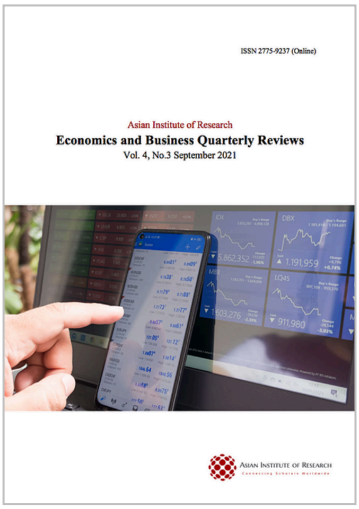

Economics and Business Quarterly Reviews

Yovo, Koffi, and Ganiyou, Ismaïla. (2021), Improved Seeds Adoption Among Smallholder Rice Farmers in Togo: The Case of NERICA in the Savannah Region. In: *Economics and Business Quarterly Reviews*, Vol.4, No.3, 221-234.

ISSN 2775-9237

DOI: 10.31014/aior.1992.04.03.385

The online version of this article can be found at:
https://www.asianinstituteofresearch.org/

Published by:
The Asian Institute of Research

The Asian Institute of Research *Journal of Economics and Business* is a peer-reviewed International Journal. The journal covers scholarly articles in the fields of Economics and Business, which includes, but not limited to, Business Economics (Micro and Macro), Finance, Management, Marketing, Business Law, Entrepreneurship, Behavioral and Health Economics, Government Taxation and Regulations, Financial Markets, International Economics, Investment, and Economic Development. As the journal is Open Access, it ensures high visibility and the increase of citations for all research articles published. The *Journal of Economics and Business* aims to facilitate scholarly work on recent theoretical and practical aspects of Economics and Business.

ASIAN INSTITUTE OF RESEARCH
Connecting Scholars Worldwide

ASIAN INSTITUTE OF RESEARCH
Connecting Scholars Worldwide

The Asian Institute of Research
Economics and Business Quarterly Reviews
Vol.4, No.3, 2021: 221-234
ISSN 2775-9237

DOI: 10.31014/aior.1992.04.03.385

Improved Seeds Adoption Among Smallholder Rice Farmers in Togo: The Case of NERICA in the Savannah Region

Koffi Yovo[1], Ismaïla Ganiyou[2]

[1] Department of Agricultural Economics, Agricultural School, University of Lome, Lome, Togo
[2] PhD Student in Agricultural Economics, Agricultural School, University of Lome, Lome, Togo

Abstract
The low adoption of new technologies, particularly improved seeds, remains a critical issue hampering the development of agriculture in many developing countries. The objective of this research is to identify the determinants of (i) the farmer's knowledge,(ii) the adoption decision and (iii) the adoption intensity of NERICA rice varieties in the Togolese Savannah region. Probit and Tobit models were used to analyse data collected from 150 rice growers randomly selected. The results of the estimations showed that the knowledge, the adoption decision and the adoption intensity of NERICA are determined by socio-economic and institutional factors. The common factors affecting the knowledge, the adoption decision and the adoption intensity are credit access, extension service and gender. However, the adoption intensity is specifically affected by the rice income, the land ownership and the membership to a farmer's base organization. These findings suggest the necessity to improve the agricultural credit access, the extension services access and to take gender into account in policies making in order to give men and women the same chances of access to innovations.

Keywords: Agricultural Innovation, Adoption, Improved Seed, NERICA

1. Introduction

Agriculture plays an important role in the economic growth of a country through its role in increasing the income of the poor, employment and food security (Ortega and Tschirley, 2017; N'souvi and al., 2018; Breisinger and al., 2008). Several authors have emphasized the importance of food self-sufficiency for an economy (Janin, 2021; Labonne, 1986; Yabilé Kinimo, 1986). They focused on the economic consequences of a country's food dependence on imported food. Food sovereignty is seen as an instrument of commercial pressure between countries (N'souvi and al., 2018). Among agricultural products, rice occupies an important position in the world not only by its production but also and particularly by its consumption. Rice is the second most cultivated cereal behind wheat in terms of area and ranks third in relation to its production after wheat and corn. It is the staple food for more than half of the world's population (N'souvi and al., 2018). In addition to being the fastest growing food source in Africa, rice cultivation employs around one billion people living in rural areas in developing countries (Baris and al., 2017). Rice is an integral part of agricultural production systems in Africa, where it has been cultivated for over 3,000 years.

In Togo, the agricultural sector which contributes about 38% of the GDP and employs more than 65% of the working population is highly dependent on cereal production. According to the Direction of Agricultural Statistics, (DSID), over the period 2000 to 2012, the share of agricultural products in the GDP was mainly due to the production of cereals (68%). Agricultural sector has great potential to directly improve the income of the poor. Despite the important role of agriculture in its national economy, Togo is unable to meet its cereal needs including rice (N'souvi and al., 2018). This situation is explained by the low efficiency of extension services and the limited capacity of agricultural research, thus limiting the generation, dissemination and adoption of new technologies (World Bank, 2017; N'souvi and al., 2018).

Rice is a strategic crop in Togo as in other African countries (N'souvi and al., 2018). It is one of the main food crops in the country. Indeed, rice occupies third place after maize and sorghum in terms of production. Considered in Togo as a food for special occasions, rice is now consumed almost at every meal and everywhere. Its average per capita consumption in 2007 was estimated at 15 kg per year or even 20 kg in urban areas (Agbobli and al., 2007). Rice is therefore of major importance for the food and nutritional security of populations in low-income countries like Togo.

Paddy rice production has grown dramatically with the implementation of the National Investment and Food Security Program (PNIASA) over the past decade. Indeed, it increased from 85,637 tons of paddy rice in 2008 to 140,519 tons in 2017, an increase of around 39% (DSID, 2017). Despite this growth, production is still insufficient to meet national rice consumption needs. The country still resorts to massive imports every year to meet an ever increasing demand. This causes foreign exchange outflows estimated on average at US $ 7 million per year (MAEP, 2010).

Increasing local rice production and reducing imports remain the major challenge facing rice cultivation in order to contribute to food security and poverty reduction in Togo (Aboa, 2013; N'souvi and al., 2018). To meet this challenge, it must necessarily go through the intensification of rice cultivation. However, a current reading of the evolution of the yields of cultivated areas clearly shows the opposite. For example, between 2008 and 2017, the rice area increased from 36,492 hectares to 84,395 hectares, almost 57% of increase (DSID, 2017). At the same time, yields have remained almost stagnant around 1 to 2 tons per hectare (MAEH, 2015) indicating that the growth in production observed in recent years is strongly linked to the expansion of rice areas rather than to the increase in improved productivity (Pere, 2016). This situation shows once again that Togolese rice cultivation is characterized by low productivity, explained in particular by the low rate of adoption of rice innovations, primarily improved seeds and fertilizers (N'souvi and al., 2018). It is also indicated that farmers mainly use seeds of the traditional type (85%) coming either from their previous harvests or from the local market against 15% of improved seeds acquired from extension services or local non-governmental organizations (NGOs) (MAEP, 2014). The development of new rice varieties remains a major element of efforts to increase rice productivity and production (Diagne, 2006). N'souvi and al. (2018) recommend the promotion of seeds with high yields and resistant to climatic anomalies. Although many improved varieties have actually been developed and introduced by national and international agricultural research institutions to farmers, the finding is that these innovations have not always met with the expected success; some are only adopted by a part of the farmers, others are rejected after adoption. This situation reopens the debate on the factors determining the adoption of innovations and shows the importance of continuing investigations aimed at improving knowledge on the adoption of technological innovations in agriculture.

Among the improved seeds introduced and disseminated in Togo are the NERICA (New Rice of Africa) rice varieties, introduced in the years 1998 by the Association for the Development of Rice Cultivation in West Africa (WARDA now AfricaRice) with a view to increase rice yields and production to cope with food insecurity in Africa. (Kijima and Sserunkuuma, 2013), claim that this high-yielding attribute of NERICA, however, does not guarantee high adoption rates.

According to surveys by the Direction of Agricultural Statistics, (DSID, 2014), NERICAs are cultivated by only 7.4% of rice farmers in Togo on 2% of the rice areas (640ha). This shows that the adoption rate remains low about two decades after the introduction and dissemination of these improved rice varieties in Togo. This situation raises

the main question of this research, which is to know what factors should be acted on to boost the adoption of NERICAs in Togo. This enables us to measure the efforts that remain to be made for the dissemination and wide adoption of these new varieties of rice in Togo.

The research undertaken in Togo on rice focused more on the analysis of competitiveness (Yovo, 2010), the determinants of supply (N'souvi and al., 2018), the importance of varieties of rice cultivated in Togo and the poverty profile of rice farmers (Gnatoulouma and al., 2010; Komi, 2010). However, knowing the factors behind the adoption of new varieties is crucial for improving productivity and increasing the income of farmers. Thus, knowledge of the determinants of seed adoption would make it possible to put in place suitable mechanisms for better adoption and, in turn, improved productivity and income. This is why this study focuses on the factors of adoption of NERICA rice varieties in Togo. While many studies on adoption of NERICA rice verities have been limited to the determinants of adoption decision (Diagne, 2006; Kijima and Sserunkuuma, 2013), this research goes further by seeking to measure the determinants of the adoption intensity of NERICA.

The main objective of this study is to identify the factors of adoption of NERICA rice varieties in Togo. Specifically, the study aims to: i) analyse the factors that influence knowledge of NERICA, ii) identify the determinants of adoption and iii) those that influence the intensity of NERICA use.

The remainder of the article is articulated into three main sections. The first section presents the NERICA dissemination process in Togo, section 2 deals with the methodology of the study and section 3 discusses the results, draws a conclusion and some policy implications of the study.

2. NERICA rice varieties dissemination process in Togo

The NERICA rice varieties or New Rice for Africa were created in the 1990s by a team of researchers from the West African Rice Development Association (WARDA), current AfricaRice. The NERICA rice varieties are the result of interspecific crosses between African rice (*Oryza glaberrima*) and Asian rice (*Oryza sativa*) with the objective to compensate the problems of low resistance or tolerance of Asian rice varieties (Oryza sativa) and poor yields of African varieties (Oryza glaberrima) (Diagne, 2006). NERICA varieties have therefore inherited the advantages of productivity from their Asian parent (resistance to shattering, lodging resistance, yield potential) and adaptability to the growing environment of the African parent (tolerance to diseases, insects and weeds), anything that helps improve their productivity. The performances linked to these varieties have led some authors to consider NERICA as the centrepiece of the hope for a "green revolution" in Africa (Diagne, 2006). Thus, the African Rice Initiative (ARI) was created in 2001 to promote its wide dissemination in Africa in order to sustainably fight against food insecurity and poverty. This initiative, officially launched in 2002 by WARDA (current AfricaRice) has benefited from several support from technical and financial partners in particular by the African Development Bank (ADB), Japan, the United States Agency for International Development (USAID), the World Bank, the International Research and Development Center (CIRD), the Rockefeller Foundation etc (Diagne, 2006).

The NERICA varieties were introduced in Togo since 1998 for experimentation by WARDA (now AfricaRice). Their dissemination in Togo was carried out using the Participatory Variety Selection (SVP) approach advocated by WARDA and enable researchers, extension workers, agricultural producers and consumers to be involved in the choice of varieties to promote. The Participatory Variety Selection (SVP) sessions took place on experimental plots with an area of 48 m² per variety and were directly managed by the pilot producers under the supervision of researchers from the Togolese Agronomic Research Institute (ITRA) and agricultural advisers from the Institute for Advice and Technical Support (ICAT). These discussion and opinion-sharing sessions were organized in all regions of Togo at the vegetative stage and at physiological maturity with intention to collect the impressions of producers on these different varieties. After the harvest, tasting tests were organized for the final choice. Following the participatory varietal selection sessions, all the stakeholders were able to identify and retain nine (9) varieties of NERICA as preferred by Togolese farmers and consumers. These preferred varieties with their characteristics shown in Table 1 are those which have been disseminated in Togo.

Table 1: Different varieties of NERICA disseminated in Togo

Variéties	Cycle (days)	Average yield (t / ha)	Ecology	Coated grain format
NERICA 1	100	3-4	Rain-fed	Medium and aromatic
NERICA 2	100	4	Rain-fed	Long
NERICA 4	100	4	Rain-fed	Long
NERICA 6	100	3-4	Rain-fed	Medium
NERICA 7	100	4	Rain-fed	Long
NERICA 8	85	4	Rain-fed	Long
NERICA-L-14	120	5	Lowland / Irrigated	Long and thin
NERICA-L-19	120	5	Lowland / Irrigated	Medium
WAS 161-B-9-2	120	5	Lowland / Irrigated	Long

Source : Aboa, 2006

ITRA's 2010 activity report indicates that the results of participatory varietal selections (SVP) enable to understand that the varietal characteristics desired by producers are based on precocity, tillering, plant height, plant homogeneity, panicle load and grain size. Bearded kernels are also sought after in strict rain to reduce guarding costs (ITRA, 2010). After the pre-extension phase, the NERICA varieties selected by the farmers at the end of the SVP were subjected to an extension program supported by WARDA (now AfricaRice) and the West and Central African Network for rice cultivation (RoCaRiz). Indeed, small grants were granted by WARDA to finance inputs (fertilizers, herbicides, seeds) for farmers. Despite the strong participatory extension process around NERICA, a survey conducted in 2014 by the Agricultural Statistics service (DSID) in collaboration with AfricaRice, indicates that NERICA are cultivated by only 7, 4% of rice farmers in Togo on 2% of rice areas in Togo. The adoption rate therefore remains low and some researchers recommended that studies should be carried out in order to identify the obstacles to NERICA adoption.

3. Materials and methods

3.1. Theoretical framework for the adoption and dissemination of innovations

Much theoretical and empirical works has been devoted to innovations and their diffusion and adoption. Studying the factors of adoption and diffusion would require a review of the concepts around innovations, diffusion and adoption.

When discussing innovation topics, we always refer to their dissemination and adoption by users. In the process of disseminating innovations, whether it is a new production technique, a new product, or a new procedure, these innovations start from a sending system and are diffused towards a receiving system. (Rogers, 1983). Rogers and Burdge (1962) define the innovation adoption process as a mental process by which an individual starts from the first information he has about an innovation to the final adoption. According to Rogers (1983), adoption can be defined as the decision to choose a given innovation as the best alternative, to apply it and to continue to use it. Theoretically, the analysis of farmers' decision to choose a new improved seed variety can be based on the randomized utility model of McFadden (1973). The utility maximization theory is applied to agriculture where the producer has in front of him several possibilities of choice. He will prefer a much more profitable alternative

choice. Thus, (Ellis, 1993) considers innovation as a technical change and defines it as the first practical use of a new, more productive technique. The innovation process consists in changing the combination, quality or quantity of inputs required to produce the same type of output. It is considered to be the change in the use of the factors of production that saves the relatively expensive factor. It is the transition from one production function to another following the use of a new input to replace an old one that is more expensive or less efficient (a high-yielding variety replacing a traditional seed in agriculture), either to the addition of a new input to existing ones (eg chemical fertilizers or pesticides), or to a better combination of existing inputs allowing the improvement of production possibilities. This response of technical progress to factor endowment is synthesized in the concept of "innovation process" (Ruttan, 1997). This process according to Rogers and Shoemaker (1971) is divided into four stages namely: awareness, interest, evaluation and finally adoption. Clearly, the adoption process refers to both the diffusion and the actual adoption of an innovation. The diffusion of an innovation is also considered as a cumulative set of individual decisions, with the decisions of members of the social system to adopt or not to adopt an innovation spread over time (Monge and al., 2008). In the same context Young (2009) assimilates the diffusion of innovations with a phenomenon of contagion, social influence and social learning. This implies that each individual faced with a choice has a reaction influenced by several factors (Martey and al., 2014).

In this research, the notion of adoption is defined as the decision to choose a given innovation as being the best alternative (Rogers, 1983), to apply it and to continue to use it (van den Ban and al., 1980). It is both the dichotomous adoption decision (adoption / rejection) and the use intensity (continuous choice of cultivated surfaces). However, it is assumed that the likelihood and use intensity of improved seeds are separate decisions. All of the factors that affect the two decisions are expected to be different. Martey and al. (2014) account for the existence of a significant number of farmers with positive desired demand for modern inputs but are too constrained to adopt them.

3.2. Study area

The study was conducted among rice-growing households in three (03) prefectures of the Savannah region in Togo. The Savannah region is located in the northern part of Togo. It lies between 10 ° 45 "and 11 ° 15" North attitude and between 0 ° 30 "and 1 ° East longitude. It is bounded to the south by the Kara region, to the north by Burkina Faso, to the east by Benin and to the west by Ghana. The savannah region is 8,470 km^2, representing 15% of the surface area of Togo (Djagni, 2007). This region is divided into five (5) prefectures which have recently been increased to seven (7) with the creation of the prefectures of Oti-sud and Kpendjal-ouest which are added to those of Tône, Cinkassé, Oti, Tandjoaré and Kpendjal.

The importance of rice production and the presence of rice-growing lowlands added to the food insecurity that reigns in the Savannah region have made this region a favourable area for the dissemination of rice-growing technologies, thus justifying its choice for the present research on the dissemination and adoption of NERICA varieties in Togo. In addition, the savannah region is one of the regions in which NERICAs have been introduced and disseminated. Participatory varietal selection tests (PVS) were conducted in several localities in the region by ITRA and ICAT. In general, there is a low use of improved seeds in this region. In fact, farmers mainly use seeds of the traditional type (85%) coming either from their crops or from the local market against 15% of improved seeds acquired from the extension services of the State or local non-governmental organizations (NGOs) (MAEP ,2014). Few studies have been carried out on the adoption of NERICAs in this part of Togo, although it represents 39% of national agricultural production.

3.3. Data source and sampling technique

The data are obtained from questionnaire surveys conducted with 150 rice producers in three (3) prefectures of the savannah region, namely the prefectures of Tône, Cinkassé and Tandjoaré. The questionnaire survey was associated with group interviews with producer organizations. The collection was financially supported by the African Forum for Agricultural Research (FARA) through the Support Program for Innovation Research (PARI). The two-stage sampling method was used to carry out the sample with the townships as the primary unit and the rice farmer’s secondary unit. The choice of townships was made in a reasoned manner, taking into account the

existence of rice-growing lowlands. The 150 rice farmers were selected using the empirical sampling method based on visiting lowland rice fields, given the unavailability of an exhaustive list of all rice farmers. It consisted in choosing the rice farmers present in the lowlands of the selected cantons. If a rice farmer is unavailable or refuses to answer the questionnaire, the interviewer moves on to the next one until the number is obtained.

3.4. Econometric models and definition of variables

3.4.1. Model specification

Models ranging from binary to multinomial have been proposed to analyze the adoption behavior of farmers (Martey and al., 2014). Usually, the econometric specification largely depends on the objectives of the study and the available data. Logit and Probit models in which the dependent variable is dichotomous are often used while the Tobit model is used to measure the intensity of technology use (Adesina and Zinnah, 1993). The econometric specification of the determinants of adoption of NERICA employs two definitions of adoption. To do this, the Probit and Tobit model were employed for the analysis with the assumption that the decision and the use are independently determined.

- **The Probit model**

Mathematically, the Probit model is represented as follows:

$$\emptyset\,(\beta x_i) = \int_{-\infty}^{\beta x_i} \frac{1}{\sqrt{2\pi}} \exp\,\left(\frac{-t^2}{2}\right) dt \quad (1)$$

Where βx_i represents, according to the law of normal distribution, the probability that individual i adopts the NERICAs; β is a vector of coefficient to be estimated; x_i is a vector of characteristics of individual i; t is a random variable distributed according to a normal distribution; exp is an exponential function.

The analysis of the results of this model will focus on determining the quality of the model and the significance of the estimated coefficients. The quality of the model is attributed by the significance threshold of the chi-square value or the likelihood ratio (LR) or by the log of the maximum likelihood. At a given threshold (1%, 5% or 10%), the model is globally significant when the value of the LR is greater than that of the chi-square at the same degree of freedom. The signs of the coefficients are important because they indicate whether the associated variation influences the probability upward or downward. In other words, these signs indicate in which way the explanatory variable influences the explained variable (Gnatoulouma and al., 2010).

Empirically, the models of the determinants of knowledge and of the adoption decision are specified as follows:

$$\text{EXPO}_i = b_0 + b_1\ AGE_i + b_2\ HSIZE_i + b_3\ EXPER_i + b_4\ SUPRIZ_i + b_5\ SEXE_i + b_6\ EDUC_i + b_7 MEMB + b_8\ EXTENSION_i + b_9\ SVP_i + b_{10}\ TENUR_i + b_{11}\ CREDIAGRI_i + \varepsilon_i \quad (2)$$

$$ADOPT_i = b_0 + b_1\ AGE_i + b_2\ HSIZE_i + b_3\ EXPER_i + b_4\ INCOME_i + b_5\ SEXE_i + b_6\ STAMAT_i + b_7\ EDUC_i + b_8\ MEMB_i + b_9\ EXTENSION_i + b_{10}\ SVP_i + b_{11}\ TENUR_i + b_{12}\ CREDIAGRI_i + \varepsilon_i \quad (3)$$

- **The Tobit model**

If we consider that the latent variable V_i enable us to estimate the intensity of use of the innovation adopted by farmer i, the Tobit model is written:

$$V_i^* = \beta' Z_i + \mu_i \quad (4) \qquad \text{With}$$

$$V_i = \begin{cases} V_i^* \ si\ V_i^* > 0 \\ 0\ si\ V_i^* \leq 0 \end{cases} \quad (5)$$

V_i, being the observable variable and V_i* the latent variable of the model. Assuming V_i is a function of the characteristics of the farmer and his holding, Z_i is the vector of the characteristics of the farmer and his holding, β' represents the parameters of the model and μ_i is the independent error term and identically distributed according

to the normal law. This model enables us to estimate the parameters from the observations of V_i and Z_i. The estimation of a Tobit model is done by maximizing the likelihood function. This method is one of the most widely used because compared to ordinary least squares, it provides unbiased estimates (Yovo, 2016).

Empirically, the model used to determine the intensity of use of improved seeds of NERICA rice is given as follows:

$$USEADOPT_i = b_0 + b_1\ AGE_i + b_2\ HSIZE_i + b_3\ EXPER_i + b_4\ INCOME_i + b_5\ SEXE_i + b_6\ STAMAT_i + b_7\ EDUC_i + b_8\ MEMB_i + b_9\ EXTENSION_i + b_{10}\ SVP_i + b_{11}\ TENUR_i + b_{12}\ CREDIAGRI_i + \varepsilon_i \quad (6)$$

3.4.2. Definition of variables

The dependent variables in the model are exposure and adoption status for the determinants of knowledge and adoption decision; and the area of land devoted to the NERICA rice varieties for analysis of the use intensity. Certain explanatory variables were introduced into the models in order to estimate their effect on the explained variable. These variables include: age of farmer, sex, membership of a rural organization, formal education, marital status, area cultivated with rice, access to credit, size of household, access to technical support, number of years of experience, participation in variety selection tests, land tenure method and income from rice sales.

The age of the farmer (AGE): This is a quantitative variable whose expected sign on adoption cannot be determined in advance. Indeed, there is no consensus regarding the effect of age on the adoption of agricultural technologies in the literature. Old people can adopt new varieties more easily than young people. They can also be nostalgic and resistant to any change. Age generally has a negative role in the adoption of innovations according to Anderson et al. (2005) because older farmers have a shorter planning horizon. They value less the long-term benefits of certain innovations. However, young operators are often under severe financial constraints which can dissuade them from investing in new technology. However, the expected effect of age on exposure is positive because greater longevity for producers allows them to be exposed to more agricultural innovations.

The farmers' gender (SEX): According to the literature, the female gender would have a negative effect on knowledge and adoption of improved varieties. Men have more access to information and inputs compared to women (Dey, 1981). It is also assumed that in Africa most extension workers are male and tend to favour men in their extension work on new technologies.

Membership of a farmers' organization (MEMB): Membership of a farmers' organization can facilitate contact with the extension service and therefore allow the farmer to be more easily exposed to new varieties. A positive sign is expected on the exposure and adoption of improved rice varieties.

Formal Education (EDUC): Education could positively influence the exposure and adoption of improved rice seeds. Formal education promotes the use of new technology. It enables farmers to seek information on agricultural innovations (Ouedraogo and Dakouo, 2017).

Marital status (STAMAT): the marital status affects access to factors of agricultural production, especially land developed for rice cultivation (Ouedraogo and Dakouo, 2017). In addition, it conditions membership of certain social groups (rice producer organization) which can be channels for the dissemination of agricultural innovations. Married status would have a positive effect on the exposure and adoption of improved varieties.

The area sown in rice (SUPRIZ): An individual who owns a large estate will seek to increase his production. However, the increase requires intensification with the use of improved seeds and therefore will seek to know the improved seeds. It should also be noted that large producers are more exposed to innovations because they are more privileged by the extension services.

Access to agricultural credit (CREDIAGRI): In the absence of credit, the unavailability of liquidity is the main problem for agricultural producers who want to buy inputs. So the lack of credit limits access to inputs. Access to

agricultural credit would therefore have a positive effect on the adoption of improved seeds. Its sign on the exhibit is undetermined.

Household size (HSIZE): large families have more labour to carry out agricultural activities (Ouedraogo and Dakouo, 2017). This would generally encourage the adoption of new agricultural technologies. Household size increases the likelihood that at least one household member will be aware of the existence of new improved varieties. A positive sign is expected on the exposure and adoption of improved rice varieties.

Access to technical support (EXTENSION): contact with extension agents through the visits they operate is indicative of the information. Therefore, this contact allows the producer to have a more in-depth knowledge of the proposed technology (cost and benefit) and therefore promotes their adoption. A positive sign is expected on exposure and adoption.

Experience (EXPER): It facilitates the adoption of innovations that reduce perceived risk, but it can have the opposite effect on the adoption of innovations that increase perceived risk (Roussy and al., 2015). The experience thus has a contrasting effect on adoption. Indeed, according to Soule and al. (2000), experienced farmers know their production context better and can take more risks, however they have a shorter planning horizon which does not encourage them to change practices. However, a positive effect is expected on exposure.

Participatory varietal selection tests (SVP): SVP is an approach that allows farmers to be involved in the process of selecting new varieties. With this approach, farmers are exposed to new varieties very early on, thus facilitating their rapid adoption. Its expected effect on exposure and adoption is positive.

Mode of tenure (TENUR): land plays a key role in the economic and social organization of village communities in Togo. It occupies a preponderant place among the factors of production (Cesar, 2016). A farmer who owns his land will invest more in it than one who has rented the land for a limited time. A positive effect is expected on the adoption of improved varieties.

Income from rice sales (INCOME): Wealth is considered to be a key factor in adoption, firstly through its effect on risk aversion (the richer an individual is, the more he is willing to take risks). In addition, the level of wealth conditions the investment and also makes it possible to bear short-term losses during the implementation of the innovation (Roussy and al., 2015). In the literature, different indicators of wealth are used: net income (Feder and Umali, 1993), social capital (Baffoe-Asare and al., 2013) or turnover. Wealth generally has a positive effect on adoption.

Table 2: Definition and signs of variables

Variable	**Définition**	**Expected sign**	
		Exposure	**Adoption**
AGE	Age of the farmer in years	+	+/-
SEXE	Binary; 1 if feminine and 0 if masculine	-	-
MEMB	Binary; 1 if a member of the Producers' Organization and 0 if not	+	+
EDUC	Binary; 1 if achieved formal education and 0 if not	+	+
STATMAT	Binary; 1 if married and 0 otherwise	+	+
SUPRIZ	Area sown with rice in hectares	+	+
CREDIAGRI	Binary; 1 if access to micro-credit and 0 if not	+	+
HSIZE	Number of household agricultural assets	+	+
EXTENSION	Binary; 1 if access to extension services and 0 if not	+	+
EXPER	Number of years of experience in rice cultivation	+	+
SVP	Binary; 1 if participation in selection test and 0 if not	+	+

TENUR	Binary; 1 if landowner and 0 if not	+	+
INCOME	Income from the sale of rice in FCFA	+	+

Source: The authors

4. Results and discussion

The results of the estimates are presented in this section. The descriptive statistics of the variables used are presented first.

4.1. Descriptive statistics

Analysis of the results shows that the study sample consists of 69% men versus 31% women. The majority (94%) of them are married, 3% are single, 2% are widowed and 1% divorced. About 96% of them practice agriculture as their main activity. Petty trade is the first secondary activity and employs nearly 3% of producers, mainly women, followed by livestock which employs less than 2% of the rice farmers in the sample. The majority of farmers (61.74%) are illiterate against 38.26% of educated people, most of whom stopped at primary or secondary level. The average age of rice farmers is around 42 years, varying between a minimum age of 16 and a maximum of 76 years with a standard deviation of 15.92. This shows that the agricultural population in Togo is aging and agriculture is less attractive to young people. The average number of years of rice growing experience is around 15 years with a maximum of 50 years and a minimum of 2 years. This testifies to the good experience of the farmers in the cultivation of rice. The average household size is 9 people with a maximum of 20 (standard deviation = 4.155) indicating the availability of family labor but also a challenge regarding land pressure. The average area sown to rice is 0.55 hectares and varies between 0.1 and 3 hectares with a standard deviation of 0.38 thus confirming that rice cultivation is still practiced by small agricultural producers. The average yield is 1960 kg / ha for the IR-841 variety, 1700 kg / ha for the NERICAs and 1000 kg / ha for the other unidentified varieties. This yield remains low compared to the potential yields of these varieties which are 6,000 kg / ha for the IR-841 variety and 5,000 to 8,000 kg / ha for the NERICAs. This is explained by the failure to follow technical itineraries and the use of seeds from previous harvests without wanting to buy new seeds each crop year and the low use of mineral fertilizers due to the low purchasing power of farmers. The overwhelming majority (77.33%) did not receive training in rice cultivation in the last three years before the survey, 76% do not have access to extension services and 75.33% do not have never participated in a participatory variety selection session. Likewise, 64% do not have access to agricultural credit and only 14% have ever received an improved seed subsidy in the past three years. Only 36.67% belong to a peasant organization or agricultural cooperative, testifying to the low level of organization. This constitutes major institutional challenges which can act as a brake on the adoption of new technologies.

Various varieties of rice are used by rice farmers. The IR-841 variety is the best known (90%) and the most used (40%). As for the NERICA varieties, they are known by nearly 65% but are only used by about 28% of rice growers. NERICA 14 and NERICA 8 are the best known and most used by farmers in the Savannah region of Togo. The main sources of knowledge of NERICA varieties are contact with ICAT and ITRA (45%) through PVS sessions and exchanges between farmers (35%). NGOs and projects have enabled 20% to learn about NERICA varieties. About 44% of the farmers in the sample obtain their seed through the Social Enterprises and Organization of Rice Producers (Rice ESOP), 34.70% rather use crops from previous campaigns, 14% exchange seeds between producers, only 6.8% manage to buy seeds from seed companies in each campaign.

Interviews with stakeholders in the field, in particular the agricultural advisers of ICAT, researchers of ITRA, some former coordinators of the NERICA dissemination project in Togo and the heads of farmers' organizations, it emerges that culinary habits, power purchase and outlets would be factors influencing the adoption of new varieties, in this case NERICAs. Indeed, agricultural producers would have financial difficulties to buy the improved seeds and would lack outlets to sell their production. Furthermore, it is indicated that consumers have a great preference for flavoured varieties which give off a good aroma when cooked, which is not the case with NERICA varieties.

4.2. Econometric analysis

4.2.1. Estimation of the determinants of exposure to NERICA rice varieties

The determinants of exposure to NERICA varieties are analysed using a Probit model. The results of the estimates presented in Table 3 indicate that the model is globally specified, because the significant Wald chi-square value of 58.88 indicates that the explanatory variables jointly influence the farmers' exposure to NERICA rice varieties. Analysis of the model coefficients indicates that exposure to NERICA is determined by all other variables except household size, area sown to rice and participation to varietal selection (SVP) sessions. Exposure to NERICA is positively influenced by years of experience in rice cultivation, female gender, formal education, rural organization membership, access to extension services and land ownership. Age and SVP participation negatively influence exposure to NERICA. These results are consistent with those of Roussy and al. (2015) who find that experience contributes to exposing producers to technological innovations. Similarly, the significance of the female gender variable is explained by the fact that women are more likely to belong to peasant associations which are the privileged frameworks for acquiring information on new varieties. Along with educated farmers who are constantly looking for new technologies and ways to increase their yield to meet the needs of the market and their families, uneducated peasants would be conservative of traditional habits, thus explaining the positive sign of the formal education variable. Belonging to a farmer organization that can facilitate contact with the extension service and therefore enable the farmer to be more easily exposed to new varieties explains the positive signs of these two variables. On the other hand, the negative sign of the age variable is explained by the fact that the curiosity of young people leads them to discover new improved varieties. Indeed, the young farmer is able to have information because of his ability to make frequent trips to come into contact with producers in other localities (Seye and al., 2017).

Table 3: Results of the Probit regression for NERICA rice varieties knowledge

Explanatory variables	Modalities	Coefficients	Z
Age	**Years**	**-0,047**	**-2,20****
Household size	Units	-0,082	-1,45
Rice growing experience	**Years**	**0,092**	**2,43****
Rice area	hectares	-0,131	-0,22
Female gender	**0/1**	**1,373**	**2,94*****
Formal education	**0/1**	**0,983**	**2,50****
Membership to rural organization	**0/1**	**1,098**	**2,89*****
Access to extension services	**0/1**	**0,822**	**1,93***
Participatory varietal selection	0/1	0,554	0,81
Land tenure mode	**0/1**	**-0,668**	**-2,05****
Access to agricultural credit	**0/1**	**-1,137**	**-2,83*****
Constant	-	1,366	2,78
Number of Observations	145		
Wald chi2 (13)	58,88		
Prob > chi2	0,000		
Pseudo R2	0,5087		

Source: computed from survey' data, 2018

*Robust z-statistics with ***significant at the 1%, **significant at 5% and * significant at 10%.*

4.2.2. Estimation of the determinants of NERICA adoption and use intensity

The results of the KLEIN rule-based multicollinearity test indicate that there is no multicollinearity between the explanatory variables used for the two models. Indeed, all the partial correlation coefficients in absolute value between the explanatory variables, apart from the values of the diagonal, are less than 0.8. Consequently, all the explanatory variables of the basic model are retained in the final model.

The determinants of the use intensity of NERICA rice varieties are analysed using a Tobit model while the adoption decision was estimated by the Probit model. The results of the estimates presented in Table 4 indicate that the two models are globally specified, because the significant wald chi-square value indicate that the explanatory variables jointly influence the farmers' adoption and the use intensity of NERICA rice varieties.

In addition, the results show that the variables that significantly determine the adoption decision are different from those that influence the use intensity NERICA with the exception of the variable access to agricultural credit. Consequently, the analysis will be done in two stages: the analysis of the determinants of the adoption decision using the estimation of the Probit model then the analysis of the determinants of use intensity of NERICAs provided by the results of the Tobit model.

The regression estimate of the Probit model of the determinants NERICAs adoption

The decision to adopt NERICAs is significantly determined by access to extension services, agricultural credit, membership of a peasant organization and female gender. All of these variables positively influence the dichotomous decision to adopt NERICAs.

Contact with extension agents through the visits they operate is indicative of information. Consequently, this contact allows the producer to have a more in-depth knowledge of the proposed technology (cost and advantage) and therefore promotes their adoption, explaining the positive sign of the coefficient of the variable (extension services) on the adoption decision.

Membership of a farmers' organization facilitates contact with the extension service and allows the farmer to be more easily exposed to new varieties with more opportunity to adopt them. The positive sign of the coefficient of the female gender variable is in accordance with the results of DSID (2014) according to which NERICAs are cultivated by 16% of women against 8% of men. These results also corroborate those found by Ouedraogo and Dakouo (2017) stating that being male decreases the probability of adopting NERICAs by 10% in Burkina Faso. The sign of the coefficient of the variable access to credit could be explained by the fact that in the absence of credit, the availability of liquidity is the main problem for agricultural producers who want to buy inputs.

The Tobit model regression estimate of the determinants of the use intensity of NERICA

According to this model, the income from rice sales, membership of a farmer organization, land ownership and access to credit significantly determine the use intensity of NERICAs by producers.

The negative sign of the coefficient of the variable Income, it is contrary to the sign expected in connection with the literature (Rogers, 1983; Griliches, 1957). According to Rogers (1983) the adoption of innovation by an individual correlates with the individual's resources and the benefits of the innovation. For Griliches (1957), wealth is considered as a key factor in adoption, firstly through its effect on risk aversion (the richer is an individual, the more risk-taking he is). In addition, the level of wealth determines the level of investment and also enables the individuals to bear the short-term losses during the implementation of the innovation (Roussy and al., 2015). This result can be explained by the fact that rice farmers cultivate several types of rice varieties. Interviews with producer organizations revealed that NERICA varieties are intended for self-consumption and are not marketed in the Savannah region and therefore do not bring in much income. In particular, the IR-841 variety is the most marketed rice in savannah region. Therefore, as the income from the sale of IR-841 rice increases, the rational farmer also increases the space allocated to this variety at the expense of NERICAs in order to increase his profit. This is the reason why an increase in the income from rice sales results in a decrease in the space devoted to NERICA. Concerning the variable relate to the membership of an organization, the negative sign is explained by the competition between different varieties available to the farmer. In fact, farmers who are members of an organisation are more likely to know many improved varieties.

This could lead to a negative influence on the intensive use of NERICA. On the other hand, access to credit and the mode of land tenure encourage the adoption of new technologies because the two variables represent the

availability of resources with effects on risk aversion (Griliches, 1957). This result is in line with Roussy and al. (2015) according to which the level of wealth conditions the investment and also enables to bear short-term losses during the implementation of the innovation.

Table 4: Estimation results of NERICA adoption decision and the adoption intensity

Variables	Probit		Tobit	
	coefficients	z-statistics	coefficients	t-statistics
AGE	-0,0126	-0,77	0,0034	0,89
HSIZE	-0,0606	-1,31	-0,0036	-0,38
EXPER	-0,0071	-0,34	0,0016	0,34
INCOME	-0,0072	-0,19	-0,0217	**-2,4****
SEXE	1,1805	**3,55*****	-0,0041	-0,06
STATMAT	-0,3316	-0,42	-0,3699	-1,65*
EDUC	0,5185	1,51	0,1175	1,53
MEMB	0,6052	**1,67***	-0,2159	**-2,83*****
EXTENSION	1,6598	**3,94*****	0,1155	1,32
SVP	0,5947	1,29	0,1455	1,37
TENUR	0,4960	1,61	0,1955	**3,02*****
CREDIAGRI	0,7892	**2,14****	0,3186	**4,05*****
Constant	-0,4205	-0,49	1,0683	4,93
Number of observation	149		149	
Wald chi2 (13)	41,52		41,52	
Prob >chi2	0,0001		0,0001	
Pseudo R2	0,3727		0,2351	

Source: computed from survey' data, 2018

Robust z-statistics with ***significant at the 1%, **significant at 5% and * significant at 10%.

5. Conclusion and Policy Implications

Rice occupies a major position in food security in low-income countries like Togo. Despite the important place of rice in the country, Togo domestic production of rice is not consistent to meet the demand for this food. Although many improved rice varieties in particular the NERICA were disseminated, the adoption rate remains weak. The present study investigated the factors influencing knowledge, adoption and use intensity of NERICA among smallholder farmers in the Togolese Savannah region. Probit and Tobit models were used to analyse data collected from 150 rice growers. The common factors affecting both the knowledge, the adoption decision and the adoption intensity are access to credit, extension service and gender. However, the adoption intensity is specifically affected by the rice income sales, the land ownership and the membership of a peasant organization. In order to increase the productivity of rice to guarantee food security, it is necessary to improve the agricultural credit access, the extension services access and to take gender into account in policies making in order to give men and women the same chances of access to innovations.

Moreover, it is also important to improve the capacity building of rice farmers through training and adequate agricultural technical assistance that enables them to improve their access to productive resources (improved seed); take gender into account in policies making in order to give men, women and young people the same chances of access to innovations, to better organize the rice farmers in cooperatives in order to facilitate their access to market and then, solving the land access problem.

References

Aboa, K. (2013). *L'importance des variétés de Riz aromatiques au Togo : Cas de IR 841.* Atelier National sur les Indications Géographiques, INFA de Tové, Kpalimé-Togo.

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions : A Tobit model application in Sierra Leone. *Agricultural economics*, *9*(4), 297-311.

Agbobli, C. A., Adomefa, K., & Labare, K. (2007). *Situation de référence sur les principales céréales cultivées au Togo : Maïs, Riz, Sorgho, Mil*. Institut Togolais de Recherche Agronomique (ITRA).

Baffoe-Asare, R., Danquah, J. A., & Annor-Frempong, F. (2013). Socioeconomic factors influencing adoption of CODAPEC and cocoa high-tech technologies among small holder farmers in Central Region of Ghana. *Journal of Experimental Agriculture International*, 277-292.

Baris, P., Zaslavsky, J., & Perrin, S. (2017). *La filière riz au Mali : Compétitivité et perspectives de marché | AFD - Agence Française de Développement*. https://www.afd.fr/fr/ressources/la-filiere-riz-au-mali-competitivite-et-perspectives-de-marche

Breisinger, C., Diao, X., Thurlow, J., & Al-Hassan, R. M. (2008). *Agriculture for development in Ghana : New opportunities and challenges*. Intl Food Policy Res Inst.

Cesar, K. A. (2016). *Prédisposition des ménages agricoles affectés par le VIH/SIDA à adopter les services de la recherche agricole : Une approche en termes de marketing social dans la région maritime et des plateaux du Togo.* [Mémoire de Master de Recherche en Agroéconomie]. Université de Lomé.

Dey, J. (1981). Gambian women : Unequal partners in rice development projects? *The Journal of development studies*, *17*(3), 109-122.

Diagne, A. (2006). Diffusion and adoption of NERICA rice varieties in Côte d'Ivoire. *The Developing Economies*, *44*(2), 208-231.

Djagni, K. K. (2007). *Capacité d'ajustement des exploitations agricoles aux processus de libéralisation de la filière cotonnière au Togo*. Centre for Development Studies, University of Groningen.

Ellis, F. (1993). *Peasant economics : Farm households in agrarian development* (Vol. 23). Cambridge University Press.

Feder, G., & Umali, D. L. (1993). The adoption of agricultural innovations : A review. *Technological forecasting and social change*, *43*(34), 215-239.

Gnatoulouma, T., Koffi-Tessio, E. M., & Diagne, A. (2010). *Profil de pauvreté et filets de sécurité des riziculteurs dans les zones d'introduction des NERICA au Togo : Cas des régions du nord-Togo*.

Janin, P. (2021). L'autonomisation alimentaire de l'Afrique en perspective. In *Le Déméter 2021* (61-78). IRIS éditions.

Kijima, Y., & Sserunkuuma, D. (2013). The adoption of NERICA rice varieties at the initial stage of the diffusion process in Uganda. *African Journal of Agricultural and Resource Economics*, *8*(311), 46-56.

Komi, T. (2010). *Profil de pauvreté et filets de sécurité des riziculteurs dans les zones d'introduction des NERICA au Togo : Cas de la région des plateaux*. Mémoire d'ingénieur, Université de Lomé.

Labonne, M. (1986). L'autosuffisance alimentaire en question. *Nourrir les villes en Afrique Subsaharienne. Paris: L'Harmattan*.

MAEH. (2015). *La politique agricole assortie du plan stratégique pour la transformation de l'agriculture au togo a l'horizon 2030 (PA-PSTAT 2030). Document de politique agricole pour la période 2016-2030*. Ministère de l'Agriculture, de l'Elevage et de l'Hydraulique (MAEH), Lomé-Togo.

MAEP. (2010). *Stratégie Nationale de Développement de la Riziculture (SNDR)*. Ministère de l'Agriculture de l'Elevage et de la Pêche (MAEP), Lomé-Togo.

Martey, E., Wiredu, A. N., Etwire, P. M., Fosu, M., Buah, S. S. J., Bidzakin, J., Ahiabor, B. D., & Kusi, F. (2014). Fertilizer adoption and use intensity among smallholder farmers in Northern Ghana : A case study of the AGRA soil health project. *Sustainable Agriculture Research*, *3*(526).

Monge, M., Hartwich, F., & Halgin, D. (2008). *How change agents and social capital influence the adoption of innovations among small farmers : Evidence from social networks in rural Bolivia*. Intl Food Policy Res Inst.

N'souvi, K., Sun, C., & Egbendewe-Mondzozo, A. (2018). Analysis of Local Rice Supply in Togo from Data in Cross Sections. *International Journal of Agricultural Economics and Management*, *8*(1), 21-41.

Ortega, D. L., & Tschirley, D. L. (2017). Demand for food safety in emerging and developing countries : A research agenda for Asia and Sub-Saharan Africa. *Journal of Agribusiness in Developing and Emerging Economies*.

Ouedraogo, M., & Dakouo, D. (2017). Assessing the adoption of NERICA varieties in Western Burkina Faso. *African Journal of Agricultural and Resource Economics*, *12*(1), 1-16.

Pere, A. (2016). *Evaluation de l'impact d'un programme d'investissement agricole sur les plans alimentaire et nutritionnel : Cas du PNIASA au Togo*. Editions Publibook.

Rogers, E. M. (1983). *Diffusion of innovations* (3rd ed.). New York : London : Free Press ;, [1983].

Rogers, E. M., & Burdge, R. J. (1962). *Community norms, opinion leadership and innovativeness among truck growers*.

Rogers, E. M., & Shoemaker, F. F. (1971). *Communication of Innovations; A Cross-Cultural Approach.*

Roussy, C., Ridier, A., & Chaib, K. (2015). Adoption d'innovations par les agriculteurs : Rôle des perceptions et des préférences. *INRA, France*.

Ruttan, V. W. (1997). Induced innovation, evolutionary theory and path dependence : Sources of technical change. *The Economic Journal*, *107*(444), 1520-1529.

Seye, B., Arouna, A., Sall, S. N., & Ndiaye, A. A. (2017). Impact de l'adoption des semences certifiées des variétés améliorées de riz sur le taux de pauvreté : Cas du Bénin. *Cahiers du Centre Béninois de la Recherche Scientifique et de l'Innovation*, *11*, 96-103.

Soule, M. J., Tegene, A., & Wiebe, K. D. (2000). Land tenure and the adoption of conservation practices. *American journal of agricultural economics*, *82*(4), 993-1005.

van den Ban, A. W., Chamala, S., & Röling, N. (1980). A new look at adopter categories and on alternative proposal for target grouping of farming community. *Indian Journal of Extension Education*, *16*(1/2), 1-18.

World Bank. (2017). *Togo : Additional financing for agriculture sector support project*. World Bank. <http://documents.worldbank.org/curated/en/598011492394445446/pdf/TOGO-PP-03282017.pdf>. (Accessed 06.11. 18). - Recherche Google

Yabilé Kinimo, R. (1986). Autosuffisance alimentaire en Côte d'Ivoire : Paradoxe ou réalisme socio-économique. *Économie rurale*, *175*(1), 44-49.

Young, H. P. (2009). Innovation diffusion in heterogeneous populations : Contagion, social influence, and social learning. *American economic review*, *99*(5), 1899-1924.

Yovo, K. (2010). Incitation par les prix, rentabilité et compétitivité de la production du riz au sud Togo. *Tropicultura*. https://agris.fao.org/agris-search/search.do?recordID=DJ2012058559

Yovo, K. (2016). Willingness to Pay for Fertilizers at Unsubsidized Price in Togo. *Scholars Journal of Economics, Business and Management*, *3*(565-574), 10. https://doi.org/10.21276/sjebm.2016.3.10.7