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The Impact of Conservation Agriculture Practice and Socio-Economic Factors on Yam Production (*Dioscorea alata and Dioscorea rotundata*) in Kalagoé (Lobaye, Central African Republic)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Few studies have been carried out on Yam (*Dioscorea alata* and *Dioscorea rotundata*) in relation with the conservation agriculture in CAR. Yam is cultivated in limited quantities despite its role in improving food security. In order to increase Yam production in the smallholder farms in CAR, the potential effect of crop management practices like nutrient application, mulching and

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minimum tillage on Yam crop yield and household financial returns, needs to be understood. A questionnaire was prepared and used as a tool for the collection of information from 100 producers of Yam without distinction of ages and sexes. In order to determinate the agronomical performance of Yam, two plots were explored. The first plot with 625m² (12.5m ×50m), known as the improved plot, is a plot on which all conservation agriculture practices were applied. The second plot, known as the traditional plot, is one on which traditional farming techniques were applied. The results of the survey show that 32% of the farmers are in favor for CA practice nevertheless 68% are not favor, which shows that a large proportion of farmers in Kalangoé are not aware of the benefits of this technique. The most widely cultivated variety is *D. rotundata*, because of its taste qualities. Some producers also grow both varieties at the same time. Some producers (28%) clear their plots by cutting down all the trees to leave the field bare, while a large number (72%) practice partial cutting by removing the shrubs to keep the large trees in order to protect the forest. A large number of producers (62%) also burn their plots for various reasons, including freeing up space and making it easier to move around the field because the plant debris from clearing prevents them from working properly. A small proportion of producers (26%) practice ploughing against 74% who do not practice this technique. The conservation agriculture practice applied to Yam gave interesting agronomic performances (growth and production parameters) than the farmers practices.

Keywords: Conservation agriculture; farmers practices; agronomic performances; socio-economic; yam.

1. INTRODUCTION

In Africa, agriculture is subject to numerous difficulties that hinder the achievement of food security and Central African Republic (CAR) is not an exception. These challenges include soil infertility due to poor management practices, poor diversification, and declining crop productivity [1]. Stakeholders have advocated for conservation agriculture as one of the panacea to problems caused by conventional agriculture in that it has the potential to redress declining soil fertility, improve crop productivity and increase profits as well as household food security [2,3] Conservation agriculture employs the principles of; minimum mechanical soil disturbance, permanent organic soil cover with crop residues or cover crops [4,5] diversified crop rotations [6,7] and appropriate use of inorganic fertilizers [8,9]. For the conservation agriculture to address the problems related to smallholder farming systems, there is a need for identification of effective region-specific conservation agriculture options for resource-poor farmers [10].

Few studies have been carried out on Yam (*Dioscorea alata* and *Dioscorea rotundata*) in relation with the conservation agriculture in CAR. In CAR the Yam is cultivated in limited quantities despite its role in improving food security. The Yam is one of the less important crops, relegated to second place in favor of cassava [11]. In order to increase the Yam production in the smallholder farms in CAR, the potential effect of crop management practices like nutrient application, mulching and minimum tillage on Yam crop yield and household financial returns, needs to be understood.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The study was conducted in the village of Kalangoé, in the region of Lobaye in Central African Republic. Kalangoé is located at 42 km from Bangui (Fig. 1). The type of climate is the Guinean forest with the alternation of two seasons: a rainy season which runs from March to mid-December and a dry season from January to February. The annual mean maximum of temperature is 30.65 ° C. The differences between the minimum and the average maximum are moderate (11.44 ° C). The average annual rainfall is in the order of 1600 mm / year and the soil has a sandy clay texture [12]. The forest area presents a very great forest diversity and a whole range of forests ranging from the dense humid forest of low altitude south of the 4th parallel to the dense dry forest north of the 4th parallel interspersed by savannas. This vegetation consists of reworked forest, secondary with *Triplochiton scleroxylon* and *Terminalia superba* [13]. Yam producers in this locality had received the technical support from the Project of Development of South-West Region (PDRSO) in CAR which was

implemented by the CAR Ministry of Water and Forests.

2.2 Field Survey and Focus Group

A questionnaire was prepared and used as a tool for the collection of information from 100 producers of Yam without distinction of ages and sexes. The questionnaire focused on the perceptions of CA techniques, farmers practices for yam production, the different grown accessions, strategies for selling freshly harvested tubers, and problems concerning the production and marketing practices, diseases and pests against stored product and the management of pests and diseases. The local authorities of Kalangoé played a facilitating role during the discussions which helped to collect the necessary information. The survey method consisted of interviewing each producer individually. Qualitative data (perception of the population, socio-economic characteristics, farming practices, the different varieties grown, problems encountered in production and marketing, and the origin of buyers) and quantitative data (farm yields, marketing prices, farm income) were collected ([14], [15]).

2.3 Cropping System and Experimental Design

The first plot with 625m² (12.5m ×50m), known as the improved plot, is a plot on which all conservation agriculture practices have been applied. Tillage treatments remained on the same plots and the crops were rotated through these each year in a Maize, Groundnut and Cowpea crops depending on the farmer and the marketing value of the cultivated leguminous crop in the village. There was no removal of crop residues from Maize, Groundnut and Cowpea crops plots during or after harvesting operation. The Bananas were harvested manually in accordance with local practice to reduce losses of bunches , with mature plants pulled by hand at ground level bunches of threshed, with crop residues not returned to plots ([16], [17]).

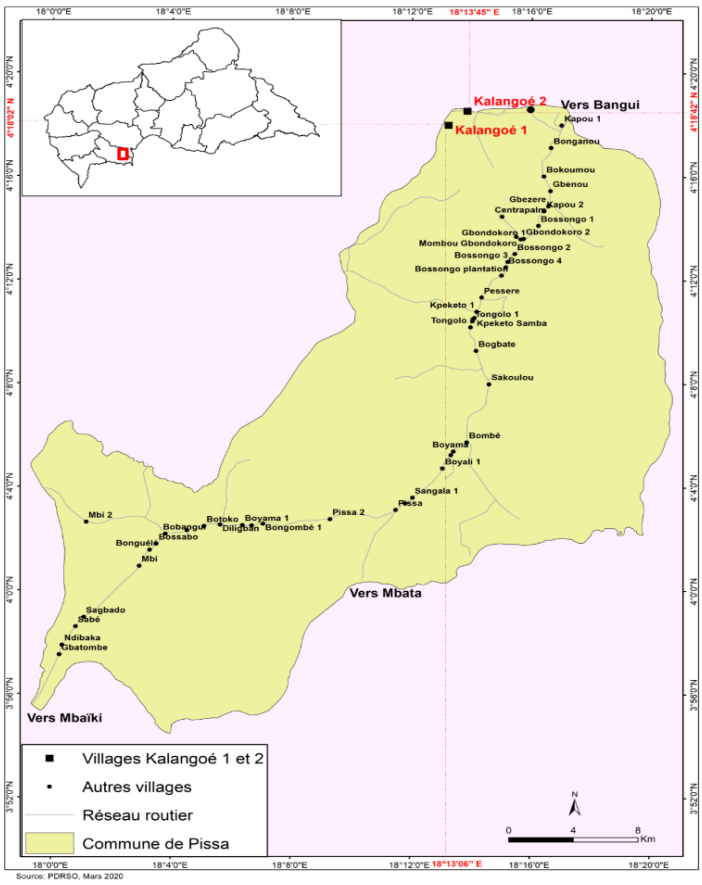

Fig. 1. Location of the study area

The second plot, known as the traditional plot, is one on which traditional farming techniques were applied. The CA systems tested correspond to minimum of tillage plus Yam (*Dioscorea alata* and *Dioscorea*) in association with banana crop plus taro (*Colocassia esculenta* L.) plus plant cover [18].

2.4 Measured Parameters and Data Analysis

Parameters such as tuber length, width, weight and girth were measured on a sample of 40 tubers per selected at random plot and the yield was then extrapolated in tons per hectare.

The survey data were performed with XLSAT 2008 software, according to sex and age group. The effect of the accession factor on the different agronomic parameters was assessed by means of analysis of variance (ANOVA) with one classification criterion using the R software version 3.1.3. The Shapiro-Wilk test was used to verify the normality of the data and the different tests were validated at the 5% threshold. The different graphs were realized with the Excel spreadsheet.

3. RESULTS

3.1 Profile of Yam Surveyed Producers

The majority of the surveyed producers are adults (80%) followed by young people (18%) and the elderly (2%) (Fig. 2). The majority of the respondents were men (60%) compared to 40% of women.

3.2 Cultivation Site and Cropping System

Yams need fertile soil and a high requirement for sunlight, as well as a minimum of moisture for their growth. Thus, the majority of Yam producers (50%) claim to grow yams both in the savanna and in the forest, while some prefer only the savanna (20%) and only the forest (30%) (Fig. 3).

Yam is most often grown in Kalangoé village in association with other crops, the main are banana, taro, maize, cassava and groundnuts.

3.3 Motivation of Yam Surveyed Producers Concerning the Conservation Agriculture

The results of the survey show that 32% of the farmers are in support of CA practice nevertheless 68% do not, which shows that a large proportion of farmers in Kalangoé are not aware of the benefits of this technique. Thus, the forest conservation and increased soil productivity are the most cited motivations by the Yam surveyed producers (Fig. 4).

3.4 Varieties Grown

Two varieties of yam are cultivated in Kalangoé (*D. alata* and *D. rotundata*). The most widely cultivated variety is *D. rotundata*, because of its taste qualities. Some producers also grow both varieties at the same time (Fig. 5).

3.5 Timing of Yam Cultivation

The period of planting Yams is between the months of March and April because of the first rains (Fig. 6).

3.6 Harvest Time of Yam

Yam producers detect the maturity of tubers by the drying out of the leaves, some producers harvest before the tubers mature. The harvest period for the majority of producers is between December and January but also between November and December (Fig. 7).

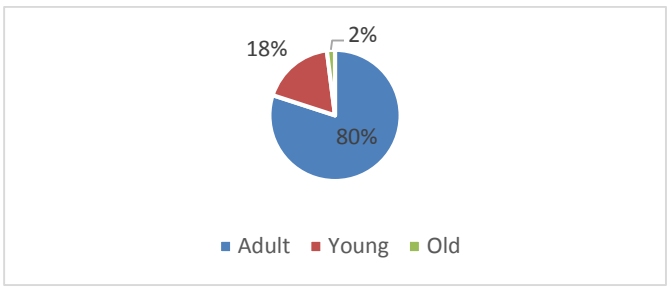

Fig. 2. Proportion of different age of surveyed producers

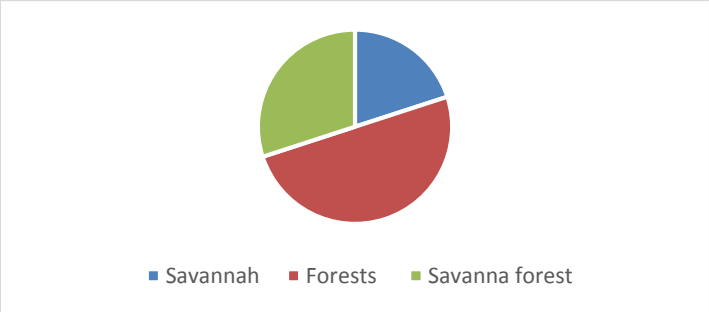

Fig. 3. The different locations of yam cultivation

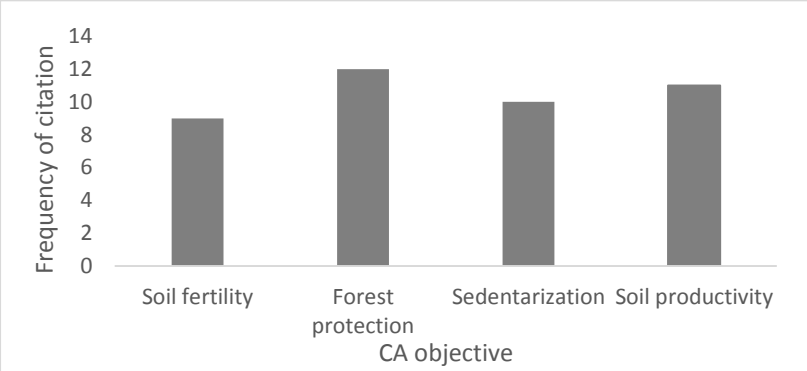

Fig. 4. Motivation for Conservation agriculture practice

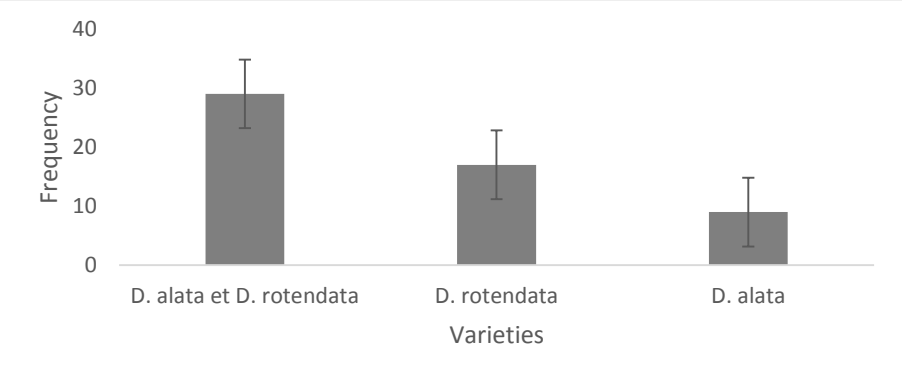

Fig. 5. Frequency of cultivated Yam varieties

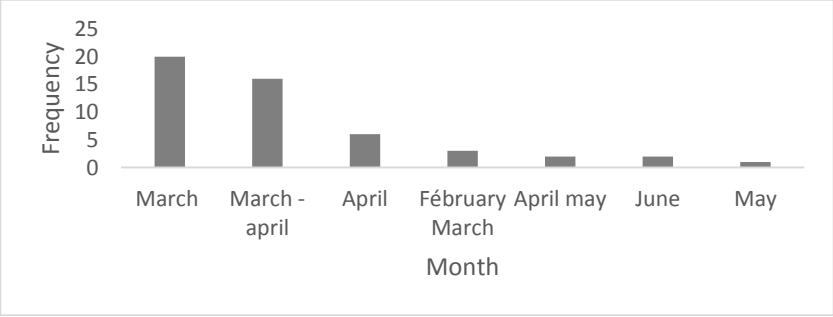

Fig. 6. Periods of yam cultivating at Kalangoé

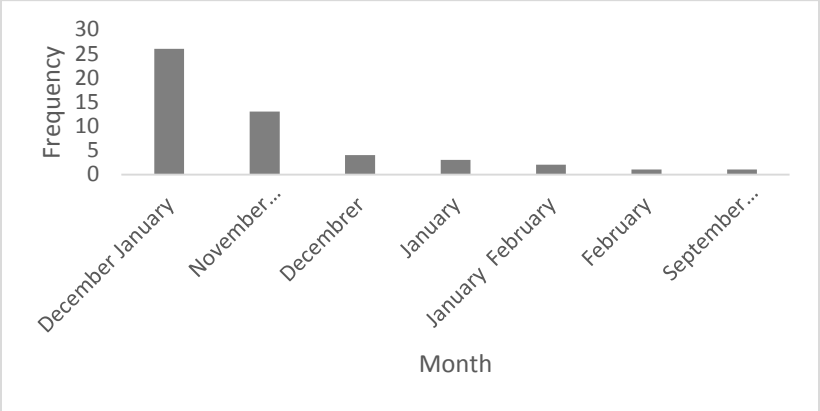

Fig. 7. Harvesting period for yam

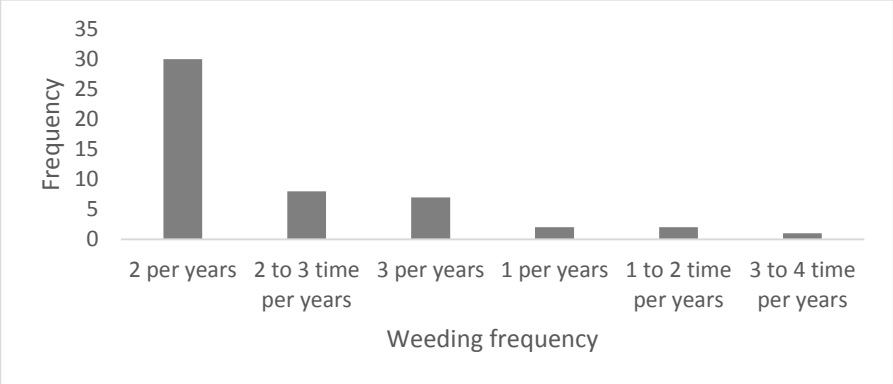

Fig. 8. Frequency of maintenance of yam fields per year according to producers

3.7 Soil Preparation

Some producers (28%) clear their plots by cutting down all the trees to leave the field bare, while a large number (72%) practice partial cutting by removing the shrubs to keep the large trees in order to protect the forest. A large number of producers (62%) also burn their plots for various reasons, including freeing up space and making it easier to move around the field because the plant debris from clearing prevents them from working properly. A small proportion of producers (26%) practice ploughing against 74% who do not practice this technique.

3.8 Yam Crop Maintenance

Crop maintenance is one of the most effective means of obtaining expected yields. Thus, the number of times a yam plot is weeded depends on the producer. Many farmers weed twice or 2-3 times per year (Fig. 8). The survey also revealed that neither fertilizers nor insecticides are used in yam cultivation in the study area.

Table 1. Average income by type of economic activity in Kalangoé villages

Headings	Amount (F.CFA per farmer)	Equivalent in USD
1. Non-agricultural activities	158 000	315
2. Cassava cultivation	59 400	118.8
3. Palm wine	43 167	86.33
4. Firewood, sawdust and charcoal	36 607	73.21
5. Forest crops (plantain and taro)	24 067	48.13
6. Market gardening	7 533	15.06
7. Gathering and hunting	2 067	4.134
8. Yam	20900	41.8

Table 2. Identified constraints and proposed actions for improvement

Type of constraints	Description	Proposed actions improvement / Strengths
Socio-economic	• Total lack of knowledge of the socio-economic role of yam cultivation by the population • - Early harvesting • - Permanent risks of theft • - Risks of possible damage caused by bush fires • - Activity practiced mainly by adults. • - No association of yam producers in the village	• - Some farmers are interested in growing yams; • - To sensitize these producers and others to inculcate in them the desire and the importance of this culture; • - Encourage the involvement of youth and women in this activity; • - Support the creation of an association of yam producers; • - Create conditions for the delivery of products in super markets, hotels, restaurants, etc.
Technical	• - No technical support services • - Lack of knowledge of technical itineraries; • - No extension of yam cultivation techniques in the village • - Poor cultivation practices (burning, poor planting of seedlings, etc.)	• Set up an adapted support-advisory system to improve practices
Phytopathological and environmental	• - Prevalence of diseases and pests • - Climatic variability	• - Provide appropriate crop protection products and teach them how to use them to treat crops when needed; • - Initiate producers to adapt to climate change
Materials/equipment	• - Difficulty in saving good quality seed • - No use of fertilizers	• - Provide essential inputs and the right way to use them according to the respective role • - Training for the establishment of good quality nurseries

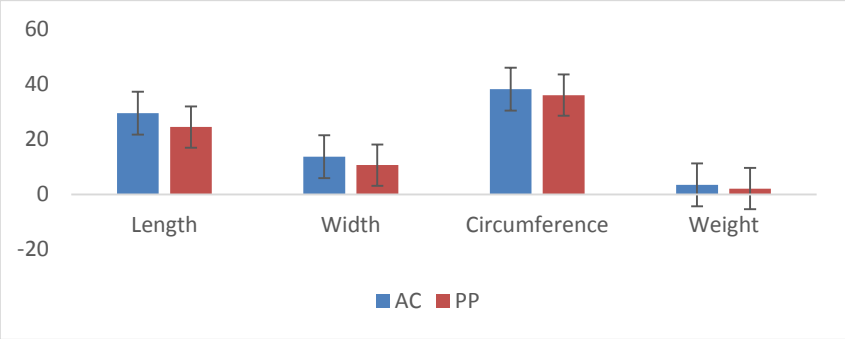

Fig. 9. Agronomic parameters according to conservation agriculture and farmers practices (FP)

Table 3. Results of the ANOVA on agronomic parameters

Parameters according to the two types of practices	P-value
Tuber width	0.0239 *
Tuber length	0.00106 **
Tuber circumference	0.00106 **
Tuber weight	0.0212 *

3.9 Socio-economic Importance of Yam Production in the Study Area

The analysis of socio-economic importance of yam production takes into account the income of producers. The sale of yams provides income to producers even though the conditions for the production of this crop are not met; the income resulting from these sales is not negligible. One yam plant produces two to three tubers, with a minimum price of 1 USD per tuber.

Assuming that a producer has ten yam plants and improves production techniques, the level of his production will improve and the sale of his harvest could generate an income of at least 40 USD /production. The revenue from the sale of yams can be used to improve cultivation techniques in order to increase the quantity and quality of production. They are also used to provide the scholar fees for children, health costs, food, etc., for the producers families.

The data collected from yam farmers show that the income generated by the sale of this crop contributes significantly to the overall income of the farmer (Table 1).

3.10 Analysis of Constraints and Proposals for Improvement

Four main factors limit the development of yam cultivation in Kalangoé. Table 2 contains the nature of the constraints identified and the proposed solutions.

3.11 Comparison of Agronomic Performance between the Conservation Agriculture to Farmers Practices

The conservation agriculture practice applied to Yam gave interesting agronomic performances (growth and production parameters) than the farmers practices (FP). The differences obtained are statistically different according to Table 3.

The difference observed is significant for tuber width and weight but highly significant for tuber length and circumference (Table 3). The yield obtained on the CA plots was 6.560 T/ha compared to 3.136 T/ha on the PP plot.

4. DISCUSSION

The results of the survey show that 32% of the farmers are in support of CA practice nevertheless 68% are not. The motivations for adopting CA techniques include forest conservation and increased soil productivity. Conservation agriculture is less developed for two reasons, namely acceptance, which differs from one region to another, and the unfavorable climate in some regions ([19], [20]). However, CA is the way forward for agricultural development in Africa [21].

Two varieties of yam (*D. alata* and *D. rotundata*) are cultivated in Kalangoé. The most widely cultivated variety is *D. rotundata*, because of its taste qualities. Some producers also grow both varieties at the same time. The association of *D. cayenensis* and *D . rotundata* is very appreciated in Ivory Coast. In fact, the lumpiness and springiness of the mass varied markedly with species. Greyish colour, fibre content, easiness to mould and sweetness differed among the varieties. Preferences were tested by a group of traditional yam consumers. foutou made from *D. cayenensis*-rotundata was preferred due to textural attributes. foutou made from *D. alata* was disliked [22].

The period of Yams planting is between the months of March and April because of the first rains. The harvest period for most producers is between December and January, but also between November and December. Although many producers harvest early, some do so after full maturity. The majority of those surveyed (50%) stated that they grow yams both in the savannah and in the forest, while some prefer only the savannah (20%) and only the forest (30%). The yam belt of West Africa spans from the humid forest where yam is cultivated for food security to the northern Guinean savanna where yam is also cultivated as a cash crop ([23], [24]). Yam is traditionally planted as the first crop, after a long-term fallow as it is considered to be demanding in terms of soil fertility [25]. In the following years, the field is cultivated with other staple crops and/or perennial crops. Yam is usually grown without any external input using own tubers as planting material (so called yam seed). In areas where land is scarce, farmers grow yam after only a year of fallow or without fallow [26]. In Benin, the yam cultivation needs a fertile soil and a high requirement for sunlight but also a minimum of moisture for its growth [27].

Yam is not one of the most popular crops in Kalangoé, and is most often grown in association with other crops, the main ones being plantain, taro, maize, cassava and groundnuts. Some producers (28%) clear their plots by cutting down all the trees in order to leave the field bare, while a large number (72%) practice partial cutting by removing the shrubs in order to preserve the large trees in order to protect the forest. A large number of producers (62%) also burn their plots for various reasons, including freeing up space and making it easier to move around the field, as the plant debris from clearing prevents them from working properly. Yam cultivation is not practiced consecutively on the same plot and the crop rotation system is recommended to maintain and improve soil fertility ([28], [29]). But beyond this requirement, which makes yam a space-consuming crop and contributes to environmental destruction, *Dioscorea* is produced either in pure monoculture or in polycultural associations. Alternative to sustain plant nutrition are the use of less demanding yam cultivars, to make a better use of microorganisms fostering plant nutrition, to intercrop yam with legumes, to add organic mulch, or to recycle wastes as sources of nutrients. Current research is identifying cultivars of *D. alata* able to produce large tuber yields when planted in acid, alkaline or saline soils ([30], [31]).

The low yields observed on farmers plots can be explained by the fact that the shifting cultivation adopted techniques by farmers do not allow for the maintenance of soil fertility, and therefore not enough humus or organic matter (OM), as these were destroyed by fire during the establishment of the crop. The shifting cultivation practices negatively influence yam yields [32]. On the other hand, the fairly high trend in yam tuber yields on plots that received Conservation Agriculture techniques is only the consequence of this practice. The maintenance of fertility and therefore the loosening of the soil, which creates favorable conditions for the development of tubers and mineral nutrition ([33], [34]).

5. CONCLUSION

The results of the study show that only 32% of the producers are in favor of adopting CA techniques. The motivations for adopting these techniques are forest conservation and increasing soil productivity. In Kalangoé, two varieties of yam are grown, *D. alata* and *D. rotundata*. Some producers (28%) clear their plots by cutting all the trees while others (72%) practice partial cutting by removing only the shrubs. The practice of burning plots is also recurrent (62%) in order to get rid of the vegetation debris resulting from clearing. Plowing is practiced by the majority of producers (74%) because of its importance for crops associated with yams. The sale of harvested products is done in the village (76%).

Further research is needed across the agro-climatic zones that should address in detail the effects of various types of CA, crop rotations and mulch covers on weed management, on nutrients, pests and water management, on

residue levels, sowing depths, dates and density, and on fertilizer rates.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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