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Effect of malaria incidence and rainfall pattern on crop productivity among farming households: Evidence from North-Central, Nigeria

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ABSTRACT: This study was conducted to establish a direct link of malaria incidence and rainfall pattern on farmer's productivity. In a cohort of farming households in Kabba/Bunu Local Government Area of Kogi State, rainfall pattern, malaria incidence and household farming activities were carefully monitored on a weekly basis over an 8 months period (May to December, 2012). Malaria diagnosis was confirmed among febrile household members using Plasmodium *falciparum* Histidine-Rich Protein II (PfHRP2) malaria rapid diagnostic test (mRDT) kit (Parachek®). Data was collected on the factors of production as well as on the number of kilograms produced by the households for a range of crops such as maize, sorghum, cowpea, cassava, pepper, and yams. Data was also collected on febrile episodes among family members and other relatives within the households and on rainfall pattern. Descriptive statistics and production function were used to analyze the data. A total of 72 households participated in the study involving 432 household members. Malaria incidence was varied with rainfall pattern and crop productivity. Most of the farmers operate on a small scale and mainly cultivated cassava and yam. Malaria affected at least three-quarter of the household's members. The study area recorded an average malaria prevalence of 103 per 1000, 7 rainy days and 256 mm of rainfall. Rainfall days and intensity was highest in the months of October and July respectively. Land, family labour, seed, and fertilizer are the major factors influencing crop production in the study area. The study revealed that cassava, yam, maize and pepper outputs were higher for households with a low incidence of malaria compared to high incidence households except for sorghum. Number of rain days in the study area is important to mosquito breeding which translate to increased malaria incidence thereby having negative effect on crop productivity. Creating awareness on the use of mosquito net and targeted seasonal malaria control strategies should be applied during the peak malaria prevalence period to reduce malaria incidence and enhance agricultural productivity in the study area.

Keywords: Crop productivity, farming households, malaria incidence, Nigeria, rainfall.

INTRODUCTION

Malaria is caused by five species of parasites of the genus *Plasmodium* that affect humans namely *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi* (White et al., 2014; WHO, 2015a). Malaria due to *P. falciparum* is the deadliest form and it predominates in Africa; *P. vivax*is less dangerous but more widespread, and the other three species are found much less frequently (WHO, 2008). Malaria parasites are transmitted to humans by the bite of infected female mosquitoes of more than 30 anopheles' species. Globally, an estimated 3.3 billion people are at risk of malaria, with populations living in Sub-Saharan Africa having the highest risk of been infected: Approximately 80% of cases and 90% of deaths estimated to occur in the WHO African Region, with children less than five years of age and pregnant women most severely affected (WHO, 2015b). Malaria is an entirely preventable and treatable disease, provided the currently recommended interventions are properly implemented. These include (i) vector control through the use of insecticide-treated nets (ITNs), indoor residual spraying (IRS) and, in some specific settings, larval control, (ii) chemoprevention for the most vulnerable populations, particularly pregnant women and infants, (iii) confirmation of malaria diagnosis through microscopy or rapid diagnostic tests (RDTs) for every suspected case, and (iv) timely treatment with appropriate anti-malarial medicines (according to the parasite species and documented drug resistance) (Iwuafor et al., 2016; Mokuolu et al., 2016; Tesfazghi et al., 2016; WHO, 2015b). Malaria in Nigeria is currently present in all parts of the country but with varying incidence and prevalence rate across the nation. Areas such as coastal, riverine, forested and urban areas are endemic areas (Adesina et al., 1999; Adesina, 2005; Laah and Zubairu, 2008).

Health problem has been found to be a major influence on agricultural productivity in Nigeria and malaria has been a contributor to ill health in Africa (Chima et al., 2003; Fink and Masiye, 2015; Josephson et al., 2014; Mboera et al., 2010; Shayo et al., 2015). Malaria is highly endemic in Nigeria and it remains one of the major public health problems and a leading cause of morbidity and mortality in the country (Hay et al., 2010; Snow, 2015). With a prevalence rate of 919/100,000, it accounts for 40% of diseases reported at the public health centers, 30% of all childhood deaths and 11% of maternal deaths (FMH, 2007). The occurrence of malaria is closely related to naturally existing environmental and climatic conditions. Estimates shows that 90% of the global burden of malaria is attributable to environmental factors (WHO, 1998). The incidence, severity of malaria is also affected substantially by human activities, water and agricultural developments. The monetary loss to the economy as a direct result of malaria infections has been estimated as ₦132 billion (Jimoh et al., 2007). The incidence of malaria infection varies widely according to geographic region, season, environment and socio-economic status of individuals. The burden of malaria in Kabba/Bunu LGA, like any other part of Sub-Saharan Africa has been major public concern. Crop productivity is important as Government seek to diversify the economy and feed the nation. Conditions like malaria have the possibility of reducing the availability of labour which can adversely affect crop productivity in agriculture. No study in the study area to the best of the researchers' knowledge has been carried out to ascertain the incidence of malaria by monitoring farmers in a longitudinal manner and carry out medically certified test to ascertain in reality the occurrence of malaria and make analysis based on that in relation to rainfall pattern and crop production. This study, therefore, determined the incidence of malaria in the study area, determined the prevalence of malaria per 1000 population in the study area, identified inputs affecting crop output of malaria affected households and examined rainfall pattern as it impact on malaria incidence and crop out put in the study area. This study as against other studies therefore developed a methodology that ascertained malaria incidence with the use of RDT test kit and determined the actual incidence of malaria in the study area hence addressing the direct link/effect of malaria incidence and rainfall pattern on crop productivity. This study, therefore, seeks to establish a direct link between malaria incidence and rainfall pattern on farmer's productivity.

METHODOLOGY

Study area

This study was carried out in Kabba/Bunu Local Government Area of Kogi State. It falls within the guinea savannah zone and located in the western part of the state. The geographical coordination is 7°49′43″N and 6°04′23″E, with an estimated population of 145,446 (NPC, 2006). The study area has a tropical savannah climate with distinct wet and dry seasons. The wet season ranges from April to October while the dry season is from November to March. The annual temperature varies between 27 and 37^{0}C with relative humidity between 30 and 40% in January and rises between 70 and 80% in July to August. Malaria transmission, based on climatic parameters occurred between (May and October). The study area is a typical village setting comprised of farming household and characterized by indecent environment, poor housing, busy environment, exposed surface water in gutters and wells. These aforementioned are all breeding grounds for mosquito which in turn inject malaria parasites on the farming households. About six and half months of the rainy season create favourable conditions for malaria transmission in the study area. The soil in the study area is predominantly sandy loam in texture. The indigenes are farmers engaging in crop production, rearing of livestock and fish rearing. Kabba/Bunu has suitable ecological and climatic conditions for the production of arable crops such as yam, cassava, cocoyam, maize, millet, rice guinea corn, palm produce, cowpea and others.

Sampling

The population for this study comprises of farming households in Kabba/Bunu Local Government Area of Kogi State. The sampling is based on a cohort longitudinal study. A two-stage sampling technique was employed in selection of sample for this study. In the first stage, 12 villages were randomly selected from the local government area. The second stage involved a random selection of six farming households from each selected village. Thus, a total of 72 households were used for the study. Each member of the selected households was included in the study.

Data collection

Primary data were used for this study. Data were collected through the administration of the structured questionnaire. The primary data were obtained between the months of May to December. The structured questionnaires were designed in three different forms. The first was designed to capture the socio-economic characteristics of the household heads; the second was designed to monitor the occurrence of malaria in the households on a weekly basis through the assistance of well-trained nurses. While the third form of the administered questionnaire were used in collecting information on farming activities per month by trained enumerators. Information collected includes data on agricultural production, malaria occurrences in the households and on rainfall pattern in the study area. The cohort households were followed up for eight months; from May to December, in order to document malaria incidences and farming activities of the households within the farming cycle. During this period, data were collected on febrile episodes i.e. fever episode in index subject (household head), dependent first-degree relative (wives and children) and other relatives within the households (second degree relative).

Tests for malaria were carried out on household members using malaria Rapid Diagnostic Test (mRDT) that is based upon the detection of *Plasmodium falciparum histidine-rich protein ii antigen (PfHRP-II)*. This is a very simple and easy to deploy test that is currently recommended by the World Health Organization for the community level testing for malaria parasite (WHO, 2006). Malaria testing was carried out by twelve trained health workers one per village. In order to document the incidence of malaria in the study area, the weekly visit was made to the farmers' household by the health workers. Activities during the visit included an audit of family members and their wellbeing; identifying the occurrence of fever within the preceding week and conducting a malaria parasite test upon any member of the family with fever or history of fever within the preceding week. Any member of the family with a fever or history of fever in the previous week is tested using the mRDT. Data were also collected on rainfall days and intensity on a daily bases and compiled per month in the study area.

Data analyses

The data collected was analyzed using descriptive statistics and Cobb-Douglas production function. The descriptive tools that were used include the following: tables, mean, mode, standard deviation, percentages and graphs.

Cobb-Douglas Production Function is expressed as:

$$LnQi = \beta_0 + \beta_1 In(X_1) + \beta_2 In(X_2) + \beta_3 In(X_3) + \beta_4 In(X_4) + \beta_5 In(X_5) + \beta_6 In(X_6) + e$$

Where: i = 1…. N, Qi = crop output (grain equivalent), X_1 = Land (ha), X_2 = Family labour (man-days), X_3 = Hired labour (man-days), X_4 = Quantity of seed (grain equivalent), X_5 = Quantity of chemicals (lit), X_6 = Quantity of fertilizer (kg), E= Error term, β_1(s) = Unknown parameters to be estimated and In = Natural Logarithm.

RESULTS

Characteristics of study population

The cohort for the study is made up of 72 households which comprises of 258 children, 75 male adult and 99 female adults giving a total of 432 household members in the cohort used for the study. Table 1 presents the socioeconomic characteristics of the household heads in the study area. The majority of household heads (93%) were males. The mean age of the household heads was 54 years with above half (55.6%) of the household heads within the age group of 41– 60 years. The maximum age of respondents was 72 years and the minimum age of 30 years. The more active and virile age groupings of 21 to 40 were relatively low.

The mean household size for farming household was 6 persons while the minimum and maximum were 2 and 16 persons in a household respectively. Most of the household heads were educated with about 44% having a post-primary education while 27.8% had no formal education.

Analysis showed that (80%) of the households cultivated cassava as a sole crop, 40.28% cultivated maize as sole crop while only 16.67% planted yam as a sole crop. Yam was intercropped with cassava by 40.28% and with pepper by 37.50% of the households. Maize and cassava were intercropped by (31.49%) and with sorghum by (20.83%) of the households respectively. The commonest form of intercropping in the area are yam/cassava, yam/pepper, and maize/cassava respectively while about 20% of the farming households intercropped maize/sorghum (Table 2).

Household's composition and malaria episodes

Table 3 presents malaria occurrence in the household in the study area. Malaria episode among children was highest with 22.45% in October, followed by 19.89% in May. The lowest malaria episodes were recorded in different months for the different household categories; 2.25% for children in September, 5.49% for adult male and 5.6% for adult females in December respectively. In the month of October, 19.78% of the male had malaria. The highest malaria episodes for a female adult member of the

Table 1. Socio-economic characteristics of household heads in the study area.

Characteristics	Frequency (N=72)	Percentages
Gender of Household heads		
Male	67	93.1
Female	5	6.9
Marital Status		
Married	67	93.1
Widow	5	6.9
Level of Education		
Non-formal Education	20	27.8
Primary Education	20	27.8
Secondary Education	14	19.1
Adult education	4 9	5.6
Tertiary education	14	19.4
Age (Years)		
21-30	1	1.4
31-40	12	16.7
41-50	18	25
51-60	22	30.6
>60	19	26.4
Mean	54	
Household Size (No of persons)		
<5	25	34.7
5-10	44	61.1
11-15	1	1.4
>15	2	2.8
Mean	6	

Table 2. Cropping patterns of farming households.

Crops	Frequency*	Percentage
Maize	29	40.28
Cassava	57	79.17
Yam	12	16.67
Yam/Pepper	27	37.50
Maize/Cassava	23	31.94
Yam/Cassava	29	40.28
Maize/Sorghum	15	20.83
Others	10	13.88

*Many of the farmers cultivated more than one crop.

household were recorded in May with about 16.9% having malaria and October with about 22.5% of the female household members with malaria. Malaria episode was highest in the month of October for all the households' composition in the study area. In all, malaria affected at least three-quarter of the households.

Frequency of malaria and prevalence per 1000 persons in the study area

Figure 1 shows the frequency of malaria and prevalence per 1000 population in the study area. The incidence of malaria episodes in the study area was measured based

Table 3. Description of household composition and malaria episodes during the period of study.

Months	Children		Male Adults		Female Adults	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
May	39	19.89	13	14.2	12	16.9
June	25	12.75	8	8.79	8	11.3
July	21	10.71	13	14.2	6	8.5
August	21	10.71	12	13.19	11	15.5
September	5	2.25	10	10.98	8	11.3
October	44	22.44	18	19.78	16	22.5
November	26	13.26	12	13.19	6	8.5
December	15	7.65	5	5.49	4	5.6

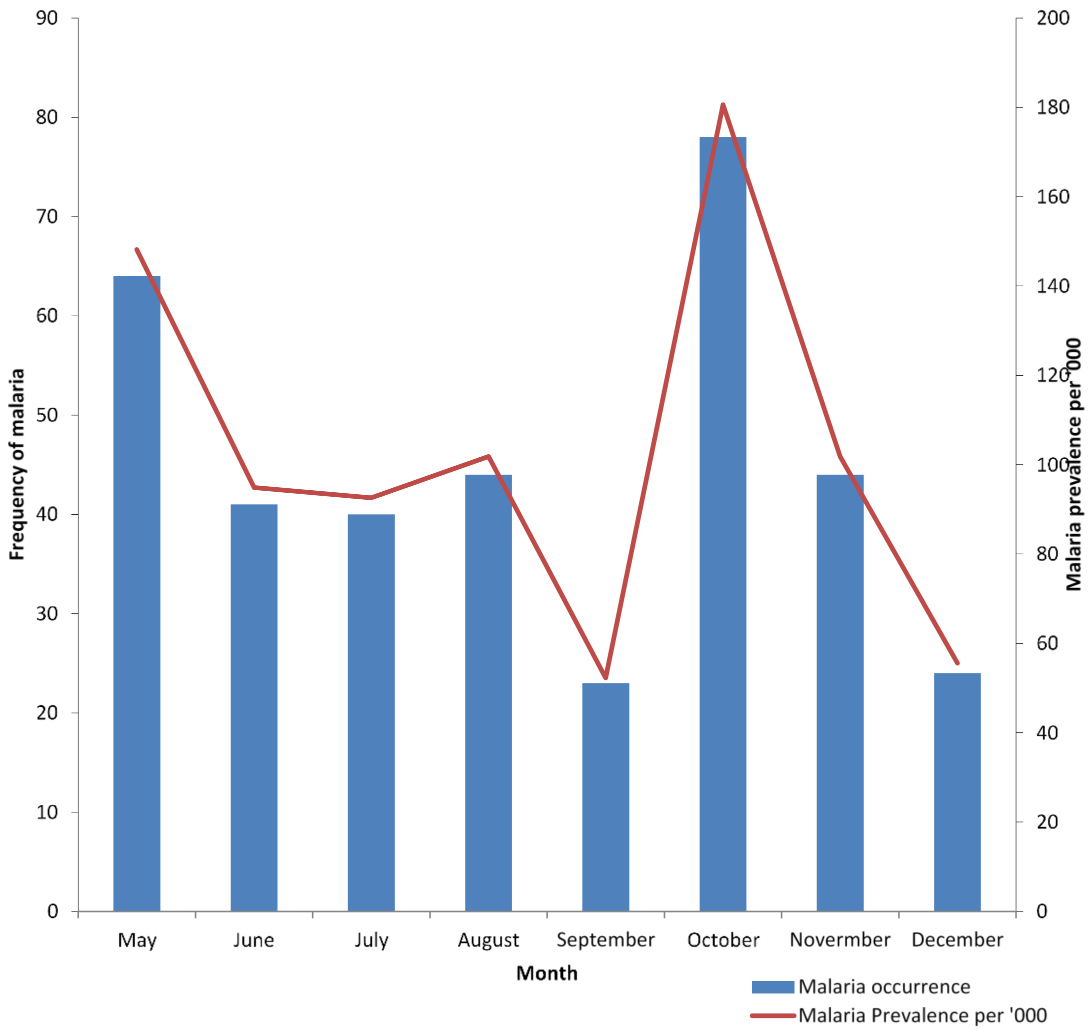

Figure 1. Frequency of malaria and prevalence per 1000.

on the numbers of members affected per household. Malaria occurred most in the month of May and October with about 17.87% and 21.78% of the household being infected. Fewer malaria episodes were observed in the months of September and December with about 6.42% and 6.70% of households with malaria incidence in the study area. The average prevalence of 103 per 1000 was recorded in the study area. Malaria episode was highest in

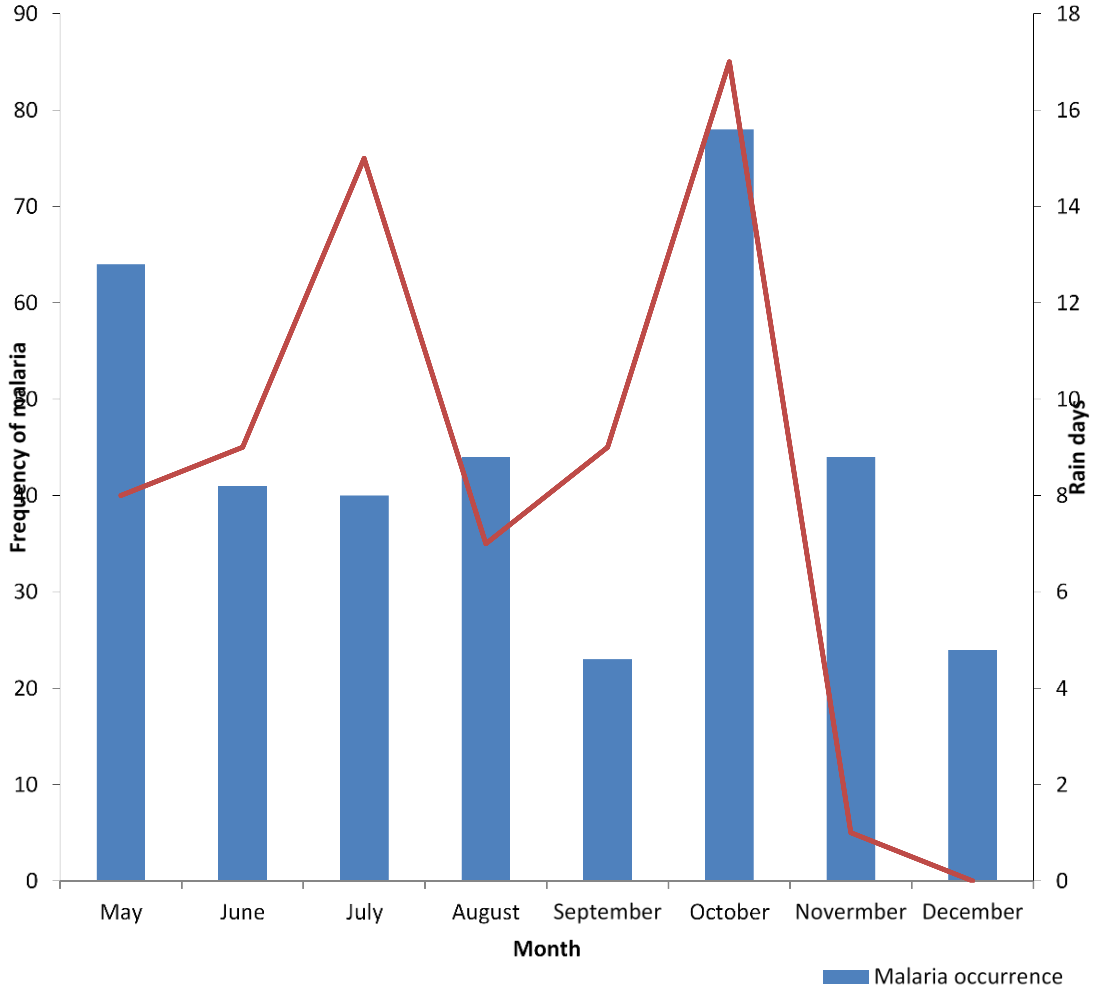

Figure 2. Malaria morbidity and rain days.

the months of October with the prevalence of 180 per 1000. The lowest incidence rate was recorded in September with household having 52.24 prevalence rates per 1000.

Malaria incidence and rainfall pattern

Figures 2 and 3 present the incidence of malaria varied with a number of rainfall days and intensity in the study area respectively. The average rainy days per eight months covering the period of the survey was 7 days. Rain days were highest in the month of July and October as shown in Figure 2. The study area experienced 15 days of rainfall in July and 17 days of rainfall in October respectively. The least rainfall was recorded in the month of November as rain was only experience once in the study area. The study further revealed that the rain day for all the months covered by the study was above average in the study area except for November.

Rainfall intensity in the study area is shown in Figure 3. The average amount of rainfall in the study area during the period of the survey was 256 mm. The study revealed that more than 60% of the household members had malaria in the months of May with 230 mm rainfall. Rainfall intensity was highest in the month of July recording 446.5 mm. In October, 377 mm of rainfall was recorded and this coincided with the period of highest malaria occurrence in the study area.

Crop productivity of malaria affected households

Severity of malaria in the farming household

Households in the study area had at least one episode of malaria. Based on the occurrence of malaria households were categorized into two. Low malaria households are those that had less than 20% malaria incidence within the eight months of the study, while high malaria incidence households had above 20% episodes of malaria. Therefore, households with the proportion of less than 0.2 were categorized as low malaria incidence household,

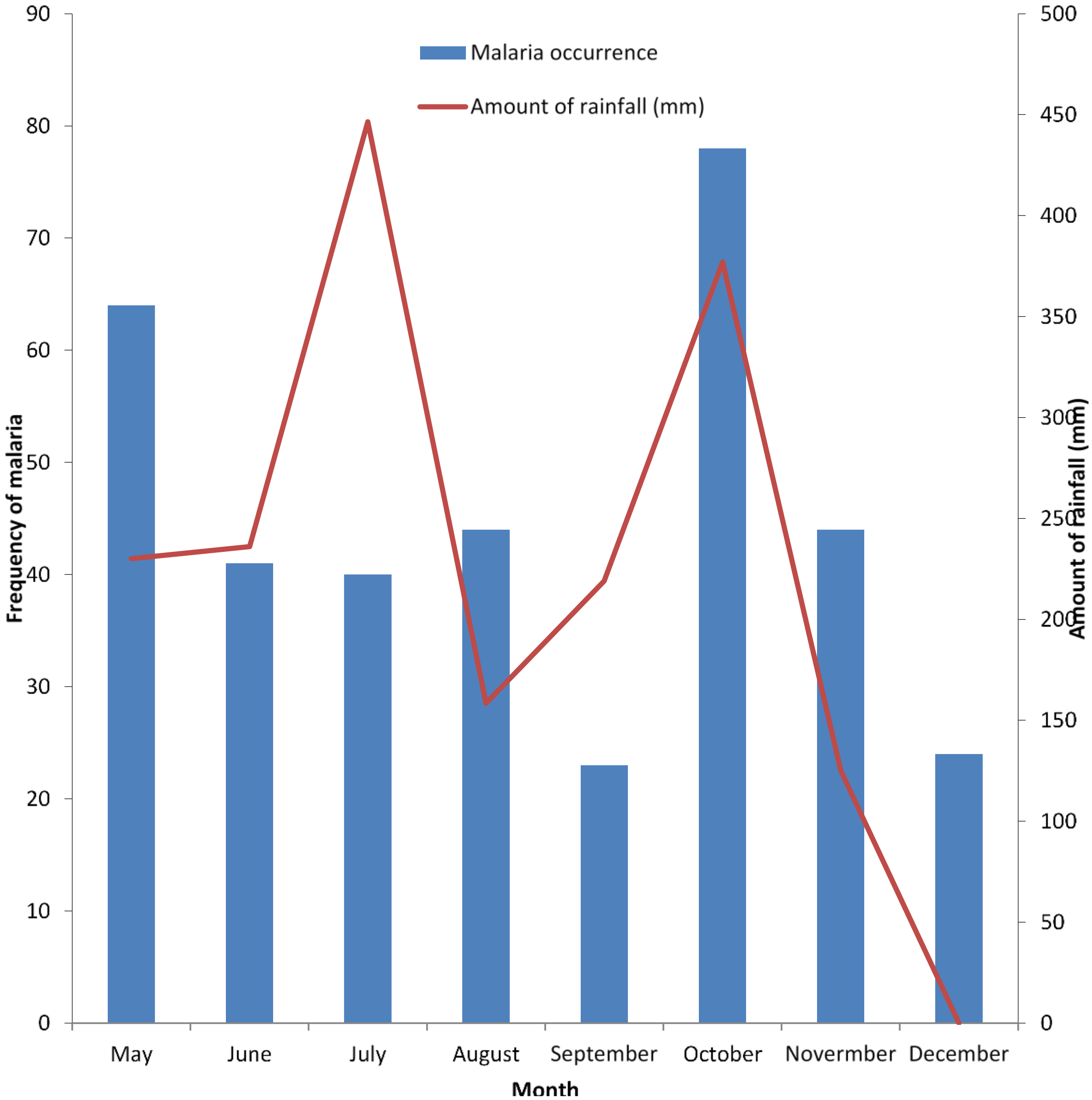

Figure 3. Malaria morbidity and amount of rainfall.

Table 4. Proportion of malaria in the farming household.

Incidence	Frequency	Percentage
High malaria	62	86.11
Low malaria	10	13.89
Total	72	100

while those with proportion greater than 0.2 were categorized as high malaria incidence households.

Table 4 presents the classification of malaria households based on the severity of malaria in the 72 household with malaria. In order to compare the inputs and outputs of malaria affected farming households in the study area, households were categorized into two; high malaria incidence households and low malaria incidence households. The majority of the households (86.11%) had high malaria incidence. Less than 15% fell within the low malaria household category (13.89%). This corroborates the assertion of Hay et al. (2010) and Snow (2015) that

Table 5. Cobb-Douglas production function estimate.

Variable	Coefficient	Standard error	t- Value
Land (ha)	0.648 ***	0.156	4.16
Family labour (mandays)	-0.529***	0.153	-3.36
Hired labour (mandays)	-0.009	0.072	-0.13
Seeds (GEW)	0.310***	0.121	2.55
Fertilizer (kg)	0.573*	0.031	1.85
Chemical (liters)	-0.084	0.095	-0.88
Constant	9.718	1.332	7.29
R^2	0.90		
F- statistics	136.38*		

(*) (**) (***) significance at 10%, 5% and 1% respectively.

Table 6. Average crop yield per farming household in kg.

Crops	Sum	Mean	Minimum	Maximum	SD
Cassava	1640000	22777.78(12480.97)	1200	72800	15024.83
Yam	611700	8495.83 (4655.25)	1000	33200	6125.80
Maize	60070	834.31 (457.15)	100	8000	1033.89
Pepper	12795	177.70 (97.37)	08	1200	295.16
Sorghum	5,335	75.10 (40.60)	58	100	193.30
Total*	951,638.00	13,217.19	1911	32,613.33	6,414.87

Figures in parenthesis are values in kg/ha, Figures in* are grain equivalent weight values.

malaria is highly endemic in Nigeria.

Production function analysis

Table 5 presents the Cobb-Douglas production function of farming households in the study area in order to determine the extent to which the input used explain the variability of malaria households' output. The coefficient of multiple determinations (R^2) was 0.90. The three coefficients of the physical variables, land, seed, and chemicals were significant at 1% and 10% level of probability respectively and confirmed to a priori expectation of a positive sign. Family labour was significant at 1% level of probability and negatively affects the output of the farming households.

Output characteristics of malaria household

The average output realized in the study area was 13,217.19 grains equivalent for the major crops cultivated as shown in Table 6. Results of the analysis revealed that an average yield of 12480.97 kg/ha of Cassava, 4655.25 kg/ha of Yam, 457.15kg/ha of Maize, 97.37 kg/ha of Pepper and 40.60kg/ha of Sorghum was realized.

Crop output and malaria incidence

Figure 4 presents the results on the analysis of malaria morbidity and crop productivity. Results revealed that except for sorghum, production was higher for low malaria morbidity households compared to high morbidity households.

DISCUSSION

Results in Table 1 revealed that household practiced both monocropping and intercropping implying diversity in production as well as fragmentation of land holdings. Households had an average of 1.83 hectares of farm land cultivated. From the findings of the study on the incidence of malaria (Table 3), it can be deduced that malaria varied in the different months considered from May to December (i.e 230 mm (68), 236 mm (41), 446.5 mm (40),158.5 mm (44) , 219 mm (23) ,377 mm (78) ,125 mm (44) and 0 mm (24) respectively). This corroborates the assertion of Devi and Jauhari (2006) that malaria is related to rainfall changes. The incidence of malaria was highest in the month of October for all household composition viz; children, male and female adult respectively. This has its consequences on the man-days available for farming activities. Malaria episodes have both the direct and indirect effects. When children are ill, it affects the mothers and even the attention of the household heads to farming activities. While for male and female adults, it has a direct effect on their level of participation in farming activities and by extension on their productivity. This is in line with the

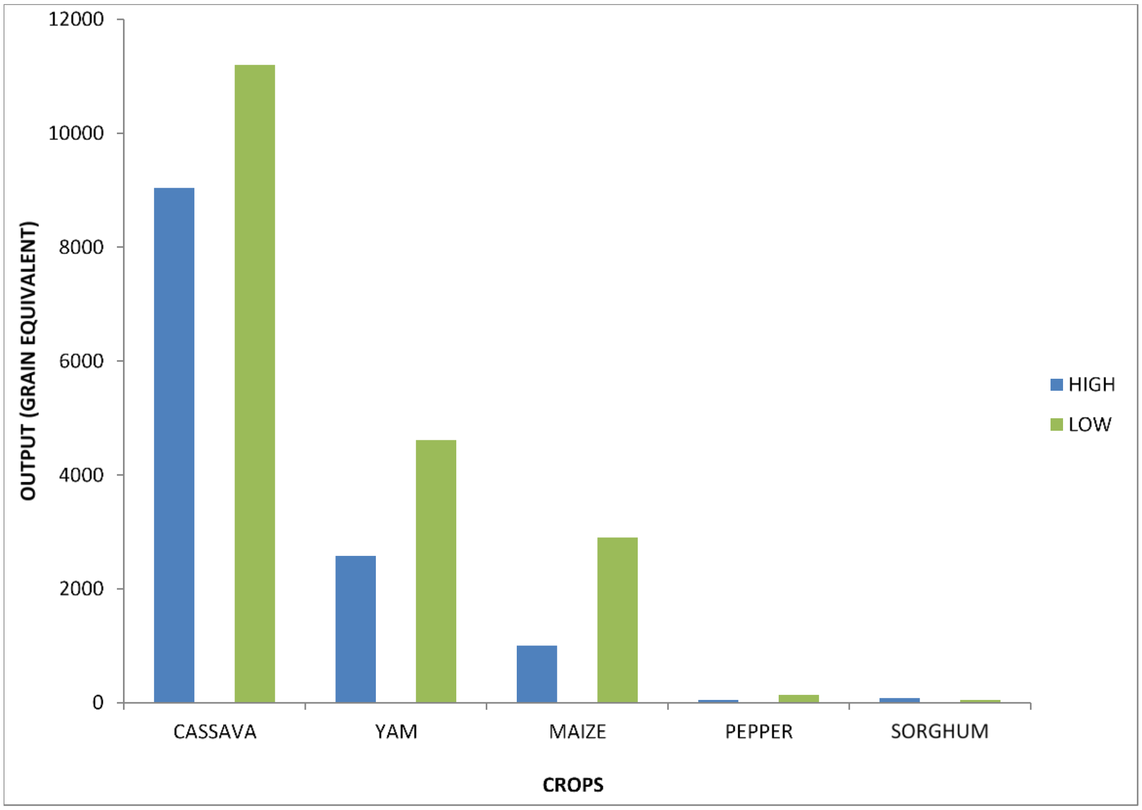

Figure 4. Analysis of malaria morbidity and crop productivity.

findings of Asante (2009) who ascertained that malaria impacted negatively on agriculture in terms of causing loss of potential able-bodied adult labour as well as a reduction in labour quality, time diverted towards caregiving and reduced funds to hire labour.

Malaria incidence varied with rainfall days and rainfall intensity (Figures 2 and 3 respectively). Highest rainfall day was observed in the month of October which coincided with the highest malaria incidence thus implying that rainfall days increase the incidence of malaria in the study area. This finding does not conform to that of Singh and Sharma (2002) in India who observed that there was no relationship between rainfall and malaria incidence. When malaria incidence was varied with rainfall intensity, the month of July recorded the highest amount of rainfall followed by October which recorded the highest prevalence and incidence rate in the study area. The implication of this finding is that amount of rainfall increases the breeding of mosquitoes, resulting in increased malaria incidence and day loss thus, affecting farming activities which may lead to low productivity. Comparatively, the variability in the levels of malaria incidence observed in July with highest rainfall intensity and October having lower rainfall intensity is probably due to the level of usage of protective measures in the different months by the households. The finding indicates that the relationship between malaria incidence and rainfall intensity is not linear. This is in line with the finding of Huang et al. (2011). They observed that increase precipitation may not increase malaria incidence. According to Briët et al. (2008), a reduction in malaria transmission was found shortly after heavy rain. The result on Table 5 revealed that the three coefficients of the physical variable except family labour confirmed to a priori expectation of a positive sign. The positive coefficient of land, seed, and fertilizer implies that as each of these variables is increased, *ceterisparibus*, output increases. This in line with the finding of Mohammed et al. (2013) in their study on the economic assessment of Okra production in Kabba/Bunnu Local Government Area, Kogi State, Nigeria. They discovered that land and seed have positive and significant effect on output. The negative signs of family labour imply an increase in this variable and decreases output. The non-conformity of family labour coefficient to a priori expectation was probably due to high malaria incidence in the study area. Crop output realized by malaria household was highest for Cassava, followed by Yam and least for sorghum (Table 6). Based on the classification of malaria households into high and low incidence, it can be deduced from findings (Figure 4) that low malaria incidence households are more productive (Mohammed et al., 2019) and eradicating the scourge of malaria in the study area would improve their productivity level.

Conclusion and recommendation

Based on the findings of the study it can be concluded that rainfall pattern has a direct and indirect relationship with malaria incidence. Number of rain days in the study area is important to mosquito breeding which translate to increased malaria incidence thereby having negative effect on crop productivity. Increase in the amount of rainfall (intensity) decreases malaria incidence as observed in the month of July. The continued use of land, improved seeds, chemical and eradication of malaria will lead to increased output. It is therefore recommended that awareness should be created on the use of mosquito nets. The area should be targeted for free net distribution and training on utilization. Targeted seasonal malaria control strategies should be applied during the peak malaria prevalence period.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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