



Effect of Cocoa (*Theobroma cacao*) Plantation Types on the Distribution of Anuran Communities in Ore, Ondo State, Nigeria

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ABSTRACT: Anuran species diversity and abundance were evaluated in different farming status of cocoa plantation in Ore, Ondo State, Nigeria. Applying the combination of visual encounter survey (VES) and acoustical survey (AES), the different farms surveyed were categorized as; 1) pure cocoa farms with pesticides applied (PCWP); 2) pure cocoa farms without pesticides application; 3) intercropped cocoa farms with pesticides applied (ICWP); and 4) intercropped cocoa farms without pesticides application (ICNP). The surrounding primary/secondary forest (PSFV) was sampled applying the transect method. A mean total of 690 ± 2.6 anurans belonging to 28 species, 14 genera and 9 families were recorded during the study. Out of these, 10, 19, 17, 22 and 26 species were recorded respectively from PCWP, PCNP, ICWP, ICNP and PSFV. The anuran species richness was significantly different between the different cocoa plantation status and the forest sites ($F_{4,10} = 20.55$, $P < 0.01$). The highest mean number of individuals (190 ± 9.5) was observed at ICNP followed by PSFV (183 ± 5.7), while the least was at PCWP (77 ± 8.0). There was also significant difference ($F_{4,10} = 150.48$, $P < 0.01$) between the abundance of anuran species at the various sites. Diversity indices (Shannon and Margalef) showed that the forest sites had the greatest (3.204 and 4.799) respectively while the pesticide using pure cocoa farms had the least (1.853 and 2.072). Generally, the result of the study clearly indicated that pesticide use cocoa farms were significantly lower compared to other sites. Farmers are encouraged to engage in intercropping (polyculture) especially with food and economic crops in a biodiversity friendly manner which could have similar characteristics of a natural ecosystem, thereby enhancing the biological diversity of agro-ecosystems. © JASEM

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Introduction

Nigeria is situated in the Guinea forest region of West Africa. This biodiversity hotspot region encompasses all of the lowland forests of political West Africa, stretching from Guinea and Sierra Leone eastward to the Sanaga River in Cameroun (www.cepf.net/where_wework/regions/africa/guinea_n_forest). In this region logging, mining, hunting, unsustainable farming practices and human population growths are placing extreme stress on the forests which are threatening biological species. Presently this region is seriously threatened by deforestation, forest degradation and fragmentation (Bakarr *et al.*, 2001; Beier *et al.*, 2002; Hillers *et al.*, 2008).

In Nigeria, about 65.2% of the vegetation has been lost to agricultural practices and only 4.9% are undisturbed, mangrove and montane forests (www.fao.org). NEST (1991), described the plant cover of the country as a patchwork of farmlands,

plantations and secondary vegetation at varying stages of regrowth and maturity.

Cocoa (*Theobroma cacao*) is an important cash crop in Nigeria (Taphee *et al.*, 2015) which was introduced in 1887 from the Amazon basin in South America (Ayoride, 1966). Presently Nigeria is the fourth leading exporter of cocoa in the world after Ivory Coast, Indonesia and Ghana (Cadoni, 2013). There are over 500,000 cocoa farmers engaged in cocoa production in Nigeria, producing more than 200,000 tons of cocoa per year from over 600,000 hectares of land. Over 50% of this quantity is produced in Ondo State alone with substantial quantities produced in Oyo, Ogun and Osun States (Taphee *et al.*, 2015). Western Nigeria remains the predominant cocoa zone accounting for 94% of Nigeria's output (Ojo, 2003). The contributions of cocoa to the nation's economic development are vast and have been reported by many authors (Olayide, 1969; Folayan *et al.*, 2006). Therefore agriculture has continued to play a dominant role in the provision of

food, raw materials for industries, employment for the majority and foreign earnings which are used in financing development activities particularly the permanent crops such as cocoa (Fadipe *et al.*, 2012).

However, agricultural practices such as cocoa agro-ecosystems results in habitat loss, degradation, fragmentation and the creation of monoculture habitats which does not support anuran diversity. Habitat loss lowers anuran species diversity by reducing natural habitats (Cushman, 2006), and increasing population isolations (Arens *et al.*, 2007), inbreeding (Anderson *et al.*, 2004), edge effects (Urbina-Cardona *et al.*, 2006) and discontinuity between terrestrial and aquatic habitats (Becker *et al.*, 2010).

Also exacerbating the loss of biological diversity in the agro-ecosystems is the use of chemical control methods. Production and revenues from cocoa could be substantially higher if the plants were not confronted with strong parasitic pressures, diseases and insect pests (Mahob *et al.*, 2014). In order to achieve this desire, farmers are engaged in the use of pesticides that reduces parasitic pressures to acceptable levels (Tadu *et al.*, 2013).

Information on the effect of cocoa agro-ecosystems (modified habitats) on anurans is lacking, especially taking into cognizance the different status of the cocoa plantation. Due to the manipulation and caretaking of the various farms by the farmers, 1) some farms are grown with the use of herbicides and pesticides regularly, 2) some with the irregular use of herbicides and pesticides, 3) those farms grown and intercropped with cola nut, banana, plantain and cassava food crops with the regular use of herbicides and pesticides and 4) those farms grown and intercropped with other food crops without the regular use of chemical control. This study aims to access the effects of these different cocoa plantations on the diversity, abundance and distribution of the anuran community.

MATERIALS AND METHODS

Study Sites: The study took place at a farming location about 15km from Ore town in Ondo State (Figure 1). There were several cocoa farms located among primary/secondary forests vegetation. Two farms each were selected based on the usage of chemical control methods and type of planting (non-intercropping or intercropping). These categories were;

1) those using herbicides (such as Foler 525, Gramoxone) and insecticides (such as Cocostar 210EC, Basudin 600EC) regularly. In these farms, the farmers planted only cocoa plants and applied the chemical control method at least twice a year. These farms were given the name 'Pure Cocoa With Pesticide' (PCWP).

2) those irregularly using chemical methods of control (had not been applied for the past ≥ 5 years). The farmers in this category irregularly apply the chemical control method at least once every two or three years. But prior to the sampling, it was established that the farmer had not applied the control method for the past five years. These farms were given the name 'Pure Cocoa No Pesticide' (PCNP).

3) cocoa farms grown and intercropped with cola nut (*Cola nitida*), banana (*Musa sapientium*), plantain (*Musa paradisiaca*) and cassava (*Manihot esculenta*) using herbicides and insecticides regularly. In these farms food crops were planted among the cocoa plants. Farmers ate the produce from these food crops directly and some were sold to gain income. Chemical control method was applied at least twice a year. These farms were given the name 'Intercropped Cocoa With Pesticide' (ICWP).

4) cocoa farms grown and intercropped with food crops in which chemical control method have not been applied for over ≥ 5 years. This was given the name 'Intercropped Cocoa No Pesticide' (ICNP).

The primary/secondary forest surrounding the various farms was used as control (PSFV). The GPS of the study sites are shown on Table 1 and parts of the sites are shown on Plates 1-3.

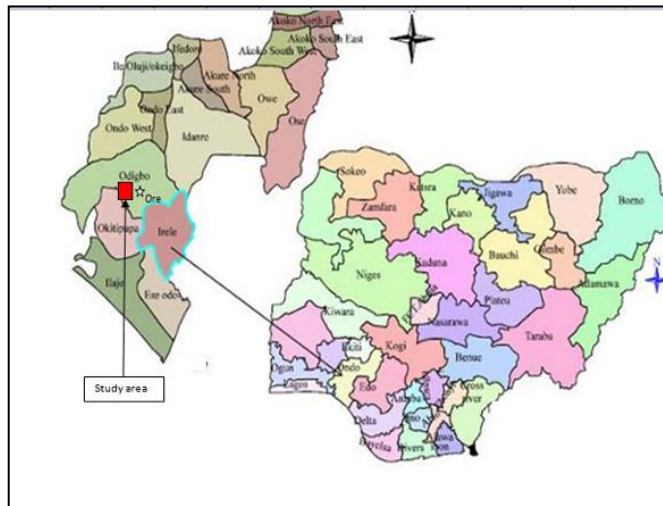


Fig.1. Map of Ondo State (projected from map of Nigeria) showing study area near Ore, Odigbo Local Government. (Map adapted from www.google.com.ng)

Table 1. Short habitat characterization and GPS location of the study sites.

Study Site	Short habitat status characterization	Acronym	GPS Location
1A	Pure cocoa farm with the use of pesticides	PCWP	6.797936N, 4.836292E
1B	Pure cocoa farm with the use of pesticides	PCWP	6.789754N, 4.811573E
2A	Pure cocoa farm without the use of pesticides	PCNP	6.819754N, 4.786854E
2B	Pure cocoa farm without the use of pesticides	PCNP	6.808845N, 4.825306E
3A	Intercropped cocoa farm with the use of pesticides	ICWP	6.784300N, 4.836292E
3B	Intercropped cocoa farm with the use of pesticides	ICWP	6.781572N, 4.808827E
4A	Intercropped cocoa farm without the use of pesticides	ICNP	6.778845N, 4.844532E
4B	Intercropped cocoa farm without the use of pesticides	ICNP	6.800663N, 4.811573E
5A	Primary/Secondary forest vegetation	PSFV	6.776117N, 4.797840E
5B	Primary/Secondary forest vegetation	PSFV	6.814299N, 4.792347E



Plate 1a-c. a- Pure cocoa farm; b- Road through the primary/secondary forest; c- Intercropped cocoa farm

Sampling Technique: The study was conducted during the rainy season (June-August) for three consecutive years (2012-2014). The sites were visited and sampled for one week in each month giving a total of 21 days yearly. Each cocoa plantation had a

quadrate of 90 x 90m installed using red tapes to demarcate the study area. As much as possible all microhabitats utilized by the anurans were incorporated in the quadrate. A combination of visual encounter survey (VES) and acoustical survey (AES)

(Rodel and Ernest, 2004) were conducted in each quadrat. This was done in order to estimate anuran diversity and abundance of each study area.

Due to the nature of the forest (some area being impenetrable), the transect sampling method was applied (Rodel and Ernest, 2004). There were a total of five transects, each measuring 100 x 5m. Some of the foot paths used by hunters and farmers were partially used as transects. All anuran species observed on the transects and 5m on each side were recorded. The transects were patrolled between 0500 and 0700hr in the morning and 1800 to 2000hr in the evening. All microhabitats were thoroughly searched by three individuals (researcher and two field assistants). To avoid duplication of results, toe clipping of individuals were done according to Donnelly *et al.*, (1994). Identification and Statistical Analysis

Anuran species were identified to the genus and species level using literature published by Rodel (2000) and juveniles were identified by literature published by Channing *et al.*, (2012). Individuals caught were recorded and immediately released. However some were used as voucher specimens.

Descriptive statistics was performed using SPSS ver. 16 (SPSS 2007) and the one-way analysis of variance (ANOVA) was used to ascertain if significant

difference exists between the different status cocoa farms regarding species diversity and abundance. The Duncan's Multiple Range (DMR) test analysis was applied to locate significant difference between means of the various sites. The ecological indices were obtained using the PAST (ver. 2.17) programme.

RESULTS AND DISCUSSION

A mean total of 690 ± 2.6 anurans belonging to 28 species, 14 genera and 9 families were recorded during the study. Out of these, 10, 19, 17, 22 and 26 species were recorded respectively from PCWP, PCNP, ICWP, ICNP and PSFV (Table 2 and Figure 2). The forest sites had the greatest number of species followed by the cocoa farm intercropped with food crops not utilizing pesticides, while the least number was observed in pure cocoa farms applying chemical control methods. The anuran species richness was significantly different between the different cocoa plantation status and the forest sites ($F_{4, 10} = 20.55$, $P < 0.01$). Multiple comparisons of means using the Duncan's Multiple Range (DMR) test analysis (PCWP^a, PCNP^b, ICWP^c, ICNP^{cd}, PSFV^d) showed that forest and cocoa farm intercropped with food crops not applying pesticide were not significantly different

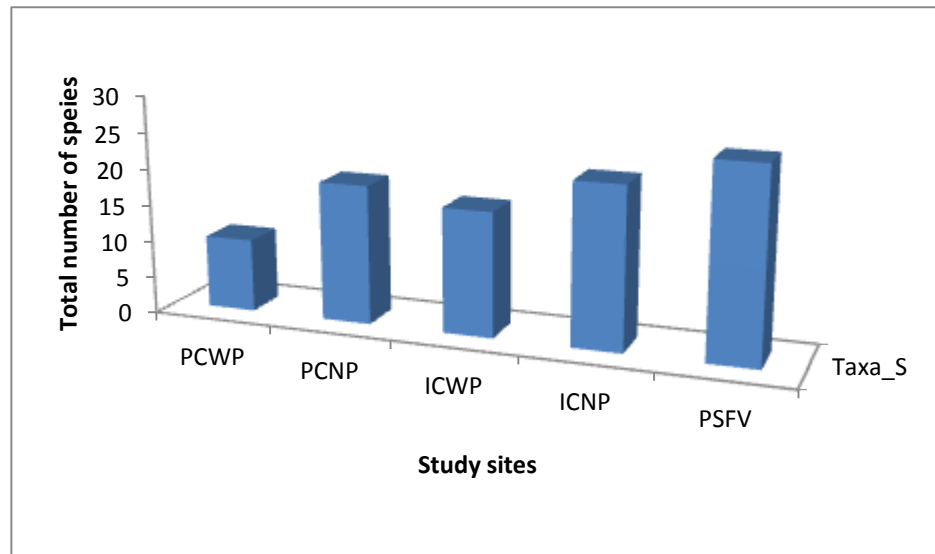


Fig. 2. Total number of species across sites

The highest mean number of individuals (190 ± 9.5) was observed at ICNP followed by PSFV (183 ± 5.7), while the least was at PCWP (77 ± 8.0). See Figure 3. Non-pesticide treated PCNP sites had a greater abundance (133 ± 6.4) than pesticide treated sites of PCWP (77 ± 8.0) and ICWP (107 ± 3.1). There was also significant

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difference ($F_{4, 10} = 150.48, P < 0.01$) between the abundance of anuran species at the various sites. Multiple comparisons of means using the Duncan's Multiple Range (DMR) test analysis (PCWP^a, PCNP^b, ICWP^c, ICNP^d, PSFV^d) also showed that forest and cocoa farm intercropped with food crops not applying pesticide were not significantly different.

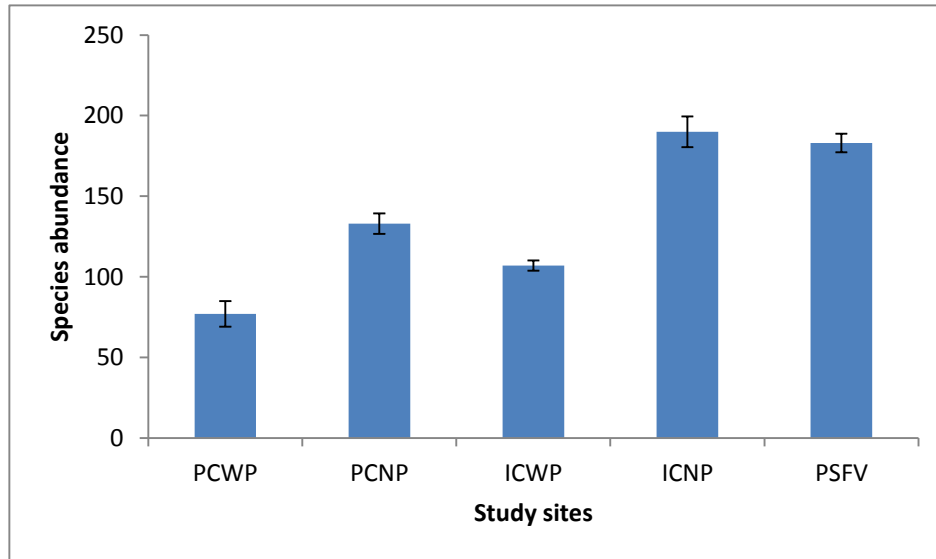


Fig. 3. Mean abundance of individuals across sites

Both diversity indices (Shannon and Margalef) showed that the forest sites had the greatest (3.204 and 4.799) respectively while the pesticide using pure cocoa farms had the least (1.853 and 2.072) (Figure 4). Similarly, the evenness and equitability indices were highest in the forest sites but now least in the pure cocoa plantation not applying the use of chemical control methods (Figure 5). Some of the anuran species observed in the survey are shown on Plate 2a-d.

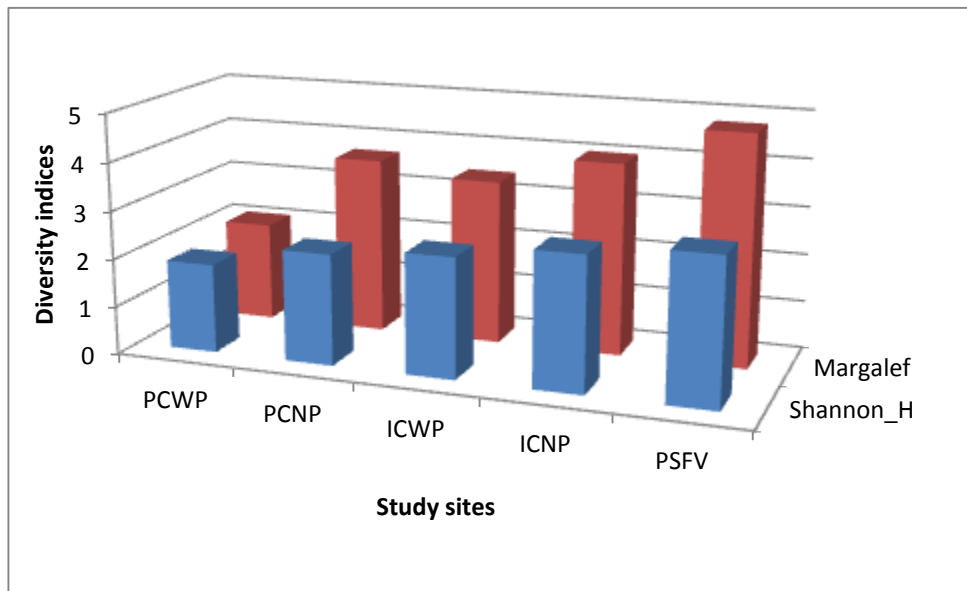


Fig. 4. Diversity indices across sites

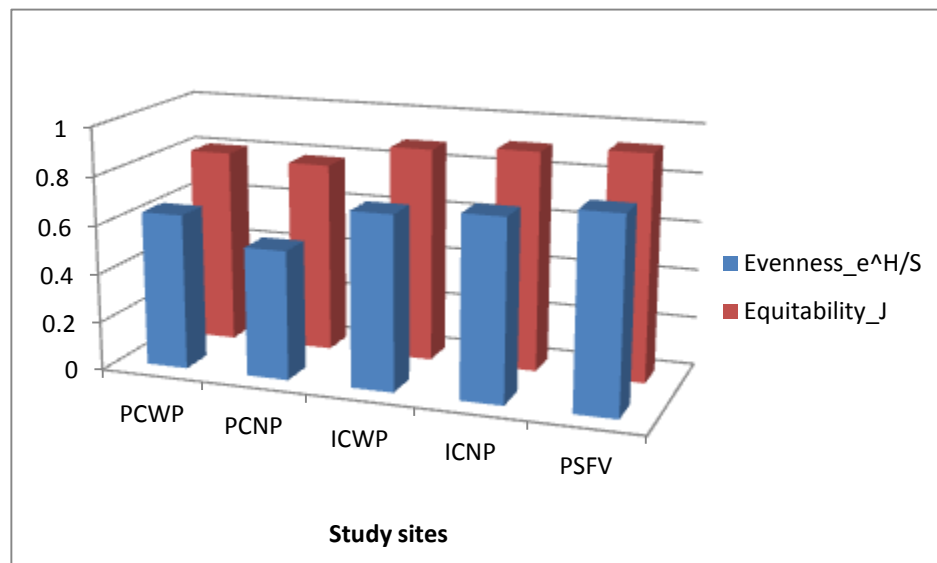


Fig. 5. Evenness and equitability indices across sites

Table 2. Mean abundance of anuran species in four different types of cocoa farms and control sites.

Anuran Species	PCWP	PCNP	ICWP	ICNP	PSFV
PIPIDAE					
<i>Xenopus muelleri</i>		2±2.3	4±1.5	10±1.7	6±2.0
HEMISOTIDAE					
<i>Hemismus marmoratus</i>		1±0.6		2±1.7	4±1.5
BUFONIDAE					
<i>Amietophrynus regularis</i>	21±3.0	32±3.2	18±2.0	26±4.0	12±2.1
<i>A. maculatus</i>	11±3.1	18±2.5	9±0.6	16±3.5	8±2.0
<i>Nectophryne afra</i>					4±2.9
DICROGLOSSIDAE					
<i>Hoplobatrachus occipitalis</i>		2±1.0	6±2.6	11±4.4	6±2.0
RANIDAE					
<i>Hydrophylax albolabris</i>					14±3.6
<i>H. galamensis</i>		1±0.6		1±0.6	4±1.7
<i>Aubria subsigillata</i>				2±1.2	2±0.6
PTYCHADENIDAE					
<i>Ptychadena pumilio</i>	22±3.2	28±4.0	18±0.6	21±7.5	14±0.6
<i>Ptychadena oxyrhynchus</i>	6±2.1	4±2.6	4±0.6	6±2.5	2±1.0
<i>Ptychadena bibroni</i>		1±1.2		2±1.0	
<i>Ptychadena mascareniensis</i>	3±0.0	6±1.2	8±3.0	8±1.0	4±2.1
<i>Ptychadena longirostris</i>		3±0.6	2±1.5	4±1.2	1±1.0
<i>Ptychadena aequiplicata</i>					6±2.6
PHRYNOBATRACHIDAE					
<i>Phrynobatrachus accraensis</i>	8±2.0	14±1.0	8±1.7	12±2.6	2±0.6
<i>Phrynobatrachus francisci</i>			1±1.0		
<i>Phrynobatrachus plicatus</i>		2±0.6		3±1.7	5±1.2
<i>Phrynobatrachus sp</i>				1±0.6	2±1.0
ARTHROLEPTIDAE					
<i>Arthroleptis variabilis</i>	1±0.0	6±3.5	2±0.6	8±1.2	19±5.5
<i>Leptopelis viridis</i>	2±1.2	6±2.1	14±4.2	20±4.6	18±4.6
<i>Leptopelis boulengeri</i>		1±1.5	1±1.0	3±1.5	9±3.5

HYPEROLIIDAE					
<i>Afrixalus dorsalis</i>	1±1.2	2±0.6	3±1.5	8±2.3	12±4.5
<i>Hyperolius nasutus</i>			2±2.3	8±0.6	6±1.2
<i>Hyperolius-fusciventris burtoni</i>	2±0.0	3±1.2	5±2.3	12±1.6	8±0.6
<i>Hyperolius guttulatus</i>					9±3.6
<i>Hyperolius concolour ibadanensis</i>		1±0.6	2±1.5	6±1.5	4±0.0
<i>Phlyctimantis boulengeri</i>					2±1.5



Plate 2a-d. Anuran species a- *Leptopelis boulengeri*; b- *Afrixalus dorsalis*; c- *Hyperolius guttulatus*; d- *Xenopus muelleri*

This study attempts to reveal the effect of different cocoa plantation farming types on the diversity and abundance on anuran communities. Clearly, significant difference occurred between sites where pesticides were applied. Pesticides are used to control pests and diseases thereby enhancing cocoa production. The importance of cocoa in the economy of Nigeria cannot be overemphasized, as its popularity and earnings has made this sub-sector an area of interest to policy makers especially due to its contributions to total Gross Domestic Product (GDP) and being the highest foreign exchange earner among all agricultural commodities (Oyekale *et al.*, 2009). But despite the importance of the use of pesticides in enhancing cocoa production, results show it has a negative effect on anuran diversity and abundance. There was a significant reduction in anuran population at sites where pesticides were applied. This signifies the negative effect of these chemicals

on the existence of these species. According to Bruhl *et al.*, (2013), the negative effects of pesticide are probable since their skin is highly permeable to allow gas, water and electrolyte exchange with the environment. The dermal uptake processes of chemicals has shown to be two orders of magnitude faster than in mammals (Quaranta *et al.*, 2009), suggesting that for terrestrial amphibian life stages present in crop fields, pesticide uptake through the skin might represent a likely exposure route (Bruhl *et al.*, 2011). Also with a life cycle occurring both in the terrestrial and aquatic environments, with migrations to and from spawning waters, anurans are exposed to toxicants in both environments (Fryday *et al.*, 2012).

Pesticides may hamper growth and development, and they may cause developmental and behavioural abnormalities in amphibians (Sparling *et al.*, 2000; Boone and Bridges, 2003). Sources of contaminants

from pesticides may provoke stress response disrupting the endocrine system which could alter reproductive potentials of anurans (Hayes, 2000). Hayes *et al.*, (2002) showed that the herbicide atrazine used commonly induced hermaphroditism and demascularized the larynges of exposed African clawed frog (*Xenopus laevis*) males. Therefore all these factors could lead to the decline of anuran population which was observed at the sites where pesticides were applied in this study.

From results it was observed that the forest sites (control) had the highest diversity of anuran species compared to the monoculture sites. About 18% of species were present only at the forest sites. Species composition often varies across different land use types and regimes and species that requires specific ecological conditions that are not available in modified land uses maybe more affected than others (Rathod & Rathod, 2013). This may be true for forest species such as *Phlyctimantis bouleengeri*, *Hydrophylax albolabris*, *Nectophryne afra*, and *Ptychadena aequiplicata* that were absent from the cocoa farming sites in this study.

In monoculture sites there has been reduction in the biodiversity of plants which also directly leads to animal species reduction. Wild ecosystems (e.g. forests) are diverse and contain wild population of plants and animals each with a unique adaptation to its environment. The monoculture system lacks this variability, hence reduces the diversity of species existing therein. Hence the reduction of species observed in the monoculture sites compared to the forest in this study. Similar observations were made by (Young *et al.*, 2001; Green, 2003; Cushman, 2006) who revealed that the replacement of natural environments by man-made habitats is one of the major causes of change in population and community structure of amphibians around the world. Human-induced impacts can influence amphibian population by modifying the physical structure of the habitat, the frequency and distribution of reproductive sites such as streams, lakes and temporary ponds (Metts *et al.*, 2001).

From the multiple comparisons of means using the Duncan's Multiple Range (DMR) test, there was no significant difference between the forest site and the cocoa farm intercropped with food crops not applying pesticide. Intercropping (polyculture) increases the variability of plant species which directly affects the diversity of animal species. This gives somewhat a close resemblance to a natural ecosystem, enhancing the variability of organisms. Similar concept includes

the plant shade system in which other fruiting and timber species are inserted between the cocoa plants to provide shade (Heinen, 1992). The provision of intercropped food crops among cocoa plants will probably enhance on the local level biodiversity in the tropical agricultural landscape.

The diversity, evenness and equitability indices were highest in the forest and intercropped cocoa farms not applying pesticides. This further buttress the fact that intercropping has a positive impact on biodiversity conservation. It is important that farmers engage in intercropping other food crops or economic crops with cocoa plants to enhance local biological diversity which would favour the existence of the anuran species.

Conclusion: With the conversion of most pristine habitats, agricultural land area is becoming one of the largest terrestrial biome existing today. Food and economic crops planted are expected to produce maximum yield, therefore the eradication of pests and diseases negatively affecting production and revenues are achieved by the application of pesticides. The negative environmental impacts of pesticides are tremendous as majority of the chemicals reach destinations other than their target species, affecting non-target species such as anurans. It is pertinent to note that reductions in the use of pesticides will greatly improve the biodiversity status of any crop plantation. Farmers are also encourage to engage in intercropping (polyculture) especially with native forest food and economic crops in a biodiversity friendly manner which could have similar characteristics of a natural ecosystem, thereby enhancing the biological diversity of agro-ecosystems.

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