International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

Improving the assessment of good agricultural practice adoption in cashew production: A contributory approach

Mouhamadou Djima Baranon [1, 2, *], Paulin Akouegninou [2], Amos Kipkorir Langat [1] and Youssouf Bouzir [1]

[1] *Pan African University Institute for Basic Sciences, Technology, and Innovation (PAUSTI), Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya.*

[2] *Ecole Nationale de Statistique, de Planification et de Démographie (ENSPD), Université de Parakou, Benin.*

International Journal of Science and Research Archive, 2023, 09(02), 520–536

Publication history: Received on 19 June 2023; revised on 28 July 2023; accepted on 31 July 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.9.2.0606

Abstract

This study aimed to propose a new approach for calculating the adoption rate of cultural practices in cashew production, challenging the conventional method that assigns equal weight to all practices. Through an in-depth analysis using multiple linear regression and field data, it was revealed that different practices have varying impacts on cashew yields, which the traditional approach neglects. To address this bias, a weighted approach was introduced, considering the relative importance of each practice. By recalculating the adoption rate using this new method, a more precise and balanced view of practice contributions was obtained. A comparison with the existing approach showed significant differences, as the current method underestimated certain practices' importance, distorting the overall assessment. In contrast, the weighted approach provided a more realistic estimation. These findings underscore the necessity of revising the approach to assess cultural practice adoption in cashew production accurately. Incorporating relative weights allows for a more informed evaluation, enabling farmers, policymakers, and researchers to adopt more efficient practices and optimize yields. This study serves as a valuable contribution, emphasizing the significance of considering relative weights in evaluating cultural practices, providing a strong foundation to guide decision-making in cashew production.

Keywords: Agricultural practices; Adoption; Yield; Weighting; Approach

1. Introduction

In any development process, innovation plays a key role. This is evident insofar as “the same causes produce the same effects”. Economic growth is one of the benefits that innovation brings to a given society. Indeed, innovation can lead to an increase in productivity; in other words, it would allow an increase in production starting from the same inputs [1]. Innovation is therefore recognized as an essential driver of economic progress and is beneficial for all actors in an economy: consumers, companies, the State [2] [3].

In the agricultural sector, it plays a key role in the development of emerging sectors [4]. Thus, creating and promoting novelties has become a major concern for agricultural research and development organizations. This could contribute a lot to the optimization of the means of production and the efficient use of inputs. Given the importance of agriculture for the development of African countries, innovation in this sector would contribute significantly to social and economic well-being and to development in general. [5]. The promotion of good agricultural practices can be observed in many African countries, including Benin. These good practices aim not only to maximize yields but also to preserve biodiversity. Very recently, in Benin, as in many other African countries, innovative techniques have been introduced to maximize agricultural productivity, particularly in the cashew sector. It is important to note that this sector captures the attention of the various development actors, with regard to the various advantages it offers. Today, this sector

* Corresponding author: Mouhamadou Djima Baranon

employs more than 200,000 people (producers and traders); it contributes about 8% to national export income, 24.9% to agricultural exports, or 7% of agricultural GDP [6, 7]. The sector benefits from the intervention of several national and international organizations through various actions such as support and advice to producers on good cultural practices (pre-harvest, harvest and post-harvest). Among other organizations, we can cite the National Federation of Cashew Producers of Benin (FENAPAB), Benin-Cashew, the Interprofessional of the Cashew Sector of Benin (IFA-Benin), etc.

Yield per hectare is a key indicator used to assess cashew production. One hectare of cashew allows an average yield of 1200 kg, while in Benin, producers are faced with an average yield of 150 to 350 kg per hectare. [8]. Which is about a quarter of the norm. However, studies have shown that the country's climate is favorable to the good yield of this cash crop. Among the causes of its poor performance stand out the poor cultural practices in terms of production. [9].

In addition, in the analysis of the state of the cashew sector, the rate of adoption of good farming practices is a key indicator. [10]. A good approach to its calculation would better enlighten the various actors in the search for solutions to the challenges facing the industry today. Several authors have proposed approaches to its calculation [11, 12, 13, 14]. But this indicator currently suffers from a shortcoming, which is that of giving the same weight to the different practices. This underestimates, on the one hand, the contribution of certain practices and overestimates, on the other hand, that of others. Thus the decisions made on the basis of this indicator are subject to shortcomings.

As it stands (with the allocation of identical weights to the practices), the rate of adoption of good agricultural practices does not allow relevant decisions to be made. In addition, their correction could help improve these practices and promote harmonious development of the cashew sector. This is the basis of the need to conduct the present research which will make it possible to correct the bias induced by the current calculation approach.

This study attempts to answer the following questions: What are the weaknesses related to the current method of calculating the rate of adoption of cultural practices in the production of cashew nuts? What approach would allow the minimization of the biases induced by this approach for calculating the rate of adoption of cultural practices in the production of cashew nuts?

The answers to the questions set out above are part of a research approach aimed at: Highlight the weaknesses of the calculation of the rate of adoption of cultural practices in the production of cashew nuts; Contribute to the design of a new calculation approach to correct the bias of the current approach.

2. State of the question related to the measurement of the rate of adoption of cultural practices

The literature review on how to calculate the rate of adoption of cultivation practices in agriculture highlights different approaches and methods used by researchers and practitioners to assess and quantify the adoption of cultivation practices. Here is an overview of the main trends and contributions in this field:

2.1. Approach based on binary indicators

The approach based on binary indicators is one of the methods commonly used to assess the rate of adoption of cultural practices. This approach consists of assigning a binary value (0 or 1) to each practice according to its adoption by farmers. The adoption rate is then calculated by taking into account the number of practices adopted in relation to the total number of practices evaluated.

This simple and easy-to-use method has been widely applied in many studies on the adoption of agricultural practices. For example, in a study by Smith et al. (2018), researchers used binary indicators to assess the adoption of different soil conservation practices on farms. They assigned the value 1 if a practice was adopted and 0 if it was not. [15]. By aggregating the indicators, they were able to calculate the overall adoption rate of soil conservation practices in the study region.

Another study by Johnson et al. (2019) used binary indicators to assess the adoption of agroforestry practices among smallholder farmers. They assigned the value 1 if a farmer had planted trees on his land and 0 if he had not. By calculating the adoption rate based on these indicators, researchers were able to compare adoption levels between different regions and identify factors that influenced the adoption of agroforestry practices. [16].

It should be noted that the approach based on binary indicators has limitations. It does not take into account the intensity or frequency of adoption, but is limited to a binary measure (yes or no). Moreover, it does not take into account the differences in weight between cultivation practices, which can lead to a simplified assessment of adoption. However, this approach is still useful for obtaining an initial estimate of the adoption rate and for identifying the most widely adopted practices.

In summary, the approach based on binary indicators is a simple and practical method to assess the rate of adoption of cultural practices. It has been widely used in many studies, including those conducted by Smith et al. (2018) and Johnson et al. (2019). However, it is important to take into account its limitations and to complement this approach with other methods for a more in-depth evaluation of the adoption of cultural practices.

2.2. Logistic regression models

Logistic regression models are widely used to analyze the factors that influence the adoption of cultural practices. This statistical approach makes it possible to identify the variables significantly associated with the probability of adopting a specific practice. The coefficients estimated in the logistic regression models also make it possible to assess the relative importance of each variable in the adoption process.

In a study by Garcia et al. (2017), researchers used a logistic regression model to analyze the determinants of adoption of water conservation practices on farms. They collected data on various variables such as water availability, adoption costs, education level of farmers, etc. Model results showed that water availability and adoption costs were significant factors in farmers' decision to adopt water conservation practices or not. [17].

Another study by Nguyen et al. (2019) used a logistic regression model to assess the factors influencing the adoption of sustainable agricultural practices by smallholders in Vietnam. The researchers considered variables such as social capital, access to information, economic benefits, etc. The results showed that social capital and access to information were important determinants of the adoption of sustainable agricultural practices. [18].

These examples illustrate the use of logistic regression models in the study of the adoption of cultural practices. These models allow for in-depth analysis of the individual, economic, social and environmental factors that influence adoption. Moreover, they provide information on the direction and the intensity of the effect of the different variables on the probability of adoption.

It is important to note that the use of logistic regression models requires rigorous data collection and adequate formulation of explanatory variables. Moreover, these models assume a linear relationship between the independent variables and the dependent variable, which may not always be the case in complex situations.

In summary, logistic regression models are a powerful statistical method to analyze the factors that influence the adoption of cultural practices. Studies by Garcia et al. (2017) and Nguyen et al. (2019) demonstrate the application of this approach in analyzing the adoption of water conservation practices and sustainable agricultural practices respectively.

2.3. Social media approach

The social network approach is a method of analyzing the adoption of farming practices that focuses on the social relationships and interactions between individuals. This approach recognizes the influence of social networks on adoption behaviors and decisions.

In a study by Jones et al. (2017), researchers used a social network-based approach to understand the adoption of soil conservation practices among farmers. They used data collection methods that mapped social ties among farmers and identified opinion leaders within the farming community. Using social influence models, researchers were able to analyze how the adoption of soil conservation practices spread through the social network of farmers [19].

Another study by Wang et al. (2018) examined the impact of social networks on the adoption of efficient irrigation practices among farmers. The researchers used social network analysis techniques to measure the density of social connections between farmers and assess the influence of peers on the adoption of efficient irrigation practices. The results showed that farmers with a denser social network and strong ties were more likely to adopt these practices. [20].

These examples demonstrate how the social network approach can be used to understand the mechanisms of adoption of cultural practices. By identifying opinion leaders, measuring social connections and analyzing the influence of peers, this approach makes it possible to better understand the dissemination of practices and to identify the most effective channels to promote adoption.

In his book "Social Networks and Health: Models, Methods, and Applications" (2010), Valente discusses the use of social networks to understand and promote healthy behaviors. Although the book does not focus specifically on agriculture, the concepts and methods presented can be applied to the adoption of farming practices.

Valente highlights the importance of social ties and interactions between individuals in the process of disseminating innovations. It offers models and methods of social network analysis to study how information, attitudes and behaviors spread through social relations [21]. This work can be adapted to study the adoption of cultural practices and the influence of social networks in this context.

It should be noted that Valente's work is not limited to the adoption of agricultural practices, but provides a solid theoretical basis and useful analytical tools to explore the impact of social networks on various domains, including the adoption sustainable agricultural practices.

3. Material and methods

3.1. Statistical methods and tools

Before presenting the methodological approach adopted in the context of this study, it is important to recall the current method of calculating the rate of adoption of farming practices in the cashew sector.

3.1.1. Current method of calculating the adoption rate and critical analysis

Let us designate the different cultural practices as follows:

X_1 : Association cultures
X_2 : Firewall
X_3 : Weeding
X_4 : Size
X_5 : Aeration
X_6 : Nut sorting
X_7 : Jute bag use
X_8 : Cutting
X_9 : Drying

Each of the variables is dichotomous: $X_i = \begin{cases} 1, \text{si le producteur adopte le pratique } i \\ 0, \text{sinon} \end{cases}$,

$$i = 1,2, \dots, 9$$

The adoption rate is:$t_a = \frac{\sum_{i=1}^{7} X_i}{9}$

It is clear that the same weight is given to the different practices. Overall, this weight is $1/_9$) $1/_n$when considering cultural practices.nThis may not reflect reality insofar as the practices would not have the same influence on the cashew plantations, and therefore would not act equally on the yield.

3.1.2. Analytic method

The approach used consists in showing that a better method of calculating the adoption rate exists and would make it possible to get as close as possible to reality.

The starting point is the assumption of the current mode of calculation, namely that the weight is $1/_n$for each cultural practice. The real data is then used to show that this assumption is not verified.

Let $p_1, p_2, \ldots, p_n$ be real constants representing the respective weights of the farming practices $X_1, X_2, \ldots, X_n$.

$$t_a = \sum_{i=1}^{n} p_i X_i$$

The null hypothesis (based on the current way of calculating the adoption rate) is:

$$p_1 = p_2 = \ldots = p_n = \frac{1}{n}$$

The alternative hypothesis is: $\exists\ i \leq n, p_i \neq \frac{1}{n}$

That is, the variable that provides information on the yield of cashew plantations.

The model is laid out as follows:

$$Y_i = \alpha_0 + \alpha_1 X_{1i} + +\alpha_2 X_{2i} + \cdots + +\alpha_n X_{ni} + \varepsilon_i$$

$$\begin{cases} Y_1 = \alpha_0 + \alpha_1 X_{11} + +\alpha_2 X_{21} + \cdots + +\alpha_n X_{n1} + \varepsilon_1 \\ Y_2 = \alpha_0 + \alpha_1 X_{12} + +\alpha_2 X_{22} + \cdots + +\alpha_n X_{n2} + \varepsilon_2 \\ \ldots \\ Y_N = \alpha_0 + \alpha_1 X_{1N} + +\alpha_2 X_{2N} + \cdots + +\alpha_n X_{nN} + \varepsilon_N \end{cases}$$

With $\boldsymbol{x_{ij}}$ the value of the variable (practice) $\boldsymbol{X_i}$ for the individual j and **N** the total number of observations.

$$\begin{pmatrix} Y_1 \\ Y_2 \\ \ldots \\ Y_N \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & x_{21} & \ldots & x_{n1} \\ 1 & x_{12} & x_{22} & \ldots & x_{n2} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ 1 & x_{1N} & x_{2N} & \ldots & x_{nN} \end{pmatrix} \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \ldots \\ \alpha_n \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \ldots \\ \varepsilon_N \end{pmatrix}$$

We can write :

$$Y = X\alpha + \varepsilon, \text{ with}$$

$$Y = \begin{pmatrix} Y_1 \\ Y_2 \\ \ldots \\ Y_N \end{pmatrix}, \text{, And} X = \begin{pmatrix} 1 & x_{11} & x_{21} & \ldots & x_{n1} \\ 1 & x_{12} & x_{22} & \ldots & x_{n2} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ 1 & x_{1N} & x_{2N} & \ldots & x_{nN} \end{pmatrix} \alpha = \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \ldots \\ \alpha_n \end{pmatrix} \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \ldots \\ \varepsilon_N \end{pmatrix}$$

Using the ordinary least squares (OLS) method, the coefficient matrices can be estimated. We have :

$$\hat{\alpha} = (X^t X)^{-1} X^t Y$$

X^t,the transpose of the matrix X.

On the basis of these estimated coefficients, the relative weight of the cultural practice $\boldsymbol{i}$ can be estimated by:

$$p_i = \frac{\widehat{\alpha_i}}{\sum_{i=1}^{n} \widehat{\alpha_i}}, .i = 1,2, \ldots, n$$

Under the null hypothesis, we know that $p_1 = p_2 = \ldots = p_n = \frac{1}{n}$.

It follows that $\frac{\widehat{\alpha_1}}{\sum_{i=1}^{n} \widehat{\alpha_i}} = \frac{\widehat{\alpha_2}}{\sum_{i=1}^{n} \widehat{\alpha_i}} = \cdots = \frac{\widehat{\alpha_n}}{\sum_{i=1}^{n} \widehat{\alpha_i}} = \frac{1}{n}$

$$\Rightarrow \widehat{\alpha_1} = \widehat{\alpha_2} = \cdots = \widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i}$$

$$\widehat{\alpha_1} = \widehat{\alpha_2} = \cdots = \widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \Rightarrow \begin{cases} \widehat{\alpha_1} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \widehat{\alpha_2} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \ldots \\ \widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \end{cases}$$

$$\Rightarrow \begin{cases} \widehat{\alpha_1} + 0\widehat{\alpha_2} + \cdots + 0\widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ 0\widehat{\alpha_1} + \widehat{\alpha_2} + \cdots + 0\widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \ldots \\ 0\widehat{\alpha_1} + 0\widehat{\alpha_2} + \cdots + \widehat{\alpha_n} = \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \end{cases}$$

$$\Rightarrow \begin{pmatrix} 1 & 0 & 0 \ldots & 0 \\ 0 & 1 & 0 \ldots & 0 \\ \ldots & \ldots & \ldots \ldots & \ldots \\ 0 & 0 & 0 \ldots & 1 \end{pmatrix} \begin{pmatrix} \widehat{\alpha_1} \\ \widehat{\alpha_2} \\ \ldots \\ \widehat{\alpha_n} \end{pmatrix} = \begin{pmatrix} \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \ldots \\ \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \end{pmatrix}$$

Let , and $R = \begin{pmatrix} 1 & 0 & 0 \ldots & 0 \\ 0 & 1 & 0 \ldots & 0 \\ \ldots & \ldots & \ldots \ldots & \ldots \\ 0 & 0 & 0 \ldots & 1 \end{pmatrix} \hat{p} = \begin{pmatrix} \widehat{\alpha_1} \\ \widehat{\alpha_2} \\ \ldots \\ \widehat{\alpha_n} \end{pmatrix} q = \begin{pmatrix} \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \\ \ldots \\ \frac{1}{n}\sum_{i=1}^{n} \widehat{\alpha_i} \end{pmatrix}$

Then, we have: (Under the null hypothesis).$R\hat{p} = q$

We then calculate the statistic:

$$\mathbf{F} = {}^{(\mathbf{R\hat{p}} - \mathbf{q})^{\mathbf{t}}[\hat{\boldsymbol{\sigma}}^{\mathbf{2}}\mathbf{R}(\mathbf{X^tX})^{-\mathbf{1}}\mathbf{R^t}]^{-\mathbf{1}}(\mathbf{R\hat{p}} - \mathbf{q})}/_{\mathbf{n}}$$

Under the null hypothesis: $\boldsymbol{F} \sim \boldsymbol{F}(\boldsymbol{n}, \boldsymbol{N} - \boldsymbol{n} - \mathbf{1})$ Fischer's law with degrees of freedom $(n, N - n - 1)$

$\boldsymbol{R^t}$, the transpose of the matrix $\boldsymbol{R}$ and is the estimated variance $\hat{\boldsymbol{\sigma}}^{\mathbf{2}}$**.**

If the calculated statistic F is greater than that read on the Fischer table with degrees of freedom $(n, N - n - 1)$, the null hypothesis is rejected.

3.2. Data used

As part of this study, the data is used to simulate the process described above. These data come from a survey organized in January-February 2020. Given the unavailability of a database providing information on the list of cashew producers in the study area, the “Snowball” technique was used to identify the producers to be surveyed. The choice of this method is mainly due to the fact that no sampling frame is available on producers at the time of data collection. A total of 278 producers were surveyed. In addition to general information (individual and household level), the questionnaire covers income, expenses, information on planting, cultivation practices, harvesting and marketing. Questions relating to these sections were administered face-to-face.

Once the data was completed, arrangements were made to make it available electronically for analysis. For this purpose, an input mask has been designed in the CS Pro software (dictionary of variables, data entry application, form). A single entry was adopted. After data entry, frequency tables and cross tables were made to identify inconsistencies. Any inconsistencies detected have been corrected.

4. Results

This section is structured as follows: an overall description of the surveyed population, a differential analysis (descriptive and explanatory) of the yield of cashew trees according to the adoption of cultural practices together with the study of the bias associated with the current method of calculating the adoption rate and an adequate proposal for the method of calculating this indicator.

4.1. Description of the studied population

A set of 278 producers was surveyed. Table 1 presents the socio-demographic characteristics of the producers surveyed.

Table 1 Socio-demographic features of the respondents

Variable	Observations	Percentage (%)
Household Head Gender		
Female	21	7.55
Male	257	92.45
Education		
No level	193	69.42
Primary and above	85	30.58
Status		
Foreign	1	0.36
Aboriginal	277	99.64
Mode of land acquisition		
Purchase	12	4.32
Donation	125	44.96
Legacy	141	50.72
Membership		
Non-cooperative member	41	14.75
cooperative member	237	85.25
Access to credit		
No access	124	44.6
Access	154	55.4
Agricultural advice		
No access	39	14.03
Access	239	85.97
Appreciation		

No appreciation	229	82.37
Appreciation	49	17.63

Most respondents are men. They represent about 9 out of 10, or 92.5%. In addition, more than 3 out of 4 of respondents have no level of schooling; in particular 69.42% of them are concerned, while 30.58% have at least the primary level. In this last category, we find those with the primary level, the secondary level (general and agricultural) and the higher level (University).

From the point of view of residence in the area, almost all of the respondents are indigenous. Of the 278 producers, only one is foreign, which represents 0.36%. Contrary to what one might imagine, access to land intended for the production of cashew nuts is not exclusively obtained by inheritance. Moreover, 50.7% acquired their land by this mode (inheritance); more than 4 out of 10 (45%) benefited from a donation while 4% bought it.

Moreover, the producers surveyed generally tend to form a cooperative: more than 8 out of 10, or 85.25% are in the case. Slightly more than half access agricultural credit as part of their agricultural activities. This is 55.4% against 44.6% who do not have access. However, non-access is not necessarily a refusal to adopt this source of financing. Some of those who do not have access have made a request without follow-up and others still have their files under study. The adoption of agricultural credit is therefore a common practice among the producers surveyed.

In terms of agricultural advice, more than 8 out of 10 (86%) of respondents access it. This is quite obvious since most of them belong to an organization; the support structures place more emphasis on agricultural farmers' organizations in their interventions (which include agricultural advice). Regarding the ability of the producer to appreciate the quality of the nuts, less than 2 in 10 (17%) manage to demonstrate this skill. It is indeed a technique consisting in determining the KOR (Kernel Output Ratio), on the one hand, and in concluding that the nuts are of good quality if the value exceeds a given threshold.

Table 2 summarizes some descriptive statistics on the population studied. This concerns the age of the head of household, the size of his household, the amount of family labor, the number of plantations owned, the total area of cashew trees in his possession, the total amount of nuts sold (in Kg), yield (quantity/area), selling price, income, average number of trees per hectare, average age of trees, time generally taken to get to the plantation and the distance between his home and the plantation.

Table 2 Statistics on heads of household, production and sale of cashew nuts

Variables	**N**	**Mean**	**SD**	**min**	**max**
Household Head age	278	46.06	10.82	25	79
Household size	278	11.56	5,497	1	39
Family labor	278	6,097	3,992	0	24
Number of plantations	278	1,565	0.969	1	6
Area	278	6,361	6,350	0.500	53
Quantity (Kg)	278	2478	2883	100	20000
Yield	278	370.4	177.8	16.67	800
Price per Kg	278	349.2	69.95	200	450
Income	278	875664	1.036e+06	25000	7.65e+6
Number of trees per hectare	278	104.1	10.53	70	150
tree age	278	13.14	5.25	2	35
Planting time	278	18.56	14.84	2	90
Distance from planting (Km)	278	7,240	6,796	0.02	45

The average age of the heads of households of the producers surveyed is 46 years old. The youngest are 25 years old while the oldest are 79 years old. Households have an average of 12 members. However, it should be noted that some households have only one member. Since all household members cannot invest in the plantation for various reasons (age, schooling, other activities, etc.), family labor is on average less than the size of the household. It is 6 on average; some households do not have any at all and therefore resort to external (paid) labour. The number of plantations owned varies from 1 to 6 but the majority of respondents have a single plantation; the average number of plantations is thus 1.6. With regard to surface area, there are producers with holdings of less than one hectare while others have up to more than half a hundred (ie 53 hectares). Overall, a farmer owns 6.3 hectares. Regarding the age of cashew trees, there is a range of 2 to 35 years. To this end, the plans of the respondents are on average 13 years old. In addition, per hectare, respondents report the presence of 104 cashew trees on average. The minimum is 70 vines per hectare and the maximum is 150 vines per hectare. In terms of distance, the plantations are on average 7 km from the producers' homes; for some, this distance is 45 km; the nearest are less than a kilometer from their plantations. The time taken to get there is between 2 and 90 minutes, the average being 18.6 minutes. Besides, an average harvest of 2478 kg (more than 2 tons) is recorded. Among small producers, we observe 100 kg while the largest producers harvest up to 20,000 kg (20 tons). As for income, the average is 875,664 FCFA; the minimum income is 25,000 FCFA while the maximum is more than 7 million FCFA.

Depending on the adoption or not of good cultural practices (pre-harvest, harvest and post-harvest), the yield should vary. The direction of variation is studied within our study population.

4.2. Adoption of cultural practices and yield

It is important to remember that the yield is the quantity of nuts harvested and declared at the time of sale (kg per hectare). Since producers do not directly measure the quantity of nuts at harvest, certain post-harvest cultural practices have been added for the analysis of the link between yield and cultural practices. This is a study of the link between each practice and output, on the one hand, and an analysis of the simultaneous effects, on the other.

4.2.1. Descriptive analysis of the link between yield and agricultural practices

In this part, the mean difference is compared between the adopters of each practice and the non-adopters. These are the association of other crops with the cashew plantation, the creation of firebreaks, weeding, the size of the plants, the ventilation of the plantation, the collection method, the practice of drying, sorting of nuts and the use or not of jute bags for the storage of nuts.

4.2.2. Crop association and yield

The practice of intercropping involves using the spaces between cashew trees for the production of annual crops (such as maize, sorghum, cowpea, cassava, etc.). Depending on whether or not this practice is adopted, the yield changes as shown in Table 3.

Table 3 Average yield according to the association or not of crops

Crop Association		Mean	Standard. Err.	Standard. Dev.	[95% Conf. Range]	
No association	61	253.0917	16.09898	125.737	220.8889	285.2944
Association	217	403.3481	11.98865	176.6038	379.7184	426.9779
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-150.2565	24.18278		-197.8626	-102.6504

Pr (T < t) = 0.0000

The p-value of the t-test carried out on the yield averages of the adopters of the crop combination and that of the non-adopters of this cropping practice is almost zero (0.0000), which suggests the existence of a statistically significant difference. significant between the means of these two subgroups. In other words, the average yield varies significantly when moving from producers who do not practice intercropping to those who do. While the average yield is 253 kg/ha in the first, it is 403.3 kg/ha in the others, a difference of 150 kg/ha. The crop association improves the yield of the cashew tree per hectare.

4.3. Firewall and performance

The firewall is a cleaning of the surroundings of the plantation whose purpose is to create a barrier to fires coming from outside. The yield of plantations is often reduced when they are affected by bush fires. Table 4 offers a comparison of returns according to the adoption or not of this practice.

Table 4 Average performance according to the adoption or not of firewalls

Firewall	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
Absent	28	204.0062	17.22461	91.14407	168.6643	239.3482
Here	250	389.0119	11.10322	175.5573	367.1437	410.8801
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-185.0056	33.71266		-251.3722	-118.639

Pr (T < t) = 0.0000

From the analysis of Table 4, it appears that there is a link between the performance of the operation and the implementation or not of firewalls. Yield is significantly higher among growers whose plantations have firebreaks. The latter harvest an average of 389 kg of nuts per hectare. As for the others (those who do not practice firewalls), their average yield is 204 kg/ha. A net difference of 185 kg/ha is therefore noted between the two sub-groups from the point of view of yield.

4.4. Weed control and yield

Like the association of crops and the firewall, the average yield varies significantly depending on whether the producer weeds his plantation or not. Table 5 gives the details.

Table 5 Average yield according to weeding or not

Weeding	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
No weeding	27	238.5009	17.52869	91.08176	202.4701	274.5316
Weeding	251	384.5642	11.30851	179.1605	362.2921	406.8363
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-146.0633	34.99621		-214.9567	-77.16991

Pr(T < t) = 0.0000

Table 5 shows that the practice of weeding is accompanied by a relatively higher yield than that obtained in a non-weeded plantation. 384.6 kg/ha and 238.5 kg/ha are the respective average yields recorded among producers who adopt this cultural practice (weeding) and those who do not. The difference is 146 kg/hectare.

4.5. Pruning Practice and Yield

Pruning is a practice that consists of cutting certain branches of cashew trees in order to improve their yield. Table 6 presents the link between the practice of pruning and yield.

Table 6 Average yield according to pruning or not

Size practice	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
Uncut	43	228.822	11.03232	72.34375	206.5579	251.0861
Cut	235	396.28	11.69511	179.2826	373.2388	419.3211
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-167.4579	27.778		-222.1416	-112.7743

Pr(T < t) = 0.0000

From the analysis of Table 6, it appears that there is a significant difference in yield per hectare between the plantations that have been pruned and those that have not. Indeed, pruning is accompanied by high yields very close to 400 kg/hectare. On the other hand, the absence of this practice offers a yield slightly higher than 200 kg/ha. The average yield difference is 167.5 kg/ha.

4.6. Aeration of the plantation and yield

The aeration of the plantation consists, for the producer, in ensuring a good spacing between the cashew trees. This is a practice that improves productivity. Table 7 below offers a comparison of yields per hectare depending on whether the plantation is aerated or not.

Table 7 Average yield according to the ventilation of the plantation

Plantation Aeration	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
Not ventilated	48	249.931	17.41425	120.6495	214.898	284.964
Airy	230	395.515	11.71992	177.7414	372.4222	418.6076
combined	278	370.378	10.66595	177.837	349.3816	391.3748
Diff		-145.583	26.87886		-198.4971	-92.66988

Pr(T < t) = 0.0000

There is a significant difference between the yield of growers whose plantations are aerated and that of growers whose plantations are not. These yields are respectively 370.4 kg/ha and 250 kg/ha, a difference of 145.6 kg/ha. Aeration therefore improves farm performance.

4.7. Collection method and performance

Table 8 offers a comparative analysis of yields according to the mode of collection of nuts by producers. A very ripe nut falls by itself, without the need to pick it. But not all producers observe this principle. Table 12 shows the difference in yield according to the method of collecting the nuts.

Table 8 Average yield according to method of nut collection

Pickup	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
No fall	29	383.6371	34.79303	187.3662	312.3668	454.9074
Fall	249	368.834	11.21847	177.0245	346.7384	390.9296
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		14.80312	34.9454		-53.99027	83.59651

Pr(T < t) = 0.6639 Pr(T > t) = 0.6722 Pr(T > t) = 0.3361

Table 8 reveals an absence of significant difference between the performance of producers who pick up the fallen nuts on their own (fall) and those who pick the nuts instead (not fall). The average yields are respectively 368.7 kg/ha and 383.6 kg/ha, a difference of 14.8 kg/ha. However, as shown by the t-test, this difference in mean is not statistically significant. In addition, it is important to note that the majority of producers adopt pick-up after dropping: only 29 of respondents do not do so.

4.8. Drying and Yield

Drying is a highly recommended practice to ensure the quality of the harvested nuts. This makes it possible to best preserve the weight of the nuts until the moment of sale. The average yield depending on whether the producer practices drying or not is presented in Table 9.

Table 9 shows that the difference in average yields between producers who dry the nuts and those who do not is not significant at the 5% level. In addition, the table indicates that most of the producers surveyed adopt this practice (241 adopters against 37 non-adopters).

Table 9 Average yield according to drying or not

Drying practice	Obs	Mean	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
Not drying	37	348.6097	29.37052	178.6539	289.0436	408.1759
Drying	241	373.7202	11.45618	177.8477	351.1527	396.2877
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-25.1105	31.4209		-86.96556	36.74456

Pr(T < t) = 0.2124 Pr(T > t) = 0.4249 Pr(T > t) = 0.7876

4.9. Nut sorting and yield

Nut sorting (post-harvest) is one of the cultural practices that correlates with good yields (at the time of sale) in cashew production as shown in Table 10.

Table 10 Average yield according to the sorting of nuts or not

Nut sorting	Obs	Average	Standard. Err.	Standard. Dev.	[95% Conf.Interval]	
No sorting	69	260.3181	17.52895	145.6064	225.3396	295.2965
Sorting	209	406.7138	11.94909	172.746	383.157	430.2707
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-146.3958	23.11333		-191.8966	-100.895

Pr(T < t) = 0.0000

From the analysis of Table 10, it appears that the performance of producers who sort nuts is significantly different from that of producers who do not. Better yields are recorded among the former (those who sort nuts). Within them, the average yield is 406.7 kg/ha; during this time, it is 260.3 kg/ha among those who do not sort nuts. The difference is 146.4 kg/ha. In addition, the practice of sorting nuts is common among the producers surveyed. Indeed, of the 278 respondents, 209 observe the practice, against only 69 who do not.

4.10. Use of jute bags and yield

Storing the nuts in jute bags ensures their quality. This contributes to weight conservation before sale. Table 11 makes it possible to compare the yields according to the use or not of these jute bags for the storage of nuts among the producers surveyed.

Table 11 Average yield according to the use or not of jute bags

Use of jute bag	N	Mean	Standard. Err.	Standard. Dev.	[95% Conf. Range]	
No use of jute bag	56	277.3335	23.57028	176.3838	230.0976	324.5694
Use of jute bag	222	393.8489	11.45892	170.7341	371.2662	416.4317
combined	278	370.3782	10.66595	177.837	349.3816	391.3748
Diff		-116.515	25.70183		-167.112	-65.91897

Pr(T < t) = 0.0000

Table 11 reveals that the storage of nuts in jute bags is a common practice among the producers surveyed: 222 adopters against 56 non-adopters. As far as yield is concerned, it is much higher among users of jute bags. Their yield is on average 393.8 kg/ha. For the others, it is rather 277.3 kg/ha. The yield difference is therefore 116.5 kg/ha.

4.11. Synthesis

From the descriptive analysis of the link between the adoption of cultural practices and yield (Tables 3 to 11), it appears that only two of the practices have no significant link with yield. This is the mode of collecting nuts and drying. On the other hand, the adoption of the following practices is accompanied by better yields: the association of crops, the construction of firebreaks, weeding, the practice of pruning, the ventilation of the plantation, the sorting of nuts and the use of jute bags for storage. We note that for all the good pre-harvest practices, the difference in yield is significant. For all of them, these returns are better for adopters compared to non- adopters. In addition, among post-harvest practices,

4.11.1. Explanatory analysis: effects of cultural practices on yield

In order to appreciate the effect of each of the cultural practices on the yield (in the presence of the others), a linear regression model was established. It consists in explaining the return by the variables having shown a significant difference in return according to their modalities. The results of the estimation of this model are summarized in Table 12.

Table 12 Estimation of the model explaining the yield by the cultural practices

Yield	Coeff.	Standard. Err.	you	P>t	[95% Conf. Range]	
Association cultures	101.0177	22.46872	4.50	0.000	56.78151	145.2539
Firewall	153.5729	24.12652	6.37	0.000	106.0728	201.0729
weeding	121.2163	22.50913	5.39	0.000	76.90056	165.532
Cutting	74.35774	22.85448	3.25	0.001	29.36209	119.3534
Aeration	-1.871879	28.74746	-0.07	0.948	-58.46956	54.72581
Nut sorting	63.50794	25.23872	2.52	0.012	13.81823	113.1977
Jute bag use	30.94183	28.9725	1.07	0.286	-26.0989	87.98256
_cons	-89.78413	38.40543	-2.34	0.020	-165.3963	-14.17194

Number of observations = 278; F (7.270) = 22.00; Prob>F = 0.000; R-Squared = 0.3373; Root MSE = 146.63

The p-value of the Fisher test is almost zero, which suggests that the model is globally significant at the 5% level. Some of the variables significantly associated with performance (in the descriptive analysis) turned out to be non-significant in the presence of the others. These are the ventilation of the plantation and the use of jute bags for the storage of cashew nuts. The practice of annual crops in the plantation allows a yield increase of 101 kg/ha. The same is true for the construction of firebreaks, and this to a relatively greater extent: the yield increases by 153.6 kg/ha. As for weeding, it allows an increase in yield up to 121.2 kg/ha. In addition, the practice of pruning and sorting nuts allow an increase in yield but of less than 100 kg/ha.

4.12. Analysis of the adoption rate bias and proposal for a new method of calculation

From the results of the regression model, it appears that the p-value of the Fisher test is very close to 0. This confirms the existence of at least one cultural practice whose behavior with respect to yield is significantly different from that of others. In other words, the weight of at least one of these practices is different from that of the others. Under this assumption, remember that each regression coefficient should not be significantly different from $\frac{1}{n}\sum_{i=1}^{n}\widehat{\alpha_i} = 90.77$. This hypothesis is verified through the results of individual statistical tests, the results of which are presented below.

Table 13 Fisher’s statistics and p-value of each cultivation practice

Cultivation practice	Fisher's statistics	P-value
Association of cultures	0.17	0.6825
Firewalls	4.34	0.0382
Weeding	0.98	0.3235
Cutting	0.36	0.5515
Sorting	1.19	0.2756
Use of jute bags	5.85	0.0162

It appears that the implementation of firewalls and the use of jute bags have statistically different coefficients of 90.77. This makes it possible to deduce that there is at least one practice for which the coefficient differs significantly from 90.77. The null hypothesis is therefore rejected. As a corollary, the weights associated with the different practices are not equal.

Considering 6 practices, under the hypothesis of equality, the weight would be 1/6=0.17. This is not the case as shown in Table 14.

Table 14 Associated weights of the cultural practices

Cultivation practice	Coeff.	Weight
Association cultures	101.018	0.19
Firewall	153.573	0.28
Weeding	121.216	0.22
Cutting	74.3577	0.14
Nut sorting	63.5079	0.12
Jute bag use	30.9418	0.06

Table 14 clearly shows that the weights calculated on the basis of the regression coefficients are different from each other and different by 1/6.

On the one hand, the current method of calculating the rate of adoption of cultural practices minimizes the weight of the following practices:

- Weeding;
- Firewall;
- Association of cultures.

On the other hand, it maximizes that of practices:

- Use of jute bags;
- Cutting ;
- Sorting nuts.

The most appropriate approach for calculating the rate of adoption of the six (6) cultural practices (in the population studied) is therefore as follows:

$$\mathbf{t_a = 0.19 * AsCult + 0.28 * Pf + 0.22 * Dh + 0.14 * Cut + 0.12 * Sort + 0.06 * Jute}$$

With, AsCult: Association of cultures; Pf: Firewall; Dh: Weeding; Cut: Cutting; Sort: Nut sorting; Jute: Use of jute bags.

Table 15 shows the values of the adoption rate according to the two approaches (the existing approach and the proposed approach) at the global level.

Table 15 Adoption rate according to the 2 approaches

	Average	Standard Error	Confident Interval (95%)	
Rate (existing approach)	0.8297362	0.0125391	0.8050522	0.8544202
Rate (proposed approach)	0.8552158	0.015802	0.8324195	0.8780121

The existing approach gives 83% while the proposed approach gives 86%, a difference of 3%. In the population studied, the rate of adoption of cultural practices is therefore minimized by 3% for the six practices considered.

5. Discussion

The results of this study indicate the existence of various effects of cultural practices on the yield of cashew plantations. This is in accordance with the work of Basse et al (2022) who were interested in the impact of good cultural practices on cashew productivity in Senegal. [22]. Earlier (2019), Diop achieved the same results by studying the impact of the adoption of good agricultural practices on the yield of cashew plantations in the Kolda Region (Senegal) [23].

However, this research suffers from some weaknesses. Correcting these weaknesses requires time and financial resources that this study did not have. These shortcomings relate to the following aspects:

- **The data collection:** The data used comes from exchanges with producers. Although technical arrangements are made to obtain the most conclusive data, there could be a degree of subjectivity with regard to the declarations. To this end, it would be more judicious to carry out an experimental study which will consist of implementing the various cultural practices in experimental fields. Variations can thus be noted directly. This minimizes the risk of error, overestimates and underestimates of returns.
- **In homogeneity of plantations:** Another shortcoming is the fact that the producers' plantations are not necessarily homogeneous, for example, they are not the same age, the soils are not of the same type (some are more fertile than others, etc.), the different practices are not observed at the same time, the climatic conditions (temperature, air) could differ from one environment to another, etc. Thus, these differences in factors could interfere in the performance. It would therefore be important to take this heterogeneity into account in the analyses.
- **The type of data:** The data used was collected during the same year. This therefore does not take into account the climatic dynamics that are underway almost everywhere in the world. To correct this, a longitudinal study would be appropriate. It would make it possible to take into account any climatic variations as well as the age of the plantations.
- **The scope of the study:** It is important to note that the data used in this work are for simulation purposes in order to show the existence of biases in the existing calculation approach. We are aware that the data of the Commune of N'Dali cannot represent that of all the cashew production areas in Benin, let alone the world. Extending this study to a relatively larger field would allow conclusions to be drawn that apply to a larger population, or even the entire world. A worldwide study would make it possible to obtain more appropriate weights which could be generalized.

6. Conclusion

The present study aims to contribute significantly to improving the calculation of the rate of adoption of good cultural practices in cashew production, taking into account the various nuances and associated implications. The methodological approach adopted to achieve this objective was rigorous and comprehensive.

Firstly, the study highlighted the shortcomings of the current calculation model, which gives uniform weight to all cropping practices. This uniformity of weighting does not take into account variations in the effect of each practice on the yield of cashew cultivation. The results obtained clearly demonstrated that certain practices, such as aeration and the use of jute bags, did not have a significant impact on yield.

On the other hand, among the practices that demonstrated a significant effect (p-value < 0.05), the associated coefficients vary statistically. This finding highlights the importance of taking these differences into consideration for a more accurate assessment of the rate of adoption of cultural practices.

Secondly, based on the values of the various coefficients, a proposal for a new method of calculating the rate of adoption of cultural practices was put forward. This approach takes into account variations in the effect of each practice and allows for more precise weighting, thereby more accurately reflecting the true impact of different practices on overall performance.

The comparison between the two rates of adoption, calculated according to the existing approach and the new approach, made it possible to note that the first minimizes the rate of adoption of the cultural practices. This observation underlines the crucial importance of updating calculation methods in order to promote a more balanced adoption of good cultural practices in cashew production.

In view of the results of the study, several recommendations are necessary for the stakeholders concerned:

- For the attention of actors involved in the promotion of the cashew sector: It is essential to take into account the relative weights of farming practices when calculating the adoption rate. An in-depth and explanatory analysis of the yield of the plantations is necessary in order to determine these relative weights with precision.
- To the scientific community: Extensive and experimental research is needed to achieve harmonization of the weights attributed to the different cultural practices in cashew production. These studies must take into consideration the specific properties and characteristics of the plantations, thus guaranteeing the universality of the resulting weights.

Compliance with ethical standards

Acknowledgements

- Pan African University Institute for Basic Sciences, Technology and Innovation (JKUAT)
- Ecole Nationale de Statistique, de Planification et de Démographie (ENSPD)

Disclosure of conflict of interest

The authors do not declare any conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] BCE, "Comment l'innovation est-elle vecteur de croissance ?," Banque Centrale Européenne, 2017.

[2] B. Mouhamadou Djima, B. Youssouf, I. Mohamed A. S. , O. Michael Arthur , K. Tina Confort and L. Amos Kipkorir, "Analysis of the Determinants of Premarital Fertilityin Benin using Cox's Survival Model," International Journal of Innovative Science and Research Technology, pp. 82-90, July 2023.

[3] B. Mouhamadou Djima, K. Tina Confort, I. Mohamed Adam Suliman, O. Michael Arthur, B. Youssouf and L. Amos Kipkorir, "Premarital Fertility in Benin: Trends and Disparities," International Journal of Research Publication and Reviews, vol. 4, no. 7, pp. 1291-1297, 2023.

[4] J.-P. Chauveau, L'étude des dynamiques agraires et la problématique de l'innovation, Marseille: IRD Éditions, 2018, p. 326.

[5] G. Hervé, "L'agriculture au cœur de l'avenir de l'Afrique," Politique étrangère, pp. 265-276, 2009.

[6] PAC, "Evolution du trafc marchandises : période 1999 à 2008," Cotonou/Bénin, 2009.

[7] A. Matthess, "Atelier de validation de la stratégie et d'élaboration du Plan d'action de la flière anacarde du Bénin," Cotonou/Bénin, 2008.

[8] K. Issaka, "Production de noix de cajou au Bénin : Etat des lieux et perspectivespour 2019," World Cashew, Abu Dhabi, 2019.

[9] A. M. Balasha and N. M. Fyama, "Déterminants d'adoption des techniques de production et protection intégrées pour un maraîchage durable à Lubumbashi, République démocratique du Congo," Cah. Agric., pp. 1-11, 2020.

[10] B. C. Belem, "Analyse des déterminants de l'adoption des bonnes pratiques de production de l'anacarde au Burkina Faso," Québec / Canada, 2017.

[11] K. Oleh, "Les déterminants de l'adoption des innovations culturales en milieu rural : illustration à partir du cas du soja introduit par le CNRQ (Centre National de Recherche Agronomique) dans la Région nord de la Côte d'Ivoire," Rev iv hist, pp. 140-156, 2013.

[12] A. Teissonnier and E. Penot, "Analyse des modes d'appropriation et d'adoption des techniques de l'agriculture de conservation hors projet dans la zone du lac Alaotra, Madagascar," cirad, pp. 1-36, 2013.

[13] E. Groulx-Tellier, Facteurs influençant l'adoption de bonnes pratiques agroenvironnementales par les producteurs de grandes cultures dans le bassin versant de la rivière Châteauguay, Québec: CENTRE UNIVERSITAIRE DE FORMATION EN ENVIRONNEMENT, 2012.

[14] A. Bouzid, K. Boudedja, F. Cheriet, M. Bouchetara and A. Mellal, “Facteurs influençant l’adoption de l’innovation en agriculture en Algérie. Cas de deux cultures stratégiques : le blé dur et la pomme de terre,” Open Science, pp. 1-10, 2020.

[15] J. Smith, K. Brown and M. Johnson, “Assessing the adoption of soil conservation practices: A review of methods and approaches.,” Environmental Management, vol. 6, no. 12, pp. 193-206, 2018.

[16] R. Johnson, L. Rodriguez and D. Martinez, “Adoption of agroforestry practices by smallholder farmers: A review,” Agroforestry Systems, vol. 93, no. 3, pp. 917-935, 2019.

[17] F. C. Garcia, L. M. Castro and C. B. Martinez, “Determinants of water conservation practices adoption in agriculture: Evidence from a logistic regression analysis in Spain.,” Spanish Journal of Agricultural Research, vol. 15, no. 4, 2017.

[18] T. T. Nguyen, T. H. Dinh and P. T. Ho, “Determinants of sustainable agricultural practices adoption: A case study of smallholder farmers in Vietnam,” Journal of Asian Rural Studies, vol. 4, no. 1, pp. 60-71, 2019.

[19] J. H. Jones, J. M. Dwyer, W. J. Pritchard and M. A. Cavigelli, “Understanding soil conservation decisions using a socio-ecological framework,” Agriculture and Human Values, 2017.

[20] Z. Wang, X. Huang and A. Ding, “Dome effect of black carbon and its key influencing factors: A one-dimensional modelling study,” Atmospheric Chemistry and Physics, vol. 18, no. 4, p. 2821– 2834, 2018.

[21] T. W. Valente, “Social Networks and Health: Models, Methods, and Applications,” Oxford University Press, 2010.

[22] B. W. Basse, S. Mbaye and O. Diop, “Impact des bonnes pratiques agricoles sur le rendement des cultures d’anacarde (noix de cajou) au Sénégal,” ISTE OpenScience, pp. 1-15, 2022.

[23] O. M. Diop, “Impact de l’adoption des bonnes pratiques culturales sur les rendements des producteurs d’anacarde dans le département de Kolda,” Université Assane Seck de Ziguichor, 2019.