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Using Production Innovations to Reduce Climatic Shocks: Insights from Cocoa Farmers in Santchou, West Region, Cameroon

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ABSTRACT

In tropical Africa, agricultural systems are highly vulnerable to the vagaries of weather. This study seeks to establish the nexus between climate change and production innovations adopted by cocoa farmers and stakeholders. Adopting a mixed methods approach, questionnaires were administered to 101 purposively selected cocoa farmers and in-depth interviews were carried out with 11 stakeholders of the cocoa sector. Climatic data for the period 1981 to 2019 was downloaded from NASA power. Quantitative and qualitative analysis of the data collected revealed a falling trend for cocoa yields due to a change in climatic conditions. The study found that cocoa production innovations have been adopted by farmers. Improvement in the construction of nurseries (27.7%), spacing of cocoa plants (17.8%), timing in fertilizer application and cocoa treatment (20.8%), use of improved seedlings (33.7%) have lessened the adverse effects of climate on cocoa production. It was revealed that regular follow up is important to detect diseases or pests quickly and take timely and appropriate actions while the spacing of cocoa trees can be modified to increase yields and minimize the impacts of climate change. Proper fertilization helps improve resistance to pests and diseases and enhance plant ability to withstand climate extremes. However, cocoa farmers have challenges adopting these innovations due to their technical, financial and information limitations. The adoption of innovations needs to be enhanced through capacity building, information dissemination and financial assistance to farmers.

Key words: Climatic shocks, cocoa production, production innovations, adaptation, Santchou

INTRODUCTION

Climatic factors (temperature, rainfall, humidity and sunshine) are essential for the growth of the cocoa crop (Owoeye & Sekumade, 2016), but the major determinants of cocoa growth are temperature and rainfall (Tosam & Njimanted, 2013). In the humid tropics, these conditions have made cocoa production an important economic activity, contributing significantly to the gross domestic product of many countries, including Cameroon. Cocoa is a tropical crop grown in most tropical areas in the world such as Brazil and Indonesia, with roughly about 70% of the world's total outputs produced by West African countries such as Ghana, Ivory Coast, Nigeria and Cameroon (Schroth et al., 2016). This is due to the availability of favorable cocoa production conditions in these areas such as the soil types and the climate found among countries along the West African coastline.

However, climatic shocks associated with prolonged drought does not only make it difficult to establish new cocoa farms (Anim-Kwapong & Frimpong, 2004) but results in a reduction in Leaf Area Index (LAI) leading to a reduction in cocoa yields (Adjei-Nsiah & Kermah, 2012). Changes in temperature during critical growth period, such as flowering causes a reduction in seed numbers and high evapotranspiration which affects the plant water demand (Challinor & Wheeler, 2007).

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According to Oyekale (2015), changing climate also leads to the emergence of new pests and diseases that affect cocoa and equally reduces the host's resistance to pesticides. In relation to this, Lawal & Emaku (2007) established a positive correlation between the outbreak of black pod disease and significant changes in temperature and humidity during the fruit bearing stage. Rainfall affects cocoa yields more than any other environmental factor (Adjei-Nsiah & Kermah, 2012) because the pattern of its cultivation is related to rainfall distribution (Owoeye & Sekumade, 2016), and therefore produces well under minimal but sustained water availability all year (Oyekale, 2015).

Given the established trends in weather patterns and its potential impacts on cocoa production, adaptation has become unavoidable, either planned or spontaneous. Considered as an adjustment to actual or expected climate and its effects in order to moderate or avoid harm and exploit beneficial opportunities (IPCC, 2014) serves it purpose when its application reduces the intensity of a person's vulnerability and increases their adaptive capacity and increases their wellbeing (Berhe, 2016). According to Codjoe et al. (2020), adaptation includes policies and measures to reduce exposure to climate variability and extremes and the strengthening of capacities.

Innovating cocoa production methods is one of such options that has gained importance in recent times. In Cameroon, 241,000 tons of cocoa are produced annually and Cameroun is the fifth cocoa producer in the African continent (Marthe et al., 2022). The provision of support services for cocoa sectors experienced transformation since the beginning of the 90's (Marthe et al., 2022). Cocoa quality and sustainability are major issues for Cameroon that have led to a fall in cocoa prices. The inadequacy of phytosanitary treatments coupled with poor fermentation, drying and storage conditions have led to a drop of the quality of Cameroonian cocoa (Fule, 2013). Cocoa production and productivity growth in Cameroon has been hindered due to the ageing of the cocoa farmers, limited access to credit, low level of education and low adoptability of innovations (Fule, 2013; Mukete et al., 2018).

This central production in the country's agricultural economy has been, since 2002, the subject of several "recovery plans" aiming to significantly increase cocoa yields, and thus the production of cocoa, by sharing scientific and technical knowledge (Syndhia et al., 2021). Santchou has an equatorial climate and is experiencing the effects of global climatic aberrations. Many studies on cocoa production innovations have targeted quality improvement but this work seeks to ascertain the role of these innovations in climate change adaptation. This study therefore bridges a technical and policy gap in climate change adaptation by employing the perspectives of small scale cocoa farmers.

MATERIALS AND METHODS

The Study Area

Santchou is located on the Mbo plains and geographical, it lies between Latitude **5° 16'** and **5º25' N** and Longitude: **9° 58** and **10º7 E** (Figure 1). Administratively, it is located in the Menoua division of the West region of Cameroon and inhabited predominantly by the Mbo people whose principal activity is crop farming. It is bordered to the north by mount Manegouba, to the south by the cliff of Dschang and to the East by Kekem. It has an equatorial climate of the Guinea type and it is marked by two seasons, being the rainy and dry season. The rainy season begins from March to mid-October and the annual rainfall ranges between 2000-3000 mm with average temperatures of 24.6^{0}C (Bateman et al., 2023). These conditions favor the growth of the cocoa plant.

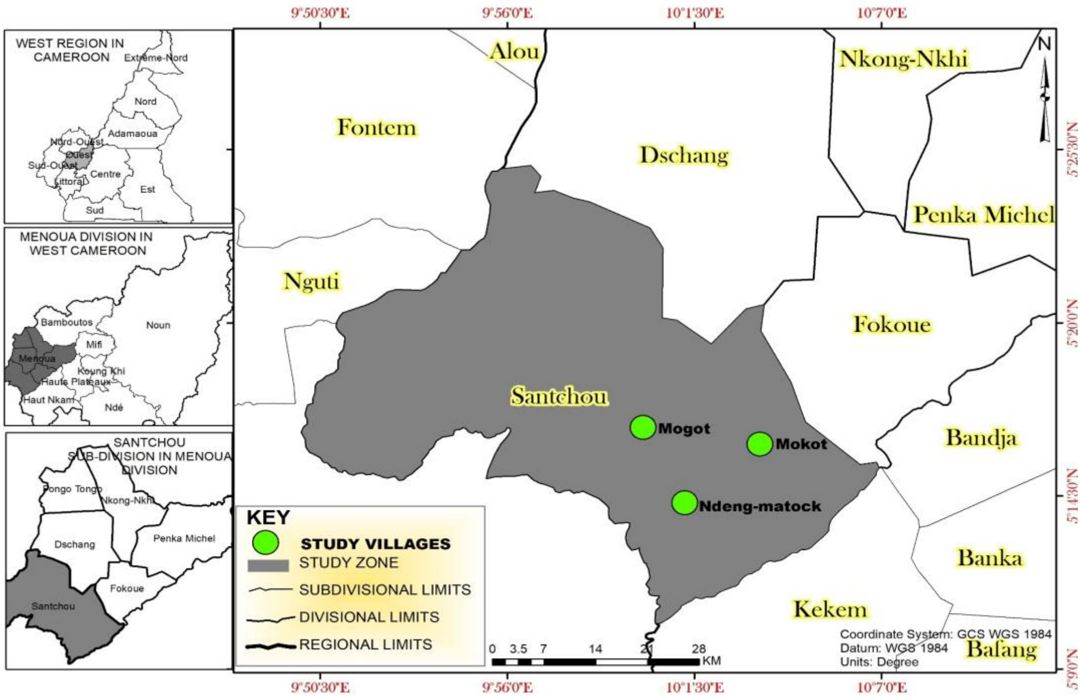

Figure 1: Location of Santchou sub-division within Menoua
Source: INC-National Institute of Cartography; field work (2023)

The vegetation of the Santchou is dominated by semi-deciduous forest, shrubby savanna, sub-montane forest, periodically inundated swamp-forest and grassland *(*Melifokeng & Meli, 2015). The rich biodiversity of this area led to its designation as a fauna reserve at National level in 1987. It covers 70.26 km2 and it is managed by State (Digital Observatory for Protected Areas 1987, DOPA). Nevertheless, the preservation of the reserve has not been effective. Agricultural activities, especially the adoption of cocoa a s the principal cash crop have significantly contributed to the degradation of the reserve. Many cocoa production villages such as Mogot, Ndeng-Matock and Mokot) are located within the reserve. Increasing the size of cocoa farms hs been a strategy adopted by small scale farmers in recent times, given that they have limited technological know-how and the finances to embark on intensive cultivation. This option has contributed significantly in the elimination of natural forests for the establishment of cocoa plantations with the negative effects on global warming.

Data Collection and Treatment

Using a mixed methods approach, data was collected from both secondary and primary source. Secondary data was collected mainly from the internet, reports and archives in institutions working with cocoa production. Primary data sources included field observation which permitted to identify the state of cocoa pods rot, the physical state of cocoa trees infected, the spraying of cocoa techniques, the spacing of cocoa techniques and the techniques of nursing cocoa. A questionnaire survey was carried out with purposively selected 101 peasant cocoa farmers from the main production zones or villages. Those selected for this survey must have been into the activity for more than 25years. This temporal scope was judged sufficient to observe climate related impacts and evolution in farming practices. Given the in-availability of in-situ data, climatic data was downloaded from NASA power for the study area for the period 1981 to 2020. Also, 11(eleven) key informant interviews were conducted at the delegation of agriculture and rural development for Santchou, cocoa farmers associations, local NGOs and large scale cocoa farmers. Interviews were broadly focused on perception of climate variability, effects of climate variability on cocoa production changes in production techniques/innovation and challenges in innovation adoption.

Data analysis was done using quantitative and qualitative methods. Questionnaires were coded and treated with the help of a Statistical Package for social sciences (SPSS) version 23.0, using descriptive statistical methods while interviews were transcribed and treated in Atlas.ti version 7.5 using content and thematic analysis. To establish variability and trends in climatic patterns, the anomalies were computed mainly for rainfall and temperatures which are the main drivers of cocoa production in the zone.

RESULTS

The Ecology of Cocoa Production

Santchou is located in the western highlands of Cameroon and has equatorial climate of the Guinea type. Two seasons mark the area, being the rainy and dry season. In August torrential rainfall results from the strong Monsoon winds from Southern Cameroon and conversely strong dry north easterly winds blow from the North from November to January. The rainy season begins from March to mid-October and the annual rainfall ranges between 2000-3000 mm with average temperatures of 24.60C (Bateman et al., 2023). The area receives abundant insulation during the day, reaching its peak in January when the North East Trade winds sweeps across the area.

Cocoa plants respond well to relatively high temperatures, with a maximum annual average of 30– 32ºC and a minimum average of 18 – 21ºC (OICC, 2011). Rainfall should be plentiful and well distributed through the year. An annual rainfall level of between 1,500mm and 2,000mm is generally preferred. Dry spells, where rainfall is less than 100mm per month, should not exceed three months. Also, a hot and humid atmosphere is essential for the optimum development of cocoa trees. In cocoa producing countries, relative humidity is generally high: often as much as 100% during the day, falling to 70-80% during the night (OICC, 2011). The cocoa tree will make optimum use of any light available and traditionally has been grown under shade. Its natural environment is the forest which provides natural shade to trees. Shading is indispensable in a cocoa tree’s early years (Tankou, 2015). Cocoa needs a soil containing coarse particles and with a reasonable quantity of nutrients, to a depth of 1.5m to allow the development of a good root system. Below that level it is desirable not to have impermeable material, so that excess water can drain away. Cocoa will withstand waterlogging for short periods, but excess water should not linger. The cocoa tree is sensitive to a lack of water, so the soil must have both water retention properties and good drainage (Tankou, 2015; Bateman et al., 2023). Cocoa can grow in soils with a pH in the range of 5.0-7.5. It can therefore cope with both acid and alkaline soil, but excessive acidity (pH 4.0 and below) or alkalinity (pH 8.0 and above) must be avoided. Cocoa is tolerant of acid soils, provided the nutrient content is high enough. The soil should also have a high content of organic matter: 3.5% in the top 15 centimeters of soil. Soils for cocoa must have certain anionic and cationic balances. Exchangeable bases in the soil should amount to at least 35% of the total cation exchange capacity (CEC), otherwise nutritional problems are likely. The optimum total nitrogen / total phosphorus ratio should be around 1.5 (Bateman et al., 2023).

Climatic Anomalies and Trends in Santchou

The climatic conditions in Santchou are conducive for cocoa production but climatic aberrations have been observed in the last few decades that tend to alter the natural ecology of cocoa production. An observation of the main climatic elements of temperature and rainfall has shown an alternation between periods of positive and negative anomalies that goes beyond the optimal growth conditions (Figures 2 and 3).

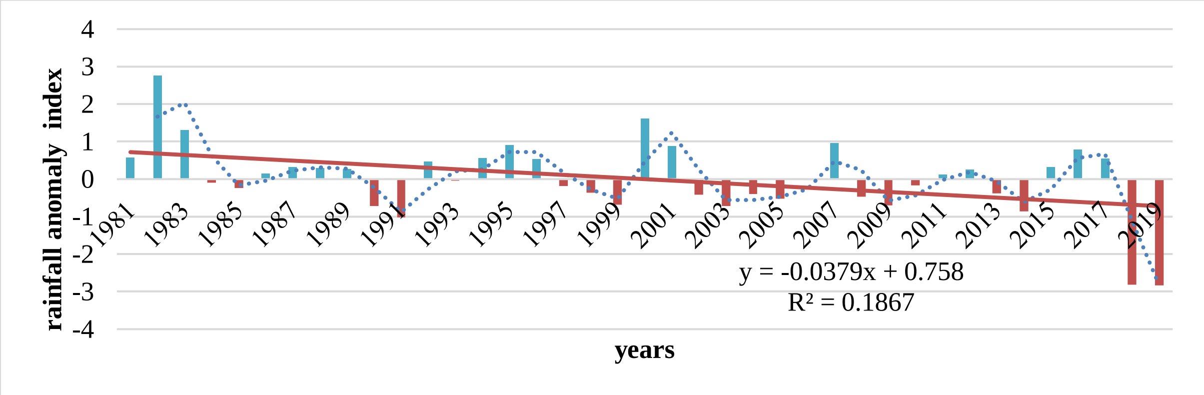

Figure 2: Inter-annual rainfall anomaly

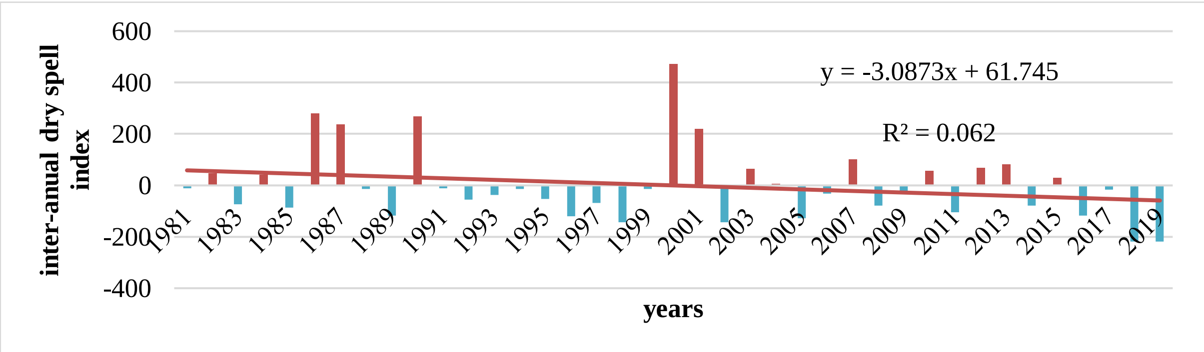

Figure 3: Inter-annual variation in the dry spell index

These climatic anomalies have had negative effects on cocoa production. Positive anomalies are years that registered rainfall above the average or mean amounts meanwhile negative anomalies stand for years with rainfall below the annual average and such anomalies are a very powerful indicator of rainfall variability. The year of positive anomaly which recorded extreme humidity is 1982 (RAI> 2), 1983 and 2000 also with high humidity (2 <RAI>1), followed by the other years of positive anomalies with 0 <RAI>1 such as 1981, 2016 and 2017. On the contrary, negative anomalies were recorded in 1984, 1985 and 2014 faces moderate dryness (RAI> 0<-1), with 2018 and 2019 facing extreme dryness (RAI> -2). Years of positive anomalies are years of potential floods since more rainfall is recorded meanwhile negative anomalies means deficit rainfall and dry spells with multiplication of pest and diseases (Plate 1). Farmers reported a fall in rainfall amount, characterized by frequent dry spells and marked seasonal disparities.



Cocoa rot disease | Black pods disease | Hairy cocoa branches pest

Plate 1: Cocoa diseases and pests common in Santchou

The questionnaire survey revealed that 55.45 % of cocoa farmers have experience emergent diseases in their farms such as trunk bursting by caterpillars and the development of thick hairy branches, 3.96 % have witnessed rot and yellow leaf fall in their farms while 40.59% of cocoa farmers experience all of the mentioned diseases in their farms. Interviews revealed that the emergence of some pests and diseases as well as the increase in the magnitude of their impacts on the cocoa plant is caused by the change in global climatic patterns. Cocoa follows a specific calendar but climatic aberrations have made it difficult for farmers to respect their activity calendar. It is confirmed that 87.13% of cocoa farmers do not follow or use the agricultural calendar against only 12.87% of cocoa farmers. Stakeholder discussions also revealed that these climate related consequences, coupled with challenges in treatment, drying and preservation have affected the quality of cocoa produced in this area.

Cocoa Production Innovations that Lessen Climatic Shocks

The adoption of new practices and the improvement on existing practices is an aspect of adaptation observed in the Santchou cocoa farms. Innovations in this paper look at the technical aspects as well as the policy and organizational aspects that have helped the population cope with the vagaries of weather. Hence, we have on farm and off farm innovations.

On-farm innovations

Improvement in farming techniques

Findings revealed that cropping techniques and systems of cocoa production in Santchou have been improved upon in the last two decades. The change in production method that are primarily aimed at increasing yields have proven to be resilient in the context of climate change (Plate 2).

Photo A. Cocoa nursery

Photo B. Cocoa spacing technique

Photo C. Fertilizers application

Plate 2: On-farm innovative techniques

Rather than simply spreading seeds in area and allowing them to germinate as was the case a few decades ago**,** the construction of nurseries has been the departure point of cocoa production innovations. When cocoa seeds have been fermented; they are selected put into nylon peppers filled with nutrient rich soils. This soil type is the tropical black earth which is rich in nutrients with a high porosity that permits fast germination. Photo A shows a nursery system in which seedlings are shadowed to with palm fronts. This creates a micro climatic environment the curbs the effects of extreme events such as dry spells. This technique equally reduces the impacts of heavy downpours that can burst cocoa leaves and slow its growth. The shadowed nursing technique the nursing also provides minimum sunlight and moderate temperatures needed for proper germination. Another innovative technique applicable during transplanting is the respect of spacing (Photo B). This is one of the techniques that cocoa farmers in Santchou have been putting in place in order to increase their output and it is mostly done on recent or new cocoa farms. The interval of this cocoa spacing is mostly 3 to 5 meters as compared to the ancient spacing method of planting which was 1 to 3 meters. This method is adopted by 17.8% of farmers. By spacing the cocoa trees, the branches do not collide when they grow to maturity and this enhances maximum growth. In situations of disease outbreak, there will less propagation and effective control during spraying. Interviews revealed that this method, though it occupies a lot of land yields better and healthy cocoa pods. Photo C shows a fertilizer application technique. Here, fertilizer is sprinkled round the cocoa tree at a distance of about one meter so that the fertilizers enter on the roots without touching the trunk because the temperature of the fertilizers can kill or affect the cocoa tree. This method has equally reduced the negative impacts of heavy rainfall during fertilizer application. Interviews revealed that holes dug around the plant prevent the fertilizer from being eroded due to runoff. This there ensures maximum fertilization of the plant.

Interviews revealed that in order to cope with rapid soil exhaustion, pests and diseases, cocoa farmers have innovated in the type and manner of application of chemical fertilizers, pesticides and insecticides. Fertilizers are used by cocoa farmers to enhance nutrient levels, increase yield and quality, combat nutrient deficiencies, address soil degradation, manage tree health, promote sustainability, and maximize profitability. Though these inputs have been into use for over decades now, it was revealed that proper education and guidance are vital to ensure balanced fertilizer use and optimal benefits. Insecticides commonly used in Santchou are "Monchan" and "Callomil super". They have as role to combat diseases like cocoa pods rot as well as other fungal infections. They are applied between November and early March through the spraying method. These are dryer months where there is relatively low humidity, low pressure and high solar energy. On the other hand, during the period from July to October with high amounts of rainfall, there is need for regular and well calculated treatment. In santchou, "Copper Fungicide" "Nordox 75WG" are used to prevent and control various fungal diseases on plants that spread due to increased humidity and have become more prevalent under changing climate conditions.

Off-farm innovation techniques

Adoption of improved cocoa varieties

The use of improved varieties of cocoa by most farmers in Santchou has been a major response to dry spells and pests. The species cultivated in this locality are not homogeneous. Over the years, the species has changed, especially in response to their productivity and their ability to do well in the increasingly dry climatic conditions. Most of the cocoa trees in place are of the *Forastero* species, *Amelonado* (with yellow pods), *Cundeamor* (with red pods), *Criollo* and *Trinitario* species. Many factors explain the adoption of any of the varieties such as the availability of seeds, yields and changes in environmental conditions.

Interviews revealed that cocoa is a fragile crop with yields that tend to decrease over time, putting farmers' livelihoods at risk. The African Development Bank has committed to provide funding to IRAD, the Institute of Agriculture Research for Development, where research is focused on creating adapted seed varieties. The new species of cocoa cultivated called "*Cacao Bresilien*", is a seed improved by IRAD (Agricultural Research Institute for Development) which ensures better productivity due to its adaptability to changing environmental conditions.

These second-generation seed varieties developed by IRAD allow for an average yield of 2 tons per hectare, compared to the first generation developed in the 1970s and 1980s that produced around 1 ton per hectare. The difference lies in the fact that improved varieties that are multiplied locally are resistant to emerging pests and diseases.

The adoption of these improved varieties is common among new cocoa farmers and those who have opened new cocoa farms. Some of these farmers can differentiate the species using scientific names but they refer to the color of the pods as revealed by a farmer during interviews:

".....the cocoa species with the brown color is gradually being planted by most farmers in this area. Apart from its high yielding capacity, it is observed to be less vulnerable to climatic especially when well treated. We have made this observation for over five years now......"

Photo 1: A new cocoa species adopted by cocoa farmers in Santchou

This cocoa species with brown pod has been identify as being less vulnerable to drought and pest and therefore productive than the white cocoa in terms of number of shuts per cocoa tree and sizes of cocoa pods. This species is locally referred to as "amba bar" and its expansion has been very significant.

Changes in Tenure Systems and Expansion of Farm Sizes

The productivity of cocoa trees reduces with age. As such, efforts are made to expansion farm sizes and create new cocoa farms. Land acquisition in this area is mostly hereditary, that is, from parents to children and that goes from one generation to another. Generally, women are exempted from the sharing of family land. This traditional tenure system supposes the sharing of farm land amongst children and with the rapid growth in population over the years, most of the land sizes in Santchou has been decreasing, making it very difficult for most farmers to carry expand their cocoa farms (Table 1).

Table 1: Surface area of cocoa farms in Santchou

	Estimated surface area of cocoa farmers			
Farmers responses	Less than 1 hectare	1-2 hectares	3- 4 hectares	Total
Frequencies	60	33	8	101
Percentages (%)	59.4	32.7	7.9	100.0

Source: Field work (2023)

Table 1 shows that 59.4% of cocoa farmers have farm sizes of less than a hectare, 32.7% have between 1-2 hectares, and only 7.9% had lands that are between 3-4 hectares.

Findings revealed that there has been a gradual change in the pattern of land tenure in the Santchou as a whole and in Ndend-matok, Mogot and Mokot in particular. Recent changes revealed that women now own land and mode of acquisitions have shifted from inheritance to buying (Table 2).

Table 2 shows the different modes by which farmers in Santchou acquire lands in recent times. The questionnaire survey revealed that 53.5% of the cocoa farmers bought and only 13.9% of cocoa farmers still cultivate on inherited lands. This shows a remarkable change in the tenure system. Equally, 27.7% of cocoa farmers rented their land while only 5.0% of farmers were given land free of charge. Interviews revealed that some farmers go to nearby villages to farm while some opening farms in the forest reserve.

Table 2: Mode of acquisition of cocoa farmlands in Santchou

	Sex	Inheritance	Renting	Bought	Gift	Total	Percentages (%)
	Male	10	19	45	4	78	77.2
	Female	4	9	9	1	23	22.8
Total		14	28	54	5	101	100.0
Percentages (%)		13.9	27.7	53.5	5.0	100.0	

Source: Field work (2023)

Policy Innovations

The government of Cameroon through the Ministry of Agriculture and Rural Development has been in the forefront of innovations in the cocoa sector. To enhance innovation and reduce vulnerabilities to the caprices of climate, one national research institution and three international research and development institutions have been working to promote research and development works in the cocoa sector in Cameroon. They are the Institut de Recherche Agronomique pour le Developpement (IRAD), World Agroforestry Centre (ICRAF), Centre for International Forestry Research (CIFOR), and International Institute of Tropical Agriculture (IITA).

At the national level, IRAD is the government research institute that conducts research on cocoa among other crops in Cameroon. It has carried research and put in place improved cocoa varieties that are high yielding and less vulnerable to pests and diseases. This institution has partnered with international others such as the World Bank to develop scientific knowledge on local species and promote their domestication in the farming system.

In 2021, the government set up a policy framework for sustainable and zero-deforestation cocoa. Through this platform, the State of Cameroon, private operators, international partners, and the civil society are committed to working together, both technically and financially, for the sustainable production and marketing of cocoa, the preservation and rehabilitation of forests and the inclusion of cocoa-producing communities in Cameroon. The parties are engaged to work for the long-term sustainability of the cocoa sector. Their actions will include the rehabilitation of aging cocoa farms, the provision of improved seeds, and actions to increase soil fertility. This will not only increase yields but also prevent deforestation through the creation of new plantations. The Minister of Agriculture and Rural Development said:

> "*I confirm the support provided by the Government of Cameroon for the effective implementation of this policy framework. We need to ensure that the cocoa sector not only flourishes but also benefits cocoa farmers and their communities as well as the environment. This is the only way to ensure the long-term sustainability of our cocoa economy,"* (Gabriel Mbairobe, 2021).

The proper implementation of this policy framework will help preserve the 46% of the national territory covered by forest. Officially, that forestry part of Cameroon represents 11% of the Congo basin, which is the 2nd largest forest in the world after the Amazon rainforest.

Generally, as cocoa prices began to rise in early 2000, the government saw a need to raise cocoa production by improving productivity in order to boost exports and foreign exchange. In 2006 it embarked on a "modernization" programmed consisting of; 1) sensitizing the farmers on the necessity to reinvest their money and time in cocoa farming; 2) funding research to produce cocoa breeds that are more resistant to pests; 3) multiplying these improved breeds and distributing them at subsidized prices to the farmers and; 4) organizing farmers into cooperatives. Alongside these strategies were efforts to attract younger and wealthier citizens (to fill the gap of the ageing generation and limited access to credit) to cocoa farming by facilitating their access to land, credit, other inputs like fertilizers, pesticides, technical assistance and training (business in Cameroon on the 22nd January 2021, sustainable and zero deforestation cocoa). These innovations at the level of policies in Cameroon have reduced the vulnerability of the cocoa sector to the caprices of weather and improved on production.

Challenges Faced by Cocoa Farmers in the Adoption and Implementation of Innovation

In their effort to adopt innovation and cope with the negative effects of climate change, cocoa farmers in Santchou are facing a number of challenges as revealed by the questionnaire survey (Figure 4).

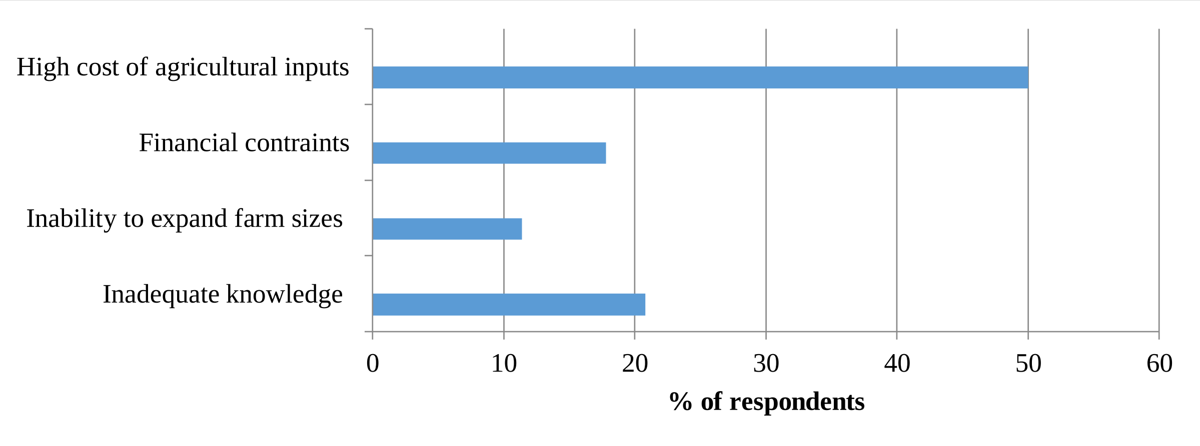

Figure 4: Challenges in innovation adoption for climate change adaptation

Figure 4 shows that 20.8 % of farmers do not have adequate knowledge on existing innovations, 17.8 % identified financial constraints as limiting their adoptive capacities, 50% are limited by the high cost of agricultural inputs such as pesticides and insecticide while 11.4% are unable to increase their farm sizes. Corroborating the questionnaire survey, interviews have shown that ineffective pest management due to inadequate knowledge, ignorance about proper planting and harvesting methods, poor post-harvest practices have resulted to low cocoa quality. Equally, farmers acknowledged the rising prices of farm inputs in the market while stressing the fact that it has limited their ability to buy inputs. Generally, increase pest attacks due to climate change has increased overall production costs for cocoa farmers thereby reducing profit margins, especially when farmers cannot offset the higher costs through increased yields. High input costs hindered farmers from adopting more advanced and efficient techniques, forcing them to rely on traditional, less effective methods of pest and disease control (Interview, 2023).

The Santchou wild life reserve has been one of the main hindrances to the expansions of farm sizes and the opening of new farms by mew cocoa farms (Figure 5).

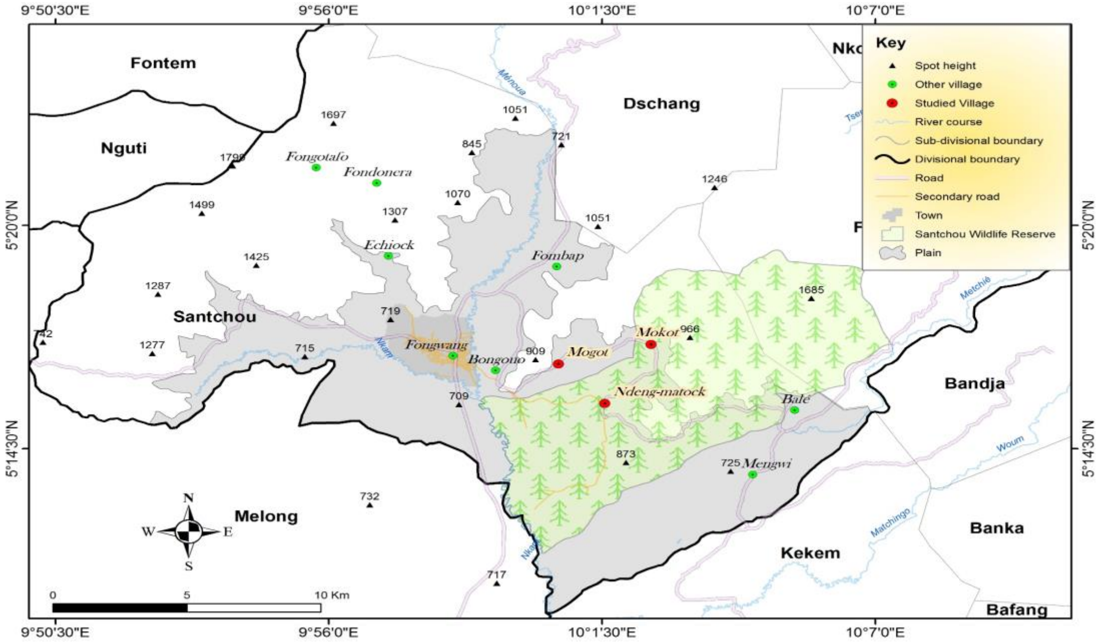

Figure 5: The Santchou Wildlife reserve and new cocoa farms
Source: INC (National Institute of Cartography, 2023).

Figure 5 shows that out of the three cocoa production villages sampled in this study, two (Mokot and Ndeng-Matock) are located within the Santchou wildlife reserve. This has hindered the expansion of cocoa farms and the development of new cocoa farms.

DISCUSSION

The natural ecology of Santchou is favourable for the growth of cocoa trees with the maim drivers of growth being rainfall and temperature. It has an annual rainfall amount ranging between 2000-3000 mm and average temperatures of 24.6^0c. These conditions are favorable for the growth of cocoa plants (OICC, 2011) and as such Cocoa production has become the main stay of the economy in Santchou. Findings revealed that despite this favorable ecology, climatic aberrations characterized by rainfall irregularities, frequent dry spells and raising temperatures. Anomalous situation occurring during specific growing stages such as germination and flowering have significantly reduced yields. An increase in the rate of pests and diseases such as cocoa rots or black pods disease, thick hairy branches, yellow leaf-fall as well as caterpillar bursting of cocoa pods are related to the caprices of climate change. In the same line, works by (Kimengsi & Tosam, 2013; Oyekale, 2015; Kosoe & Ahmed, 2022) opine that changing climate do not only alter the development of pests and diseases but also reduces the resistance of cocoa plants to pesticides.

Faced with this situation, cocoa farmers in Santchou have not been indifferent. Efforts to curb the negative effects of climate change on yields and improve on cocoa quality have passed through the adoption of innovations and improvement in local practices. In Santchou, innovations are on farm and off farm. On farm innovations include improvement in cocoa spacing, shading of nurseries, effective and timely application of fertilizers and pesticides while off farm innovations involve the adoption of improved cocoa varieties and expansion of farm sizes. Interviews revealed that these methods have significantly reduced the vulnerability of cocoa plants to climate variability and change. A research conducted by Kyere (2016) in the forest-savanna transitional zone of Ghana revealed that planting more plantain suckers as a protective shield over cocoa seedlings against excessive sunshine is one of the major adaptation strategies practiced by the farmers due to deforestation that has left large parts of the land bare. It has been shown that crop diversification and mixed cropping is helpful in terms of income opportunities that farmers maximize, making it more profitable than to specialize in one crop (Kurukulasuriya & Rosenthal, 2003). Codjoe et al. (2020) argue that it can rather reduce vulnerability by serving as an insurance to rainfall and temperature variability as different crops are affected differently by climatic events

In addition, Below et al. (2010) conclude that improved variety has a considerable potential to strengthen the adaptive capacity of farmers. An example is the hybridization of cocoa seeds to produce the hybrid type that are sunshine tolerant, matures early and give higher yields (Kolavalli & Vigneri, 2011; Aneani & Ofori-Frimpong, 2013). However, according to Lobell et al. (2008), decisions to switch crop variety cannot be made on the basis of climate alone. Different varieties have different input requirements and cost associated with their production. This has been identified as a limiting factor as farmers have difficulties baring costs that comes with the use of new crop varieties.

The cocoa sector in Cameroon in general has been undergoing innovative transformations in an attempt to improve on quality and increase its competitiveness in the world market. According to Marthe et al. (2022), the provision of support services for cocoa sectors experienced transformation since the beginning of the 90's as Cocoa quality and sustainability are major issues for Cameroon that led to a fall in cocoa prices. Studies by Fule (2013) revealed that the inadequacy of phytosanitary treatments, fermentation, drying and storage conditions have led to a drop of the quality of Cameroonian cocoa. Cocoa farmers in Santchou have difficulties expanding their farms and opening news farms. Associate to this are issues such as; ageing of the cocoa farmers, limited access to credit, low level of education and low adoptability of innovations (Fule, 2013; Mukete et al., 2018).

CONCLUSION

Climate variability and change has reduced the potential of Santchou in producing cocoa in quantity and quality. This article highlights the importance of cocoa production innovations in building resilient farming communities. Findings revealed that rainfall and temperature are major factors of cocoa production in the area but anomalous scenarios characterized by frequent dry spells have affected all the stages of growth and reduce the quality of cocoa seeds. None the less, cocoa production innovations provide a pathway for farmers to adapt to climate change, maintain their livelihoods, and contribute to environmental conservation. Innovations are adopted at two levels; on farm and off farm. Improvements in the construction of nurseries, construction of shades, mixing cocoa plants with other trees, application of fertilizers and pesticides and adoption of improved cocoa varieties that are more resistant to pest and diseases are some of the innovations adopted by farmers in Santchou. However, more than 50 of cocoa farmers are still using traditional practices that make them vulnerable to the vagaries of weather. It was shown innovation adoption is hindered by inadequate knowledge on existing innovations (20.8 %), inadequate finances (17.8%), high cost of agricultural inputs such as pesticides and insecticide (50%) and their inability to increase their farm sizes (11.4%). Hence, it is essential to scale up the adoption of these innovations to build sustainable cocoa production systems that are resilient to climate variability.

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