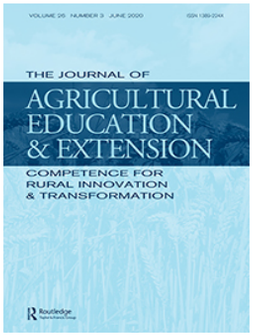

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Learning agriculture in rural areas: the drivers of knowledge acquisition and farming practices by rice farmers in West Africa*

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ABSTRACT

Purpose: This paper explores the main factors that influence farmers in acquiring agricultural knowledge and adopting technologies with the aim of better understanding the agricultural innovation systems in West Africa.

Design/Methodology/Approach: We use data collected between 2013 and 2014 across rice hubs in five West African countries: Benin, Côte d'Ivoire, Niger, Nigeria and Togo. In total, 499 household heads were surveyed using a stratified random sampling technique. Data are analyzed with the Mann–Whitney–Wilcoxon test and the Poisson regression.

Findings: The findings show that farmers' knowledge is influenced by a range of factors, including household size, training, access to formal and informal knowledge sources and community socioeconomic status. Farmers rely heavily on personal experiences and fellow farmers to adopt technologies.

Practical implications: The study suggests that key policies for strengthening the innovation systems are those that help farmers access both formal and informal knowledge sources, credit services, better welfare and information and communication tools.

Theoretical implications: The study shows the need to consider both extrinsic factors (e.g. characteristics of the technology and attributes of the external environment) and intrinsic factors (e.g. knowledge, perceptions and attitudes of the potential adopter towards the innovation) when analyzing the decision process toward technology adoption in West Africa.

Originality/Value: This initiative is to identify the conditions that will enable a more inclusive technology development and diffusion process. This is important because agricultural extension is currently undergoing a deep restructuring focused on privatizing the agricultural services in developing countries characterized by a low literacy rate.

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Introduction

According to Kolb (1984), 'learning is the process whereby knowledge is created through the transformation of experience' (38). The concept of knowledge is a topic of more interest among philosophers, especially sociologists, than an observer could ever imagine. The knowledge process has six main points: (1) generation, (2) verification, (3) transformation, (4) transfer, (5) reception, and (6) utilization (Havelock 1986). Information and knowledge are vital in agricultural development in Sub-Saharan Africa (SSA) (Zossou et al. 2017), especially in West Africa, where agriculture plays a key role in the economy.

Agriculture accounts for 35% of the gross domestic product (GDP) of West Africa, and the sector employs over 60% of the population. Farming households build their agricultural production around self-consumption. The major crops grown are food crops such as rice, which has become a strategic commodity and the first source of food calories in West Africa. Farming households cultivate rice across three main growing environments (upland, rainfed lowland, and irrigated) to meet their self-consumption and the growing market demands.

However, agricultural extension services in West Africa face numerous challenges in responding to farmers' needs. Many rural farmers are unable to access timely and up-to-date knowledge and information that would enable them to achieve optimal yields (Obidike 2011). In addition, the observed deep restructuring that is encouraged by the trend towards liberalization in agricultural extension has led to nongovernmental organizations (NGOs) and the private sector redefining their roles to fill certain niches (Zossou et al. 2009a). Globalization poses new challenges to improving the living conditions of rural populations. This situation has a profound impact on the agricultural and national extension systems for a population that is largely illiterate.

Education, learning and training in rural areas are critical elements in the fight against rural poverty and food insecurity. However, these traits are also among the most neglected in the agricultural policies of national governments and by donors (Atchoarena and Gasperini 2003; Moumouni and Streiffeler 2010). Moreover, women do not benefit as much as men from extension programs because of sociocultural constraints (Kondylis et al. 2016). Overcoming this gender gap and improving farmers' knowledge of new technologies can considerably increase their level of productivity through the adoption of improved technologies (Zossou et al. 2017). In addition, technology dissemination can be enhanced when the disseminating farmer is female, regardless of whether the contact farmers are male or female (Shikuku 2019).

Experimentation with and the adoption of technologies are influenced by the ways in which people learn (Zossou et al. 2009b). The adoption of a technology is a complex process that is neither unitary nor linear but occurs in stages or steps over time. The progression starts with a mental process whereby a person acquires enough knowledge to decide to make a change (Gars and Ward 2019). The success of an agricultural extension program is largely determined by the level of farmers' participation (Suvedi, Ghimire, and Kaplowitz 2017). This results in (i) the availability and affordability of the technologies and (ii) the farmers' expectations that the adoption will remain profitable.

These two aspects are important in technology adoption in developing countries (Foster and Rosenzweig 2010). Furthermore, there are three groups of paradigms or models pertaining to the adoption of innovations: (i) innovation-diffusion, in which the

adoption is influenced by the personal characteristics of each potential user and the effectiveness of the communication channels; (ii) economic constraints, in which the adoption is influenced by the resource endowment of the potential users; and (iii) technology characteristics and the user's context, in which the adoption is influenced by the characteristics of a technology and the agroecological, socioeconomic and institutional context of the potential users (Negatu and Parikh 1999). The third paradigm includes the importance of the perception and knowledge of the technology in the process of adoption. However, this model is scarcely used in the literature (Negatu and Parikh 1999; Shikuku 2019). In addition, awareness of the factors that influence knowledge acquisition will also facilitate the enhancement of the development and transfer of appropriate technologies (Meijer et al. 2015; Shikuku 2019). However, research on the process of acquiring agricultural knowledge in West Africa rural areas has been limited, even though a range of studies have been carried out on the adoption of agricultural technologies (e.g. Weyori et al. 2018).

This study investigates the main factors that affect the acquisition of agricultural knowledge and the adoption of technologies among rice farmers and specifically examines the existing gender gap. The study has three contributions to the existing literature. First, the determinants of knowledge have received little attention, even though knowledge is a crucial factor in technology adoption (Meijer et al. 2015). Second, the paper uses survey data from five countries. This comparison is important for drawing and measuring regional results. Third, contrary to the existing literature, the study analyzes these two concepts under the lens of gender. This integrated analysis of agricultural learning and the adoption of technologies provides an opportunity to better understand the agricultural innovation system in rural areas.

Knowledge and adoption of innovation: state of the art

Technology uptake is a complicated process that involves both the adoption of a new technology and its adaptation to existing practices. Traditionally, theories that address decision-making processes have highlighted the role of extrinsic factors such as the characteristics of the technology and the attributes of the external environment. Recently, researchers have started to pay more attention to internal decision-making processes, beyond the mere characteristics of innovations and households, to include the psychological and motivational factors involved in technology uptake. These intrinsic factors, which include the potential adopter's knowledge, perceptions and attitudes towards the innovation, play a key role, but have been less studied (Meijer et al. 2015; Shikuku 2019).

Knowledge studies on the uptake of innovations have been conducted since the 1980s; however, these studies have rarely been applied to rice technology adoption, especially in SSA (Ajayi 2007). Weyori et al. (2018) recently analyzed the adoption of technology in Ghana (West Africa), although with less emphasis on knowledge. In addition, the analysis of factors affecting knowledge is scant (Shikuku 2019).

The first phase of the decision-making process regarding adoption is the development of knowledge of the innovation, which corresponds to the model proposed by Rogers (1995). Farmers can obtain knowledge about a new technology, how to apply it, and its outcomes in terms of products, yield, potential environmental benefits, risks and costs. This knowledge forms the basis of the perceptions and attitudes that this individual develops towards the technology.

Whereas knowledge refers to factual information and an understanding of how a new technology works and what it can achieve, perceptions refer to views that farmers hold based on their felt needs and prior experiences; these perceptions do not necessarily align with reality. An individual's knowledge and perceptions then determine his attitude towards the technology. This process represents the third model presented by Negatu and Parikh (1999) and is the model that guides this survey. We, therefore, expect that a positive attitude towards agricultural innovation will increase the likelihood of adoption and that a negative attitude will reduce the probability of adoption. There are numerous extrinsic variables that help shape knowledge. According to Meijer et al. (2015), these extrinsic variables can be grouped into three categories: characteristics of the farmer, characteristics of the external environment, and characteristics of the innovation. However, the importance of these characteristics in the knowledge of agricultural innovation has received little attention in the literature. More recently, Shikuku (2019) used social distance, as a characteristic of the farmer in Meijer et al. (2015)'s model, to explain knowledge acquisition by analyzing farmer-to-farmer extension approaches.

Research methodology

Data collection

Data were collected between 2013 and 2014 in the key rice sector development hubs in five countries in West Africa (Benin, Côte d'Ivoire, Niger, Nigeria and Togo). Rice sector development hubs are zones where rice research products are integrated across the rice value chain to achieve development outcomes and impacts. In the hubs, the Africa Rice Center (AfricaRice) and national research institutes introduce, evaluate and validate new rice technologies and work with development partners to facilitate the training of farmers, the dissemination of technologies and the establishment of linkages among actors along the rice value chain.

The hubs were selected based on the major rice-growing environments per country. Lowland rainfed rice-growing environments were dominant in the surveyed hubs, with the exception of Niger, where irrigated rice-growing environments are dominant. A stratified random sampling technique was used to select interviewed household heads based on their rice activities and the gender of the household head. Sixteen villages were selected in each hub based on the following stratifying criteria: (a) rice-growing environment, (b) village accessibility based on road conditions, and (c) rice as the dominant crop. Using the list of all households in each village, 10 households were randomly selected from each of the 16 villages, with adjustments made to the sample for it to include at least 30% women farmers. In total, 160 rice-farming households were selected from each hub.

Data collection was automated using tablets and the Mlax web-based application that sends collected data to a central database managed by AfricaRice, with online access given to the national agricultural research system (NARS) partners. The computer-based data collection avoided many biases associated with paper-based questionnaires, such as mistakes made when recoding answers, changing the variable values and recoding the test answers for numerical variables. In addition, the computer-based questionnaire provides the geographic coordinates and the possibility of translating the questionnaire into audio in the local language to avoid misinterpretation of the questions by enumerators.

Data processing and analysis

Data were processed with STATA 13.1 and focused on socioeconomic and demographic characteristics, rice production, knowledge and use of rice farming technologies, relationships with farmers' organizations, relationships with national and international agricultural research and extension services, households' income, and access to information. Some needed variables in the database had missing data, which reduced the sample size to 499 households. Missing data were a result of the many rounds that it took to collect the data, as some household heads had left the villages during the last rounds before the exercise was completed.

Data analysis focused on four main rice farming activities: land clearing, plowing, crop establishment and weed management. For each of these activities, a list of the methods used for rice farming in the hubs was participatorily identified with rice farmers during an exploratory phase (Table 1). These methods were presented to households to collect data on their level of knowledge, use and access to the technologies, sources of information, and the evaluation of their characteristics.

Each surveyed head of household was presented with 15 rice farming methods and asked to score each method they were aware of. In this study, we refer to this score as the knowledge level of the rice farming method. The same procedure was used for the sources of knowledge and the use of farming methods.

The Mann–Whitney–Wilcoxon test was used to determine the differences between women and men in their level of knowledge and their use of rice farming methods.

To identify the factors that influenced the level of knowledge and the level of use of rice farming technologies, we estimated a Poisson regression. The Poisson distribution models the probability of y events (counts). It assumes that the dependent variable (Y) has a Poisson distribution, and the logarithm of its expected value can be modeled by a linear combination of known and unknown parameters (Cameron and Trivedi 2005). This regression is similar to logistic regression, which also has a discrete response variable. However, the Poisson response is not limited to two specific values, as in a logistic regression. The dependent variable in the Poisson model is the count number of rice farming methods known and used by the head of household. This variable trait shows the appropriateness of the use of the Poisson regression model.

Table 1. Rice farming methods and equipment on which data were collected.

Rice farming activity	Rice farming methods
Land preparation/clearing	Burning
	Mulching
	Uprooting
	Removing of weed from the field
	weeding
Ploughing	In-line ploughing
	Levelling
	Weed incorporation into the soil
Crop establishment	Broadcast sowing
	Sowing in rows
	Straight-row sowing
	Sowing in holes
Weed management	Manual weeding
	Mechanical weeding
	Use of herbicide

Different explanatory variables were used, including own-experience, household welfare, input (requirement) level related to the target method and output level (performance of the method). The own-experience variable score is the number of times the head of household responded favorably to developing and experimenting new technologies, based on their own knowledge and experiences and drawing their own conclusions.

The household welfare score is the number of times the household responded favorably to the questions related to the following key characteristics (identified by farmers through the participatory exploratory phase): home ownership, modern water supply, modern source of lighting (electricity and solar panels), using gas to cook, modern toilets, and access to phone, radio and television. During data processing, the infrastructure score was calculated using an arithmetic sum of the number of times each head of household responded favorably to the existence of each of the following infrastructures in their village: water supply, school infrastructure, health care center, pharmacy, public electricity, administrative service, market, communication networks and good roads.

The input level related to the target method is the arithmetic sum of the household heads' response to questions related to their perception of the following key points: work speed, cash demand, time required, quantity of labor required, level of its fit to the social context (manners, habits and moral), cost of acquisition, and operation/maintaining cost. The output level is the arithmetic sum of each head of household's response to questions related to their perception of the following points on the use of the method: quality of work performed, ease of use, and level of performance. The perception of the input and output levels of technologies was measured using a scale of 0 for weak, 1 for normal and 2 for high.

Results

Sociodemographic characteristics

Table 2 shows the summary statistics of the sociodemographic characteristics of the rice farmers. The surveyed heads of households were, on average, 47 years old across the two genders. The annual rice income was, on average, US $890, which was used to feed an average of seven people. The data showed a high illiteracy rate (63%). Most of the heads of households (87%) were active in agriculture. Approximately 56% of the heads of households were members of associations, showing that West Africans tend to belong to social networks.

Approximately 34% of the heads of households and 21% of the other members of the households had attended rice training. Approximately 18% of the heads of households were connected to a farmers' organization, 32% were connected with local NGOs, 6% were connected with international NGOs, 23% were connected with national research and extension services, and 12% were connected with micro-finance institutions (MFIs). Of the surveyed head of households, 83% had access to rural radio, and 46% had access to television.

Gender in knowledge and use of rice farming technologies

The Mann–Whitney–Wilcoxon test (Table 3) of the whole sample showed that there was no gender gap concerning the level of knowledge and the practice of rice farming methods

Table 2. Definition of variables and socioeconomic profile of surveyed households.

Variables	Definition	Mean (std. dev.) Farming methods (n = 499)
Age	Age in years for the household's head	46.24 (12.49)
Education	0 = none; 1 = Coranic literate; 2 = primary/ secondary; 3 = University	0.66 (0.92)
Household size	Number of individuals in household	6.77 (5.43)
Annual rice income	Annual household income in 10^3 FCFA[a]	889.59 (698.44)
Household head attended rice training	1 = The household chief has attended a rice training; 0 = otherwise	0.34 (0.47)
Other household's member attended rice training	1 = Another member of the household attended a rice training; 0 = otherwise	0.21 (0.42)
Group membership	1 = Member of a group; 0 = otherwise	0.56 (0.50)
In relation with farmers' organization	1 = in connection with a farmers' organization; 0 = otherwise	0.18 (0.39)
In relation with local NGOs	1 = was in connection with local NGOs; 0 = otherwise	0.32 (0.47)
In relation with international NGOs	1 = was in connection with international NGOs; 0 = otherwise	0.06 (0.24)
In relation with national research & extension services	1 = was in connection with national extension & research services; 0 = otherwise	0.23 (0.42)
In relation with Micro-Finance institutions	1 = was in connection at least once with Micro-Finance institutions; 0 = otherwise	0.12 (0.32)
Preferably primary source of information	0 = Word of mouth; 1 = Town crier; 2 = Local and religious organization; 3 = NTIC	0.88 (1.20)
Agriculture as principal activity	1 = yes, 0 = otherwise	0.87 (0.33)
Listen to the radio	1 = yes, 0 = otherwise	0.83 (0.37)
Watch the television	1 = yes, 0 = otherwise	0.46 (0.50)

[a]Annual household income in 10^3 FCFA. The currency rate used is US $ 1 = 528.83 FCFA as in December 2014.

in Benin, Nigeria or Togo. We noted a gender gap in Côte d'Ivoire and Niger through the disaggregated data at the country level, where women had lower levels of knowledge and use of rice farming methods compared to men. This implies disparity among West African countries in terms of the knowledge and practice of rice farming methods. This result may be explained by the different factors affecting the knowledge and practice of rice farming methods in these countries. These factors will be analyzed in the next section.

Table 3. Gender disaggregated data on the levels of knowledge and use of rice farming technologies in rice hubs

Level of knowledge and use			Mean (SD) Whole sample	Benin $n1$ = 139 $n2$ = 141	CI $n1$ = 49 $n2$ = 38	Niger $n1$ = 106 $n2$ = 72	Nigeria $n1$ = 102 $n2$ = 78	Togo $n1$ = 103 $n2$ = 85
Rice farming methods n = 499	Level of knowledge	Women	7.64^{α} (2.84)	9.21^{a} (2.21)	4.17^{c} (1.94)	5.47^{e} (3.02)	6.42^{g} (1.83)	7.73^{i} (2.49)
		Men	7.71^{α} (2.64)	8.94^{a} (2.32)	7.27^{d} (2.39)	6.60^{e} (2.55)	6.99^{g} (2.42)	8.53^{i} (2.66)
	Level of practice	Women	6.46^{β} (2.41)	7.73^{k} (1.92)	4.17^{m} (1.94)	4.33^{o} (2.35)	5.08^{q} (1.62)	6.81^{s} (2.12)
		Men	6.67^{β} (2.33)	7.92^{k} (2.04)	6.30^{n} (2.13)	8.90^{p} (2.34)	5.60^{q} (1.66)	7.51^{s} (2.43)

Note: Different superscripts (α, β) within the same variable (knowledge/use) denote populations of the whole sample which are significantly different, based on the Wilcoxon–Mann–Whitney test with significance level of 5%. Different superscripts (in letter) in the same country within the same variable (knowledge/practice) denote populations which are significantly different based on the Wilcoxon–Mann–Whitney test and a significance level of 5%. $n1$ = number of households surveyed on rice farming methods. $n2$ = number of households surveyed on rice farming equipment. CI = Côte d'Ivoire.

Drivers of knowledge of rice farming technologies

Table 4 shows the determinants of the level of knowledge of rice farming technologies of each head of household using the Poisson regression model. The results showed that the main drivers of knowledge of rice farming technologies were as follows: training, association with farmers' organizations, access to international NGOs, agriculture as a main activity, household size, access to MFIs and listening to rural radio. In addition, country dummy variables also affected the level of knowledge of rice farming technologies. This outcome is in line with the disparity observed above among the five countries in terms of the knowledge and practice of rice farming methods.

The level of knowledge of technologies varied across the different agroecological and sociocultural zones. The country dummy variables included in the Poisson regression models were found to be highly significant, particularly that of Benin compared with the other four countries. We observed a significant positive effect for Benin on the level of knowledge and practice of rice farming technologies. Household members' attendance of training sessions on rice farming was a significant determinant, and we noted a positive effect on their level of knowledge. The training sessions on rice farming were mostly face-to-face sessions organized by farmers' organizations, local NGOs, national research and extension services, or international NGOs in collaboration with local institutions.

Table 4. Determinants of the level of knowledge of rice farming technologies: Poisson regression.

	Rice farming methods	
Independent variables	Coefficient ± Std.Err.	Probability
Constant	1.800 ± 0.116	0.000***
Gender	−0.044 ± 0.043	0.307
Age	0.001 ± 0.001	0.286
Household size	0.005 ± 0.003	0.070*
Annual rice income	0.00 ± 0.000	0.995
Household head attended rice training	0.135 ± 0.043	0.002***
Other member of the household attended rice training	−0.003 ± 0.047	0.948
Group membership	−0.017 ± 0.037	0.635
In relation with farmers' organization	0.127 ± 0.048	0.008***
In relation with local NGOs	0.030 ± 0.042	0.476
In relation with international NGOs	−0.122 ± 0.072	0.092*
In relation with national extension & research services	0.040 ± 0.044	0.363
In relation with micro-finance institutions	0.104 ± 0.053	0.051*
Preferably primary source of information	0.005 ± 0.018	0772
Education	0.024 ± 0.021	0.247
Agriculture as principal activity	0.108 ± 0.053	0.042**
Listen to the radio	0.182 ± 0.053	0.001***
Watch the television	−0.013 ± 0.036	0.723
Infrastructure in the village	0.004 ± 0.009	0.660
Wellbeing level	−0.020 ± 0.014	0.162
« Côte d'Ivoire »	−0.186 ± 0.726	0.010**
Niger	−0.332 ± 0.062	0.000***
Nigeria	−0.230 ± 0.070	0.001***
Togo	−0.111 ± 0.053	0.030**

Note: The dummies 'Côte d'Ivoire', Niger, Nigeria and Togo are defined relative to the dummy Benin that is why the latter does not appear in the table.

*Denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

The heads of households' relationship with farmers' organizations also significantly increased their level of knowledge. This result implies that belonging to farmers' organizations help heads of households access more information on rice farming technologies. However, we also observed a negative correlation between the heads of households' relationship with international NGOs and their level of knowledge. This outcome shows that services provided by international NGOs do not seem to improve the knowledge of rice farming methods. This might be because international NGOs work through local agencies, and their outcomes are based on the performance of these local agencies. The regression model showed a positive correlation between agriculture as the main activity and rice farming technology knowledge. Rice cultivation is a part of agriculture, and the technologies used for rice farming are part of all the technologies used in agriculture.

Similarly, we observed that the household's size positively affects the level of knowledge of rice farming technologies. A significant positive effect was also noted for access to MFIs on the level of knowledge of the heads of households. Finally, we observed a significant positive correlation between listening to rural radio and the heads of households' level of knowledge on rice farming technologies.

Drivers of use of rice farming technologies

The level at which households used rice farming technologies was significantly connected to their knowledge of those technologies (Table 5). This result can be explained by the fact that the adoption of an innovation starts with a mental process in which a person acquires enough knowledge to decide to make a change.

Empirical results also showed that farmers who acquired knowledge on the technologies from their own experiences and from their fellow farmers (social networks) were more likely to adopt those technologies than were other farmers. This implies that the process of acquiring agricultural knowledge is very important in SSA given its context of low literacy rates and high levels of rurality.

Discussion and implications

The gender gap observed in Côte d'Ivoire and Niger, whereby women had lower knowledge levels and lower usage of rice farming methods compared with those of men, is consistent with the findings previous studies such as Baden and Milward (1997) and Manfre et al. (2013). This outcome is due to challenges such as (i) the sociocultural constraints that limit women from accessing extension and advisory services and (ii) the unavailability of women to effectively interact and communicate with agricultural advisory staff due to more home responsibilities compared with those of men. Additionally, the women surveyed in this study were heads of households, and according to Manfre et al. (2013), they are more vulnerable to poverty because they depend on men and lack the right to own property. This vulnerability explains women's lack of financial support to acquire and use rice farming technologies even if they have the necessary knowledge.

Zossou et al. (2017) suggest that one way to overcome the gender disparity in communication is to use less gender-biased extension information and communication

Table 5. Determinants of the level of use of rice farming technologies: Poisson regression

	Rice farming methods	
Independent variables	Coefficient ± Std.Err.	Probability
Constant	0.982 ± 0.154	0.000***
Gender	−0.044 ± 0.046	0.348
Age	0.000 ± 0.001	0.855
Household size	0.000 ± 0.003	0.773
Annual rice income	0.00 ± 0.000	0.727
Household head attended rice training	0.064 ± 0.063	0.305
Other member of the household attended rice training	−0.016 ± 0.520	0.760
Group membership	−0.007 ± 0.039	0.839
Information from national & international research & extension institutions[a]	−0.022 ± 0.030	0.470
Information from farmers' organization[a]	0.024 ± 0.071	0.732
Information from farmers [a]	0.028 ± 0.014	0.048**
Own experience[a]	0.037 ± 0.015	0.018**
Access to micro-finance institutions	0.031 ± 0.087	0.715
Preferably primary source of information	0.007 ± 0.019	0705
Education	0.010 ± 0.023	0.646
Agriculture as principal activity	−0.001 ± 0.057	0.982
Listen to the radio	0.022 ± 0.058	0.704
Watch the television	−0.002 ± 0.039	0.956
Infrastructure in the village	0.001 ± 0.010	0.905
Wellbeing level	−0.020 ± 0.016	0.200
knowledge level of methods[a]	0.081 ± 0.014	0.000***
Perception on input level to use methods[a]	−0.005 ± 0.006	0.375
Perception on output level to use methods[a]	0.003 ± 0.002	0.279
« Côte d'Ivoire »	−0.061 ± 0.083	0.462
Niger	−0.039 ± 0.070	0.576
Nigeria	−0.126 ± 0.077	0.099*
Togo	0.013 ± 0.053	0.803

Note: The dummies 'Côte d'Ivoire', Niger, Nigeria and Togo are defined relative to the dummy Benin, which is why the latter does not appear in the table.

[a]Count data = score = number of times the household has responded favorably to the question / Std.Err. = Standard Error.

*Denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

tools such as videos, mobile/android phones, radios, televisions and social networks in rural areas in SSA. The noted lack of significant gender gap in Benin, Nigeria and Togo, which may have a bias on the result of the whole sample, could be attributed to activities that promote a gender-based approach, thereby giving more attention to women in development interventions. Indeed, giving the importance of women in the rice value chain, AfricaRice and national partners have adopted many gender-sensitive approaches. These include training courses in which at least 30% of the attendees are women and the use of videos in the diffusion of innovations (Zossou et al. 2009a). Moreover, Shikuku (2019) found that engaging women in dissemination has a greater effect on the acquirement of knowledge and the adoption of improving farming technologies regardless of whether the contact farmers are male or female. However, the effect of including women among disseminating farmers empowers more female farmers (Kondylis et al. 2016; Shikuku 2019). Benin benefited from such interventions when it was the temporary headquarters of AfricaRice for 12 years (2004–2016). This impact was also noted by the overall higher level of knowledge and practice of rice farming technologies among the Beninese heads of households, who may have benefited directly from the interventions of AfricaRice. Nigeria and Togo, which are two neighboring countries of Benin, also benefit from the promotion of a gender-based approach in the diffusion of rice farming technologies. Although Niger also borders Benin, it is possible that sociocultural and religious

factors in the predominant Muslim country may contribute to the observed gender disparity. A similar disparity was also observed in Côte d'Ivoire.

Other determinants of knowledge, such as participation in training sessions on rice farming, had a significant positive effect on farmers' level of knowledge. A report by the Forum for Agricultural Research in Africa (FARA) concluded that

> innovative farmer information systems are a blended learning process in which face-to-face interaction, learning by doing, learning through evaluation and experience, participatory research, etc. convert the generic information into location-specific knowledge and then empower its members through horizontal transfer of knowledge. (Gakuru, Winters, and Stepman 2009, 21–22)

Membership in farmers' organizations also increased the level of knowledge of rice farming technologies. Grouping farmers into organizations is not a recent phenomenon in African rural societies. This method has played an important role in rural economies, policies, agricultural extensions and cultures (Renay 2010). However, the farmers' organizations in African rural areas face some governance issues that can negatively affect their social cohesion. Zossou et al. (2009a) note that power is often concentrated in one leader or few leaders of the farmers' organizations, which causes conflict that negatively affects their community cohesion. More than getting farmers organized, agricultural extension systems need to refocus on social cohesion (Swanson 2006) and social distance (differences in socioeconomic and biophysical characteristics between network nodes) (Santos and Barrett 2010; Shikuku 2019). Shikuku (2019) found that social distance shapes the diffusion of agricultural knowledge and reinforces the idea that social learning can help to address informational constraints on the adoption of agricultural technologies.

Surprisingly, the presence of international NGOs is not beneficial for improving the knowledge of rice farming technologies because international NGOs generally collaborate with local NGOs, farmers' organizations and public services staff who are often named the appropriate actors to promote participatory research and development (Rhoades 1994). The need for international NGOs to act through intermediaries may bias the expected outcomes if inappropriate intermediaries and beneficiaries are selected (Smith 2003; Zossou et al. 2009a; Brüntrup-Seidemann 2011). This situation may negatively affect community cohesion and farmers' trust in these organizations.

The larger the household size, the higher the level of knowledge of rice farming technologies. This finding is consistent with those of Zossou et al. (2017), who showed an exchange of agricultural information and knowledge at the household level. This solidarity at the family level is common in African values and cultures (Whitehouse 2011). In addition, agriculture as the main livelihood activity increases the knowledge of technologies. The diversity of crops that characterizes SSA (World Bank 2007) is, in this case, an advantage because it expands the opportunities to learn about agricultural technologies.

Similarly, access to MFI services is also beneficial for farmers to know more rice farming technologies. Akwaa-Sekyi (2013) observed that most rural banks have contributed greatly to agricultural development in rural communities. However, the capacity of rural people should be strengthened in the same way as business entities to make micro-finance services worthwhile (Alani and Sani 2014). Despite the great role that MFIs play in promoting agriculture in rural areas, they face high operating costs

(Olusanya and Oyebo 2012) that limit their access to rural people, especially poor farmers. The micro-finance sector in Africa is as diverse as the continent itself, with an array of approaches and funding by both formal and informal financial sectors (United Nations 2000).

In line with previous studies (Girard 1992; Farm Radio International 2008; Zossou et al. 2015), rural radio increases households' level of knowledge of rice farming technologies. Agricultural extension could benefit from both the reach and the relevance of local broadcasting through participatory communication approaches (Chapman et al. 2003). Innovative rural extensions and learning approaches using mass information and communication tools such as video, mobile/android phone, radio and social networks are opportunities to bridge the gap between researchers, extension workers, and farmers (Zossou et al. 2017, 2009a). These extension tools, if well used, can reach millions of illiterate farmers and provide them with agricultural knowledge in a language that they understand.

We found that the higher the knowledge level of rice farming technologies, the higher the level of the use of these technologies. As noted by van den Ban et al. (1994) and Negatu and Parikh (1999), the adoption of an innovation correlates with a mental process in which a person acquires enough knowledge to make a change. The process of acquiring agricultural knowledge is very important in SSA given its context of low literacy rates and high levels of rurality.

In addition to the level of knowledge of rice farming technologies, farmers who obtain knowledge of the technologies through their own experiences are more likely to adopt the technologies than are other farmers. This outcome is consistent with the generation and verification steps of the knowledge processes (Havelock 1986), which makes farmers more confident. The success of any sustainable development program is largely determined by the level of participation of farmers (Axinn 1997). As noted by Nederlof and Odonkor (2006), it is important to engage farmers in problem design and to support adult education and farmer experimentation. This process allows farmers to draw their own conclusions. Pretty (2006) suggests that farmers must experiment more and therefore incur the costs of making mistakes and acquiring new knowledge and information.

The creation of conducive learning opportunities is, therefore, a major condition of moving towards sustainable agriculture development in SSA. Farmers who obtain knowledge about the technologies from their peers are also more likely to adopt the technologies than are other farmers. Zossou et al. (2017) showed that 'colleague farmers' is the most quoted source in acquiring knowledge and information on rice farming technologies in West Africa. This confirms the importance of social capital and networks in rural areas in Africa and confirms the need for the effective participation of farmers in technology design and out scaling. This finding is in line with those of Weyori et al. (2018) who showed that strengthening the social network within the innovation system will enhance the adoption of improved farming technologies. However, Shikuku (2019) recently found that the impact of disseminating farmers or farmer-to-farmer approaches on improved farming technology knowledge and adoption depends on social distance. This dependence is the reason why Kondylis, Mueller, and Zhu (2017) found a limited impact of the disseminating farmer approach using a field experiment in Mozambique.

Conclusions

The paper analyzed the main factors that influence farmers in acquiring agricultural knowledge and adopting technologies with the aim of better understanding the agricultural innovation system in West Africa. The presence of AfricaRice and its contribution to the rice sector in Benin might have contributed—directly or indirectly—to the significant absence of a gender gap in the knowledge and use of rice farming technologies in Benin, Nigeria and Togo (which border Benin). A gender disparity was observed in Niger (a border country of Benin with a predominantly Muslim religion) and Côte d'Ivoire, thereby confirming the negative impact of socioeconomic, cultural, religious and institutional constraints on women's knowledge, access to and adoption of agricultural technologies in Sub-Saharan Africa.

To overcome this gender bias, new gender-sensitive (tested and proven) rural extensions and learning approaches should be adopted, such as farmer-to-farmer videos, mobile phones, radios, televisions and social networks. The use of these new information and communication tools in agricultural extensions can stimulate community members to learn and thus reduce their dependence on group leaders. It is also an excellent way to illustrate technologies' principles and encourage rural people to create their own innovations. Improving farmers' knowledge of agricultural technologies may have a positive impact on the adoption of these technologies. However, the use of technology is often related to access to financial resources, which is a limiting factor for female heads of households. Therefore, low-cost innovations such as free android applications and videos on YouTube could help to increase the accessibility to new gender-sensitive rural extensions and learning approaches.

Farmers' organizations play a key role in agricultural extension programs because of their social capital and influence in rural areas. However, to be effective, they need to address challenges such as disparities, social exclusion, power monopolization, the selection bias of participants in capacity building sessions, and conflicts of interests. Agricultural research and development agencies should enhance the community cohesion that gives people a sense of shared responsibility and engagement. Community leaders are the key contributors to the agricultural extension system and should also be targeted in capacity building programs.

All these determinants of innovation adoption are included in the three pillars of an innovation system (learning, linkages, and institutions) and are a combination of extrinsic factors and intrinsic factors. Policies that focus on access to both formal and informal agricultural knowledge sources, credit services, rural radio, and satisfactory welfare programs may help farmers improve their level of knowledge and their adoption of new technologies. A new extension approach should focus on a knowledge-based method through the reinforcement of formal and informal sources of knowledge and new gender-sensitive and low-cost rural extensions and learning methodologies.

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