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Farmers' perception on the benefits and constraints of Farmer Managed Natural Regeneration and determinants of its adoption in the southern groundnut basin of Senegal

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Abstract Farmer Managed Natural Regeneration (FMNR) is a simple and inexpensive practice for restoring vegetation cover on degraded land, unlike reforestation. Current knowledge on the socioeconomic factors that may influence its adoption is limited. The objective of this study is to analyze the socioeconomic determinants of FMNR adoption by communities. 197 households were surveyed. The probit model was used to identify the socioeconomic determinants of adoption. The results show that ethnicity, access to external support, receptivity to technological innovations, mode of land acquisition and the importance of production are determining factors in the adoption of FMNR. According to farmers, FMNR contributes to improving soil fertility and soil moisture conservation (21% and 17% of farmers, respectively). According to them, the FMNR improves the supply of wood (18 %) and non-timber forest products (13 %). The main constraints to the scaling up of this practice are, respectively, illegal logging (42%), animal roaming (29%), and the difficulties of using animal traction in a farm having many trees/shrubs (12 %). These results provide an overview of the considerations to be integrated for the success of FMNR as a strategy to strengthen the resilience of communities and ecosystems to climate disturbances.

Keywords Agro-ecology · Agroforestry · Degraded land · Farmer's perception · FMNR · Senegal

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Introduction

Like most Sahelian countries, Senegal has been facing a decline in woody populations for several decades (Bakhoum 2012; Ndiaye et al. 2013). This degradation is partly due to natural factors, notably climatic deterioration, salinization and land acidification (MEDD 2014). It is mainly exacerbated by anthropogenic action through anarchic exploitation, bush fires and unsuitable land clearing/cultivation techniques (Faye et al. 2008; Bakhoum et al. 2012). This situation is more alarming in the agro-ecological zone of the groundnut basin where nearly 2.5 million hectares of land are degraded, i.e., 2/3 of the country's arable land (CSE 2007). In this area, the massive and continuous production of groundnuts, accompanied by a high population density, has disturbed the ecological

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balance. Agroforestry parks are threatened due to the ageing of trees (Sanogo et al. 2019). The lack of their regeneration can be attributed to environmental (climate change), human (grazing, fire and the elimination of spontaneous regenerated individuals from the park) and regulatory (forestry code) factors. This phenomenon is increasingly aggravated by the variability of rainfall (Ba and Reenberg 2003), thus calling for strategies for sustainable management of ecosystems including agroforestry parklands. The strategies to be deployed must be based on emerging context adapted to the vegetation cover rehabilitation approaches, among which (Farmer Managed Natural Regeneration, integrated management of inter-village silvopastoral areas, domestication of forest fruit trees, reforestation with best fit species). Of the listed practices, FMNR is based entirely on the preservation and maintenance of seedlings of native species that are already in place and therefore does not require any nursery or planting operations (Sanogo et al. 2019). Thus, FMNR appears as a cheap option for restoring the vegetation (Reij and Garrity 2016). In Senegal, the adoption of FMNR is very low compared to Niger where nearly five million hectares have been revegetated using this method (Reij et al. 2009). Nevertheless, actions have been initiated in some localities such as the Thiès region (Diallo 1992; Badji et al. 2015), Kaffrine (Bakhoum et al. 2012; Sanogo et al. 2017) and Fatick (Camara et al. 2017; Sanogo et al. 2019). Through some of these actions, the agro-ecological and socioeconomic impacts of FMNR have been documented (Bakhoum et al. 2012; Badji et al. 2015; Binam et al. 2015; Camara et al. 2017; Sanogo et al. 2019; Bayala et al. 2019). In turn, data about drivers of adoption are scanty (Sanou et al. 2017). Therefore, the present study aims to generate data on the socioeconomic determinants of adoption of FMNR by rural households. Specifically, the study sought to (i) determine producers' perceptions of the socioeconomic and environmental values arising from the practice of FMNR, and (ii) identify factors explaining FMNR adoption.

Materials and methods

Presentation of the study area

The study was conducted in the southern groundnut basin of Senegal in the rural municipality of Ndiognick, Kaffrine region located at 12°06' N latitude and 15°33' W longitude (Fig. 1). Composed of 55 villages, the rural municipality of Ndiognick has an average density of about 84 inhabitants per km^2. Based on data from the National Agency of Civil Aviation and Meteorology (ANACIM), the average annual rainfall in this region was 665.2 ± 169.4 mm for the period 1951–2017. With nearly 80 % of arable land, the rural municipality of Ndiognick has two types of soils that are tropical ferruginous soils with little or no leaching alfisol/dior soils (30 %) and tropical red ferruginous soils or lithosol/deck-dior (70 %).

Sampling methods

In this study, a two-degree stratified random survey was used. Ten (10) of the 55 villages in the municipality were selected. The choice of villages to be investigated was based on objective criteria such as the level of adoption of FMNR, intervention of FMNR extension projects and engagement of populations. The second degree sampling aimed at retaining 5 % of the total number of households in the villages retained in the municipality. On the basis of this sampling and data on farm households collected from agricultural extension services, 197 farmers were randomly selected. Table 1 shows the number of respondents per village.

Method of data collection

Socioeconomic surveys, including semi-directive interviews with heads of households, were favored.

These surveys collected information on socioeconomic characteristics of households, farmer's perception of FMNR, and the socioeconomic and environmental values that might arise from FMNR practice.

Respondents' profile

The survey covered (197) household heads with 95 % of men. The respondents were mainly polygamists with 52 % of adopters and 77% of non-adopters. The few household female (5 %) surveyed were widows adopters and non-adopters included. Wolof was the

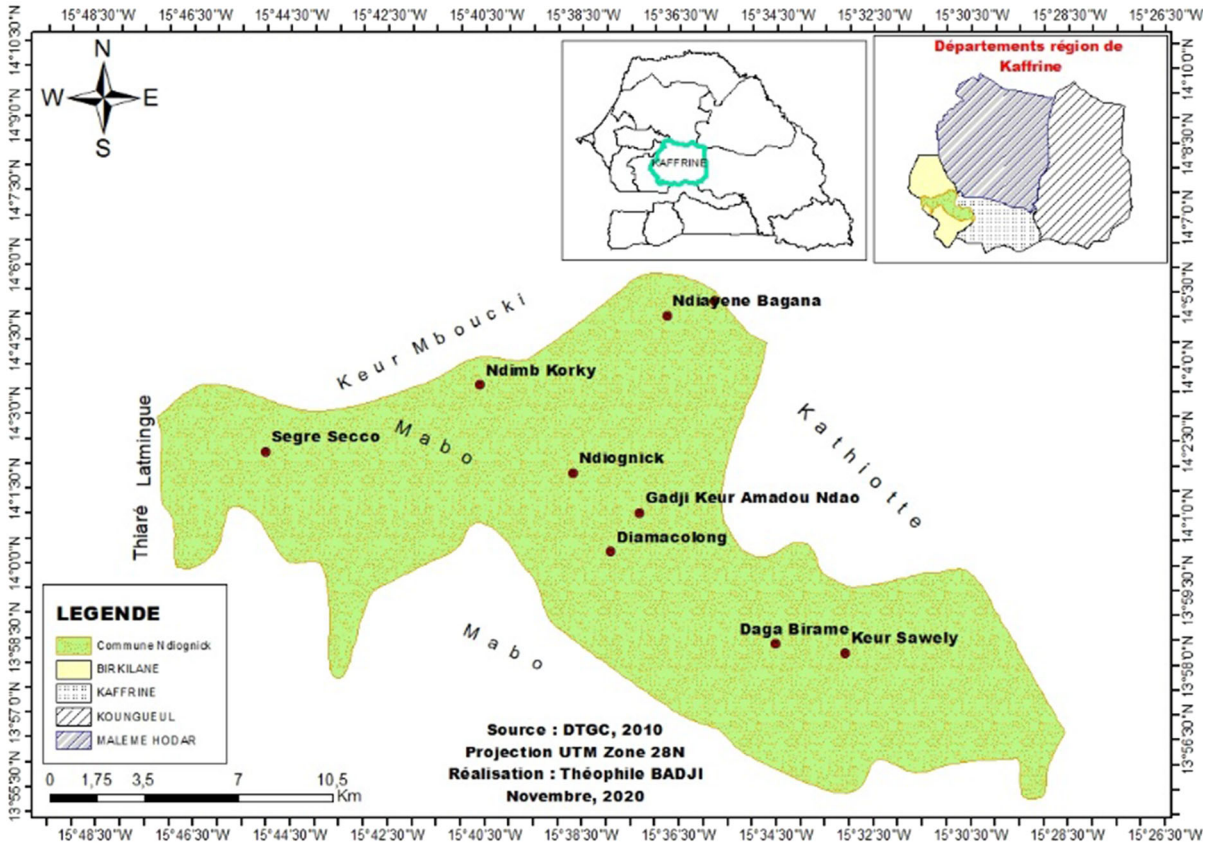

Fig. 1 Map of the rural municipality of Ndiognick in the Groundnut Basin in Senegal

Table 1 Number of respondents for the adoption of Farmer Managed Natural Regeneration by village in the rural municipality of Ndiognick in the Groundnut Basin in Senegal *Source*: Established by the authors

Villages	Household sample
Daga Birame	24
Grodji Amath Ndao	24
Keur Babou	13
Keur Sawelly	23
Ndiamacolang	24
Ndiayène Bagana	11
Ndimbou Korki	24
Ndiognick	26
Ségéré Bambara	20
Ségéré Secco	8
Total	197

dominant ethnic group in the area, with 67 % of adopting and 95 % of non-adopting households. The population was mainly in the informal education (Coranic and literacy) with 84 % of adopting compared to 91 % of non-adopting households. The low respondents in the formal education were relatively higher in adopters (9.8 %) than non-adopters of households (6.2 %). For the illiterates, the adopters were 4.1 times higher than the non-adopters.

Probit model specification

The probit model was used to analyze the socioeconomic determinants of FMNR adoption in the rural municipality of Ndiognick. Probit or logit model is generally used when the variable to be explained Y_i is binary (has two modalities). In practice, the probit and logit models are very similar in terms of statistical fit. Differences are noted only in the case of very large samples, because the behavior of the two probability laws differs only at the extremes. In this work, the aim was to estimate the decision to adopt or not to adopt

FMNR in Ndiognick. The probit model is specified as follows :

$$Y_i^* = \theta_0 + \theta_1 X_{1i} + \theta_1 X_{2i} \ldots + \theta_K X_{Ki} + \epsilon_i = X_i\theta + \epsilon_i(1)$$

$Y_{i\,i}^*$, the variable to be explained;

the vector $X_i = (X_{1i}, X_{2i}, ..., X_{Ki})$correspondstoth eobservablescharacteristicsoftheindividu*i*;

the vector $\theta = (\theta_{0,}\theta_1, ...\theta_K)$represents the coefficients of each of these characteristics;

ϵ_i, the error terms. It follows a normal law: $\varepsilon_i \sim N(0,1)$.

Let now be the binary variableY_i, *such that* $Y_i = 1$ *when individual i adopts FMNR, and* $Y_i = 0$ *when individual i does not adopt FMNR. Assuming that* $Y_i^* \geq 0$ when $Y_i = 1$ *and* $Y_i^* < 0$ *when* $Y_i = 0$, *the Probit model suggests that* :

$$\Pr(Y_i = 1|X_i) = \Pr\left(Y_i^* \geq 0|X_i\right) = \Pr(X_i\theta + \epsilon_i \geq 0) = \Pr(\epsilon_i \geq -X_i\theta) = \Pr(\epsilon_i \leq X_i\theta)$$

Explaining the values of Ythrough X is equivalent to estimating the probability that $Y_i = 1$ knowing X_i or $Y_i = 0$knowingX_i, which would be the same.

The explanatory variables used are shown in Table 2. The variable to be explained is the probability of adopting.

FMNR. This dichotomous qualitative variable takes the value 1 if the producer has adopted FMNR and 0 otherwise. For estimation requirements, some of the qualitative variables were transformed (Table 3). This transformation concerns four (4) explanatory variables: matrimonial status, ethnicity, level of education and mode of land acquisition. Thus, we have retained (i) the "married" modality which represents 96 % of the matrimonial status variable of the sample; the "Wolof" modality which represents 76 % of the ethnic groups of the sample; the " alphabetized" modality which groups together farmers who are schooled or alphabetized in Arabic or French, which represents a proportion of 95 % in the sample; the " heritage" modality which represents 83 % of the modes of acquisition of cultivated land. The transformations thus carried out made it possible to dichotomize the multinomial variables.

For these categorical variables, the aggregation of modalities was done according to the rule of Fotheringham and Wong (1991). This theory shows that when small units are aggregated to form large units, the correlations between the variables of the merged units are often higher than those of the disaggregated level. In this study, the significance tests done with the basic modalities of FMNR adoption were not significant, so we used the transformation model of Fothering and Wong (1991).

Data analysis

This work is based on the one hand on a descriptive analysis method of qualitative and quantitative variables to characterize the peasant's perception of the FMNR. On the other hand, it is based on an econometric analysis method of qualitative variable to analyze the probability of adopting this agroforestry technology. For the analysis of determinants of FMNR adoption, STATA software was used. Beforehand, a univariate analysis using the t test identified the variables associated with the adoption of FMNR with a probability less than or equal to 10 %.

Results

Farmers' perception on the density of FMNR and conserved species

Figure 2a shows that the majority of adopters (61 %) keep less than 20 shrubs ha^{-1}. Nevertheless, some farmers (21 %) keep between 30 and 40 shrubs ha^{-1}. Figure 2b shows that the woody species frequently conserved as FMNR in the fields are *Piliostigma reticulatum* (26.6 % of adopters), *Combretum glutinosum* (18.8 % of adopters), *Guiera senegalensis* (17.3 % of adopters), *Ziziphus mauritiana* (13.5 % of adopters) and *Faidherbia albida* (8.2 % adopters). *Piliostigma reticulatum* has the highest citation frequencies due to its ability to provide fodder (40.8 %), service and fuel wood (36.0 and 33.6 %), rapid growth (32.2 %) and fertilization potential (27.8 %). According to 50 % of farmers, *Ziziphus mauritiana* is the most widely used species in FMNR for human consumption. These two species (*Piliostigma reticulatum* and *Ziziphus mauritiana*) contribute to improving incomes according to 33.3 % and 37 % of farmers, respectively.

Table 2 Definition of the variables used in the probit model for the adoption of Farmer Managed Natural Regeneration in the rural municipality of Ndiognick in the Groundnut Basin in Senegal

Variables	Description	Measure	Justification	Expected effect
Age	Age of farmer or head of household	integer	It is supposed that an experienced household head is more conscious of climate and environmental issues (Diaby et al., 2020).	+
STATMAT	Matrimonial status of the farmer or head of household	Dummy 1 married (monogamous / polygamous); 0 others	Married people seek to maximize profit because of their level of responsibility. To this end, they are open to adopting new technologies that can improve their productivity. On the other hand, they are more exposed to risk because of their responsibilities; the result of failure would be worse than for single people (Diouf et al., 2019)	+/-
ETHN	Ethnicity of the farmer or head of household	Dummy 1 Wolof; 0 others	Ethnicity can influence access new technologies negatively or positively (Diouf et al., 2019)	+/-
SCOL	Level of education of the farmer	Dummy 1 literate, 0 nonliterate	Education promotes the creation of a mental attitude for the acceptance of new practices related to "intensive information" and "intensive management" (Caswell et al., 2001).	+
TOTALW	Number of active persons	Continuous	It is presumed that the number of agricultural labors is an important variable affecting the adoption of new technologies (Diaby et al., 2020).	+
SUPCHP	Farm area	Continuous	Farmers seek to maximize their profit, regardless of the size of the farm they are growing. We expect them to look for all relevant practices to improve their production (Diouf et al., 2019).	+
MODEACQUISTER	Mode of land acquisition	Dummy 1 "heritage" 0 "non heritage	Successional ownership of plots is a factor that influences the farmer's choice or decision-making on the farm's production system (Diaby et al., 2020).	+
SEMCERTIFIE	Access to certified seeds	Dummy 1 "certifies" 0 "Other	It is assumed that the use of certified seed in crop plots is one of the determining factors in agricultural productivity and therefore may increase the likelihood of adopting FMNR.	+
NBGROSRUM	Number of big ruminants	Continuous	Animal parking in farms and bare plots encourages the development of FMNR, and in return FMNR helps to satisfy the animals' forage needs. (Diaby et al., 2020).	+
NBREQUIPAGRI	Number of agricultural equipments	Continuous	It is presumed that the number of agricultural equipment is an important variable affecting the adoption of new technologies.	+/-
ASSOCULTURALE	Practice of crop association	Dummy 1 "association" 0 "pas d'association	Crop association is presumed to be one of the determining factors in agricultural productivity and therefore may increase the probability of FMNR adoption.	+

Table 2 continued

Variables	Description	Measure	Justification	Expected effect
ACA	Access to agricultural credits	Dummy 1 "access" 0 "no access	Access to credit is a factor that strengthens farmers' capacity to produce (Diaby et al., 2020).	+
AACST	Access to support and advice from technical services	Dummy 1 "access" 0 "no access	Collaboration with agricultural development partners affects the probability of adopting FMNR (Diaby et al., 2020).	+
STATRES	status of the head of household	Dummy 1 "Indigenous" 2 "Migrant"	Residents are less open to innovations and this variable should therefore have a negative effect on access to new technologies (Diouf et al., 2019).	-

Table 3 Explanatory table of the logic behind the aggregation of some variables in the probit model for the adoption of Farmer Managed Natural Regeneration in the rural municipality of Ndiognick in the Groundnut Basin in Senegal

Name of variable	Basic modalities		New modalities	
	Proportion (%)		Proportion (%)	
Matrimonial status	1 = Monogamous married	36.55	1 = Married (monogamous married or Polygamous married)	96.45
	2 = Polygamous married	59.90	0 = Not married (Divorced or Widowed)	3.55
	3 = Divorced	1.52		
	4 = Widowed	2.03		
	5 = Single	0.00		
Ethnicity	1 = Wolof	76.65	1 = Wolof	76.65
	2 = Serer	1.52	0 = Other (Serer or Peulh or Mandigo)	23.35
	3 = Peulh	6.60		
	4 = Mandingo	15.23		
	5 = Other	0.00		
Education	1 = No education	4.08	1 = Literate (Literate or Primary or Coranic or Secondary or Higher education)	95.94
	2 = literate	0.51	0 = No education	4.06
	3 = Primary	5.10		
	4 = Coranic	86.73		
	5 = Secondary	3.06		
	6 = Higher	0.51		
Mode of land acquisition	1 = Heritage	89.13	1 = Heritage	83.25
	2 = Gift	3.26	0 = Other (Gift or Loan or Pledge or Lease)	13.75
	3 = Purchase	0.00		
	4 = Loan	3.26		
	5 = Pledge	1.09		
	6 = Lease	3.26		
	7 = Sharecropping	0.00		
	8 = Other	0.00		

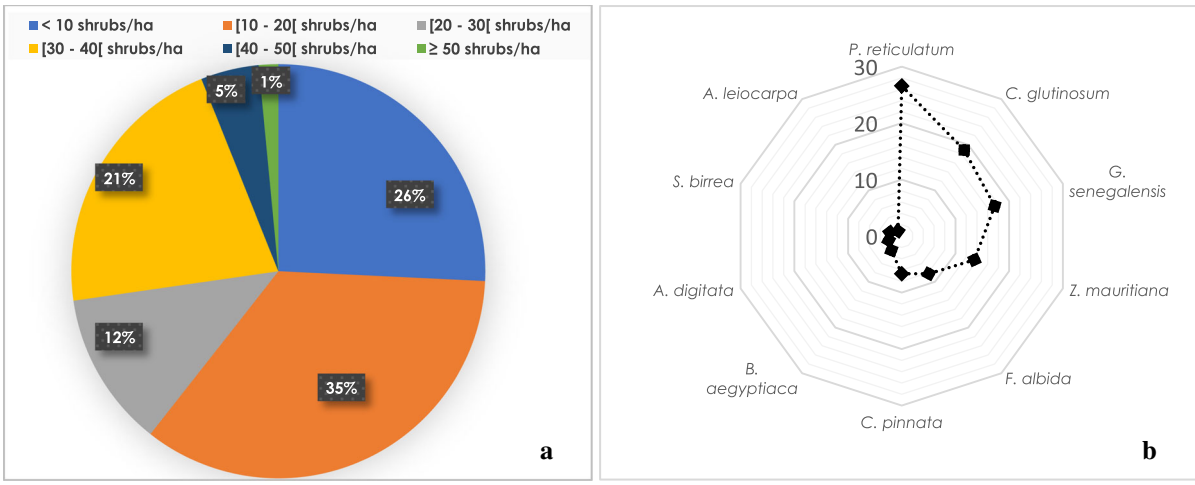

Fig. 2 Density of FMNR in farms **a** and conserved species **b** of Farmer Managed Natural Regeneration in the rural municipality of Ndiognick in the Groundnut Basin in Senegal

Duration and motivation of FMNR practice

The results show that the majority of farmers (87 %) started FMNR during the last fifteen (15) years (Fig. 3a). A significant proportion of new adopters (23 %) are noted in the last five (05) years (2013–2018). The intervention of projects to promote FMNR was the reason for its adoption among 41 % of farmers and for personal initiative among 24 % of farmers (Fig. 3b).

Advantages and constraints of FMNR

The results show that the practice of FMNR has a number of advantages (Fig. 4a) and constraints (Fig. 4b). Among others, it contributes to soil fertility improvement (21 % of respondents), wood supply (18 % of respondents), soil moisture conservation (17 % of respondents), NTFP supply (14 % of respondents), diversification of plant and animal species (10 % of respondents), fodder supply (9 % of respondents) and re-greening of the land (9 % of respondents). However, farmers noted a number of constraints related to the practice of FMNR. These are

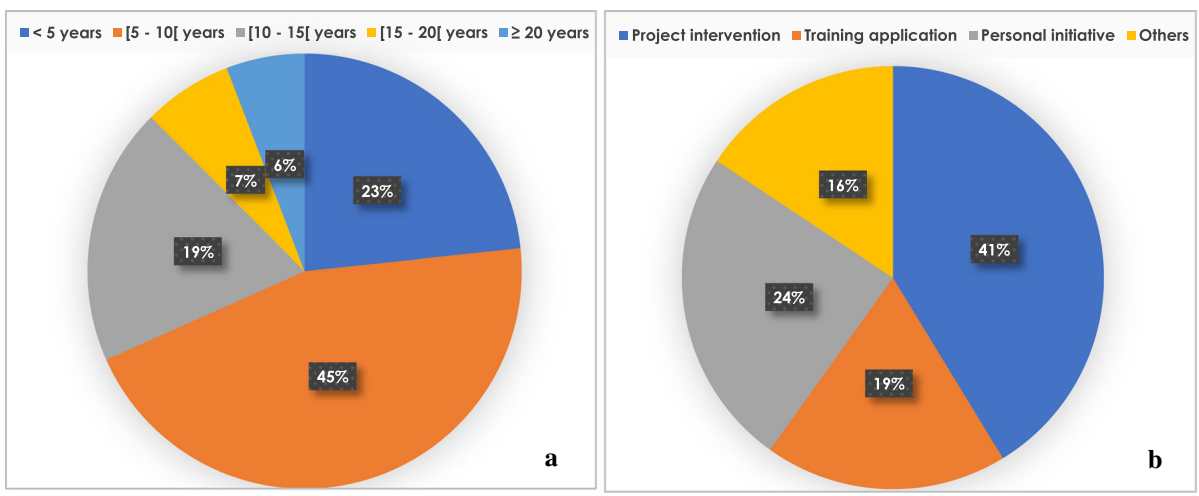

Fig. 3 Duration **a** and origins of practice **b** of Farmer Managed Natural Regeneration in the rural municipality of Ndiognick in the Groundnut Basin of Senegal

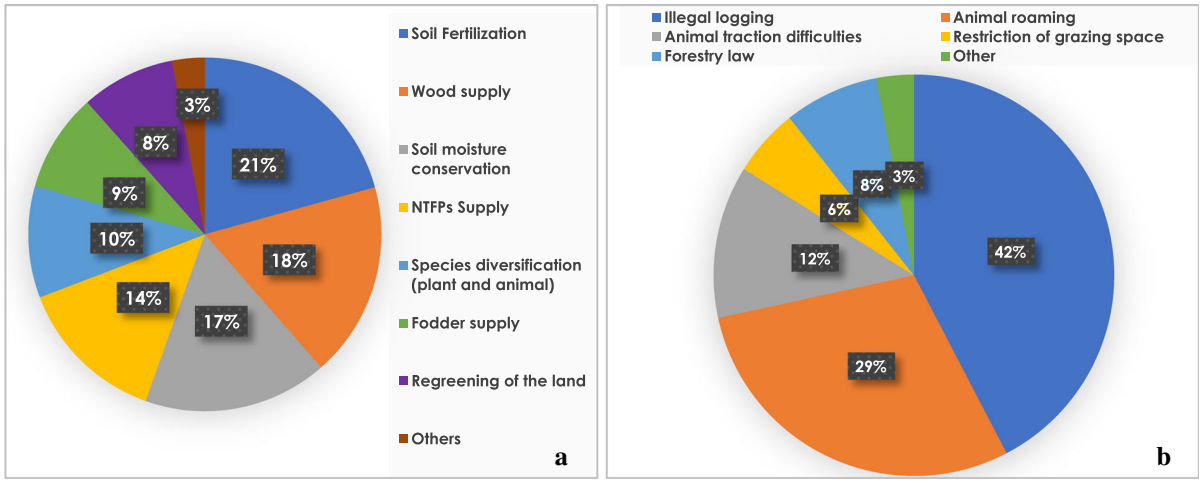

Fig. 4 Advantage **a** and constraint **b** of Farmer Managed Natural Regeneration according to the farmers' perception of the rural municipality of Ndiognick in the groundnut basin in Senegal

mainly illegal logging (42 % of respondents) with 44 % of adopters and 36 % of non-adopters, animal roaming (29 % of respondents) with 30 % of adopters and 23 % of non-adopters, and difficulties of using animal traction in a farm which have many trees/shrubs (12 % of respondents) with 11 % of adopters and 21 % of non-adopters. According to 11 % of non-adopters, FMNR leads to a reduction in grazing space compared to 5 % of adopters.

Discriminatory socioeconomic factors in FMNR adoption

The adoption rate observed in the sample is 67.01 % (Table 4). Difference tests on socioeconomic variables show discriminating effects between FMNR adopters and non-adopters. The average age of the adopters is 50 years compared to 52 years for the non-adopters. Wolof represent 67 % of the adopters against 95 % of the non-adopters. Adopters of FMNR have an average of 08 ha of cultivable land compared to 06 ha for non-adopters. The most common method of acquiring land is heritage among both adopters (87 %) and non-adopters (75 %). The practice of crop association and the use of certified seeds are noted, respectively, by 80 % and 46 % of adopters against 66 % and 29 % of non-adopters. In addition, adopters have more agricultural equipment and big ruminants compared to non-adopters. The results also show that 45 % of the adopters have access to agricultural credits and 25 % have access to support and advice from technical services compared to 25 % and 15 % of non-adopters, respectively.

Econometric estimations of the determinants of FMNR adoption

The results of the validity tests in Table 5 show that the probit model, used in this work, is globally significant (probability of LR chi2 = 0). Similarly, the probability associated with the Hosmer–Lemeshow test (0.64) is greater than 10 %, which indicates the good quality of the probit model's adjustments. Moreover, the percentage of correct predictions with the probit model is equal to 75.13 % (good ranking). Furthermore, coefficient estimates show that the variables age, matrimonial status, alphabetization and access to technical services are not significant. On the other hand, ethnicity and the number of agricultural equipment owned reduce the probability of adopting FMNR. However, labor force employed, farm area, heritage of farm, use of certified seed, number of livestock owned, practice of crop association and access to agricultural credit increase the propensity to adopt FMNR.

Discussion

The present study showed that farmers have a positive perception of FMNR practice. It provides them goods

Table 4 Descriptive statistics of the variables used in the model for the adoption of Farmer Managed Natural Regeneration in the rural municipality of Ndiognick in the Groundnut Basin in Senegal *Source*: Survey results, 2018

Variables	Sample		Group		
	Average	Standard deviation	FMNR Adopters	Non Adopters	Differential test
Variables to explain					
FMNR Adopters			67,01	32,99	
Explanatory variables					
Age	50.51	11,38	49,57	52,43	− 2,85*
Matrimonial status	0,96	0,01	0,96	0,96	0,00
Wolof	0,76	0,03	0,67	0,95	− 0,28***
Alphabetized	0,95	0,01	0,95	0,98	-0,03
Labor force	9,36	0,32	9,41	9,26	0,15
Farm area	7,38	0,31	7,99	6,14	1,85***
Heritage	0,83	0,03	0,87	0,75	0,12**
Certified seed	0,41	0,03	0,46	0,29	0,17**
Number of big ruminants	4,48	4,43	5,13	3,17	1,96**
Number of farm equipment	37,04	0,78	38,56	33,94	4,62***
Crop association	0,76	0,03	0,80	0,66	0,14**
Agricultural credit	0,38	0,03	0,45	0,25	0,20***
Technical Services	0,24	0,03	0,28	0,15	0,12

Statistics are obtained at the farm level. Stars denote conventional significance levels from tests of comparison of means. Significance of 1% is represented by ***, 5% by ** and 10% by *.

and services including supply services (wood, NTFP and fodder supply), regulation services (soil fertilization and soil moisture conservation) and support services (diversification of animal and plant species, regreening of the land). FMNR has enormous importance in the livelihoods of the rural people especially in providing fuel wood, food/fruits, construction materials and farm equipment (Kibru et al. 2020). However, the density of FMNR is still low in farmers' fields. The issue of FMNR density in the Sahel has been addressed by some authors. Sanogo et al. (2019) showed that the density of FMNR in the fields of adopters should be between 35 and 65 trees. ha^{-1}. The study conducted by Binam et al. (2015) in Burkina Faso, Mali, Niger and Senegal showed that an active adopter of FMNR has at least a density of 70 trees. ha^{-1} of different sizes and equitably distributed in the farms. This can be explained by the farmers' perception that the practice of FMNR is subject to a certain number of constraints, including illegal cutting, animal browsing, difficulties in using animal traction in a farm with many trees/shrubs and the forestry code. Sanogo et al. (2019) identified illegal cutting of trees by transhumant for fodder or by local people for fuel and service wood and animal browsing as the main constraints to the dissemination of FMNR. Illegal cutting is an important degradation factor that threatens the regeneration of species of high economic value (Larwanou et al. 2010; Larwanou and Saadou 2012). Difficulties in using animal traction in a farm with many trees/shrubs has been cited by Camara et al. (2017) as a major constraint to the adoption of FMNR. According to Kibru et al. (2020), the major problems mentioned by FMNR's adoptant in Tigray, Ethiopia include shading effect of the trees on crops, birds, competition for space, and water and nutrient competition.

The low density of FMNR can also be explained on the one hand by the poor seedling establishment in the farms and on the other hand by the method of shrub management applied in the fields by farmers in the groundnut basin. The latter consists of cutting the shrubs present in the farms during clearing at the end of the dry season (May - June) and burning some or all of the biomass. Studies have shown that in kaffrine region, the overall average tree density is low

Table 5 Results of probit model estimates of the probability of adoption of assisted natural regeneration in the rural municipality of Ndiognick in the Groundnut Basin in Senegal *Source*: Survey results, 2018.

Variables	Coefficient *(Standard deviation)*	Marginal effects (dy/dx) *(Standard deviation)*
Age	− 0,005	− 0,002
	(0,10)	*(0,00)*
Marital Status	− 0,533	− 0,144
	(0,60)	*(0,13)*
Wolof	− 1,069***	− 0,278***
	(0,36)	*(0,07)*
Alphabetized	− 0,394	− 0,113
	(0,84)	*(0,20)*
Labor force	0,101*	0,033*
	(0,05)	*(0,02)*
Farm Area	0,151**	0,050**
	(0,06)	*(0,20)*
Heritage	0,525*	0,186*
	(0,28)	*(0,11)*
Certified seed	0,447**	0,146**
	(0,22)	*(0,07)*
Livestock owned	0,132**	0,043**
	(0,06)	*(0,02)*
Number of farm equipment	− 0,087*	− 0,028*
	(0,05)	*(0,01)*
Crop association	0,544**	0,191**
	(0,25)	*(0,09)*
Agricultural credit	0,669***	0,201***
	(0,23)	*(0,07)*
Technical Services	0,326***	0,101
	(0,29)	*(0,08)*
Constant	1,828	
	(1,31)	
N	197	
Pseudo R^2	0,2116	
LR chi2 (13)	52,86***	

The variable explained is the propensity to adopt FMNR (dummy variable). Values in parentheses (italic) represent standard deviations. Significance of 1% is represented by ***, 5% by ** and 10% by *

(Bakhoum et al. 2013; Sanogo et al. 2019). According to Lohbeck et al. (2020), intensity of land use (grazing and agricultural practices) and dispersal limitation (seed source availability) were the most important factor influencing regeneration.

The dominant species in FMNR in the study area are *P. reticulatum*, *C. glutinosum*, *G. senegalensis*, *Z. mauritiana* and *F. albida*. The regenerative potential of these species can be explained by their adaptation to the climatic conditions and the shrub management method applied in the fields by the farmers (Bakhoum et al. 2012; Seghieri et al. 2005). The majority of the species are conserved because of their rapid growth, their fertilizing role and their contribution to the supply of wood for service, firewood and fodder (Binam et al. 2015; Bayala et al. 2019). Only a few species contribute to human food and income generation. These results show the interest of enriching the FMNR with improved forest fruit trees in order to create value chains from the production.

In the southern groundnut basin of Senegal, the probability of adopting FMNR decreases with membership of the 'Wolof' ethnic group. This result could be explained by the way in which the park is managed

by farmers of this ethnic group, who have an extensive farming system. Indeed, the Wolof have a strong propensity to clear new areas and overexploit resources, unlike the other ethnic groups in the area (Bambara, Serer and Peulh) who seem.

more concerned about maintaining soil fertility through intensive land development systems. Indeed, Sall (2015).

noted that the Wolof, politically highly structured and socially hierarchical, do not have a great agrarian tradition, unlike the Sereres, who have the characteristic of being a true peasant society using highly sophisticated agricultural techniques. Sidibé (2003) described the 'Wolof' ethnic group as obstinate land clearers, resistant to intensive systems and without 'environmental awareness.' According to this author, the 'Wolof' farmers focus on the extension of land areas with the logic of increasing yields with less investment. Sidibé (2005) reported that Wolof farmers have played a leading role in the expansion of groundnut cultivation, which is at the heart of the degradation of parks and land in the groundnut basin of Senegal. Through intergenerational transmission, this practice continues to be perpetuated by 'Wolof' farmers, as shown by the replication of groundnut basin cropping systems in the Pata zone of the Casamance Natural Region of Senegal (Sidibé 2002; Touré et al. 2019).

Land tenure influences the probability of adoption of FMNR in the southern groundnut basin of Senegal. In fact, the acquisition of farms by heritage favors the adoption of FMNR because it confers a right of ownership that allows the land to be valorized without the risk of being disappropriated (reassign), in contrast to borrowing, renting, pledging and sharecropping. These findings corroborate those of previous studies who have shown that land ownership rights promote the adoption of agroforestry practices (Sanogo et al. 2004; Lawin and Tamini 2018; Akrofi-Atitianti et al. 2018).

This finding is further supported by the fact that in the study area, the probability of adopting FMNR increases when the farmer uses one (01) additional hectare of land. This is justified by the fact that in Senegal, with the law on the national domain, the valorization of the land through the plantation/preservation and maintenance of trees makes it possible to secure the land in order to appropriate it sustainably. According to Sanogo et al. (2004), one of the reasons for the adoption of agroforestry by farmers in the groundnut basin of Senegal is the fact that it provides a way of access to land ownership.

It was also shown that in the study area, the use of good farming practices (certified seeds and crop associations) promotes the adoption of FMNR. This can be explained by the fact that generally the users of good farming practices are innovators who have access to external support in terms of technical capacity building. These 'leaders' are always sought after by external stakeholders, so they are always in contact with innovations. According to Akrofi-Atitianti et al. (2018), producers' access to extension services has a significant positive effect on the adoption of innovative practices. Also, Levasseur et al. (2009) showed in their study that access to information is often a determining factor in the use of a new technique.

The results also showed that the probability of adopting FMNR increases with producers' access to agricultural credit. Since FMNR is an investment whose benefits (wood, fruit, and soil fertilization) are perceptible in the medium and long term, having a source of finance can be a motivation for adoption. Studies have shown that access to credit is a key factor in the adoption of new agricultural technologies (Jara-Rojas et al. 2010; Sale et al. 2014; Binam et al. 2017; Fabrice and Yann 2018; Mwungu et al. 2018). According to Louppe and Yossi (2000), the technologies proposed by research and development are only adopted if the farmers have the necessary resources or are economically interested in them. An analysis of previous work by Sanogo (2014) on the adoption of agroforestry technologies has shown that economic, organizational, policy and institutional factors limit technology adoption more than technical factors.

Conclusions

In the drylands of the Sahel, land degradation is one of the greatest threats to the traditional livelihoods of millions of people. In this area, drought, food insecurity and the loss of productive and fertile land threaten the livelihoods of farming and pastoralist communities. FMNR is one of the endogenous strategies used by communities to address these constraints. The results show that ethnicity, access to external support, receptivity to technological innovations, mode of

acquisition and area of cultivated land and the importance of production are determining factors in the adoption of FMNR. FMNR has a positive impact on ecosystem services. It faces constraints such as illegal logging, animal roaming, difficulties in using animal traction, and the forestry code. The density of shrubs conserved in FMNR by the majority of adopters remains low compared to existing literature. It could be further improved but this should follow investigation on the optimal density of shrubs to be conserved in a tree-crop system. Regreening programs in the Groundnut Basin should place particular emphasis on sensitization and capacity building of communities, especially the Wolof ethnic group, on the ecosystem services resulting from the conservation of trees in the fields through FMNR. In order to minimize the impact of animal roaming on FMNR, there is also an urgent need to develop local strategies for sustainable management of grazing land that bring together pastoralists and farmers.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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