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Original Research Article

Factors determining adoption of smallholding rubber agroforestry Systems (RAFS) in Nigeria

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Abstract

This study investigated the factors determining adoption of rubber agroforestry decisions in Nigeria. Primary data on farming practices were collected from 200 samples of rubber smallholder farmers through a structured questionnaire. The data collected were analysed using descriptive statistical procedures and the logistic econometric model. The results indicated that farmers' participation in on-farm trial demonstrations, accessing agricultural knowledge through trainings, extension contact, education level, membership of farm organisation and attitude of farmers towards intercropping were positively associated with increased adoption of rubber agroforestry in Nigeria. Contacts with extension agents were significant at 1% whereas other variables that were positively associated with rubber agroforestry systems were significant at 5%. Adoption decision was based on the fact that rubber agroforestry would not only meet their food needs but also increase the household income. Variables such as off-farm income, average distance from rubber land to farmers' residence, negatively influenced adoption of rubber agroforestry at 1% and 10% level, respectively. Social participation, household size, farming experience in growing rubber and other crops, did not significantly influence adoption. Based on these observations, policy inputs are provided.

Keywords: Adopters; questionnaire study; intercropping; logit model; rubber agroforestry system (RAFS)

INTRODUCTION

Rubber (*Hevea brasiliensis* Muell Arg.) is produced on 150,000 ha within the rainforest agro-ecological zone of Nigeria in Abia, Anambra, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ekiti, Oyo, Ondo, Ogun, Imo, Enugu, and Ebonyi states. It is also grown in marginal area of Kaduna, Benue and Taraba states (Aigbodion 2019). The improvement of productivity of rubber farming system is crucially important, especially for smallholding rubber farms in Nigeria since more than 70 percent of the world's natural rubber production comes from smallholding sectors. The challenge rubber farmers face is that a rubber tree has a long gestation period of about 5 to 7 years, a period during which the rubber plantation cannot be tapped for latex and hence no income is accrued from the huge capital investment and maintenance of the plantation. This situation has remained a disincentive to rubber farmers and has made rubber enterprise unattractive, especially to small-scale farmers in Nigeria.

One possible approach that may assist smallholder rubber farmers is to adopt Rubber Agroforestry Systems (RAFS) that create a source of income capable of back rolling the cost of plantation maintenance, take care of his family food needs and other personal expenses. Hence, a timely adoption of appropriate plantation management practices that is capable of utilising the under-utilised land resources and increases the revenue base of the enterprises is important to the attainment of the drive to increase rubber production in Nigeria. Some of the crops that are environmentally compatible with rubber without negative effects to either crop include pineapple, maize, vegetables, plantain, cocoyam, pepper, melon, and yam among others (Mesike et al. 2009). The intercropping can be done with mature/immature rubber plantations depending on the type of crop to intercrop with the rubber plants.

Hence, to revamp the production of rubber in Nigeria, RAFS was designed, for the deliberate integration of high value trees, arable crops and animals into rubber plantations. Thus, RAFS makes maximum use of resources, serves as a source of revenue for farmers especially during the gestation period of rubber and provides a buffer against rubber price instability in the international market (Okwu-Abolo et al. 2020).

Numerous benefits accrue to farmers and the natural environment from RAFS. Some of these benefits include: the rubber trees can be tapped for their latex one year earlier than usual; reduce runoff and soil erosion; increase soil moisture, organic matter and micro-organisms; root systems of both plants are enhanced in size and spread; increase in farmers income, and minimise crop failure and environmental shocks (Esekhade et al. 2014; Okwu-Abolo et al. 2020). The potential adoption of rubber intercropping system serves as a means to improve food security, farmer's income and livelihood (Tetteh et al. 2019). However, in spite of the enormous benefits of RAFS, many rubber smallholders have not adopted the technology (Esekhade et al. 2014).

Farmers' decision to adopt or not to adopt a technology is assumed to be the outcome of a complex set of factors related to the farmers' objectives and constraints (Bonabona-Wabbi, 2002). In other words, there are certain factors – including market forces, social, institutional, and management factors that affect the likelihood that farmers adopt a technology. Thus, if each farmer and each technology can be classified based on a core set of variables, then it is possible that the probability of a farmer adopting that technology could be estimated. Arisara et al. (2018) reported that RAFS is an alternative form of agriculture to compliment biological integrity, crop diversity and financial stability. RAFS produce and make available not only additional products for the farmers but also essentially have functions such as biodiversity conservation, soil conservation, watershed protection, and carbon sequestration. Shi et al. (2017) concluded that factors determining adoption of intercropping among rubber smallholder farmers in Xishuangbanna, China include ethnicity, household wealth, family labour, nature of rubber plots, age of rubber trees and geographic condition.

The National Agricultural Research Institutes (NARIs) of Nigeria are generally responsible for generating and developing innovations for increasing agricultural productivity. However, there are numerous examples of promising innovations that have not been taken up by farmers. Obviously the question arises, why are some of these technologies not widely adopted by farmers? Is it the lack of compatibility of new technologies with the existing farming systems and/or are there other socio-economic factors that inhibit and constrain their adoption? This present study attempts to answer such questions with regard to establishing the factors that affect adoption of RAFS in Nigeria.

By pointing out these factors that influence RAFS technology adoption, this study will provide guidance to the RAFS researchers for enhancing the program's effectiveness and also to make more informed decisions on how to promote RAFS adoption.

The following hypotheses were tested:

i) Farmers' educational level, contacts with extension agents and trainings positively influence adoption of RAFS
ii) Farmers' membership of farm organization and participation in on-farm trial demonstration influence adoption of RAFS
iii) Adoption is negatively influenced by off-farm income and average distance from rubber land to farmers' residence.

MATERIALS AND METHODS

Study area and data

The population of the study comprised rubber farmers registered with National Rubber Producers, Processors and Marketing Association of Nigeria (NARPPMAN). A multi-stage random sampling technique was adopted for the selection of 200 rubber smallholders on whom well-structured personal interview schedules were administered. In the first stage, four major rubber growing states in Nigeria namely Edo, Delta, Ogun and Akwa Ibom states were purposively selected based on their scale of rubber production. The second stage involved a purposive selection of two communities from each state. The communities selected included Iguoriakhi and Udo in Edo state; Utagbuno and Egbudu-aka in Delta State; Ibiade and Ikenne in Ogun State; Onna and Nsit Atai in Akwa Ibom State. Lastly, a purposive non-random sampling was used to select 50 farmers each from the four states.

The data collected were analysed using descriptive statistical procedures and the logistic econometric model.

Measuring technology adoption

To assess the relative contribution of significant factors, a multivariate logistic analysis was employed following the method developed by (Green and Ng'ong'ola, 1993; Mbata, 1994; Sharma, 1997; Rajasekharan and Veeraputhran, 2002; Herath and Takeya, 2003). Logistic model analysis overcomes most of the problems associated with linear probability models and provides parameter estimates that are asymptotically consistent and computationally easier to use (Pindyck and Rubinfeld, 1981).

Most econometric modellings that are used to estimate the effect of explanatory variables on the observed economic phenomena employ linear models:

$$y = a + \sum_{i=1}^{n} b_i X_i + e \qquad (1)$$

where y is a continuous random variable,
$x = x_1 \ldots x_n$ are the variables that explain y,
a is a constant
and $b = b_1 \ldots b_n$ are the parameters that ultimately describe the effect a change in x has on y.
i denotes the i-th individual and n is the number of observations.
But for the smallholder's decision to adopt or not to adopt RAFS technologies, the random variable y is not continuous. Instead, it is discrete or dichotomous.

When dichotomous, $p = P(Y = 1 | X)$
(Probability of adoption of RAFS) (2)

$1 - p = P(Y = 0 | X)$
(Probability of non-adoption of RAFS) (3)

$X = 1 | X$ could, for example, mean adoption of intercropping immature rubber stand and $Y = 0 | X$ mean non adoption given all Xs. Note that this adoption is an end-result of farmers' decisions based on economic theory. An economic unit (a farmer in this case) makes rational decisions to maximise expected utility. The utility associated with each technology is a function of the possible outcomes from adopting each technology, thus:

$$U_0 = f(b[X_0] \qquad (4)$$

$$U_I = f\,b[X_1] \qquad (5)$$

where:
U_1, U_0, are the expected utility levels with and without the technology,
X_1, X_0, are socio-economic and other characteristics of farmers.
$b = b_1 \ldots b_n$ are parameters that describe the effect of farmers characteristics on utility.
When $U_1 > U_0$, the assumption is that a farmer adopts a technology, or simply, that $Y = 1 | X$ in equation 2. Now by substituting equation 1 into equation 2, it becomes:

$$p = P\left(a + \sum_{i=1}^{n} b_i X_i + e\right) \qquad (6)$$

For, $Y = 1 | X$. Equation 6 can be expressed as

$$p = \alpha + \sum_{i=1}^{n} \beta_i X_i + e \qquad (7)$$

There is a similarity between equation 7 and equation 1. The outcome of a continuous random variable, y, is replaced by p the probability of adoption. But equation 7 is linear, hence would show probabilities of <0 and >1 at low levels and high levels of X, respectively. To ensure that p is positive and restricted to the [0,1] range, equation 7 is reformulated as:

$$P(Y = 1 | X) = \frac{e^{\alpha + \Sigma \beta X + e}}{1 + e^{\alpha + \Sigma \beta X + e}} \qquad (8)$$

where: p (.) = Probability that a RAFS technology is adopted, α = Constant term, $X = A$ set of core explanatory variables
β = A vector of unknown parameters
e = Disturbance term
Reformulation of equation 8 yields

$$\frac{P(Y = 1 | X)}{1 - p(Y = 1 | X)} e^{\alpha + \Sigma \beta X + e} \qquad (9)$$

This is the odds ratio, or the probability of adoption of RAFS packages divided by the probability of non-adoption. Transforming Equation 9 into a logistic function gives

$$\left[\frac{P(Y = 1 | X)}{1 - p(Y = 1 | X)}\right] = \alpha + \sum_{i=1}^{n} \beta_i X_i + e \qquad (10)$$

Equation 10 is also known as the logit (p). By defining $\frac{P}{1-P}$ as the odds of adoption and modelling p with the logistic function above, it is equivalent to estimating a linear regression model where the continuous outcome y has been replaced by the logarithm of the odds of adoption. Thus, the final form of the logistic model therefore becomes

$$Y = \alpha + \sum_{i=1}^{n} \beta_i X_i + e \qquad (11)$$

where:
Y is the probability of adoption of RAFS which is dichotomous
$\sum$ is the summation sign
α is the constant
β_i is the parameter estimate of the ith term
X_i is the coefficient estimate of the ith term
where X_i represents mature rubber land size (MRS), immature rubber land size (IMRS), contacts with extension agents (EXTS), membership of farm organisation (FORG), availability of off-farm income (OFI), farmers age (AGE), educational level (EDUC), farmers attitude towards rubber agroforestry (ATT), household size (HSIZ), usage of hired labour (HIRE), farmers experience in growing rubber (FEXP), farmers experience in growing other crops (FEXPOC), gender of farmer (GEND), participation in on-farm trial demonstration (ONFAM), access to farm credit (CRED), attendance of training on rubber agroforestry (TRAIN), distance between farmers residents and rubber farm (DIST).

To estimate logistic model coefficients, the method of maximum likelihood estimation (MLE) is more appropriate than Ordinary Least Squares because MLE gives unbiased and efficient estimates (Amemiya, 1981; Agresti and Finlay, 1997). Maximum likelihood finds the function that will maximise the ability to predict the probability of the dependent variable based on what is known about the independent variables. Thus, a maximum likelihood estimate of regression coefficients is the value of the parameter that is most consistent with the observed data in that if the parameter equalled that estimate, the observed data would have a greater chance of occurring than if the parameter equalled any other possible value.

Empirical model

The variables were selected based on literature of past adoption studies.

Farm size has been described as the first and probably the most important determinant of adoption (Doss and Morris, 2001; Daku, 2002). This is perhaps because farm size can affect and in turn be affected by the other factors influencing adoption. According to the report of Abara and Singh (1993) and Fernandez-Cornejo (1998) on agricultural technology adoption, the effect of farm size was positive.

The serious cash shortages faced by small farmers partly due to deteriorating output prices and increasing external input prices makes the availability of credit to be an important determinant of farmers' adoption decision. Furthermore, access to credits is expected to increase the probability of adoption. Herath and Jayasuriya (1996); revealed a positive significance between access to credit and adoption of improve technology.

Good extension programs and contacts with producers are a key aspect in technology dissemination and adoption. Most studies that used this variable in the context of agricultural technology showed its strong positive influence on adoption. In fact, Yaron et al. (1992) reported that its influence can counterbalance the negative effect of lack of years of formal education in the overall decision to adopt some technologies.

The impact of social participation is expected to have a positive effect on adoption based on innovation diffusion theory. Membership of social organisations such as farmers' cooperative and other associations has been found to be very important in changing the attitudes of farmers towards new agricultural practices and thereby enhancing the adoption of such practices (Zeller et al. 1998; Ogunlana, 2004). Such an organisation serves as a forum for gaining access to information, credit and other productive inputs (Cavligia and Khan, 2001). A study by Omobolanle (2007) indicated that membership of cooperatives positively influences the adoption of new practices by farmers in Nigeria due to the fact that they obtained information about new technologies from such organisations.

Off-farm income is an important factor affecting technology adoption. It can influence adoption in either a negative or positive manner. Farmers' practices that heavily draw on their leisure time may inhibit adoption. However, practices that leave time for other sources of income accumulation may promote adoption.

Studies that have sought to establish the effect of education on adoption in most cases relate it to years of formal schooling (Tjornhom, 1995; Feder and Slade, 1984). Generally, education is thought to create a favourable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices (Waller et al. 1998; Caswell et al. 2001).

Attitudes towards RAFS have been considered in the model as a psychological factor that would affect RAFS. In the literature, attitudes have been defined as the degree of a farmer's positive or negative feelings towards an innovation. It is assumed that attitudes largely depend on household values, beliefs and circumstances (Sharma and Kumar, 2000).

A large number of family members (relative to household size) working on the farm reduces the farms' external labour requirements and is hence assumed to positively affect the adoption of intercropping. Thus, household size is expected to increase the probability of the adoption of RAFS.

The previous experience of farmers can be expected to either enhance or diminish their level of confidence. It is anticipated that with more experience, farmers could become risk-aversive regarding the adoption of a technology.

The distance between a farmer's residence and the rubber farm is employed as a measure of security and expected to have a negative sign.

RESULTS AND DISCUSSION

Summary statistics of RAFS in Nigeria

A summary statistics of the mean characteristics of the study population, adopters and non-adopters, for both the continuous and non-continuous variables of the RAFS is presented in Table 1 and 2. There is a significant difference in the mean values of the number of extension visits, farming experience of other crops (FEXPOC) and the attitude towards intercropping between the adopter and non-adopter populations. The adopters have more frequent contacts with extension agents (EXT) than non-adopters, and majority of the adopters (88.5 %) have positive feelings towards intercropping compared to the non-adopters (11.5 %). This finding is in line with Yaron et al. (1992), who reported that contacts with extension agents counterbalance the negative effect of lack of years of formal education in the overall decision to adopt some technologies. Most of the adopters have a higher number of years of schooling (15.6 years) compared to the non-adopters (13.4 years). The adopters' farming experience with other crops (18.4 years) is higher than that of the non-adopters (12.7 years).

Estimated logit model

The empirical logistic model was adopted for estimation of RAFS using Econometric View (EVIEW) software version 7.1. The logit model solution is given in Table 3. The parameter estimate of the logit model was obtained by Quadratic Hill Climbing iterative procedure. The likelihood ratio test had a χ^2 value of 79.43 with 12 degrees of freedom, implying that the estimated model is highly significant. Hence, the model is considered to be a good fit and also consistent with

Table 1. Characteristics of RAFS Adopters and Non-Adopters – continuous variables

variable	Total (n = 200)		Adopters (n = 84)		Non-adopters (n = 116)		*P*-value
	Mean	SD	Mean	SD	Mean	SD	
MRS (ha)	5.52	5.06	6.23	5.37	4.32	4.17	0.433
IMRS (ha)	4.12	4.13	4.23	3.72	3.98	2.76	0.143
EXT (number)	4.27	2.52	4.25	2.53	2.82	2.37	0.002
AGE (years)	46.23	18.12	48.16	18.41	36.72	19.54	0.413
EDUC (years)	16.61	3.74	15.61	3.72	13.41	5.38	0.004
HSIZE (number)	8.45	4.23	8.36	4.79	7.61	3.56	0.762
FEXP (years)	20.62	13.56	18.46	13.34	16.43	15.47	0.341
FEXPOC (years)	18.62	11.78	18.43	10.56	12.72	9.55	0.003
DIST (km)	5.43	4.12	5.24	4.76	6.28	3.97	0.231

SD – standard deviation; for explanation of abbreviations used, see page 52
Source: own calculations

Table 2. Characteristics of RAFS Adopters and Non-Adopters – Non-continuous variables

Variable	Adopters	Non-adopters
FORG (% yes)	46.5	53.5
OFI (% yes)	12.5	87.5
ATT (% yes)	88.5	11.5
HIRE(% yes)	62.5	37.5
ONFAM (% yes)	42.5	57.5
CRED (% yes)	64.5	35.5
TRAIN (% yes)	88.5	21.5

Source: own calculations; for explanation of abbreviations used, see page 52

Table 3. Maximum likelihood estimates of rubber agroforestry adoption model

Variable	Coefficient estimates	Standard error	z ratio	Marginal effects
MRS	0.160	1.129	0.142	0.004
IMRS	0.183	1.043	0.175	0.521
EXTS	14.891***	5.536	2.689	0.134
FORG	3.133**	1.301	2.408	0.352
OFI	–2.096*	1.157	-1.812	0.133
AGE	5.190	3.621	1.433	0.065
EDUC	2.191**	1.048	2.091	0.041
ATT	2.184**	1.056	2.034	0.268
HSIZ	2.515	1.789	1.406	0.064
HIRE	2.429	1.652	1.470	0.127
FEXP	0.551	1.498	0.368	0.337
FEXPOC	0.027	0.771	0.035	0.224
GEND	0.162	1.126	0.144	0.004
ONFAM	3.378**	1.417	1.384	0.265
CRED	0.166	1.128	0.147	0.006
TRAIN	4.086**	1.755	2.328	0.223
DIST	–9.304***	3.465	–2.685	0.238

Log likelihood = –152.12, Likelihood ratio = 341.23, Model χ^2 = 79.43 (0.001) (df = 12), McFadden's R2 = 0.82, Iterations = 7, *significant at 10%, **significant at 5%, ***significant at 1%. Source: own calculations; for explanation of abbreviations used, see page 52

theory. The goodness of fit measure, McFadden R^2 (0.82), indicated a very satisfactory fit. This measure may be interpreted in a similar way to R^2 in the linear regression context.

Six variables *viz*, extension contact, membership of farm organisation, education level, attitude of farmers toward intercropping, farmers' participation in on-farm trial demonstrations and accessing agricultural knowledge through trainings were positively associated with increased adoption of RAFS in Nigeria (Table 3). The influence of extension contact on adoption of RAFS is of major importance. Access to extension is linked to education. Farmers with better education invest more in information acquisition and they accumulate knowledge that leads to adoption. The positive significant effect of membership of farm organisation provides enhanced access to information relating to RAFS. This finding is in line with Omobolanle (2007) who concluded that membership in cooperatives positively influences the adoption of new practices by farmers in Nigeria due to the fact that the farmers obtained information about new technologies from such organisations. As would be expected, education also has positive and significant effects on adoption of RAFS as exposure to education increases farmers ability to obtain, process and use information about improved technology. This finding is in line with Caswell et al. (2001), who opined that education creates a favourable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices. The attitude towards RAFS has a significant impact on the probability of adoption. The on-farm trial demonstration of RAFS also has a significant impact on the probability of adoption. This indicates that previous knowledge gained by farmers in RAFS through on-farm trial demonstration makes them to believe that RAFS would be harmless to the rubber trees.

In Table 3, two variables were shown to have significant negative impacts on the probability of adoption of RAFS in Nigeria. Off-farm income is negatively significant with the probability of adoption. This may be due to a lack of resources such as labour for farming activities due to off-farm activities. Average distance from rubber land to farmers' residence also has a negative significant impact on adoption. Theft problem is one of the major problems of RAFS. The results indicate that rubber smallholders will adopt RAFS when the farm is closer to their residence.

The marginal impact of changes in the independent variables on the probability of adoption of rubber agroforestry system was evaluated at the mean of the continuous variable and mode of the non-continuous variables. The implication of the marginal impacts is that in every 1 % increase in extension visits per month, the probability of adoption of RAFS increases by 0.13 %. On the other hand, in every 1 % decrease in the average distance from rubber land to farmers' residence, the probability of adoption of RAFS increases by 0.24 %. The marginal effect also show that 5 % increase in farmers membership of farm organisation, educational level, attitude towards RAFS, on-farm trial demonstration and training, the probability of adoption of RAFS increases by 0.35 %, 0.04 %, 0.27 %, 0.27 % and 0.22 %, respectively. The marginal effect on off-farm income reveals that a 10 % decrease in off-farm income increases the probability of adoption of RAFS by 0.13 %

CONCLUSION AND POLICY IMPLICATION

This study established the current state of factors affecting RAFS in Nigeria. Moreover, since RAFS involves a variety of practices that are specific to crops and livestock such as intercropping food crops and medicinal plants with immature rubber plantation, intercropping high value tree crops at the periphery of rubber plantations and integrating mini-livestock into mature rubber plantations, measuring its adoption in terms of return on investment is necessary.

Extension contact was found to be the most influential variable that had a positive impact on RAFS. Since extension is the main source of information for small farmers, appropriate policies need to be designed to improve its efficacy for farmers to achieve increase agricultural productivity. Membership of farm organisation serves as a forum for access to information, credit and other productive inputs.

Farmers' educational level also had a positive impact on adoption. Government should therefore place more emphasis on policies and strategies that would expand primary education and increase school enrolment rates of children in rural areas to achieve better instruction and later on increased agricultural productivity.

The attitude of farmers toward RAFS had a significant impact on its adoption. In terms of marginal impacts, an increase of 5 % in the farmers with a positive attitude towards RAFS would increase the number of adopters by 0.27 %. These data show how important the improvement of awareness is in order to enhance RAFS in Nigeria.

Another important factor with a positive influence on RAFS adoption was farmers' participation in on-farm trial demonstrations. It should be noted that adoption of RAFS is expected to be increased more through farmers having hands-on experience. This suggests that the introduction and promotion of technologies should be preceded by encouraging higher farmer participation in on-farm trial demonstrations as a means of increasing farmers' practical experience with the introduced technologies.

On the other hand, off-farm income and average distance from rubber land to farmers' residence demonstrated a negative impact on RAFS in Nigeria. Most of the farmers have other sources of income which they rely upon, apart from rubber farming. They are engaged in trading, civil service and artisanal activities. The distance between the rubber land and the farmer's residence reveals that theft is one of the major causes impeding RAFS in the sector. Appropriate policies need to be designed to improve securities in rural areas and to achieve increased agricultural productivity. Better roads are also essential for the likelihood of adoption as it improves the farmers' timeliness of accessing their farms and reduce transportation.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to research, authorship and publication of this article.

ETHICAL COMPLIANCE

The authors have followed the ethical standards in conducting the research and preparing the manuscript.

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