Analysis of the determinants of fertilizer use decision by farmers in Senegal using a logit model

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Abstract

In Sub Saharan Africa, agriculture plays a central role against hunger and in poverty alleviation. However, it has been noted that agricultural productivity in this area is one of the lowest in the world. One of the reasons of this fact is a decrease of soils fertility due to a lack of nutrients in the soils. To reverse this trend, a solution would be using improved agricultural technologies, like fertilizer. This article aims at determining factors influencing farmers to use fertilizer in Senegal. Data have been collected in five agro ecological zones namely Peanut Basin, Casamance, Niayes, Eastern Senegal and Senegal River Valley. The study sampled 734 household heads for the analysis. For this purpose, a logit model has been estimated through the Maximum Likelihood procedure. Results revealed that household size, gender, relation with extension and research services, farmer organization membership, perception of the cultural practices impact on the land regeneration, connection with Agri-inputs suppliers, cropping cereals and vegetables were statistically significant. The policy implications for a better use of fertilizer are: (i) strengthening extension services capacities in terms of logistics and human resources; (ii) sensitizing farmers to join farmers' organizations; (iii) strengthening farmers' capacities in specific themes like good agricultural practices; (iv) putting in place proximity selling points to facilitate fertilizer access to farmers living in isolated areas.

Key words: fertilizer; agricultural productivity; logit; Maximum likelihood.

Les déterminants de la décision d'utilisation de l'engrais par les producteurs au Sénégal

Résumé

En Afrique Sub Saharienne, l'agriculture joue un rôle essentiel dans la lutte contre la faim et dans l'éradication de la pauvreté. Toutefois, dans cette partie du monde, la productivité agricole y est très faible par rapport aux autres régions. Une des raisons avancées constitue la baisse de la fertilité des sols à cause d'un manque de nutriments dans le sol. Pour pallier ce fléau, une solution pourrait être le recours à des technologies agricoles améliorées, notamment les engrais. L'objectif de cet article est d'étudier les déterminants de l'utilisation de l'engrais par les producteurs au Sénégal. Les données ont été collectées dans cinq zones agro écologiques à savoir le Bassin Arachidier, la Casamance, les Niayes, le Sénégal Oriental et la Vallée du fleuve Sénégal. L'étude a impliqué 734 chefs de ménage. A cet effet, un modèle logit a été estimé par la méthode du maximum de vraisemblance. Les résultats ont montré que la taille du ménage, le sexe, la relation avec les services de recherche et de vulgarisation, l'appartenance à une organisation de producteurs, la perception des producteurs de l'impact des pratiques culturales sur la régénération des terres, la connaissance d'un réseau de fournisseurs d'intrants agricoles et la culture de céréales et de légumes se sont révélés statistiquement significatifs. Ainsi, les recommandations formulées sont les suivantes : (i) renforcer les capacités des services de vulgarisation en termes de logistique et ressources humaines ; (ii) inciter les producteurs à être membres d'organisations de producteurs ; (iii) renforcer les capacités des producteurs sur des thématiques spécifiques telles que les bonnes pratiques culturales ; (iv) mettre en place des points de vente de proximité pour faciliter l'accès de l'engrais aux producteurs vivant dans des zones éloignées.

Mots clés : engrais ; productivité agricole ; logit ; maximum de vraisemblance

محددات قرار استخدام الأسمدة من قبل المنتجين في السنغال

ملخص

في أفريقيا جنوب الصحراء، تلعب الزراعة دورًا أساسيًا في مكافحة الجوع والقضاء على الفقر. ومع ذلك، في هذا الجزء من العالم، فإن الإنتاجية الزراعية منخفضة للغاية مقارنة بالمناطق الأخرى. أحد الأسباب المطروحة هو انخفاض خصوبة التربة بسبب نقص المغذيات في التربة. للتخفيف من هذا المشكل، يمكن أن يكون أحد الحلول هو استخدام التقنيات الزراعية العصرية، ولا سيما الأسمدة. الهدف من هذه المقالة هو دراسة محددات استخدام الأسمدة من قبل المنتجين في السنغال. تم جمع البيانات في خمس مناطق إيكولوجية زراعية، وهي حوض الفول السوداني وكازامانس ونيايس وشرق السنغال ووادي نهر السنغال. شملت الدراسة 734 رب أسرة. لهذا الغرض، تم تقدير نموذج "لوجيت" بأسلوب الاحتمالية القصوى. أظهرت النتائج أن حجم الأسرة، والجنس، والعلاقة مع خدمات البحث والإرشاد، والعضوية لمنظمة المنتجين، وتصور المنتجين لتأثير الممارسات الزراعية على تجديد الأراضي، ومعرفة شبكة موردي المدخلات الزراعية وزراعة الحبوب والخضروات كانوا مؤشرات ذات دلالة إحصائية مهمة. وبالتالي، فإن التوصيات المقدمة هي كما يلي: (1) تقوية قدرة خدمات الإرشاد من حيث اللوجستيات والموارد البشرية؛ (2) تشجيع المنتجين على أن يكونوا أعضاء في منظمات المنتجين؛ (3) تقوية قدرة المنتجين على مواضيع محددة مثل الممارسات الزراعية الجيدة؛ (4) وضع نقاط بيع للقرب لتسهيل وصول الأسمدة إلى المنتجين الذين يعيشون في المناطق النائية.

الكلمات المفتاحية: الأسمدة، الإنتاجية الزراعية، "لوجيت"، أقصى احتمال

Introduction

In Sub Saharan Africa (SSA), agricultural sector has continued to be the major drive for sustainable development, rural poverty reduction and a reliable source of food for subsistence. Yet, agricultural productivity has continued to decline over the last decades and poverty levels are rising (Olwande *et al.,* 2009). In contrast, agricultural productivity growth in the Sub-Saharan region lags behind productivity in other regions in the world. In 2016, the agricultural total factor productivity annual growth rate in SSA (except South Africa) was estimated at -0.04% while it was estimated at 0.036%, 0.022%, -0,003% and -0.028% respectively in North America, Asia (except West Asia), Europe (except USSR) and Oceania (USDA, Economic Research Service, 2019). Many farmers are facing severe decline in crop yields, which have adverse effects on economic growth and development (Hassan *et al.,* 1998). A major constraint impeding higher productivity among farmers is soil infertility related mainly to low nutrients in soils (Wanyama *et al.,* 2009). Increasing agricultural productivity in the Sub-Saharan Africa is an urgent necessity. And one of the fundamental ways of improving agricultural productivity is through introduction and optimal use of improved agricultural technologies (Akpan *et al.,* 2012). In addition, achieving agricultural productivity growth will not be possible without developing and disseminating yield-increasing technologies because it is no longer possible to meet the needs of increasing numbers of people by expanding areas under cultivation (Solomon and Bekele, 2010 in Gebresilassie, 2015)

Fertilizer has become the prominent technology used by farmers across the world. However, its use in the West Africa and Africa has been low. Studies conducted by Akpan *et al.* (2012), revealed that the average intensity of fertilizer use in West Africa, is only 8 kilograms per hectare of cultivated land which is much lower as compared to other developing regions. Interestingly, there are a lot of factors which impedes the use of fertilizer in West Africa.

Senegal is in the same path regarding what stated earlier. In rural areas, farmers are facing food insecurity and poverty with a poverty rate estimated to 57% (Mbow, 2017). This situation is intensified by poor soils, random rains, and low agricultural productivity. Despite several strategic initiatives undertaken by the Senegalese Government and the continuous support from the development partners to disseminate technologies that could improve productivity, the increase of agricultural yields remains lower compared to the demographic growth. This might be explained by the low level of fertilizer use. In the country the average quantity of fertilizer used has been estimated at 16,4 kg/ha in 2016 (World Bank, 2016)[1]while according to Liverpool-Tasie and Takeshima (2013); Agbahey *et al.,* (2015) it is estimated at 86 kg/ha in Latin America, 104 kg/ha in South Asia and 142 kg/ha in Southeast Asia, while in Western Europe and USA, fertilizer use intensity is up to 288 kg/ha on average (Babasola *et al.,*2017). Although extension services made many efforts in promoting such technologies towards farmers, their work seems to be unproductive in terms of fertilizer utilization and the reason why is still unknown. Until now, there is almost no investigation on factors influencing fertilizer use in Senegal as found in other countries such as (Yabi *et al.,* 2016 ; Sigué *et al.*, 2018). To bridge this gap, this article aims at identifying the determinants of fertilizer use decision by farmers in Senegal. The policy implications drawn from this study might help the Government to more sharpen its fertilizer distribution system as the main fertilizer buyer. The rest of the paper is

[1] https://donnees.banquemondiale.org/indicator/AG.CON.FERT.ZS?name_desc=true

organized as follow: the second section explains the estimation methodology used, the third section describes and analyzes the results obtained following the estimation and the last section brings some concluding and remarks.

Methodology

Theoretical framework

As stated earlier, this work aims at investigating the factors influencing farmers' decision to or not use fertilizer (organic or inorganic). Considering this case, the outcome variable is represented as follows:

Y_i = 1 if the i^{th} farmer uses fertilizer or 0 otherwise.

For such types of dependent variable, either probit or logit model are appropriate where the choice of either of them is a matter of preferences (Greene, 2000 in Abebe and Debebe, 2019). Indeed, these two models provide quite same results. The only difference rests upon the fact that distribution function for the logit model is a logistic distribution and the one for the probit is a centered and reduced normal distribution. In this paper we use the logit model to perform our analysis, following the same approach in As Sunny *et al.,* (2018). This model enables not only identifying individuals' features of the two groups, but also estimate the influence of these characteristics (Afsa, 2016). In binary response models, interest lies primarily in the response probability (Wooldridge, 2002). Let consider the following equation.

$p_i = \text{Prob}\ (Y = 1|\ x_i) = F\ (x_i, \beta)$

With x_i the explanatory variables, $F(.)$ the distribution function and β the vector of parameters to be estimated.

When the logit model is considered, *F* takes this following form (Hurlin, 2003)

$$\forall\ \omega \in R,\ F\ (\omega) = \frac{e^{\omega}}{1+e^{\omega}} = \frac{1}{1+e^{-\omega}} = \Lambda\ (\omega)$$

Replacing ω by (x_i, β), we fall to this equality:

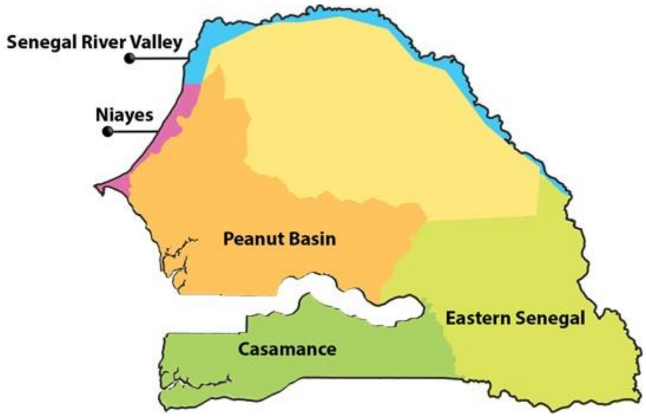
$$p_i = \Lambda\ (x_i,\beta) = \frac{1}{1+e^{-x_i,\beta}}\ \forall\ i = 1,\ldots,N$$

Thus, the logit model defines the probability associated to the event Y_i = 1 as the distribution function value of the logistic distribution at the point x_i,β. In other words, it is the chance of the i^{th} farmer to use fertilizer given some covariates.

Description of the study area

Located in the extreme west of West Africa with a seafront of over 700 km on the Atlantic Ocean which limits it to the west, Senegal covers an area of 196,712 km². The country is located in the extreme west of the African continent, between 12°5 and 16 °5 North latitude and 11°5 and 17 °5 West longitude. Senegalese territory is limited to the north by Mauritania, to the east by Mali and to the south by Guinea and Guinea Bissau. The Republic of Gambia constitutes an enclave within Senegalese territory. The Cape Verde Islands are located 560 km off the Senegalese coast. In 2017, the country's population was estimated at 15,256,361 people. The women represent 7,659,420 and men 7,596,941, i.e. 50.20% and 49.80% (ANSD, 2020).

Data have been collected within the frame of the Feed the Future Senegal Dundël Suuf project baseline study. The survey was conducted countrywide from July 14th to 27th, 2020, involving 13 out of the country's region, except Dakar where agricultural activities are not developed compared to the rest. As a recall, Feed the Future Senegal Dundël Suuf is a project funded by the United States Agency for International Development (USAID) and coordinated by the International Fertilizer Development Center (IFDC). Specifically, the project aims at increasing availability and use of new and quality fertilizers through efficient private sector-led supply systems to improve and sustain soil fertility in Senegal. The project comprises three components: (i): Improved and appropriate fertilizer formulas developed and made available to farmers; (ii) Proven and environmentally sound fertilizer products and technologies disseminated and upscaled, and (iii) Improved fertilizer policy and regulatory environment. Five agro-ecological zones (AEZ) are targeted namely the Peanut Basin, Casamance, Niayes, Eastern Senegal and Senegal River Valley.



Map 1. Project's intervention areas

For each AEZ, priority crops have been recommended in line with the Agricultural policy of the Government ongoing, the natural endowments and farmers' agricultural traditional practices. The table below summarizes priority crops for each zone.

Table 1. Priority crops by AEZ

AEZ	Priority crops
Senegal River Valley	Irrigated rice and vegetables
Niayes	Vegetables
Peanut Basin	Legumes (peanuts, cowpea), dry cereals (sorghum, millet, maize) and vegetables
Casamance	Upland and irrigated rice, dry cereals (sorghum, maize), peanuts and vegetables
Eastern Senegal	Dry cereals (sorghum, maize), peanuts and vegetables

Sampling method

Agricultural households have been targeted with a focus on the household head. A « multistage » sampling method was used. The first step consisted in identifying study areas from information provided by the project team that could be targeted to receive the intervention of the project. The second step was the selection of representative villages of the intervention areas. This process was inclusive with the involvement of research and extension services (ANCAR, DRDR, ISRA), farmers ‘organizations like RESOPP and the project zonal focal points. Lastly, when the villages identified, a random selection has been done to choose the households of interest. The survey involved 12,507 individuals but this study focused just on the household heads. The STATA software has been used for data analysis. After data processing, information on 734 household heads were taken into consideration for this study, including 452 heads who used fertilizer and 282 who didn’t.

Postestimation tests

To verify the robustness of our model we perform a series of tests.

The first one we achieve is a specification error test. In other words, we want to make sure that all independent variables relevant to explain our model have been mainstreamed and one should not be able to find any additional predictors that are statistically significant except by chance. We use the STATA command *linktest* for this purpose. Secondly, we run the Hosmer-Lemeshow goodness-of-fit test. The last test we perform is a receiver operating characteristic (ROC) analysis. It is about to graph the ROC curve and calculate the area under it.

Empirical application

As a result of what has been said previously, the model to be fit is:

$$\text{Prob}(Y = 1| x_i) = \Lambda (\beta_0 + \sum_{i=1}^{12} xi\beta i)$$

The table below summarizes what each variable involved in the model stands for. In addition, the opportunity will be ceased to establish the expected impact (sign of the estimated parameter, β_i) of each covariate on the outcome, based on the literature about this thematic (see table 7 in annex).

Table 2. List of variables

Notation	Name
Y	Farmer’s decision (dependent variable)
x_1	Household size
x_2	Gender
x_3	Experience
x_4	Relation with extension and research services
x_5	Participation in fertility program
x_6	Farmer organization membership
x_7	Perception of the cultural practices impact on the land regeneration
x_8	Fertilizer dosing issues
x_9	Connection with Agri-inputs suppliers
x_{10}	Literate
x_{11}	Cropping cereals
x_{12}	Cropping vegetables

The parameters of the model will be estimated using the Maximum Likelihood procedure.

Results and discussion

Descriptive statistics results

The table below shows the t-test performed for the quantitative variables.

Table 3. Quantitative variables description

Variables	Mean			
	Combined	Fertilizer users	Nonusers	Difference
Household size	9.64	9.1	10.5	-1.4***
Experience	29.62	28.8	30.94	-2.14**

*** means significant at 1%
** means significant at 5%
* means significant at 10%

Source: From field survey, 2020.

It appears that those who do not use fertilizers capitalize more years in practicing agriculture and have bigger households.

We conducted a test of proportions for the qualitative variables to check out whether there is difference between the two groups.

Table 4. Qualitative variables description

Variables	**Mean (%)**		
	Fertilizer users	**Nonusers**	**Difference**
Gender	96	91	5***
Relation with Extension services	37	10	27***
Participation in fertilizer program	25	7	18***
Farmer organization membership	75	35	40***
Perception of the cultural practices impact	48	14	34***
Fertilizer dosing issues	38	22	16***
Connection with Agri-inputs suppliers	56	29	27***
Literacy	63	53	10**
Cropping cereals	46	56	-10***
Cropping vegetables	39	13	26***

Source: From field survey, 2020.

The results revealed that for all variables excepted “cropping cereals”, the proportion for those using fertilizer is significantly higher than the one for those who do not use it.

Overall, this brief description shows that the two groups are different as per the variables of interest. So, what are the ones that affect the decision of using fertilizers?

Estimation results

Empirical results obtained after estimating our model are confined in table 5. the LR test performed shows that, overall, the explanatory variables jointly contribute to explaining farmers' decision to use fertilizer. Most of the variables implied in the estimation are significant.

Table 5. Parameters estimation results

Variables	Parameters	Coefficients	Std errors
Constant	β_0	-2.152***	0.48
Household size	β_1	-0.027*	0.015
Gender	β_2	1.25***	0.401
Experience	β_3	-0.005	0.006
Relation with extension and research services	β_4	0.767**	0.316
Participation in fertilizer program	β_5	0.401	0.36
Farmer organization membership	β_6	0.999***	0.201
Perception of the cultural practices impact on the land regeneration	β_7	1.159***	0.224
Fertilizer dosing issues	β_8	0.304	0.209
Connection with Agri-inputs suppliers	β_9	0.33*	0.196
Literacy	β_{10}	-0.113	0.188
Cropping cereals	β_{11}	0.557**	0.219
Cropping vegetables	β_{12}	1.201***	0.287
LR chi2 (12)	**235.80**		
Prob> chi2	**0.0000**		
Pseudo R2	**0.2411**		
Number of observations	**734**		

Discussion

The specification error test results (table 6) show that the linear predicted value (_hat) and the linear predicted value squared (_hatsq) are respectively significant and non-significant. This means that our link function is correctly specified[2]. Results in table 7 display that there is no evidence of poor fit. As a result, the area under the ROC curve equals 0.8173, so our model has good predictive power. Thus, all the robustness tests conducted state that our model is correctly specified, and the variables involved can explain properly the rationale behind using fertilizer in Senegal.

Estimation results reveal that 8 of 12 of the variables engaged in the model are significant. Except household size, all the significant variables have positive influence on the farmer's decision to use fertilizer.

[2] For all the tests results, see annexes.

The finding related to the household size is in line with Akpan *et al.,* (2012). This could be because in developing countries, the costs of farm production usually increase with family expenditure and farm size implying that family labor is a complement to fertilizer. This is similar to what reported by Staal *et al.,* (2003), Chianu and Tsujii (2005) and Amanze *et al.,* (2010).

The variable gender is significant with positive influence. In other words, being a male increase the chance of using fertilizer. This could be explained by the fact that males are more representative in farmers' organization, have better access on agricultural inputs and technologies, etc. Wanyama *et al.,* (2009) obtain similar result among arable crop farmers.

Being in touch with extension services and belonging to a farmers' organization increase the opportunity of using fertilizer. This is understandable because, as expected, being strengthened by these organizations increases knowledge about the relevance of fertilizers on plants. Mostly these organizations provide fertilizers and other incentives to improve yield. In addition, farmers are mostly influenced by their community mindset. This finding converges to what has been stated in other agricultural adoption studies conducted by Diiro and Sam (2015) and Mmbando and Baiyegunhi (2016), institutional factors influence farmers decision to use fertilizer. Studies conducted by Simtowe *et al.,* (2016) concluded that social capital and network such as farmers' organization membership are very significant in explaining farmers' adoption of fertilizer. The membership of farmers' group disseminates information and knowledge on technologies to improve yield.

Being convinced that their agricultural practices contribute to the improvement of their land's fertility led farmers to use fertilizer. What was not expected. Maybe farmers understood that fertilizer should come as a support of these agricultural techniques to ensure the sustainability of their soil's fertility.

Having agri – inputs suppliers around encourages the use of fertilizers. Indeed, In West Africa, the fertilizer distribution network is dominated by wholesalers who rely on retailers to supply producers (CEDEAO, 2006). Unfortunately, this network is barely connected to rural areas and retailers are mostly established in towns. Mostly, farmers travel far distance to be able to purchase fertilizers. Additional transaction costs make the fertilizer more expensive as well. Thus, distance and higher price could serve as a deterrent to use fertilizer. So as found, producers located close to fertilizer selling points are more likely to use it.

The type of crop grown by famers determine fertilizer usage. From the study, farmers growing cereals and vegetables are more likely to use fertilizer. As already stated, being monitored by extension services, and belonging to farmers' organizations strengthen producers' agricultural competences. In practicing over several years, they know that these crops are fertilizer intensive.

Contrary to what many studies pointed out (see Hattam and Holloway, 2005); Akpan and Aya, 2009), this one found that experience and literacy were not significant in explaining farmer's decision to use fertilizer. Similarly, our results are in the same vein with Fufa and Hassan (2006), Zhou and al (2010) and Djokoto *et al.,* (2016). The latter reported that there is no correlation between farming experience and agricultural technology adoption, arguing that farmers with longer experience usually learn multiple ways of overcoming challenges, hence, may either stick to their old practices or try new techniques to improve their farming which leads to higher intensity of fertilizer adoption. According to Minot *et al.,* (2000), farmers know the importance of using fertilizer outside the formal education system and through oral channels rather than written media. Many farmers in West Africa do not have formal education but are able to use fertilizer effectively through some form of training by donors and farmer associations. Their conclusions are consistent with studies by Zhou *et al.,* (2010).

Conclusion and recommendations

Agriculture is a key sector in Senegalese economy with a contribution to the GDP estimated to 8%. Indeed, 60 to 70% to the active population rely directly or indirectly on agricultural activities. Around 74% of agricultural households are located in rural areas (ANSD, 2014). Despite the critical role that the agricultural sector plays in the country's economy, there are low yields due to low fertilizer usage. This article intended to analyze factors influencing famers to use fertilizers. Estimation results revealed that features like gender, relation with extension services, being member of farmers' organization, being linked to an agri – inputs suppliers' networks, etc. increase the chance of using fertilizer while having a big household size induces farmers not to use fertilizer. However, policymakers at the continental level acknowledged[3] that without a Green Revolution, alleviating poverty and food insecurity impeding Africa's economic growth and development will be unreachable. That is why it is sine qua non to increase the level of fertilizer use. In this line, our study brings some policy implications from the results obtained.

- Strengthening extension services capacities in terms of logistics and human resources to keep monitoring farmers and reinforcing their capacities in good agricultural practices.
- Sensitizing farmers to join farmers' organizations. This is part of the extension services assignments. An advantage of that is access to information will be facilitated for farmers and they could benefit from several trainings.
- Strengthening farmers' capacities in specific themes like good agricultural practices. The training sessions could focus on the importance of fertilizer in the crop development.
- Putting in place proximity selling points to facilitate fertilizer access for farmers living in isolated areas.

The objective of this analysis was to analyze factors that influence farmers in Senegal to use fertilizer. For further investigations, it would be interesting to estimate the level of adoption rate and intensity of fertilizer. Results of this expected study will help public authorities to meet the Abuja goal namely increasing the level of use of fertilizer to an average of at least 50 kilograms per hectare.

[3] Cf Declaration of Abuja in to 2006 in favor to an African Green Revolution

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Annexes

Table 6. Specification error test results

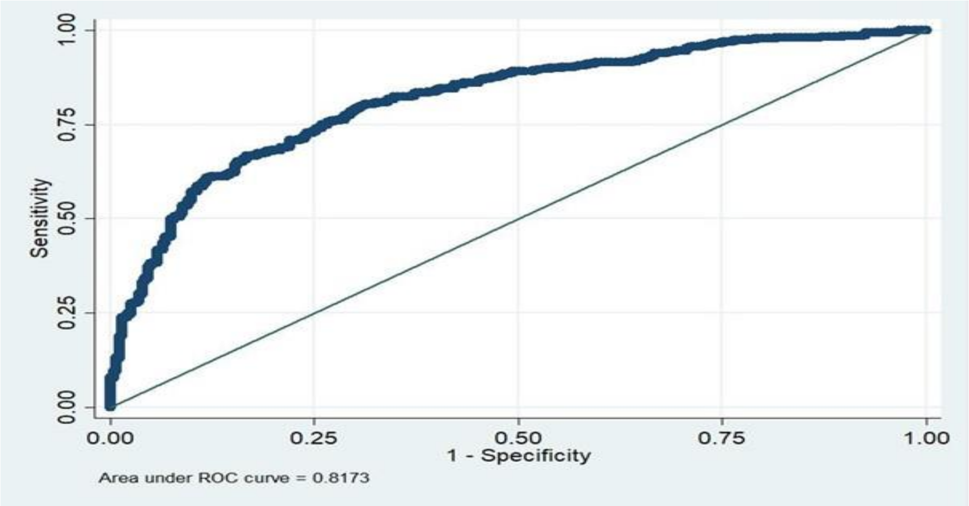
Variables	Coefficients	Std errors
Constant	-0.012	0.111
_hat	0.989***	0.098
_hatsq	0.011	0.057
LR chi2 (12)	**235.83**	
Prob> chi2	**0.0000**	
Pseudo R2	**0.2412**	
Number of observations	**734**	

Table 7. Hosmer-Lemeshow gof test results

Hosmer-Lemeshow chi2(8)	**8.74**
Prob> chi2	**0.3651**
number of groups	**10**
Number of observations	**734**

Table 8. List of variables

Notation	Nature	Criteria	Expected impact on the outcome/ rationale
Y	Qualitative	=1 if farmer uses fertilizer or 0 otherwise	
x_1	Quantitative		Positive/ Having an important labor force can help spreading fertilizer.
x_2	Qualitative	Male = 1 and Female = 0	Positive/ Men, according to their status (generally household head) have more access to inputs (land, credit, seeds, fertilizer, etc.)
x_3	Quantitative		Positive or Negative/ Over years, some farmers can find interest in using fertilizer; but other people, for environmental reasons could be pessimistic in the use of this product.
x_4	Qualitative	= 1 if has been coached and 0 = No	Positive/ Being strengthened by these services can increase knowledge about how important fertilizers on plants are.
x_5	Qualitative	= 1 if has participated and 0 = No otherwise	Positive/ Being involved in such programs can increase farmers knowledge about the relevance of fertilizing
x_6	Qualitative	= 1 if being member and 0 = No	Positive /Belonging to a Farmer organization can facilitate access to agricultural inputs and strengthen capacities on how to use fertilizer
x_7	Qualitative	= 1 if the farmer believes that his/her cultural practices contribute to the land regeneration and 0 = No	Negative/Farmers do not need to use fertilizer because they are convinced that agricultural practices applied can improve his soil fertility.
x_8	Qualitative	Having problem in dosing fertilizer (1 = Yes 0 = No)	No effect/ Farmers generally use fertilizer even though they do not know the dosing recommended by the Research
x_9	Qualitative	Knowing an Agri-inputs suppliers' network (1 = Yes 0 = No)	Positive/ Being connected with this network facilitate access on fertilizers
x_{10}	Qualitative	= 1 if having received any kind of education and 0 = No	Positive/ Education helps farmers to know how to use fertilizer appropriately; literate farmers are more opened about technologies adoption.
x_{11}	Qualitative	1 = Yes 0 = No	Positive or Negative/ depends on how the crop is considered: staple crop or cash crop.
x_{12}	Qualitative	1 = Yes 0 = No	Positive. Farmers know that these crops have important needs in fertilizers.



Graph 1. ROC curve