300 cubic meters of water, which can secure a portion of production and contribute to the food security of an average household of about seven people. Supplemental irrigation must be expanded if food security for all is to be achieved, especially in Sahelian areas. (Institutional actor from the Government office of Hydraulic Installations and Irrigation development, personal communication, May 6th, 2019).

> The first function of this new technology considered was the food dimension. Indeed, we are in a context of climatic variability where unforeseen events limit food self-sufficiency (even if food self-sufficiency was not achieved, farmers were actually better off before climatic variability). (Institutional actor from the International Institute for Water and Environmental Engineering, personal communication, May 8th, 2019).

Table 3. *Frequency, Rank and Scale of the Elements of the Social Representation of "Supplemental Irrigation" for Institutions*

Expressions	**Citation frequency**	**Average citation rank**	**Average word scale**
Core of the representation			
Water supply	17%	1.67	1.11
Food security	15%	1.75	1.25
Support for agricultural production	11%	1.83	1
First periphery			
Dry spells	17%	2.11	-1
Contrasting elements of the representation			
Innovation	5%	1	1
Family farms	2%	1	1
Second periphery			
Beneficial	9%	2	1
Difficult	8%	2.25	-1
Support to farmers	2%	3	1
Solidarity and social cohesion	2%	3	1
Not difficult	2%	2	1
Rainfed agriculture	2%	3	0

Table 4 continued

Ground	2%	3	0
Loss of agricultural land	2%	3	-1
Economic viability issues	2%	3	-1
Maintenance issues	2%	3	-1

Source: Authors.

4.1.3. Contrasted representation of an innovation perceived as beneficial by farmers but also as risky and difficult. For farmers, "supplemental irrigation" was spontaneously more particularly associated with "beneficial" (i.e., positively connoted by the interviewees) and "leakage" (negatively connoted because leaks represent an obstacle to the practice of supplemental irrigation) (see Table 4). The word "difficult" (negatively connoted) was also often mentioned but ranked lower, thus appearing in the first periphery. The contrasted elements identify the term rather than give a contrasting view of it. Indeed, few farmers (cf. the contrasting elements) view supplemental irrigation primarily as an external technique ("water supply," "project"), or as a solution for their village ("no water"), or as not attractive due to economic constraints ("expensive"). The second periphery elements provided details about the social representation of this technique: supplemental irrigation was associated with positively connoted words such as "manufacturing bricks," "support for rainfed crops" and "social cohesion," and a few negatively connoted with words such as "false promises" and "risk of drowning".

Table 4. *Frequency, Rank and Scale of the Elements of the Social Representation of "Supplemental Irrigation" for Farmers*

Expressions	**Citation frequency**	**Average citation rank**	**Average word scale**
Core of the representation			
Beneficial	19%	1.47	1.05
Leakage	19%	1.79	-1
First periphery			
Difficult	14%	2.21	-0.93
Contrasting elements of the representation			
Water supply	4%	1.75	1.25
Project	1%	1	1
No water in the village	2%	1	-1
Expensive	1%	1	-1
Second periphery			
Brick manufacturing	1%	3	2
Support for rainfed crops	3%	2	1.33
Assistance to improve living conditions	2%	2	1

Table 5 continued

Social cohesion	2%	2.5	1
Courage	2%	3	1
Market gardening	3%	2.67	1
Sustainable practice	1%	2	1
Water retention	2%	2	1
Crop security	6%	2.17	1
Food security	1%	3	1
Collective (help digging the pond)	1%	2	0
Maintenance	4%	2.75	0
Abandonment	1%	3	-1
Lack of resources	2%	2.5	-1
False promises	1%	2	-1
Drainage problem	4%	2.5	-1
Risk of drowning	4%	2	-1

Source: Authors.

The social representation shows that even if farmers mentioned positive aspects of the innovation, they also emphasized the difficulties linked to its adoption ("leakage" and "difficult"). Moreover, among the three words most frequently mentioned by the farmers (see Table 4), two had negative connotations underlining the fact that there are serious difficulties involved in adopting the innovation.

Below are statements by two farmers:

> I don't have the courage to dig another pond. My pond does not hold water, so I really don't feel like continuing. Our problem is leakage. (Farmer from the region of Centre-Ouest, personal communication, June 25th, 2019).

> The main problem I have with the farm pond is leakage. It hasn't stabilized. It wasn't lined with plastic or cement. Our children and animals risk drowning because there is no wire netting. Another problem I'd like to mention is how to water the crops. Watering crops by hand is difficult. (Farmer from the region of Plateau-Central, personal communication, July 16th, 2019).

The contrasted farmers' social representations show that the innovation has interesting economic characteristics, but that its adoption involves several difficulties. However, it could also be double-talk by farmers, who often tend to say good things about a technique in the hope of being able to benefit from development projects in their village.

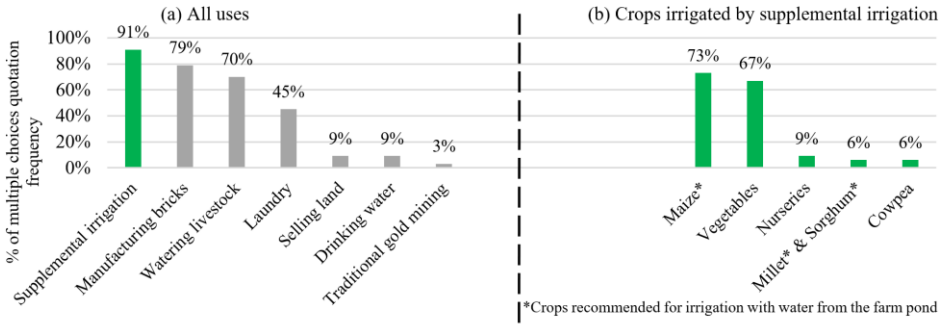
4.2. Analysis of the Farmers' Process of Adopting Innovation – Case of Supplemental Irrigation From Farm Ponds

4.2.1. Preferences and perceptions that favor adoption. This section examines farmers' preferences and perceptions that influence their decision to adopt the innovation. Two aspects are considered: the characteristics of the innovation and the risk related to its adoption.

Preferences concerning the characteristics of the innovation: the social representation showed that farmers gave more importance to beneficial aspects than to the other aspects (see Table 4), thus expressing a strong preference for the benefits of supplemental irrigation using a farm pond. The beneficial character is the "multi-purpose uses" of the farm pond (see Figure 1), which was the utility expected by farmers who adopted the innovation.

Our study shows that farmers have taken ownership of the innovation. Farmers do use it for the main purpose promoted by development actors (to irrigate rainfed crops): only 9% of farmers who dug a farm pond did not practice supplemental irrigation. However, all the interviewees also used their ponds for other purposes: 79% of them to make bricks, 70% to water livestock, and 45% for laundry (see Figure 1)[6]. In addition, farmers irrigated several types of crops: 73% of the interviewees used their farm pond to irrigate maize, 67% of them irrigated vegetables, e.g., tomatoes, cucumbers, eggplants and peppers; and a very small number irrigated traditional crops, such as millet, sorghum and cowpea.

Figure 1: Different uses of the farm pond.



NB: Several choices were possible, because all farmers use their farm ponds for multiple purposes. As a result, the percentage of quotation frequency should be considered by use and not for the sum of all uses.

Source: Authors.

The fact that some farmers have been adopting the innovation is additionally linked to new vegetables seeds adapted to the rainy season, especially seeds developed by the Institute of Environmental and Agricultural Research in Burkina Faso. Before these new seeds, farmers were only able to grow vegetables around reservoirs after the rainy season. Today, this practice is becoming possible during the rainy season for farmers who have a source of water to irrigate crops and is profitable, as one of the farmers interviewed in the region of Plateau-Central pointed out:

> My farm pond means I can grow vegetables like eggplants, tomatoes, zucchini and okra and maize. Last year at this time in July, I had already

[6] NB: Several choices were possible, because all farmers use their farm ponds for multiple purposes (e.g., to make bricks, to water livestock, to irrigate vegetables, etc.). As a result, the percentage of quotation frequency should be considered by use and not for the sum of all uses.

> sown and my garden had started to produce vegetables. The sale of tomatoes alone earned about 500,000 CFA francs (about $870 in U.S. dollars). (Farmer from the region of Plateau-Central, personal communication, July 11th, 2019).

According to standard economic theory, a farmer is an agent who maximizes his or her utility by choosing the best innovation to adopt (Faure et al., 2018). Since the choice of adoption is linked to the characteristics of the technique (Adesina & Baidu-Forson, 1995), the preference for the multi-purpose uses of the farm pond is considered as a potential factor for adoption. In agreement with Lancaster (1966), our results also show that its multi-uses were the reason farmers adopted this innovation.

Perception of the innovation characteristics: the perception of the characteristics of supplemental irrigation based on farm ponds depended on the farmers' own experience and on the information to which they had access. Since this innovation is presented to farmers as a technique that allows them to cope with rainfall variability, we asked the farmers about their perception of rainfall variability frequency: 52% of interviewees considered it to be recurrent, 45% considered it is increasing (longer periods of dry spells), and 3% think it is decreasing. The high perception of rainfall variability may be an important factor in the adoption of the innovation, as it is intended to manage the risk of drought (Reynaud, 2009). However, McCarthy et al. (2021) found limited evidence for links between the adoption of some sustainable land management practices and weather shocks.

In addition, farmers perceived the innovation as difficult (see Table 4). This perception can be explained by the fact that more than 90% of adopters, we have met during the surveys (see Figure 1), dug and excavated their farm pond by hand using shovels and pickaxes, and more than half irrigated their crops by hand using buckets.

Risk aversion: We asked farmers about their level of risk aversion. Interviewees had to rank themselves on a scale from 0 to 10, where 0 means "very risk averse" and 10 "very high-risk taker;" 59% of farmers who adopted the innovation declared themselves to be a "very high-risk taker" and 22% a "moderate risk taker." None of the interviewees ranked themselves as "very risk averse." In agreement with many studies (Duflo et al., 2008; Menapace et al., 2015), our results showed that risk aversion is negatively correlated with the adoption of an innovation or a practice.

Below are statements made by two of the farmers:

> I am not afraid to invest. I am very willing to take risks. Although I have a handicap, I dug my farm pond with my family, it took us 3 years. (Farmer from the region of Centre, personal communication, June 20th, 2019).

> I am an adventurer. I always try to seize opportunities. We have to be careful, but we shouldn't be afraid to invest. For example, when I was young, I invested in breeding using my own resources. Between 1985 and 1986, I sold my chickens to try my luck abroad. At that time, everyone was talking about Ivory Coast, so I decided to go, to satisfy

> my curiosity and learn new things. (Farmer from the region of Centre-Sud, personal communication, July 22th, 2019).

Risk perception: to understand their perceptions of the risk related to the adoption of supplemental irrigation using farm ponds, we asked interviewees to rank the risk they perceived on a scale from 1 to 5, where 1 means "no risk" and 5 "very high-risk." Risk perception is based on the investment required to dig a farm pond and to purchase irrigation equipment, for example, a motor pump. The farmers' own experience and the different information they receive about an innovation are ways to define their perception of risks related to adopting an innovation (Marra et al., 2003). Our results showed that 44% of the farmers perceived the risk related to the adoption of this innovation as low, and 15% perceived no risk at all. However, the remaining 41% of the farmers perceived the risk as high. This contrast in perception between "no risk or low risk" and "high-risk" is explained by the fact that 85% of the farmers received financial and technical support, which explains the low perception of risk: farmers' behavior may thus differ depending on whether or not they receive funding to facilitate adoption (Ghadim & Pannell, 1999).

Our results also showed that the majority of farmers who adopted the innovation perceived the risk to be low. The widespread perception of low risk is also explained by the fact that most farmers declared themselves to be very high-risk takers. Indeed, the risks of loss are generally perceived to be high by people with high-risk aversion (Menapace et al., 2015).

4.2.2. Institutional actors play a role that impacts farmers' perceptions of the characteristics of the innovation. Our results showed that promotion by institutional actors of supplemental irrigation based on farm ponds led farmers to adopt. The role of institutional actors in farmers' behavior is manifested in the influence these actors have on the subjective norms and the perceived behavioral control of farmers (see Figure 2). The change in the perception of the nature of existing social norms was made possible thanks to the interaction between institutional actors and farmers at village level in Burkina Faso (Carlsson et al., 2002; Rodriguez-Sickert et al., 2008; Touzard et al., 2014). The involvement of institutional actors led farmers to change their way of thinking about the innovation. The refusal to adopt eventually diminished over time (Akrich et al., 1988). During the field survey, all the farmers perceived supplemental irrigation from farm ponds as compatible with their social norms and practices. For example, 45% of farmers adopted the innovation, but they continue to attend traditional rainmaking ceremonies. According to some authors, such as Lynne (1995) and Sen (1977), we can say that there is collective agreement nowadays among farmers that permits adoption of the innovation, as mentioned in the following statement of one of the proponents of traditional habits and customs:

> A farmer alone cannot decide to adopt an innovation in a village. The decision to adopt is collective and it is initially made with the agreement of the land chief. It is once the land chief or the village chief agrees that each farmer can adopt. For example, if you ask farmers about their decision to adopt when faced with a technique that is already known, they might tell you that it depends on their personal or individual commitment. However, if it is a new technique that no one has yet adopted in the village, they will tell you that the decision to adopt is up

> to the land chief. Very often, even the village chief cannot decide on the adoption of an agricultural innovation without consulting the land chief. There are traditional values to be respected at the risk of being sanctioned by the community. (Traditional actor, proponent of traditional habits and customs in Burkina Faso, personal communication, May 20th, 2019).

Institutional actors influence farmers' intentions to adopt the innovation. These actors select pioneer adopters to disseminate the technique. Adopters share certain socio-economic characteristics. For example, our results showed that most of the adopters belong to a farmer organization. Likewise, adopters either hold some responsibilities in their village, or have a high social status (Rege, 2008). They also receive at least one visit per year from a government field officer (agricultural technician), who encourages them to adopt (Combary, 2017). In general, these officers consider the farmers who benefit from support as "model" or "leader" farmers (see Bierschenk et al., 2000).

However, in some villages, the first implementation of the technique by the first adopters was a failure. Adoption success stories are rare which has had a negative influence on the farmers' own intention to adopt. For example, in 37.5% of the villages surveyed, only one farmer had adopted the innovation. Some interviewees mentioned that their failure had discouraged their neighbors from adopting the innovation. And the fear of being subjected to mockery by members of the community or the fear of losing social prestige is a social norm that may limit the adoption of the innovation (Bonavia & Brox-Ponce, 2018; Dana et al., 2006).

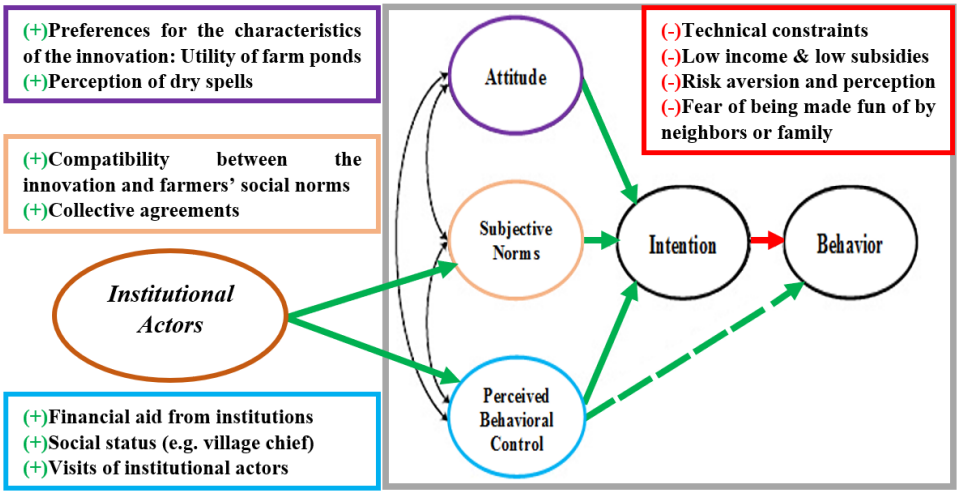
Below are statements by two farmers:

> I am the only person in the village to adopt the innovation since 2015. The others are waiting to see if it's profitable before adopting, because digging the pond is really difficult. (Farmer from the region of Centre-Ouest, personal communication, June 24th, 2019).

> People make fun of me, and I have to find a solution to waterproof my farm pond. (Farmer from the region of Centre-Sud, personal communication, July 21th, 2019)

Our results also show that farmers' preferences do not match the goals of institutional actors (see Table 3 and Table 4). Indeed, farmers adopt this innovation because of the economic advantages of multi-purpose farm ponds, such as irrigating cash crops or other profitable uses, whereas institutional actors' social representation clearly indicates that the innovation is promoted to secure the production of traditional rainfed crops in the context of rainfall variability. Farmers' adoption is linked to their attitude towards the utility and is related to self-interest (see Figure 1). When the farmers decide to adopt, they focus on the characteristics of the innovation that interest them (Adesina & Baidu-Forson, 1995; Lancaster, 1966) (e.g., multi-purpose uses and irrigating cash crops), rather than on the institutional actors' goals (Akrich et al., 1988). The social representations also show that, unlike farmers, the institutional actors mainly mentioned the positive aspects of the innovation.

Figure 2: Theory of planned behavior (Ajzen, 1991), integrating the role of institutional actors.



Source: Authors, based on Ajzen's model (1991).

4.3. Classification of Adopters According to the Social Representation and Their Socio-Economic Characteristics.

The socio-technical constraints that limit farmers are also related to their socio-economic characteristics. To identify the main socio-economic characteristics of adopters, we used a hierarchical ascending classification based on the analysis of the statements made by adopters in the social representation of supplemental irrigation. Based on Montginoul and Vestier (2018), adopters were characterized according to their answers and their socio-economic characteristics. Individuals were grouped in a small number of classes in successive groupings by assessing their similarity. The classification resulted in different classes with no preconception of their final number. The groups resulting from the data analysis were then characterized using standard statistical analysis (e.g., mean, standard deviation, minimum and maximum) to establish the interest of the standard profile obtained by this method of classification (Escofier & Pagès, 2008). We retained five groups and highlighted the most contrasted groups (see Table 5).

Table 5. *Summary of the Main Characteristics Observed from Adopters Based on the Hierarchical Ascending Classification*

Group	1st characteristic	2nd characteristic	3rd characteristic	Number
N°1	Young farmers	Member of a farmer organization	Low income (farm and off-farm)	10
N°2	Entrepreneurs	Member of a farmer organization	High off-farm income	2
N°3	Model farmers	Limited access to credit	High farm income	7
N°4	Farmer leaders	Responsibilities in the community	High income (farm and off-farm)	9
N°5	Rich farmers	Easy access to credit	High income (farm and off-farm)	5

Source: Authors.

1. The first group (young innovative farmers) contained 10 household heads who were members of at least one farmer organization. Agricultural technicians consider them innovative farmers (e.g., adoption of zaï and stone barriers). They received funding to adopt and irrigate crops manually with buckets. In this group, 80% are less fortunate, with an annual farm income of less than 500,000 FCFA, and only 20% attended school. A total of 60% of these household heads were between 18 and 30 years old. Only 30% of the households had fewer than five members. They all irrigated a maize plot, and 90% also grew vegetables (in the rainy season). They all owned their farms, which were between 0.5 and 5 ha in size. A total of 70% mentioned the word "leakage" with a negative connotation but perceived supplemental irrigation as a useful technique. They mentioned, for example, second-periphery zone elements such as "support for rainfed crops; assistance to improve living conditions; or market gardening."
2. The second group (farmers with off-farm activities—entrepreneurs) consisted of two household heads who had a low annual income but high off-farm income (i.e., more than 50,000 FCFA per month—about $87 US dollars). They did not receive any financial aid to adopt the technique. They were at least 51 years old, members of a farmer organization and held a responsibility in their community. They also owned their farms.
3. The third group (farmers involved in farming activities) is generally considered as innovative or model farmers like the farmers in the first group. The group was composed of seven household heads, 85% of whom had an annual income of more than 1 million FCFA (about $1,740 US dollars) and low off-farm income. They reported not having taken out a loan. A total of 71% were between 26 and 50 years old. A total of 85% received funding to adopt the innovation. They irrigated their maize and vegetables with water from the ponds; 28% of them had a foot pump, and 72% belonged to a farmer organization. They all owned, their farms. A total of 71% associated supplemental irrigation with the word "beneficial" and 28% with the word "difficult."
4. The fourth group (leaders) consisted of nine household heads with at least 10 people per household. Their agricultural income was between 500,000 FCFA and 1 million FCFA, and 22% of them had a monthly off-farm income of over 50,000 FCFA. They were all members of a farmer organization and were considered leaders in their community, where 77% had responsibilities. They received funding to adopt the innovation. A total of 66% of the heads of household are over 51 years old. They did not attend school; they all own their farm. Some mentioned the words beneficial (55%), difficult (44%) and leakage (33%).
5. The fifth group (rich) consisted of five households with at least 10 members, and all owned a motor pump. A total of 80% had already taken out a loan. All received funding to adopt, and they were considered innovative and rich. These household heads were under 51 years of age and had no specific responsibility in their community. They did not attend school. A total of 60% of them grew maize. They all owned their farm. A total of 80% mentioned the beneficial aspects of supplemental irrigation, and 60% the difficulties.

To sum up, this classification showed that lack of funding could limit the adoption of an innovation. Ninety percent of the adopters of farm ponds for supplemental irrigation received technical and/or financial support; 93% of them dug their pond by hand using shovels and picks, and 79% irrigated their crops by hand using buckets. Thus, farmers who cannot call on community labor or hire seasonal workers are limited in their adoption of farm ponds, as it is a labor-intensive innovation (Ghadim & Pannell, 1999). These figures explain the farmers' perception of the innovation as difficult. Additionally, more than 30% of adopters had no off-farm income, and their farm income was less than 500,000 FCFA per year, whereas the cost of building a pond is often the equivalent of this amount or more. It leads to the fact of the low rate of adoption by observability (30%) and trialability (18%). Farmers are faced with complex techniques, and most have no control over their financial capacities (Barbier, 2010). Our results also showed that land ownership is very important, and be land ownership modern or traditional, adoption is impossible without it. Land ownership is also a precondition for obtaining technical or financial support from institutional actors.

5.0 Conclusion

We combined economic and psychosocial approaches to analyze farmers' process of adopting an innovation. Semi-structured interviews with 18 institutional actors and with 33 farmers who had dug a farm pond made it possible to characterize the social representation of the innovation and to better understand farmers' behavior. Our results showed that farmers are well-intentioned with respect to adopting the innovation. Adopters have a low perception of difficulties and the risk involved, mostly thanks to the technical and financial support they receive from institutional actors. As supplemental irrigation from farm ponds is a labor-intensive innovation, family labor alone is rarely sufficient. Hence, it remains difficult for farmers to adopt it without the capacity to call on community labor or to hire seasonal workers. In general, adopters have a high social status and by means of agricultural technicians, they receive support from policy-makers, the aim of which is to create a snowball effect by relying on "leader farmers" with a reputation in their community. However, to make the technique more accessible and to guarantee better diffusion and adoption, the style of funding should target all farmers. Adopters also reported that the fear of being ridiculed if they failed to implement an innovation could prevent farmers from carrying out their intentions. The fear of being subjected to mockery by members of the community or the fear of losing social prestige is a social norm that may limit the adoption of the innovation.

Our results also showed that an innovation that does not account for the farmers' social norms can have a negative effect on their social links, e.g., trust and cooperation. This is the case concerning the risk of drowning in farm ponds, which undermines the social cohesion between communities of farmers. The agreement of traditional chiefs is still an important step in promoting an innovation. In addition, farmers' preferences and institutional actors' goals do not match. Farmers prefer to irrigate cash crops, such as vegetables, rather than subsistence crops, the latter being the goal of most institutional actors. These results show that the decision to adopt is not only based on socio-economic and technical factors. In this context, farmers' preferences and perceptions of social norms as well as the characteristics of innovations should be taken into account when designing or promoting innovations.

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