

Application of Geo-spatial Technology in Characterization of African Honeybee (*Apis mellifera*) Apiaries into Ecosystem Zones for Productivity and Pollination Service

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ABSTRACT

Seven major ecological zones of Nigeria with modern functional apiaries were mapped and sampled in the rainy season between April 2016 and October 2018 for estimating the bee foraging flight range and floral species diversity; collating satellite imagery data for geospatial zone mapping using GPS (Garmin Etrex 20) to capture the coordinates of apiaries locations and their attributes, climatic and topographic data and generating ecological zones: the wetland vegetation, savanna grassland, savanna woodland (disturbed), shrubby forest, lowland dense forest, and Highland rain forest. Honeybee flight ranges between 1 and 5 kilometer radius from where bees at the apiaries can forage for pollen and nectar. Igbeti/Malete/Buari bees forages at similar ecosystems within this range while those at Saki and Abuja apiaries have potentials to forage at different ecological zones ranging from woodland savanna to lowland and high forests. Abuja (woodland savanna and shrubby forest zones) apiaries produces average of 32 liters of honey per hive and Kwara (savanna grassland and wood land Savanna) produces average of 24 liters of honey per hive. There is also structural variation in the floral species diversity and richness as richness marginally differed at the locations. Highest index was observed in Orozo (H=2.62; Margalef = 3.05) and Agbungburu (H=2.54; Margalef = 3.06). Low index was attained at Buari (H= 2.10; Margalef= 2.32) and Igbeti (H= 2.11; Margalef= 2.62). Apiary managers and farmers acquiring relevant knowledge on apiculture and prevailing *A. mellifera* apiaries would assist management activities; contribute to better production and pollination for food security.

Keywords: Honeybee, apiaries, geospatial-mapping, flora, ecological zones.

Published Online: January 18, 2021

ISSN: 2684-1827

DOI: 10.24018/ejfood.2021.3.1.221

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I. INTRODUCTION

Honeybee *Apis mellifera* (Hymenoptera: Apidae) is a social insect known as the most economically valuable insect because of its honey production and pollinating activities. Honeybees have been described as the most useful of all insects because of its ability to provide the basic services necessary for the survival of man and other forms of life. Of the approximately 20,000 known bee species, only four are of economic importance. These species are, *Apis florea* (Dwarf honeybee), *A. dosata*, *A. cerena* and *A. mellifera* (Western honeybee) [1]. Among the four species, *A. mellifera* is the most widely distributed which have been found in Europe, Middle East, and Africa in different races [2], [3].

A. mellifera is a commercially managed bee species in apiaries in Nigeria. It is managed in various forms of hives depending on resources, its construction, or the local availability of durable wood for its construction. A beehive is an enclosed structure man-made in which the *subgenus* *Apis* lives and raises their young. *Apis mellifera* is one of the main species kept in hives in many apiaries [4].

Apiary is regarded as a place where beehives, bee artificial nesting homes provided by humans in the form of boxes of specific dimensions for keeping and raising bees for their honey. The structure varies according to location and needs. Many types of hives exist including Kenya Top Bar (KTB), Tanzania Top Bar (TTB), the Langstroth and make up apiaries [5], [6].

Flowers constitute the stronghold of bee's life upon which sustenance depends. Several flowering plants blossom at different periods of the year depending on the soil type, climatic factors, and the vegetation. The blooming time for the same nectar plants may vary considerably. The accurate knowledge of the flora blooming time, type, density, and quality of bee flora in a region is indispensable for beekeeping management. Every region has its own vegetation, climatic, topographic and honey flow and dearth periods. Such knowledge of the bee flora will help in the effective management of bee colonies [7]-[9].

The conservation of regional stocks of *Apis mellifera* requires detailed knowledge on their identity and ecology [10]. Knowledge of the *Apis mellifera* subspecies in various ecological zones of Nigeria is germane to their existence at various zones of the country. Good performance and the

development of apiaries require a good bee pasture source [11] and this depends greatly on a detailed assessment of the ecosystem and vegetation around the apiary, taking cognizance of the flora population densities and components. These are paramount to the sitting, thriving and production of the apiary.

Geospatial technology is regarded as an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, and uses data focusing on the geographic, temporal, and spatial framework [12]-[16]. The applications of geomatics have been involved in many fields of human endeavors such as precision farming, facilities management, and environmental management [17], [18].

The GIS technology has been used in beekeeping for various activities such as for the choice of the best location for the installation of the apiaries, its management, avoiding overcrowding and eradicating competition between clusters for the same flora. It is also used for the evaluation of the hives, its pattern of land use, the local flora, and for creating suitability maps for beekeeping activities [18]-[25].

The natural vegetation zones are as a joint interaction of the climate, (temperature, humidity and rainfall), land use methods and soils [26]-[28]. These factors have been modified by human activities and man's pattern of land use. The Nigerian ecological zones have been classified by many researchers. Oyenuga [29] classified the country into nine (9) agro-ecological zones as- the mangrove forest and coastal vegetation, the freshwater swamp communities, the tropical high forest zone, the derived Guinea savannah with relict forest, the Southern Guinea savannah zone, the northern Guinea savannah zone, the Jos plateau, the Sudan savannah, and the Sahel savannah.

Iloeje [30] however, further grouped the zones into: a) forests and b) savannah zones. These two major zones were further sub-divided into three zones each: Forests that consists of (i) salt-water swamp, (ii) fresh-water swamp, (iii) high forest; and b) Savannah zone that consists of (i) guinea savannah (ii) Sudan savannah, and (iii) Sahel savannah [29], [30].

The amount of honey that a bee colony produce depends on other environmental factors, equipment and appropriate management approach adopted, as well as the fundamental practice of rational beekeeping. For a good performance and the development of hives a good bee flora is needed [11]. Therefore, a detailed assessment of the vegetation around the apiary is essential, taking into account the population densities and the diversity of flowering periods. There is very scanty information in literature about honeybee (*Apis mellifera*) apiary environments in the various ecological zones of Nigeria. This work was therefore, designed to provide relevant information to fill the gap in knowledge of apiary management, production, and crop pollination.

II. MATERIALS AND METHODS

A. The Study Area

The survey of African honeybee (*Apis mellifera*) modern functional apiaries was conducted at Abuja, the -Kwali and AMAC-Orozo all within the Federal Capital Territory (FCT),

(Buari and Malete) Kwara State North central geopolitical zone, (Agungbura and Omiseeni) Ogun State, (Ikirun and Oshogbo) Osun State and (Igbeti and Saki), Oyo state of Nigeria (Fig. 1).



Fig. 1. Map of the administrative region showing locations of the apiaries.

The mean annual temperature ranges vary from 25.6 °C at Oshogbo, Ikirun axis to 26.4°C at Omiseeni/Agungbura axis while Sheda had mean annual temperature above 27 °C. Total annual rainfall increases from the south to the north with Agungbura and Omiseeni receiving over 130 mm annually while Igbeti and Malete recorded between 1100–1200 mm. At the FCT areas total annual rainfall increases eastward with Orozo receiving over 1400 mm total annual rainfall while Sheda received between 1000-11000 mm. The orographic effect of high elevation at Orozo accounted for these differences between two locations of almost similar latitudes (Table 1).

TABLE 1: CLIMATIC AND TOPOGRAPHIC DATA OF THE APIARIES AT THE STUDY AREA

Apiary locations	Mean annual Temperature (°C)	Total annual Rainfall (mm)
Oshogbo	25	1100
Ikirun	25	1200
Igbeti	25	1100
Malete	26	1100
Buari	25	1200
Saki	26	1100
Agungbura	26	1500
Omiseeni	26	1600
Sheda	27	1100
Orozo	24	1400

Extracted from Worldclim database.

GIS Mapping of ecosystem of the apiaries.

B. Climate Data

To create the climate layers of Mean Annual Temperature (MAT) and Total Annual precipitation (TAP), the climate data CLM files Tiles 26 of Worldclim.org database at 30 arc seconds resolution was downloaded and the data extracted was converted from grid raster files into ESRI ASCII in DIVA GIS and subsequently imported into ArcGIS 10.2 [31]. To obtain the climate data of the sample apiaries in the study area, high resolution climate data at 30 arc seconds was downloaded from WorldClim database. 19 bioclimatic variables data were extracted using climate point tools while Mean Annual Temperature (MAT) and Total Annual Precipitation (TAP) raster grid were extracted using climate to map tools in DIVA GIS [31], [32].

C. Satellite Imagery Data

Bands 2, 3, 4 and 5 were acquired from Landsat 8 2017 Operation Land Imagers (OLI) with 90% cloud free, the images were collected in already georeferenced (Geotiff) format. Landsat 8 comprises 2 sensors: The (OLI) and Thermal InfraRed Sensor (TIRS) which see improved signal to noise (SNR) radiometric performance and for better land-cover characterization. OLI collects data from nine spectral bands at 30 m excepts bands 8- Panchromatic which is at 15 m. Band 1 were excluded because it was designed for detection of coastal features and aerosol which was not required in this study. Seven scenes were mosaicked and subset/clip to the boundary of the study area using raster processing tools in ArcMap 10.2. Band composites were performed on bands 5, 4, and 3 for vegetation index analysis. GPS (Garmin Etrex 20) was used to capture the coordinates (Longitude and Latitude) of apiaries locations and their attributes (size, Honey quantity, Settlements name, Apiary type, Hive type) which were added in a relational table for GIS analysis.

The points coordinate was prepared in spreadsheet, saved in XLS format, and were imported and converted to ESRI shapefile using ArcMap 10.2. To determine the possible Honeybee forage flight distance and the potentials ecosystem zones from which bee source their nectar and pollen, multiple nuclei buffering was performed at 1, 2 and 5 km around the center of each selected apiaries.

D. Topographic Data

For Topographic data, a Digital Elevation Model (DEM) from NASA/Shuttle Radar Topographic Mission- SRTM at 90 m resolution was acquired from which the study area was subsets and imported into ArcMap10.2 version to reclassify the study area into 8 elevation classes using Jenks' natural breaks. The elevation data, ground survey was used as an additional referenced data.

E. Vegetation Index

Composite images of Band 4, red (R) 0.630–0.680 μm and Band 5, near infra-red (NIR) 0.845–0.885 μm of Landsat 8 OLI, 2017 were used to produce Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) as proposed by Huete [33], using L factor of 0.5 to minimize the effect of soil reflectance characteristics on vegetation. In mapping the apiaries into ecosystem zones, vegetation index was classified (Fig. 4a). NDVI and SAVI are mathematically expressed as:

$$NDVI = \frac{NIR - R}{NIR + R}$$

and

$$SAVI = \frac{NIR - R}{NIR + R + L} \cdot (1 + L)$$

NDVI values ranges from -1 to 1; -1 signifies area under water or ice, 0, area with no vegetation and 1, area with the dense vegetation (Fig. 2).

All these layers were resampled to 30 m resolution and spatially combined using Fuzzy overlay tools in ArcMap to produce the apiaries ecosystem zones.

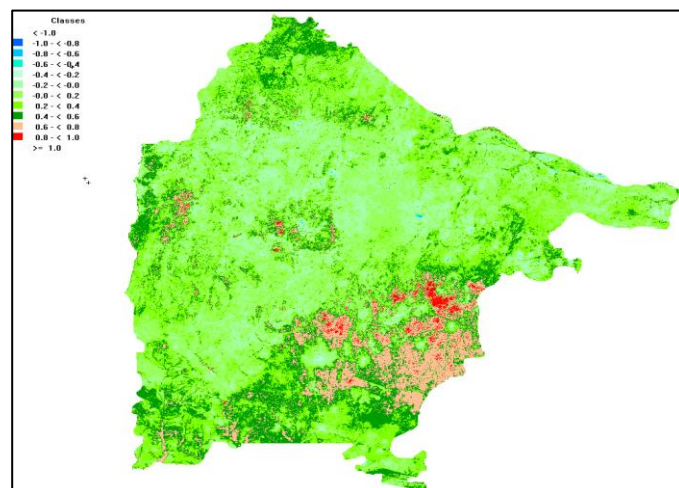


Fig. 2. NDVI classes for the study area.

F. Bee flight range and Bee flora species diversity

Given that honeybees forage distance has been estimated to be as close as 45 m and far as 5.5 km [348], to determine the possible Honey Bee forage flight distance and the potentials ecosystem zones from which bee source their nectar and pollen in our study, we performed proximity analysis in form of multiple nuclei buffering at 1, 2 and 5 km around the center of each selected apiaries [35] using ArcMap 10.4 during the period the study was conducted in the wet season.

The Bee flora species diversity survey of the apiaries at the ecological zones of Nigeria was conducted in five (5) administrative zones of the country. The estimation of floral species diversity for each site apiary was carried out using Simpson's, Shannon-wiener diversity index and Margalef's index methods using PAST with 95% level of significance.

G. Apiary's Floristic Survey and Species Diversity

The floristic survey of the ecological zones and distribution of African honeybee's (*Apis mellifera*) apiaries of Nigeria was conducted in five (5) administrative zones of the country using, a rectangular plot of fixed area of 5×20 m. The distance between transects was 20 m. Each plot quadrant was laid using systematic random sampling; where the first plot was randomly laid along transects. Then the rest consecutive quadrates were laid at equal intervals along the transects, The size of quadrate in each of the apiary 100 m² (10×10 m) quadrate according to [36].

Ten (10) randomly allocated plots in each site's apiary were sampled. Honeybee foraging plants noticed for bee visit were collected according to standard techniques [37]. Tree, shrubs and undergrowth parts were collected monthly from November 2016 to October 2018. The collected material was identified in the University Herbarium. The sampled nectareous plants were classified according to Reitz *et al.* [38], [39] and Roderjan *et al.* [40]. The estimation of floral species diversity for each site apiary was carried out using Simpson's, Shannon-wiener diversity index and Margalef's index methods using PAST with 95% level of significance.

III. RESULTS AND DISCUSSION

A. Mapping of Apiaries into Distinct Ecosystem Zones and bee Forage Distance Radius

Vegetation has been described as the most important characteristics of landscape and has provided frameworks for terrestrial ecosystems [41], [32]. Vegetation is also the feasible product of climatic variables thus vegetation pattern can be used to define the climate of an area.

Seven ecosystem zones were mapped namely: the wetland vegetation, savanna grassland, savanna woodland (disturbed), shrubby forest, lowland dense forest, and Highland rain forest (Fig. 3) Temperature is relatively uniform with an average of 25 °C and 26 °C except in high elevation at Orozo and Ikirun where it drops to 23 °C. However, there exist marked variation in total annual rainfall pattern; a total of 1500-1600 mm being recorded around Agungburu_Omiseniof lowland dense forest and at Orozo savanna woodland, while apiaries located in Igbebi and Saki recorded between 1100-1200 mm.

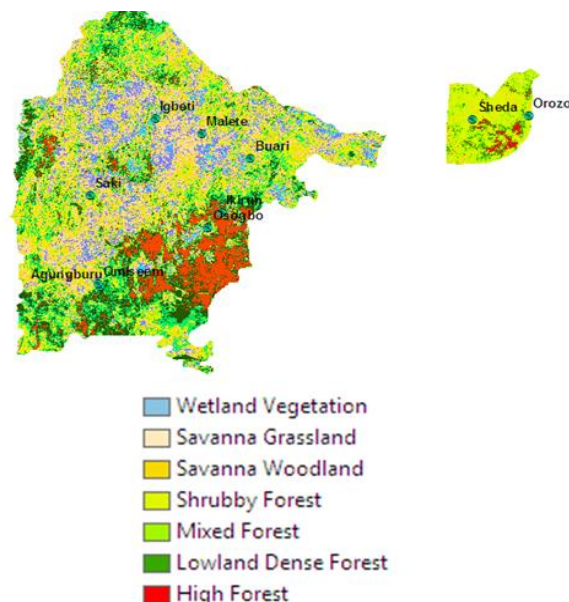


Fig. 3. The ecological zones of the apiaries of the study area.

TABLE 2: HONEY PRODUCTION OF THE APIARIES BY ECOSYSTEM ZONE OF STUDY AREA

Locations	Ecological zone	Mean Qt of honey harvestable/Hive	Longitude	Latitude	Altitude
ABUJA-Sheda	Woodland	22 liters	7° 06' 06" E	8° 54' 27" N	550 m
Orozo	Savanna/Shrubby	10 liters	7° 54' 34" E	8° 51' 42" N	900 m
KWARA-Buari	Shrubby/High Forest	12 liters	4° 56' 13.8" E	8° 28' 39.8" N	300 m
Malete	Wetland/Woodland	12 liters	4° 28' 34.4" E	8° 42' 57.5" N	350 m
OGUN-Agbungburu	Savanna	12 liters	3° 31' 13.6" E	7° 11' 11.6" N	180 m
Omiseeni	Woodland Savanna	10 liters	3° 30' 05.5" E	7° 13' 07.6" N	200 m
OSUN- Ikirun	Low dense forest	12 liters	4° 55' 42.9" E	7° 59' 59.8" N	700 m
Oshogbo	High Forest	13 liters	4° 36' 11.3" E	7° 50' 57.4" N	500 m
OYO- Igbebi	Shrubby	12 liters	4° 04' 30.4" E	8° 58' 60.0" N	600 m
Saki	Forest/Woodland	10 liters	3° 43' 04.8" E	8° 06' 53" N	500 m
	Wetland/Woodland				
	Savanna				
	Woodland Savanna				

Field data 2018.

Rainfall rather than temperature has been described as major limiting factor in ecosystems or vegetation variation in the tropics, however; topography could also influence vegetation and number of organisms [42], [43]. In this study topography has highly determined the mapping of dense forest into 2: Lowland and high land forest (Fig. 3).

Basically, the apiaries can be divided into 3 major broad but distinct categories: The Oshogbo_Ikirun occupy Forest and woodland savanna, Igbebi_Malete_Buari (Savanna grassland and wood land Savanna) while Sheda Orozo fall into woodland Savanna and Shrubby forest (Fig. 3; Table 2).

B. Honeybee Flight Range and Floristic Survey at Different Ecosystem Zones

Foraging at different ecosystem has implication on the quantity and quality of honey as the bees compare the volume and the concentration of sugars in the nectar from different plant species, and select the resource with better energy rewards, with its relationships with the different climatic and other environmental variables are directly related to the productivity of the colony [44].

Honey bee flight range at 1, 2 and 5 km show the possible ecosystem from which bee can obtain their pollen and nectar, while honey bees apiaries at Igbebi/Malete/Buari which falls under savanna woodland will forage at similar

ecosystems with similar floristic composition even at a maximum distance of 5 km, whereas the honey bees at Saki has potentials to forage at different eco zones from woodland savanna to lowland and high forest (Fig. 4) within distance of 800 m to 2 km which provide good habitat for varieties of honey bee attracting plants dominant of which are: *Blighiasapida*, *Vateriaindica*, *Mangifera indica*, *Cocos nucifera*, *Daniella olivera* and *Cynodondactylon*. Likewise, the forage distance of honeybees at Sheda and Orozo varies from woodland Savanna to shrubby forest and wetland savanna thus provide the opportunity to produce high volume of honey about 22 liters were recorded in the apiaries within this zone. The honeybee *Apis mellifera* possess the ability to recruit other bees in the hive to forage and effectively communicate the food source [45]-[48].

The honeybee therefore has preference for ecosystem with these factors in the surroundings and could forage as far as 1, 2 and 5 km as observed by the study and corroborated by the works of [47], [49]-[55].

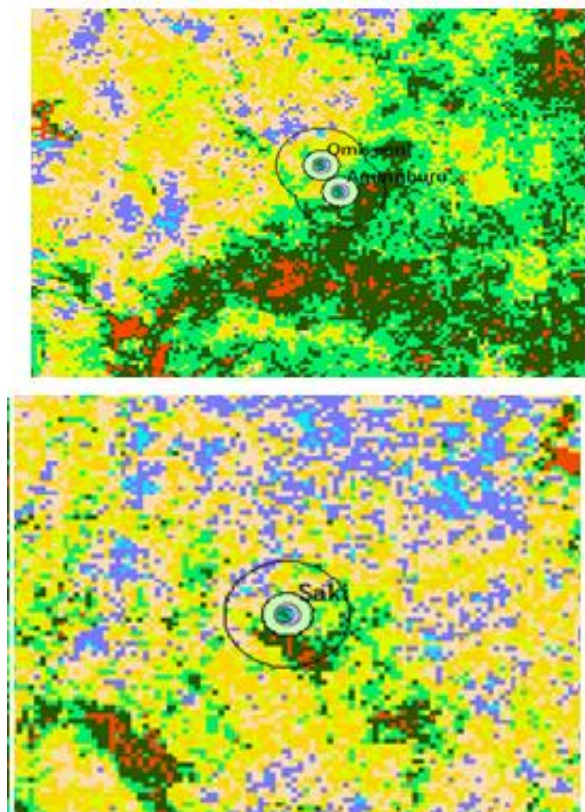


Fig. 4. Buffer Ring showing forage distance radius (1,2,5 km) of Honeybees at Omiseeni, Agbungburo and Saki.

C. The Flora Diversity Index

The result of the flora diversity at the apiaries of the ecological zones indicated, that there is variability comparing the location on the floral diversity. The diversity and richness were marginally differed at each location. Highest index was observed in Orozo ($H=2.62$; Margalef = 3.05) and Agbungburo ($H=2.54$; Margalef= 3.06) (Table 3). Similarly, the low index observed in Buari ($H = 2.10$; Margalef = 2.32) and Igbeiti ($H= 2.11$; Margalef = 2.62). Igbeiti present the highest number of individual floral encountered with low floral species diversity which could be as a result of high level of dominance (Table 4) by a few species.

The result of flora diversity of the study apiaries is in line with various researchers' view on biodiversity such as the reported cases of the Nigerian habitat and ecosystem which consists of varying degrees of species diversity. Species' diversities within the ecosystem vary greatly and higher in lowland equatorial rain forest. Species' diversity generally follows the amount of rainfall with the wetter areas being richer in species diversity in areas where they exist in the parts of Nigeria [56].

Floral diversity is mainly about species richness and vegetation and ecosystem diversity [57], [58]. The number of different species within a geographical area depends on adaptation of organism to environmental conditions and how they' tolerate' the environment [59]-[62] while structural diversity has been reported to be a major factor determining forest ecosystem [63].

TABLE 3: TREE DIVERSITY INDICES OF FLORAL SPECIES IN THE APIARIES OF THE STUDIED AREA

	Kwali	Orozo	Buari	Malete	Agbungburo	Omiseeni	Ikirun	Oshogbo	Igbeiti	Saki
Taxa_S	13	17	15	16	17	17	16	14	19	16
Individuals	61	189	409	235	187	208	173	105	961	435
Dominance_D	0.1088	0.0839	0.2031	0.0991	0.09874	0.0927	0.1124	0.1363	0.2293	0.3494
Simpson_1-D	0.8912	0.916	0.7969	0.9008	0.9013	0.9072	0.8876	0.8637	0.7707	0.6506
Shannon_H	2.369	2.621	2.105	2.464	2.537	2.561	2.424	2.335	2.105	1.72
Evenness_e^H/S	0.8224	0.809	0.5473	0.7342	0.7439	0.7618	0.7054	0.7375	0.4318	0.3489
Margalef	2.919	3.052	2.328	2.747	3.059	2.998	2.911	2.793	2.621	2.469

Field data analysis 2018.

IV. CONCLUSION

An alternative way to increase the productivity of beekeeping involving the use of *A. mellifera* as an economic activity, in areas of the country ecosystem should be by acquiring and usage of relevant, information such as geo-mapping, floristic survey, and foraging behavior as identified by this research. Understanding the suitability of different environments at the various apiaries for honeybee foraging is of central importance in the task of improving honeybee health and productivity, and honeybee habitat utilization that would assist apiary and bee management activities, contributing to better production and use of resources. Moreover, the foraging decisions made by a honeybee colony with respect to its surrounding landscape can furnish theoretical insights into how the honeybee foraging system has evolved to optimize the collection of resources in complex environments for both for hive products but more importantly bee foraging and pollination service through which food production and security could be maintain for now and the future.

V. RECOMMENDATIONS

The following: are recommended based on the findings of the research:

a. The application of geospatial techniques for proper planning and development of Nigerian ecological zone apiaries for bee adaptation, survival, and sustenance. This will also provide efficient production of hive products and pollination of crops for improved food production. These technologies have the capability to capture data from different spectral, penetrate remote areas, and integrate data from different sources.

b. The environmentalists and other stakeholders should enlighten the people on the dangers of bush burning, deforestation and other environmental degrading activity through campaigns using various media like the mass media and also be stressed in the school curriculum.

ACKNOWLEDGMENTS

Our gratitude and appreciation are due to the Tertiary Education Trust Fund (TETFUND) for providing ETF Research Grant –Ref. No:

AUTHOR'S CONTRIBUTIONS

AOM: experiment conduction, experiment design, and paper writing; SG: experiment design, data analysis and paper writing; OSO: experiment conduction and data analysis. and AAA: experiment design, and literature review.

KWASUNGR/CSP/171117/VOL4/TETF/0040 with which the research was conducted, to bee farmers of the various apiaries, staff of laboratories for analysis and our institution-Kwara State University, Malete, Nigeria for providing enabling environment throughout the period of the research.

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