Impact of Oil Palm (*Elaeis guineensis*) Cultivation on Soil Physico-Chemical Properties and Food Security of Rural Households within Mundemba Sub-division, Cameroon

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Authors' contributions

This work was carried out by author UPA and BBO. Both authors designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Both authors also managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Oil palm cropping is rapidly expanding within Mundemba. Although they have the potential to contribute to employment and economic development, the effect of their rapid expansion on soil properties and food security is largely unknown. The objective of the study is to analyze the trend in the surface area occupied by palms and farmlands between 1980 to 2020, assess the impact of oil palm cultivation on soil properties and food security. Ground Control Points (GCPs) were taken to evaluate land-use changes and soil samples were collected from palm plantations for analysis. Interviews and questionnaires were administered to household heads to gather information on food security. Results revealed that palm plantations experienced a rapid increase from 35.52ha in 1980 to 119,171.49 in 2020. Arable land also shows a progressive increase of 101.39 ha in 1980 to 518.55 ha in 2020. A significant deterioration of soil nutrients status under palm plantations compared to the adjacent farm lands was observed. Palm cultivation has resulted in food security

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issues in the area due to its lucrative nature and impact on soils properties. To improve food security farmers should be educated on sustainable crop production methods and soil management techniques.

1. INTRODUCTION

The production of vegetable oil is rapidly expanding worldwide [1] and today the world's greatest source of vegetable oil is the oil palm (*Elaeis guineensis Jacq.*). Oil palm cultivation has great potential for economic development in rural areas by generating income and creating employment opportunities [2,3]. The crop is attractive to farmers by virtue of the fact its establishment and management requires little investment compared to food crops. In recent years, there has been a massive expansion of oil palm monocultures in the tropics, at the expense of the rainforest and traditional food crops such as rice, cassava and plantains [4,5,6]. Land-use changes due to their establishment have been altering ecosystems and livelihoods throughout history. Oil palm is not new in Cameroon. People in the rainforest region of Cameroon used to harvest fresh fruit bunches (FFB) from the wild dura variety to produce palm oil and kernel oil, and fell and tap old stands of both dura and pisifera varieties to produce palm wine, which is a much-cherished liquor. The hybrid tenera oil palm variety produces the highest yield—up to eight times more—compared to food crops [7,8]. History holds that oil palm was taken from Africa and then introduced to Latin America and Southeast Asia by the end of the 19th century. Today Indonesia and Malaysia alone produce 85% of the world's crude palm oil (CPO), while Cameroon stands at the 13th position in terms of world production of CPO (www. indexmundi.com). According to Hoyle and Levang [9], Cameroon produced 230,000 tons of CPO in 2010 across an estate of approximately 190,000 ha. The production of CPO in Cameroon is undertaken by three plantation types: agro-industrial plantations, contract private plantations and independent palm oil producers. Production of palm oil has increased largely through rapid expansion of the area cultivated. Accelerated and relatively unplanned expansion of oil palm may cause a range of social problems, including reduced food security and environmental problems such as deforestation and its associated problems of climate change, loss of biodiversity and land degradation with a negative impact on soil properties and productivity resulting to low food crop yields. It is figured that almost 95% of oil palms are grown on acid, and low fertility soil [10].

The question of food security is a critical one especially in developing countries, and for generations yet unborn. With the high population growth rate nowadays, the world is running out of land to produce food. Those who will be hit hardest, are the poorest. Mundemba sub-division harbors the Korup National Park that covers a surface area of about 1260km^2.This area is protected and no human activity of any form is permitted. There is competition between conservation and agriculture resulting to intense competition on the available agricultural land between food crop production and oil palm cultivation thereby causing the rural population to be vulnerable to food shortages. The major cause of food insecurity in Mundemda is attributable to the rapid expansion of palm plantations. Using the limited arable land available to grow palms that do not contribute to food supplies is a call for concern as they compete with food crops for land, water, labor and capital and thus displace the production of basic grains and other food crops reducing their availability for home consumption and eventually provoking reduced consumption due to price increases [11]. Three-quarters of the total oil palm area in Mundenba is in the hands of the non-industrial palm oil sector and provides only half of the production due to very low yields. As highlighted by Feintrenie et al. [12], the principal cause of food insecurity is poverty in terms of low income and lack of access to education, agricultural inputs, technology and agricultural credit. In countries suffering from food insecurity, a majority of the vulnerable population depend on income and food from local agriculture. Therefore, if production of oil palm contributes to rural income, it may also go a long way to reduce food insecurity.

These issues if not properly addressed can result to food shortages that will affect food security in the subdivision. With oil palm

cultivation rapidly expanding in the area, this study seeks to analyse the trend in the surface area occupied by palms and farmlands between 1980 to 2020 and also its impact on soil physico-chemical properties and food security in the area so as to suggest putting in measures to ensure agricultural sustainability in the area.

2 MATERIALS AND METHODS

2.1 Study Area

Mundemba sub-Division is located between latitude $4^o58'$ and $49^o70'$ and longitude $8^o54'$ and $8^o9'$ E. Mundemba Sub Division is located in Ndian Division of the South West Region of Cameroon. The Division covers a surface area of 1,557km^2 with a population of about 50,503 inhabitants [13]. The area shares boundaries with Eyumojock in the North, Isangele and Ekondo Titi in the south, Konye and Dikome Balue in the east and Nigeria in the West as

seen on Figure 1. Mundemba municipality is composed of an undulating topography and the highest point is a hill with an altitude of 505m. The study area has a pseudo equatorial climate with two seasons. There is a distinct dry season (average monthly rainfall less than 100 mm) from December to February and a long and intense wet season from approximately May to October, with the heaviest rainfall (exceeding 1000 mm a month in some years) in August. Temperatures vary little throughout the year. The mean monthly maximum temperature in the dry season is 31.8° C and 30.2° C in the wet season. The average annual maximum temperature for the area is 30.6° C. (13). The soils of the area are strongly acidic (low pH) and low in nutrients (Source: Mundemba Monographic Studies, [13]). Farming is the main economic activity in the area with the cultivation of palms dominating. PAMOL, a public limited oil palm plantation adjacent to the town is the biggest local employer in this area [13].

Fig. 1. Map of Mundemba showing various soil samples sites

Palms are grown by PAMOL, small holders and individuals who market their nuts to PAMOL or mill them locally. Food crops grown include; yams, egussi, maize, coco yams, plantains, banana, cassava, beans and groundnuts.

2.2 Data Collection

Data collection for the study was from two major sources. Primary data sources involved the selection of different oil palm plantation age series from where soil samples were collected. Ground Control Points (GCPs) were taken using a handheld Global Positioning System (GPS) to evaluate land use changes. To obtain more detailed information about food security semi-structured interviews and questionnaires were administered to randomly selected household heads. Interviews and Focus Group Discussions were also held. Secondary data included data collection from documented sources especially plantation records of PAMOL on (plantation ages, areal extent, cultural practices, yields, economics, among others) and from the Sub-divisional delegation of agriculture.

2.3 Field Sampling Scheme

A purposive sampling method was adopted in the selection of the plantation age series to be able to ascertain the progressive changes in soil parameters following the establishment of palm plantations. Plantations of three age series (5, 11 and 33 years) were selected for the study. The five years old palm plantation was considered as the young plantation, 11 years as the medium aged plantation and the 33 years as the matured or old age plantation. Adjacent farm/agro forest lands served as the control.

For soil sampling, square grids of 50m x 50m (0.25ha) were superimposed on the map of the various plantation areas making sure the entire area was covered. Each plantation age series was subdivided into 25 square plots of 10 m × 10 m (100m^2). A total of 10 plots were randomly chosen for each age series and the adjacent farm/agro forest lands giving a total of 40 plots. Soil samples were collected taking into consideration the nature of the terrain at a depth of 0-30cm for both the palm plantations and the adjacent forest plots. This soil depth was chosen because oil palm is a deep feeder. From each plot, five samples were collected and mixed from where a core sample was taken. Overall, a total of forty composite soil samples

were collected for the study and analysed for soil chemical and physical properties.

Households were randomly selected for the administration of questionnaires and interviews on food security issues.

2.4 Soil Analyses

The soils samples collected were analyzed for particle size composition by the hydrometer method [14], total nitrogen using the Kjeldahl method, and organic carbon using the method of Walkley and Black [15]. The soil was leached with neutral 1M ammonium acetate to obtain soil extracts that were used for determining exchangeable cations. Exchangeable calcium, potassium and sodium were determined by flame photometry, while exchangeable magnesium was determined by atomic absorption spectrophotometry. Soil pH was determined potentiometrically in 001M calcium chloride solution, using a soil-to-solution ratio of 1:2. The bulk density was analyzed using the oven-drying method [16]. Total porosity values were calculated from bulk density values using an assumed particle density value of 2.65g/cm a [17].The physical and chemical properties of soils under the different age-categories of palms were analyzed and compared to examine the changes in soil properties during the first 33years of plantation establishment. Soils under adjacent agro forest/farmlands were analyzed to serve as the control for assessing the impact of palm cultivation on the soil. It is important to point out here that once the plantations are no longer productive, they are cut down and the area is used for food crop production. Thus, the status of soil properties will determine and influence the productivity of food crops.

2.5 Land-use Change Analysis Maps

Geographic Information System (GIS) and remote sensing techniques were used to determine land use change following the establishment of plantations in the area between 1980 and 2020.The activities that were carried out include; satellite image processing and classification for land use change detection. Erdas Imagine 9.2 software was used in the processing and analyzing the imageries.

2.6 Food Security Assessment

Food security was assessed by evaluating the quantity produced, quality and efficiency of crop

production. That is, whether there is enough food produced to feed the growing population or there are shortages. All these were assessed due to the assumption that plantations are taking up more lands that would have been used for food crop production.

2.7 Statistical Analysis of Data

The data sets were subjected to relevant descriptive and inferential statistical methods. The Statistical Package for Social Sciences (SPSS) was used for all inferential statistical analysis mainly one-way ANOVA for randomized designs followed by multiple comparisons to further separate significant levels if overall significant treatments exist. The chi-square was used to test the impact of socio-

demographic characteristics and aspects of palm plantation on food security in the area.

3. RESULTS AND DISCUSSIONS

3.1 The Trend in the Surface Area Occupied by Palms and Farmlands between 1980 – 2020

Fig. 2. present the trend in the surface area occupied by palm plantations, arable land, forest and other land uses between 1980–2020.

Land use-land cover change (LULC) analysis over the period 1980 to 2020 in Mundemba revealed four important land use-land cover classes: palm plantations, arable land, forest and build-up areas as shown in Table 1.
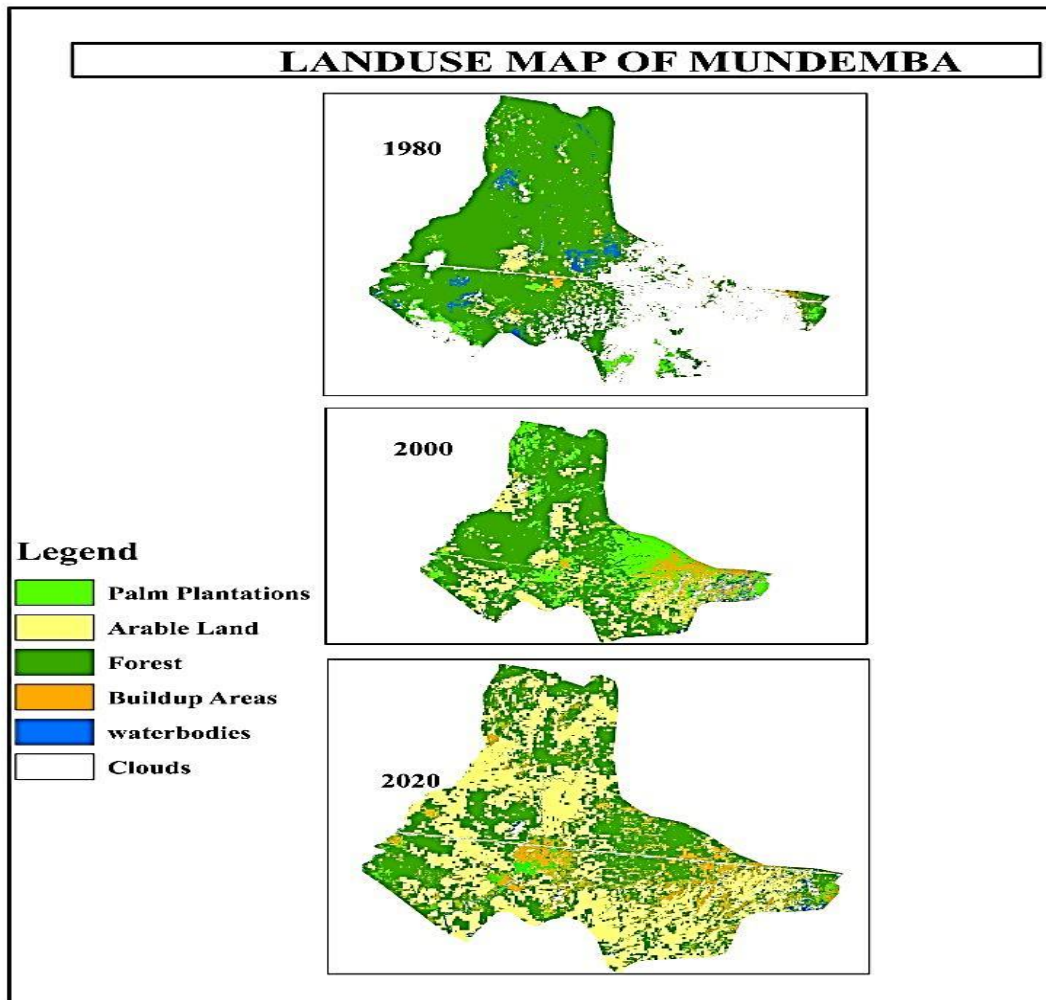

Fig. 2. land use/land cover map of Mundemba between 1980-2020

The results revealed that palm plantations experienced a steady increase between 1980 to 2020 (Fig. 3). The total surface area occupied by palm plantations and percentage increase was 35.52ha (8.74%), 120.96ha (13.42%) and 119,171.49 ha (8.52%), respectively for the years 1980, 2000 and 2020 (Table 1). The increase in the area occupied by palms can be attributed to increasing production per unit area and the cash benefits associated. Also, in the case of the state-owned palm plantations managed by PAMOL, there is an influx of people into the area from the grass field and other parts of the country in search of work and most of them end up opening their plantations. This is in line with the findings of Clough et al. [18] who observed an increase in the area occupied by palm plantations at the expense of arable land-use in Indonesian mainly for profitability.

Arable land shows a progressive increase over the years from 101.39 ha (24.95%) in 1980, 137.64 ha (15.27%) in 2000 to 518.55 ha (34.61%) in 2020 as seen in Figure 4. This increase can be attributed to an increase in the population of the area thus much land is needed to feed the growing population. Also, the main economic activity in the area is agriculture and over 95% of the population is engaged in arable farming mostly for subsistence as also opined by Lambin and Geist [19] in rural communities in Africa:. Another reason that can be advanced is that the current socio-political crisis in the South West and North West regions has caused the closure of the commercial palm plantations and for close to two years now the workers have not been paid. This have pushed them to concentrate more on food crop production for subsistence and a source of livelihood.

Table 1. Surface area occupied by various land uses in Mundemba

LULC Classes	1980 Area(ha) (%)		2000 Area (ha) (%)		2020 Area (ha) (%)	
Palm plantation	35.52	8.74	120.96	13.42	127.62	8.52
Arable land	101.39	24.95	137.64	15.27	518.55	34.61
Forest	262.31	64.56	637.30	70.69	823.66	54.97
Built up Area	7.09	1.75	5.60	0.62	28.53	1.90
Total	406.31	100	901.5	100	1498.36	100
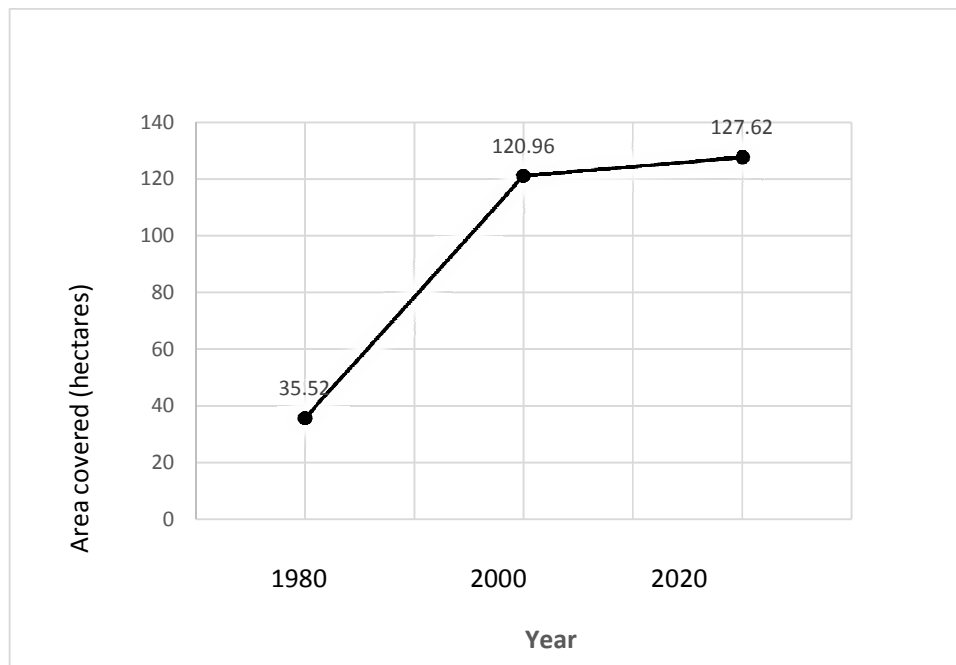
Fig. 3. Increase trend in palm plantations in Mundemba
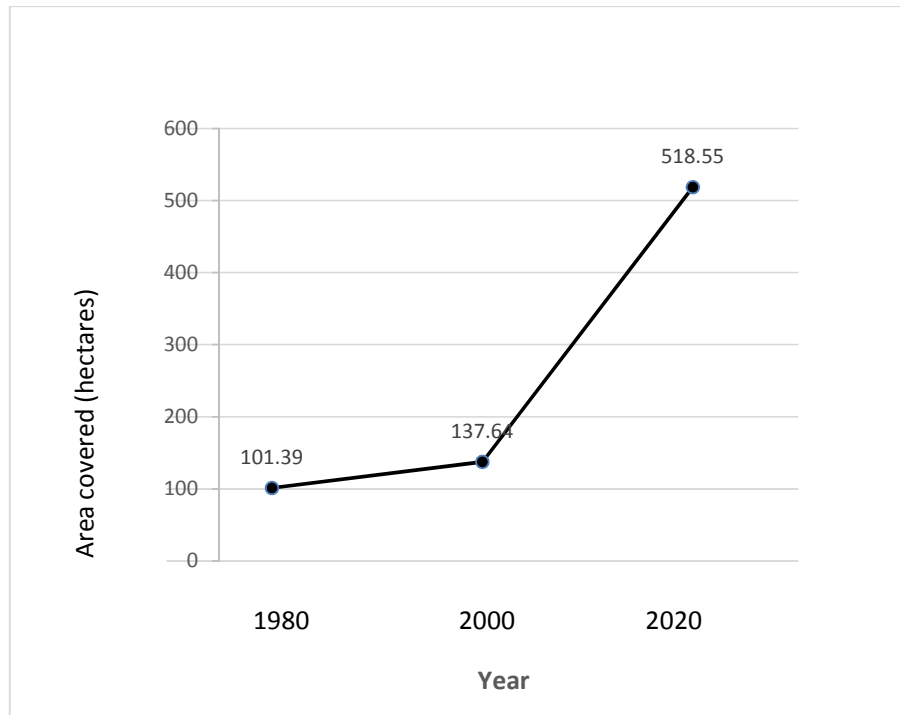
Fig. 4. Increase trend in Arable lands in Mundemba

Forest experienced a progressive increase over the years from 262.31 (64.56%) in 1980 to 637.30 (70.69%) in 2000, and 823.66 (54.97%) in 2020 as seen in Table 1. This was partly as a result of the relocation of the Ekondokondo people out of the Korup National Park and the success of the forest conservation policies in the area. This is in line with the work of Usongo et al. [20] who also observed an increase in the surface area occupied by forest within Korup area due to the effectiveness of forest policies in the area.

Built-up areas experienced a decrease from 7.09 (1.75%) in 1980 to 5.60 (0.62%) in 2000 partly caused by rural exodus in search of greener pasture and an increase of 28.53 (1.90%). The increase in built-up areas in 2020 is as a result of the fact that more population is evident in the area thus more houses as also observed by Usongo et al. [20]. The total area occupied by built up area is 41.22hectares.

The Central and West Africa 200 million hectares of remaining tropical rainforest of which the forest of Cameroon forms a part is the second largest in the world after the Amazon Basin [21] and noted for nutrient cycling. The value and importance of the tropical rainforest

to different people is as varied as the functions it provides [22]. The struggle to satisfy the basic human livelihood demands is generally accepted as the main trigger behind forest conversion in tropical areas [22]. Several studies carried out around the world revealed the negative impacts of plantation agriculture on biodiversity loss and food crop production. Koh and Wilcove [23] looking at the impact of oil palm agriculture in Malaysia and Indonesia, acknowledged that oil palm plantations in Malaysia and Indonesia have replaced forests and pre-existing cropland though their views are contrary to the situation in the study area.

3.2 Soil changes under palm plantation in the area

The mean, standard deviation and coefficient of variation of soil properties under the plantations and adjacent agroforest farmlands as seen on Table 2 and the results of the ANOVA test comparing soil properties within the plantations and adjacent farmlands and also within the different palm age series (Table 3) shows that palm plantations in the area affect soil properties. Several studies have also shown that plantation agriculture affects soil properties [24,25,20].

Table 2. Summary Statistics for soil Properties under plantations and adjacent agroforest lands

Soil properties	Control or adjacent land	5years	11years	33years	SD	Mean	CV
Total Nitrogen (N)%	0.142	0.126	0.124	0.113	0.011955	0.12625	9.469129
Calcium (Ca) (meq/100 g)	0.627	0.608	0.616	0.577	0.021463	0.607	3.535939
Magnesium (Mg)(meq/100 g)	1.96	3.94	1.73	2.03	1.024711	2.415	42.43111
Potassium(k)(meq/100 g)	1.18	2.15	2.31	2.07	0.508224	1.9275	26.36701
Sodium (Na) (meq/100 g)	0.067	0.078	0.093	0.087	0.011325	0.08125	13.93816
Humidity (%)	7.17	3.73	7.64	8.56	2.11049	6.775	31.15114
Org matter (g/kg)	30.653	29.274	32.204	26.17	2.566343	29.57525	8.677334
Org carbon (g/kg)	17.78	16.98	18.68	15.18	1.488568	17.155	8.677164
CεC	18.61	17.65	49.733	25.803	14.97147	27.949	53.56709
pH (kcl)	4.53	4.57	4.35	4.49	0.095743	4.485	2.134732
P(mg/kg) Bmg2	0	0	2.684	4.112	2.046623	1.699	120.4604

Table 3. ANOVA of soil properties within the control and the treatments

Dependent Variable	Control	Plantations	Mean Difference	Std. Error	Sig.	95% Confidence Interval		Remarks
						Lower Bound	Upper Bound	
Total Nitrogen (N) %	Control	5yrs	,015500*	.001500	.000	.01134	.01966	**
		11yrs	,016000*	.001500	.000	.01184	.02016	**
		33yrs	,026500*	.001500	.000	.02234	.03066	**
Calcium (Ca)(meq/100g)	Control	5yrs	,019000*	.003691	.007	.00875	.02925	**
		11yrs	.009500	.003691	.062	-.00075	.01975	*
		33yrs	,044000*	.003691	.000	.03375	.05425	**
Magnesium (Mg)(meq/100g)	Control	5yrs	-,99000*	.01275	.000	-1.0254	-.9546	**
		11yrs	-1,13500*	.01275	.000	-1.1704	-1.0996	**
		33yrs	-,91000*	.01275	.000	-.9454	-.8746	**
Potassium (K)(meq/100g)	Control	5yrs	-,013500*	.001218	.000	-.01650	-.00896	**
		11yrs	-,037500*	.001338	.000	-.04162	-.03440	**
		33yrs	-,030000*	.002138	.000	-.03121	-.02100	**
Sodium (Na)(meq/100g)	Control	5yrs	-,012500*	.001118	.000	-.01560	-.00940	**
		11yrs	-,027500*	.001118	.000	-.03060	-.02440	**
		33yrs	-,020000*	.001118	.000	-.02310	-.01690	**
Humidity (%)	Control	5yrs	3,44500*	.01696	.000	3.3979	3.4921	**
		11yrs	-,48500*	.01696	.000	-.5321	-.4379	**
		33yrs	-1,38500*	.01696	.000	-1.4321	-1.3379	**
Organic matter (g/kg)	Control	5yrs	,83000*	.01696	.000	.7829	.8771	**
		11yrs	-,88000*	.01696	.000	-.9271	-.8329	**
		33yrs	2,62500*	.01696	.000	2.5779	2.6721	**
CEC (meq/100g)	Control	5yrs	,97500*	.01907	.000	.9220	1.0280	**
		11yrs	-31,13250*	.01907	.000	-31.1855	-31.0795	**
		33yrs	-7,20150*	.01907	.000	-7.2545	-7.1485	**
PH (kcl)-1:5	Control	5yrs	-,19500*	.01696	.000	-.2421	-.1479	**
		11yrs	,17500*	.01696	.000	.1279	.2221	**
		33yrs	-,14500*	.01696	.001	-.1921	-.0979	**
PAss(mg/kg) Bmg2	Control	5yrs	.000	.001	1.000	.00	.00	**
		11yrs	-2,684*	.001	.000	-2.69	-2.68	**
		33yrs	-4,111*	.001	.000	-4.11	-4.11	**

* significant (p<0.05) ** significant (P<0.01)

3.3 Total Nitrogen (%)

The mean values of total nitrogen were 0.126%, 0.124%, 0.113% and 0.142% for plantations age of 5years, 11years, 33years and the adjacent forest (control) respectively (Table 2). The mean value was higher under the control than the plantations despite the use of artificial fertilizers on plantations. This difference in the percentages of nitrogen can be attributed to the fact that, there is more undergrowth in the adjacent forest than in the plantations where the amount of litter fall is less and also due to uptake by the growing palms. Table 3 reveals a highly significant difference ((P<0.01) of Total Nitrogen between the control and palm plantations. This is an indication that palm plantations in the area significantly deplete the nitrogen content of the soil. Nitrogen (N) is the fourth plant nutrient taken up by plants in the greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production [26,27]. Thus, The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub-humid tropics due to leaching.

3.4 Soil pH

Soil pH, an important chemical characteristic of the soil solution to which both higher plants and microorganisms respond so markedly to revealed a decrease with increasing age of plantation. The mean value under the control was 4.53 which indicate a strongly acidic soil and 4.57, 4.35 and 4.49 for plantations age of 5years, 11years, and 33years respectively (Table 2). A significant difference in pH exist between the control and palm plantations with the 5years plantation being the most acidic. This could be as a result of the decomposition of organic materials from the cleared area since it newly cultivated and prolonged use of N fertilizers. A decrease in pH with plantation age has also been reported by Ng et al. [28] as a result of nitrification of given N fertilizer, organic fertilizer or legumes that contains or produces NH4+which can increase the soil acidity.

3.5 Soil Organic Matter

As observed in Table 2, the mean level of organic matter is higher on 11 years old plantation (32.2%). This could be as a result of the fact that, it is at this age that much organic matter is gotten from loose bunches. The mean values within the plantations of 5, 33years and adjacent agro forest land respectively were; 29.3, 26.2, and 30.7% respectively. Generally, organic matter variation was high within the plantation and adjacent farmlands and across plantation ages (Table 2). A significant difference (P<0.01) was observed in the level of organic matter between the palm plantations and adjacent farmland. The high nutrient demands of plantation crops have been well documented. In most tropical environments, the conversion of forest vegetation to agricultural land results in a decline of the soil OM content [29]. According to PORIM [30] the level of nutrients was found to increase in the early years under oil palm plantations because of the fertilizer applications and N fixation by the leguminous cover crop. However, longer-term trends reveal a decrease in nutrients due to palm uptake and retention exceeding fertilizer applications. It is clear from the results that the ages of palm plantations, affect the level of organic matter in the soil.

3.6 Exchangeable Cations

Exchangeable-cations which are adsorbed in the adsorption complex of soil colloids and represents the ability of the soil to supply nutrients [31] showed higher mean concentrations under the plantations compared to the control with the exception of Ca. The decrease in soil pH with increasing age of oil palms is closely linked to the concertation of base cations (Ca, K, Mg and Na). Ca level under the adjacent forest was 0.63 me/100 g and that under the treatments was 0.62 me/100 g, 0.61 me/100 g and 0.58me/100 g for the plantations of 11 years, 5years and 33years respectively. It was higher under the control and shows a progressive significant decrease with the age of plantations. Therefore, the older the plantation the lesser the amount of Ca stored. Soil Mg, concentrations were higher under the 5years and the adjacent forest has the lowest concentration. Potassium concentration for the 11years, adjacent forest, 5years and 33 years plantations was 2.31, 2.18, 2.15 and 2.07 respectively. The higher values of soil K and Mg under the plantations is due to the application of fertilizers. Na concentrations were 0.093 for 11years plantations, 0.087 for 33years, 0.078 for 5years and 0.067 for the adjacent forest. Just like K it was higher under the plantations than the control. This can be attributed to the active role of palms in pedogenesis and also an increase in the use of inorganic fertilizers as attested by Ng et al. [28].

3.7 Soil Organic Carbon

Almost all organic materials in the soil come from plant residue and they help to increase the ability of the soil to retain water and to improve the stability of soil structure [32]. In general, soil organic carbon is assigned into 3 groups, i.e. fixed carbon, dissolved carbon, and biomass carbon. Results show that the age of oil palm influences the change of C-organic. The mean concentrations of soil organic carbon in the 11years, adjacent forest, 5years and 33 years plantations were, 18.680 Kg, 17.780 K g, 16.980 K g, and 15.180 kg respectively. Results revealed a decrease following plantation establishment except for the 11years old plantation which experienced an increase. The decrease is due to forest opening for oil palm plantation preparation which removed most vegetation cover. The loss of this cover triggers the loss of organic C supply into the soil. The increase of organic C content in the oil palm plantation of 11years old is caused by the fact that the planting in this age has increased the supply of organic material from the plant's stalk cuts litter and also from those of fallen male blossom [33]. A significant difference (P<0.01) in organic carbon was observed between the control and the plantations.

3.8 Soil Moisture (%).

Soil humidity percentages were 8.56%, 7.64%, 7.17%, and 3.73% for the 33years, 11years, adjacent forest and the 5years plantation respectively. Compared to the control, soil humidity was lowest under the 5years plantation and showed an increase under the plantations of 11years and 33year. The reason that can be advanced for this trend is that the five years old plantation do not have sufficient undergrowth and areal coverage that can protect the soil and minimize evapotranspiration from the soil surface compared to plantations of 11years and 33years old. Soil moisture content varied significantly (P< 0.01) between the control and the plantations. The high organic matter content of the control might have influenced its ability to retain more than the plantation treatments as organic matter is an important 'building block' for soil structure and for the formation of stable aggregates [34].

3.9 Cation Exchange Capacity (CEC)

Cation exchange capacity represents the number of exchangeable-cations adsorbed in colloid surface or the ability of the soil to supply nutrient [35,31]. Results show that cation exchange capacity was higher under the plantations of 11years and 33years compared to the control and 5years old plantation. The mean values for the 11year, 33year, adjacent forest and 5years old plantations were 49.733 cmd/kg, 25.803 cmd/kg, 18.610 cmd/kg and 17.650 cmd/kg respectively (Table 2) which are closely related to the concentration of exchangeable bases. Results revealed a high variation (53%) in CEC across plantation ages and the control and a significant difference (P<0.01) in CEC within the plantations and adjacent farmlands as also reported by Ogunkunle [36] and Kamaruzaman [37]. Cation exchange capacity indicates the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assess their fertility and environmental behavior. Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM.

3.10 Available Phosphorus

Phosphorus is known as the master key to agriculture because the lack of it in the soils limits the growth of plants [38]. In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by the very low solubility of the scarce quantity that is present [35]. It is the most common plant growth-limiting nutrient in the tropical soils next to water and N [39].

Table 2 shows that Phosphorus under control and the 5years old plantation was 0mg/kg. Values of 2.68mg/kg and 4.11mg/kg were observed under plantations of 33years and 11yeaars respectively indicating an increase under palms compared to the control. Results revealed a higher concentration under the 11yeaars old plantation compared to that of 33years old. The reduction of available P content under the 33years plantation is assumed to be due to the reduction of soil organic material as a source of available P and also its increase absorption by the oil palm because the demand of nutrient is increasing with the increase of plant age. A significant difference (P<0.01) was observed in available phosphorus between the plantations and the control (Table 2). Similar findings have been reported by Basaran et al. 2006 and Usongo. 2021.

3.11 Plantation impact on food security

The perception of household heads was sought on some aspects of palm cultivation and impact on food security in the area and the results are presented on Table 4.

The introduction of palm plantations in the Mundemba area has not only led to deforestation, but has also resulted to food security issues in the area apart from generating other land-use problems. Results of the chi-square analysis shows that there is no relationship between scarcity of food and food security in the area. The prices of foodstuffs have a highly significant impact($P<0.01$) on food security in the area. This is because palm cultivation is seen to be lucrative and those producing food crops take advantage to increase prices of foodstuffs. As a result of this, those with low purchasing power cannot afford and this results to food security problems. The results equally revealed a highly significant impact ($P<0.01$) between food coming from other places and food security. Due to over-concentration by farmers on palm production, little attention is paid to arable crops resulting in a decrease in the output. As such, food is bound to come from neighboring villages and at a higher cost due to the high cost of transportation as a result of very bad roads. There is a highly significant impact on the amount of land taken up by palm plantations and food security in the area. As palm plantations are taking up more land that would have been used for food crop production, only a small area is available for food crop production. The level to which, farmers prefer to cultivate palms rather than food crops has a highly significant impact ($P<0.01$) on food security in the area. This is so because they believe that palm cultivation is more lucrative than food crop production. Results from chi-square analyses also revealed that the lucrative nature of palm production than food crop production has a highly significant impact ($P<0.01$) on food security in the area. Also, there exists a relationship between soil fertility and palm cultivation with a highly significant impact on food security in the area since palms have rendered the soil infertile for food crop production. Chi-square results also revealed that there exists a relationship between palm plantations and arable farmlands with a highly significant impact on the rate at which farmers are transforming arable lands to palm plantations with impact on food security in the area.

Table 4. Results of chi-square test on socio-demographic characteristics and aspects of palm plantation and food security in the area

Characteristics and aspects of palm plantation and food security	Chi-Square	df	Asymp. Sig.	Remark
Does palm cultivation affect the growth of food crops in this area?	15.360[a]	1	.000	**
Food is scarce in the area	7.973[b]	3	.047	NS
Prices of foodstuffs keep increasing	41.880[c]	2	.000	**
Food crops produced in the area are far below the demand	112.133[b]	3	.000	**
Most of the food in the area is coming from other places	30.533[b]	3	.000	**
Palm plantations are taking up more land that would have been used for food crop production	72.827[b]	3	.000	**
Many farmers prefer to cultivate palms rather than food crops	66.160[b]	3	.000	**
Palm cultivation is more lucrative than food crop production	41.733[b]	3	.000	**
Palms have rendered the soils infertile for food crop production	159.067[b]	3	.000	**
The number of palm plantations is increasing	96.880[b]	3	.000	**
Farmers are transforming their arable farmlands to palm plantations	37.787[b]	3	.000	**

NS= Not Significant significant (p<0.05) ** significant (P<0.01)*

The results are in line with the findings of other researchers. Balachandaran et al., [40] highlighted that access to land to grow food in Liberia decreased significantly in Grand Cape Mount when Sime Darby set up an oil palm plantation, as did access to forests which provided an important source of food resulting in food security problems. In Chincha Peru, in the 1990s, small farmers gave up growing maize to produce cotton, a crop that gave much larger margins [41]. In Mozambique, growers of sugar cane were reluctant to plant food crops and preferred to convert all their land to cane given the high returns. This was followed by a drastic reduction in food security due to more attention on industrial crop production. Orr, [42] observed that in Malawi in the 1990s, the expansion in the production of burley tobacco resulted in less maize being produced.

4. CONCLUSION

Palm cultivation is the major cause of deforestation in the area. It has transformed the once rich tropical forest ecosystem to a monoculture poor ecosystem. Palm plantations and arable lands in the area experienced a steady increase between 1980 to 2020 and are posing a threat to the residual rainforest in the area. The findings also revealed that palm cultivation in the Mundemba sub-division has resulted in a significant deterioration of soil nutrients status when compared to the adjacent farmlands due to their high nutrient demand and uptake. Due to the lucrative nature of palms, most farmers invest their time and resources on it at the expense of food crops to the extent that most of the foodstuffs is coming from neighboring villages at a very high cost. These issues have resulted in food security problems in the area. To help improve the situation, agricultural extension workers within the subdivision should play a key role in sensitizing and educating farmers on sustainable crop production methods that would boost arable crop productivity. Sustaining and improving the production capacity of arable lands and plantations is important and maintenance of the soil resources is a key issue for sustainable production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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