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# INDICES OF POPULATION AND DIVERSITY IN ARTHROPODS IN SAVANNA FALLOW FARM FIELDS OF KANO, NIGERIA

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***ABSTRACT***
***Arthropods are diverse and make vital contributions to ecosystem functions, notably in pollination, organic matter degradation, and as prey to other animals. Also, some arthropods create menace in fields and in food stores; and some are agents of diseases to other organisms. In this work, we sought data on the population features of arthropods in fallow farmlands within Bayero University Kano, New Campus and adjoining marginal fields during April to November 2018. We randomly sampled four replicate plots of 100m x 100m, with each plot traversed by two transects of 100m. The transects were further divided into 10-point stations from which samples of five full-arm (180°) sweeps of 40 cm diameter were taken. Non-flying arthropods were sampled using pitfall traps on 10 random, 10m x 10m sub-plots made out from the larger plots. Population indices, namely, diversity, apparent density, dominance, evenness and richness were determined. The pitfall traps yielded 10 orders of arthropods compared to the sweep net with only five. The mean apparent population densities/ha$^{-1}$ were significantly higher for the pitfall trap (1017/ha$^{-1}$) than 320/ha$^{-1}$ for the sweep net. The density also differed significantly amongst certain orders. Further, all the population indices had higher values for the pitfall trap method than for the sweep net. There were strong positive correlations between arthropod abundance and rainfall pattern. Because of the looming impact of global climate changes and increasing loss of biodiversity, further investigation is recommended to focus on conservation goals.***
***Keywords: Insects, invertebrates, ecosystem, tropical, West Africa***

## INTRODUCTION

The members of the phylum Arthropoda are very diverse, often occur in large numbers, and are good indicators of the statuses of their habitats, which are equally diverse. As indicators of habitat status, they respond rather quickly to environmental changes (Alarape *et al.,* 2015). In addition to their population size and dynamics, three other important population characteristics are diversity, species richness and evenness, all of which are important variables in conservation planning and management. In fallow fields arthropods communities are so diverse and help support other organisms and ecological functions, and contribute to the stability of organisms' communities (Agwunobi and Ugwumba, 2013). Varied roles such as degrading organic matter, and mixing, loosening and aeration of soils are performed by many arthropods associated with soils (Sileshi and Mafongoya, 2006). A reduction of arthropods abundance during the dry season seems to be pronounced in the tropics where the non-rainy period exceeds four months. Hence several groups of arthropods are known to decline in number, suggesting that various macroclimatic (long-term weather changes) and microclimatic changes (temperature, photoperiod, precipitation, and humidity) and variation in the availability of food resources are important factors in triggering seasonal activity of arthropods in tropical regions, as well as, in temperate climates. However, the onset of rain is the major factor why flying arthropods are more diverse during the wet season than the dry season (Ahmed *et al.,* 2005).

In addition to the need for establishing the patterns of seasonal fluctuations in insect population sizes and diversity, there is a more serious justification for this work in the light of rapid climatic changes and alarming losses of biodiversity. This work will provide a snapshot of arthropod biodiversity status for the study period and locality, as well as, serve as a basis for future evaluation and monitoring of arthropod diversity and abundance statuses in the grass region of northern Nigeria.

## MATERIALS AND METHODS

### Study Areas

Our investigation sites were within the Bayero University Kano, New Campus (N 110 58′, E 80 25′) and adjoining marginal fields were within the Ungogo local government jurisdiction, Kano, Nigeria (Figure 1). The annual rainfall roughly over the months of May to October, greatly varies from less than 800mm to about 900 mm or more per annum, with the highest rainfall during the months of August to early September. The mean monthly temperature during the study was 33°C, with the lowest in the month of August (Geography Department, Bayero University Kano, 2018).

Original primary vegetation in this locality has been almost completely decimated (pers. observ. >40 yrs.). However, some indigenous trees, ground shrubbery, herbs and grasses still persist. The trees included *Parkia biglobosa, Albazzia chevalier, Sclerocarya birrea, and Acacia albida*. There were crops in neighboring cultivated fields. These included Guinea corn, *Sorghum bicolor* and Ground nuts, *Arachis hypogea*. Main arthropod taxa in all sites included Diptera, Hymenoptera, Isoptera and Orthopterans. There were also odonator and others (Rabiu, 2020).

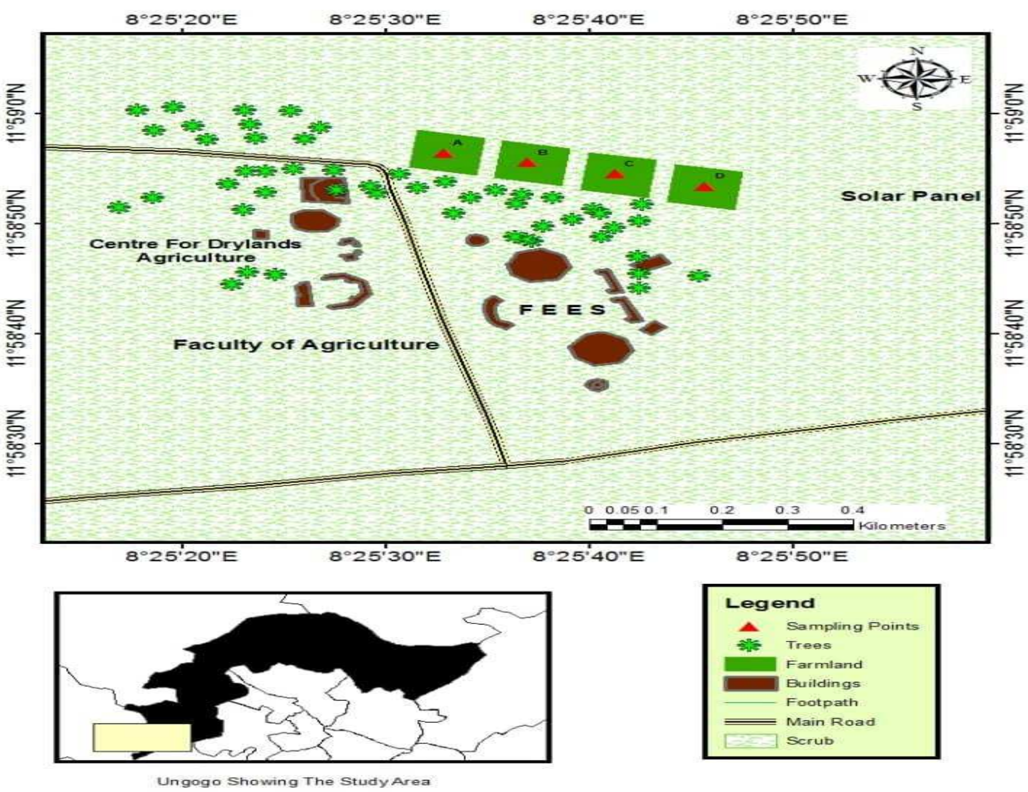


Figure 1: Sampling sites (Red triangles) within fallow fields (Green rectangles) on New Campus of Bayero University Kano, west of Ungogo Local Government Area, Kano, Nigeria.

### Identification of Arthropods

The arthropods were identified with the aid of field guides by Picker (2012) and Villet (2003). Some specimens were identified, counted and released in the field while the rest of the unidentified catch was stored in flasks with 70% ethanol, and carried to the laboratory for further identification.

### Sampling Flying Arthropods

Four replicate plots, each of 100m x 100m, and each traversed with two 100m transects were randomly laid out for sweep netting. Each transect was further divided into 10-point stations, from which samples that consisted of five full-arm (180°) sweeps of 40 cm diameter were taken. The sites was sampled for three consecutive days of every month (April – November. 2018) during morning hours 7am to 11am as described in Castro *et al.,* (2017).

**Sampling Surface and Crawling Arthropods**

Crawling arthropods were sampled using pitfall traps on 10 randomly selected 10m x 10m sub-plots made out from each of the bigger plots. The pitfall trap is made up of a tin of approximately 18cm length and 12cm width, filled with 250ml of soapy solution (Pappoe *et al.,* 2009). Two pieces of rocks were placed at opposite sides of the tin to serve as a platform on which a cardboard was placed to prevent rain water from entering the trap. The traps were inspected for three consecutive days of every month. The soapy solution was topped up occasionally.

**Data Analyses**

The analysis of apparent density (*AD*) is relative to the sampling techniques we used, in this case, sweep net and pitfall traps, and is calculated by dividing the total number of arthropods captured ($\Sigma A$) by the product of the number of functioning traps used to catch them ($T$) and the number of days for which the traps were operational ($D$). The formula was: $AD = \Sigma A /T \times D$. We analyzed the diversity of the taxa by the Shannon-Weaver index of diversity (value range of 1.5 to 3.5). We calculated the index value as: $H = - \Sigma p^s i \ log \ pi$. Where $H$ is Shannon-Weaver index of diversity; $s$ the total number of species in the sample (which we substituted with the taxon, order, given the present limitations in certainty of identifications); $i$ is the total number of individuals in one order; and $Pi$ (a fraction in decimal, is the number of individuals of one order in relation to the number of individuals in the population, and the log is to base-*2* or base-*e.*

The Simpson's index of dominance, which is the measure we adopted, is the most widely used, and is weighed towards the abundance of the commonest species, or rather order, in the case of the present study, ranges from 1 to 8, was computed by the formula: $D = \Sigma n(n-1)/N(N-i)$. Where $n$ is the number of individuals in each taxon; $N$, the total number of all individuals in all the taxa sampled. Note, in our case, order is substituted for species, for reason given above. Species richness, $R$, with 0.1 to 1 range of values, simply refer to the number of different species, which, in the present case is substituted by the number of orders for reason given earlier. Species evenness, $E$, on a value scale of 1 to 4, describes the distribution of abundance across the taxa in the site sampled. We achieved this by simply dividing $D$, from Shannon index by the natural logarithm of species richness, $R$, i.e., $E = D/lnR$.

By using T-tests we compared seasonal differences in apparent densities using Stat software (2.0 versions). We also checked for linearity between weather variables and population parameters using Pearson correlation by *R* statistical package (version 3.4, 1985). Probability for significant differences for all tests was set at P<0.05.

**RESULTS**

**Diversity of Arthropods**

Arthropod species listed by order and in some cases, by species, that were identified are noted in Table 1. with species given as those commonly representing the orders. By sampling count size, the orders Hemiptera, Coleoptera, Orthoptera and Lepidopteran were the largest. On the lower end of the size spectrum were Araneae, Scorpiones and Hemipteran.

**Table 1: Arthropods by sampling count of both sweep and trap nets at the New campus, Bayero University Kano and adjoining marginal fields.**

| Orders | Total Sampling count by order | Species |
|---|---|---|
| Hymenoptera | 418 | *Formica ligniperda* |
| | | *Componotus consibrinus* |
| | | *Messor barbarous* |
| | | *Apis malifera* |
| Coleoptera | 399 | *Astylus atromculatus* |
| | | *Holiocopris colossus* |
| | | *Psordes gratilla* |
| | | *Harpalus affinis* |
| Spirobolida | 70 | *Anadenabolus monilicornis* |
| Scolopendromorpha | 48 | *Scolopendra cingulate* |
| Arachnida | 7 | *Clubion trivialis* |
| Araneae | 1 | *Goliath biredeater* |
| Trombidiformes | 61 | *Trombidium Holosericeum* |
| Hemiptera | 2 | *Unidentified* |
| Lepidoptera | 98 | *Pieriss brassicae* |
| | | *Colias electo* |
| | | *Lampides boetic* |
| | | *Hypolimnas misippus* |
| | | *Drepanagynis cambogiara* |
| | | *Cyligramma lotana* |
| | | *Leucochitonea levubu* |
| | | *Sphingonotus cazerulans* |
| Orthoptera | 113 | *Cyrtacanthacris aeruginosa* |
| | | *Pantala plavesscenss* |
| Odonata | 83 | *Ichnogomphus ferox* |
| | | *Palpura lucia* |
| | | *Africallagma glaucum* |
| | | *Ischnura senegalenses* |
| | | *Orthetrum Julia* |
| Diptera | 21 | *Chrysomya chloropyga* |
| Arachinida | 7 | *Unidentified* |
| Blattodea | 10 | *Periplaneta Americana* |
| Scorpiones | 1 | *Androctonus australis* |

**Diversity and Population Indices by Trap Method**

The numerical summary of indices of arthropod diversity is given in Table 2, which also compares the performances of the two trapping methods – sweep net and pitfall traps. With respect to every index, the pitfall traps outperformed the sweep net sampling. With respect to all the indices of population, the pitfall trap method showed higher values than those for the sweep net method (Table 2.).

**Table 2: Comparison of the relative performances of pitfall trap method to sweep net method for arthropod diversity and population indices.**

| Population and Diversity Indices | Pitfall trap | Sweep net |
|---|---|---|
| Number of Arthropod orders | 10 | 5 |
| Apparent Population density/ha$^{-1}$ | 1017 | 320 |
| Species dominance, *D* | 4.09 | 2.1 |
| Shannon-Weiner Diversity, *H* | 2.88 | 1.29 |
| Species richness, *R* | 0.91 | 0.33 |
| Species evenness, *E* | 2.85 | 1.15 |

Keys:

- Species diversit**y** range, *H* =1.5-3.5, low species diversity range **=** 1.5-1.25 and high species diversity range = 2.5- 3.5 diversity index (*H*) range doesn't exceed 3.5
- Species dominance, *D*, range 1-8. low species dominance range = 1 - 3.9 and high species dominance range = 4 and 8. Generally higher number indicates higher diversity of arthropods.
- Species evenness (*E*) range = 1to 4, low species evenness range = 1- 2.5 and high species evenness range = 2.6 - 4.
- Species richness, *R*, range = 0.1-1, low species richness range = 0.1 - 0.5 and high species richness range = 0.6 - 1. Highest species richness doesn't exceed 1.

The overall mean apparent population density of arthropods between seasons were not significantly different, *T*-Value = -0.25, *P*-Value = 0.806 (Table 3.). The 95% CI for mean difference: (-2.037, 1.586). However, the effect of season was more apparent on the individual orders compared between the rainy and dry seasons. Notable and significant disparities by T-statistics were apparent in eight off the 14 orders, though both wet and dry values were relatively high (Table 4). Lepidoptera, orthoptera and odonator had shown virtually no seasonal difference.

**Table 3: Mean (± SD) and *P*-values for *T*-statistics of aggregate seasonal apparent density per ha$^{-1}$ of arthropod orders.**

| Orders | Rainy Season | Dry Season | *Significant Difference *P*<0.05 for *T*-statistics |
|---|---|---|---|
| Hymenoptera | 46.33 ±3.20 | 70.0 ± 1.00 | * |
| Coleoptera | 43.33 ± 3.33 | 69.50 ± 0.11 | * |
| Spirobolida | 11.33 ± 1.31 | 1.00 ± 0.11 | * |
| Scolopendromorpha | 5.62 ± 0.10 | 1.5 ±0.11 | * |
| Araneae | 0.50 ± 1.20 | 0.5 ± 0.11 | |
| Trombidiforms | 9.66 ± 3.12 | 1.5 ± 30 | |
| Hemiptera | 0.01 ± 1.21 | 1.11 ± 0.5 | |
| Lepidoptera | 13.33 ± 1.11 | 9.00 ± 2.11 | * |
| Orthoptera | 16.66 ± 1.14 | 16.50 ± 4.62 | |
| Odonata | 10.5 ± 0.10 | 10.00 ±1.00 | |
| Diptera | 3.45 ± 1.53 | 7.50 ±1.40 | * |
| Arachnida | 3.5 ± 0.10 | 0.50 ± 1.10 | * |
| Blattodea | 4.5 ± 3.41 | 0.50 ± 2.40 | * |
| Scorpiones | 1.00 ± 0.1 | 0.50 ± 0.60 | |

**Pearson's Correlation Coefficient of Arthropods with Temperature and Rainfall**

Pearson's correlation coefficient values of temperature and rainfall to arthropods is shown (Table 4). The order Hymenoptera showed positive correlation (P<0.05) with temperature (0.922) and precipitation (0.891). Also, coleopteran showed strong positive correlation with temperature (0.942) and rainfall (0.796), respectively. Lepidoptera was recorded to have strong significant positive correlation (P<0.05) with temperature (0.836) and rainfall (0.986). The table shows other strong correlations (P<0.001) between the arthropod orders and the two seasonal variables.

**Table 4: Pearson's Correlation Coefficient of Arthropod abundance with temperature-precipitation.**

| Arthropod Order | Temp ($^{\circ}$C) | Rainfall (mm) |
|---|---|---|
| Hymenoptera | 0.922* | 0.891* |
| Coleoptera | 0.942* | 0.796* |
| Spirobolida | 0.336 | 0.331 |
| Scolopendromorpha | 0.322 | 0.321 |
| Araneae | -0.737 | -0.147 |
| Trombidiforms | 0.614 | 0.542 |
| Hemiptera | -0.012 | 0.021 |
| Lepidoptera | 0.836* | 0.986* |
| Orthoptera | 0.631* | 0.671* |
| Odonata | 0.644* | 0.844* |
| Diptera | 0.221 | 0.209 |
| Arachnida | -0.341 | -0.611 |
| Blattodea | -0.121 | -0.391 |
| Scorpiones | -0.119 | 0.421 |

Correlation was significant at P<0.05, correlation coefficient with asterisks was highly significant at P<0.001

## DISCUSSION

The relatively high apparent density of Hymenoptera, as well as, relatively higher values of diversity indices, makes the order important in the grassland ecosystem of Kano, northern Nigeria. This could simply be a reflection of Hymenopteran's ubiquity and successful colonization of nearly every known terrestrial environment by accounts of Kahinde *et.al,* (2014) and Kaushik *et al.,* (2011) who suggest that Hymenoptera is among the most abundant orders of arthropods. The abundance of Coleopterans may be due to the simple reason that coleopterans have the ability of surviving a variety of terrestrial habitat by virtue of their strong external morphology that helps them withstand many a harsh environment and its changes. This assertion is supported by the findings of Agwunobi and Ugwumba (2013). The relative abundance of Diptera on cultivated and fallow sites was relatively low, not surprising since this group has for long being in association with human habitation, and the fact that they may quickly disappear in response to environmental changes (Kremen *et al.,* 2000). The near absence of the arthropod orders Arachnids, Blattodea and Scorpions in the cultivated land could also be attributed to distance from human habitations and activities. The predominantly herbivorous arthropods (Lepidoptera, Orthoptera and Odonata) appeared to have higher apparent population density during rainy season compared to the dry season, probably due to the abundance of different vegetation cover which leads to a favorable depredation of plant food resources (Alarape *et al.,* 2015).

Pitfall traps had shown higher relative performance than sweep net method, perhaps due to recent abandonment from cultivation to fallow, with the former generally having lower indices of population and diversity (Sileshi and Mafongoya, 2006). As the duration of fallowness increases, the population of flying arthropods might conceivably show an increase, hence possibly greater performance for the sweep net traps. However, Adelusi et al (2018) working in a derived savanna habitat, saw a significantly higher performance for the sweep net over the pitfall trapping method, notwithstanding a 67 percent similarity between the two trapping methods.

Samharinto *et al.* (2012) see the performances of the two trapping methods as a reflection of land management style, with fields under integrated management (IPM) showing greater values for population indices compared to fields that were not managed under IPM system. The microhabitat and height above ground may also affect estimates of population (Zartaloudis et 2007). The overall mean apparent population density between the seasons did not show a significant difference though, clearly, the larger values of Hymenopterans and Coleopterans were during the dry season probably due to the lower vegetation cover which opens the ground floor, making it easier to trap non-flying arthropods. The work of Adelusi et al (2018) in the moister, region of Benue valley offers slightly greater number of arthropod orders and about three times the population size than in our present study. This difference can be explained by the greater availability of moisture (in Benue valley) that supports more plant-based food for the arthropods. Although in temperate grassland, and except for a few taxa, the arthropod population in the prairies of Idaho was similar to the tropical grass field in the present study, i.e., from a few to 50 (Gardiner et al 2003). The arthropod taxa were more diverse in the temperate grassland than in the tropical fields of our study. Other explanation for high apparent density is a favorable plant-insect relationship by the way of phytophagy and mutualism (Akomeah *et al.* 2010). Coleoptera had high mean apparent population density due to the fact that the fallow land serves as a grazing land for the university's cattles; hence the beetles were attracted to cow dungs which serves as a source of food that helps to support their relatively high population, a view supported by Cellia et al., (2008).

The scavenging taxa (Scolopendromorpha and Spirobolida) had shown slightly higher apparent population density during rainy season, perhaps as a result food abundant supply of dead organisms during such period (Jahnavi and Neelesh, 2009). The Trombidiforms were also higher in apparent population during rainy season perhaps because of the high population of Hymenoptera species which they prey on. Therefore, higher number of Hymenopterans would indirectly determine higher number of Trombidiformes (Atobatelel *et al.,* 2008; Cellia *et al.,* 2008). Generally, lower population dynamics of arthropods during dry season could be attributed to non-availability of food, the herbivore arthropods like Orthoptera and Lepidoptera declines during dry season as reported by Lien and Yaun (2003) and Agwunobi and Ugwumba, (2013).

Pearson's correlations of arthropod population to records of values of temperature and rainfall has shown the influence of climate on the population ecology of invertebrates studied in the present work. On a less than seasonal scale, hymenopterans are known to change their activity patterns depending on the temperature of the surrounding environment; as increase in temperature causes acceleration their metabolism (Menéndez, 2007). In the coleopterans, increase in temperature may result in higher interactions within their, and in Hymenoptera and coleopteran increase in population sizes has been related to increases in rainfall, perhaps indirectly as a result of increased food availability during rainy season (Esenowo *et al.,* 2018).

For lepidoptera, orthoptera and odonata population increases with decrease in temperature because their soft body morphology they cannot withstand high temperature, so they avoid desiccation by migration (Manwar *et al*., 2016). In the present study high temperatures appeared to be moderated by heavy rains during August and early September, hence the rains and low temperature resulting in their population increases. In general, good rains support enhanced plant food availability that appears to favor increased populations of arthropods and other animals (Esenowo *et al.,* 2017).

**CONCLUSION**

The pitfall trap method offered higher values of apparent population density compared to the sweep net method. Also, the estimations of population and diversity indices, viz, diversity, evenness, dominance and richness, were relatively higher for the pitfall traps than for the sweep net. Primary climatic factors, namely, temperature and precipitation appeared to influence arthropod population characteristics, evident in strong positive correlations with abundance of arthropods, probably through the enhancement of plant foods supply. The peak rain period may have also helped moderate high temperature, thereby supporting increases in the apparent population densities of soft-bodied arthropods.

**RECOMMENDATIONS**

In spite of obvious habitat degradation in the site of our investigations, population indices, though not population sizes, appear to suggest an intermediate status of arthropod diversity. Further investigation is recommended to focus on conservation goals and plans because invertebrates are critical to the wellbeing of the ecosystem, and because of the looming impact of global climate changes on arthropods and loss of biodiversity in general.

**REFERENCES**

Adelusi, S. M., R. T. Ada, E. A. Omudu. 2018. Diversity and abundance of insect species in Makurdi, Benue State, Nigeria. *International Journal of New Technology and Research.* 4, 6, 52-57.

Agwunobi, O. D., Ugwumba O. A. (2013), A Comparative Assessment of Soil Arthropod Abundance and Diversity in Practical Farmlands of University of Ibadan, Nigeria. The *International Journal of* Environmental *Resources Research*, 1, 1-2.

Ahmed, A.B., Okiwelu S.N., Samdi S.M. (2005). Species Diversity Abundance and Seasonal Occurrence of Some Biting Flies in Southern Kaduna, Nigeria*. African Journal of Biomedical Research*, 8, 113-11.

Akomeah, P.A., Ekhator, O. and Udoka, C. (2010). Effect of temperature and rainfall and Seasonal variation of arthropod species diversity in Edo State. *Ethiopian Journal of Environmental Studies and Management*, 3. 3, 36-40.

Alarape A.A., Omifolaji J.K and Mwansat G.S. (2015). Butterfly Species Diversity and Abundance in University of Ibadan Botanical Garden, Nigeria. *Open Journal of Ecology*, 5, 352-360.

Atobatele, O.E. and Ugwumba, O.A. (2008). Seasonal Variation in species abundance of arthropods in Riminar village Osun State Nigeria (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology*, 7. 12, 62-171.

Castro, J., Tortosa F. S., Jimenez J., and Carpio A. J. (2017), spring evaluation of three sampling methods to estimate family richness and abundance of arthropods in olive groves*. Animal Biodiversity and Conservation*, 4,.2, 193–210.

Cellia, A., Harvey, Jorge G., Eduardo S. (2008), Dung beetle and Terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. *Journal of insect biology*, 1. 47–53.

Esenowo, I. K., Udoidung N. I., Akpan A. U., Archibong D. E and Umoh I. I. (2017), Evaluating the Abundance of Soil Macro-Arthropods in Idoro Community, Akwa Ibom State, Nigeria. *Asian Journal of Environment & Ecology*, 3.4, 1-8.

Gardiner, M. M., J. D. Barbour, and J. B. Johnson. (2003). Arthropod Diversity and Abundance on Feral and Cultivated Humulus Lupulus (Urticales: Cannabaceae) In Idaho. *Environ. Entomol.* 32(3): 564-574.

Jahnavi, J. and Neelesh D. (2009) Ecology, diversity and distribution of centipedes (Scolopendromorpha; Chilipoda) in the northern Western Ghats, India. 119pp.

Kahinde, J.K., Kabala L.A., Ola T.I (2014). The abundance and relative performance of pitfall traps in the capture of different ant species on the maize farm. *Journal of Insect Science,* 8, 1, 20-25.

Kaushik, S., Sharma S, Saxena M.N., Saksena D.N. (2011). Habitat ecology of zygopterans (Odonata) nyphs in certain water bodies of Madhya Pradesh. *Journal of Bombay Nat. History Soc.,* 88, 400-405.

Kremen, C., Colwell, R.K.; Erwin, T.L.; Murphy, D.D.; Noss, R.F Sanjayan, M.A. (2000). Terrestrial arthropod assemblages: their use in conservation planning. *Journal of Conservation Biology,* 7, 796-808.

Lien, V.V. and Yaun D (2003), the differences of butterfly (Lepidoptera, Papilionidea) communities in habitats with various degrees of disturbance and altitudes in tropical forests of Vietnam, *Journal of Biodiversity and conservation*, 12, 6, 1099-1111.

Manwar, N., Armah F.A and Varsha W (2016). Seasonal Variation in Diversity and Abundance of Invertebrates at Wawangs-Vithoba lake, India, *Journal of entomology,* 13, 170, 1:37-44.

Menéndez, R., 2007. How are insects responding to global warming? *Tijdschrift voor Entomologie,* 150, p. 355-365.

Pappoe, A.N., Armah F.A. and Akotoye H. K. (2009), Diversity of Soil Surface Arthropods in Cultivated and Uncultivated Fields in Coastal Savanna Zone of Ghana, *Research Journal of Soil Biology*, 1: 37-44.

Picker, M. (2012). Field Guide to Insects of South Africa. Penguin Random House, Durban, South Africa, 444 pp.

Rabiu, S. (2020). Dimensions of Home Range Structure of Agama agama in the Savanna Region of Nigeria. *Herpetological Conservation and Biology*, 15, 2, 318–324.

Samharinto, A., L. Abadi, B. Rahardjo and H. Halim (2012). The increase of arthropods biodiversity in paddy field ecosystem managed by using integrated pest management at South Borneo. *The Journal of Tropical Life Science*, 2. 3, 72-76.

Sileshi, G.A and Mafongoya P.L. (2005). Variation in macrofauna communities and functional groups under contrasting land-use systems in eastern Zambia. *Journal of Applied Soil Ecology,* 31: 49-60.

Villet, M. H. (2003). Field guide to Insects of Africa, *African Zoology*, 38, 1.189-190.

Zartaloudis, Z., E. Navrozidis & M. Copland (2007). Sampling method affects estimates of population density and reproductive maturity of summer-form pistachio psyllids, *New Zealand Journal of Zoology,* 34:4, 303-310.