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By Nat Owusu Prempeh, Ernest Frimpong Asamoah & Austin Asare

Kwame Nkrumah University of Science and Technology

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Keywords: species diversity; genetic heat index, conservation status, geostatistics, wildlife sanctuary, Ghana.

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Keywords: species diversity; genetic heat index, conservation status, geostatistics, wildlife sanctuary, Ghana.

Author α: Department of Land Reclamation and Rehabilitation, Kwame Nkrumah University of Science and Technology.
e-mail: nowusuprempeh@knust.edu.gh
Author σ: The Department of Environment Science, Faculty of Science, Macquarie University, Sydney, Australia.
e-mail: asamoahfr_imp25@hotmail.com
Author ρ: Department of Environmental Management, School of Natural Resources, University of Energy and Natural Resources (UENR).
e-mail: austin.asare@uenr.edu.gh

I. Introduction

Globally, biodiversity hotspots have declined markedly from 15.7% to 2.3% [1, 2]. The decline of these living organisms and ecological complexes are due to both catastrophic events and human land use [3, 4]. Forests within the tropical and subtropical regions are more biodiverse than in forests of other eco-zones and provide important but diverse ecosystem services such as biodiversity bank [4 - 6]. The rapidly increasing destruction of forest ecosystems is, therefore, a key threat to biodiversity conservation, particularly the interruption of gene flow by habitat loss and fragmentation [7]. The convention on biological diversity signed in 1992 in Rio de Janeiro advocates for sustainable management of natural, agricultural and forest ecosystems [8, 9]. The convention has increased the awareness and biodiversity research worldwide. However, to manage land resources sustainably, Neves et al. [6] have advocated for the adoption of a wide range of measures to describe the composition, species richness and species dominance since conservation and protection of the biodiversity of natural mosaics (i.e., forest reserves) have been a challenge. An example of such techniques and methods is the geostatistics [10, 11].

A study of spatial distribution of species in forests may portray the spatial structure and the spatial variability of biodiversity and their interactions, which are crucial for their conservation and management. There have been many reports on the efficiency of analytical techniques to describe quantitatively, the spatial pattern of organisms, environmental factors, and ecological processes. For instance, Escudero et al. [12] adopted better management techniques for the species and their habitats. Stenger et al. [13] used spatial assessment of biodiversity and recommended that minimizing the influence of human activities in critical. Moreover, Legendre et al. [14] also mentioned the appropriate statistical tests based on the spatial structure of the organisms. Telles et al. [7] also stressed that the disturbance to the demographic patterns and population increase could jeopardize their existence in the medium- and long-term.

In Ghana, land use conversions have caused the reduction of approximately 80% of its forest estate, destroying biodiversity and a resultant impact on the services the forest ecosystem provides for the rural populations [15]. Marfo[16] observed that many indigenous species such as *Milicia excelsa* and *Milicia regia*, the mahoganies (Khaya and Entandrophragma species), *Pericopsis elata*, *Nauclea diderrichii*, and *Triplochiton scleroxylon* which, mainly generate substantial revenues for Ghana's economy, have drastically reduced in numbers over the past.

The UENR wildlife sanctuary is not an exception to this human-induced biodiversity threats, considering the shrinkage of its area from 3.6ha in 1999 [17] to 2.4ha in 2017 (current study) mainly because of infrastructural expansion. The decline in the acreage of the sanctuary may threaten its floristic diversity, composition, structure, etc. The species may be subject to extinction in the near future, lest the subject of conservation. Nevertheless, for the sanctuary to be ushered under strict conversation requires that the status of the different flora components be studied. In this regard, floristic assessment of the Wildlife sanctuary is crucial in detecting the risk of extinction and changes in plant diversity over time. Information about the spatial distribution pattern of the floristic diversity of the sanctuary is also lacking. The present study, therefore, assesses the floristic diversity and composition, star ratings of species at the wildlife sanctuary and their ecological importance using their genetic heat indices. The knowledge of plant species status would serve as key indicators in enhancing conservation efforts of the Wildlife Sanctuary as well as management of protected areas in Ghana.

II. Materials and Methods

a) Study Area

The study was carried out at the wildlife sanctuary of the University of Energy and Natural Resources (UENR), Sunyani, Ghana (Figure 1). The University lies along the Sunyani-Berekum highway and covers an area of 120 acres (48.6ha). It shares a boundary with the Regional Administration, and the closest community is Fiapre towards Berekum. Forest tree outgrowths comprising indigenous tree species like *Ceiba pentandra*, *Triplochiton scleroxylon*, and exotic plant species such as *Eucalyptus grandifolia*, *Tectona grandis,* and *Senna siamea* surround the campus. The wildlife sanctuary is located in the eastern corner of the UENR campus at latitude 7˚20'50''N and longitude 2˚20'30''W and covers a total area of 3.6ha, which is about 7.4% of the UENR Campus area. The sanctuary was established to provide natural conditions for animals (wildlife) which would be used for research purposes and to serve as an educational site for students and visitors to the University [17]. On establishment, the sanctuary hosts over 68 species of plants belonging to 30 families. The well presented were Apocynaceae, Papilioniaceae, and the least dominant are Ulmaceae, Ebenaceae, and Sapotaceae. The dominant tree species was *Newbouldia laevis* and the least abundant was *Triplochiton scleroxylon*, while the dominant undergrowth was the *Psychotria spp*., which supports duikers [17]. The School of Natural Resources manages the sanctuary as a research station.

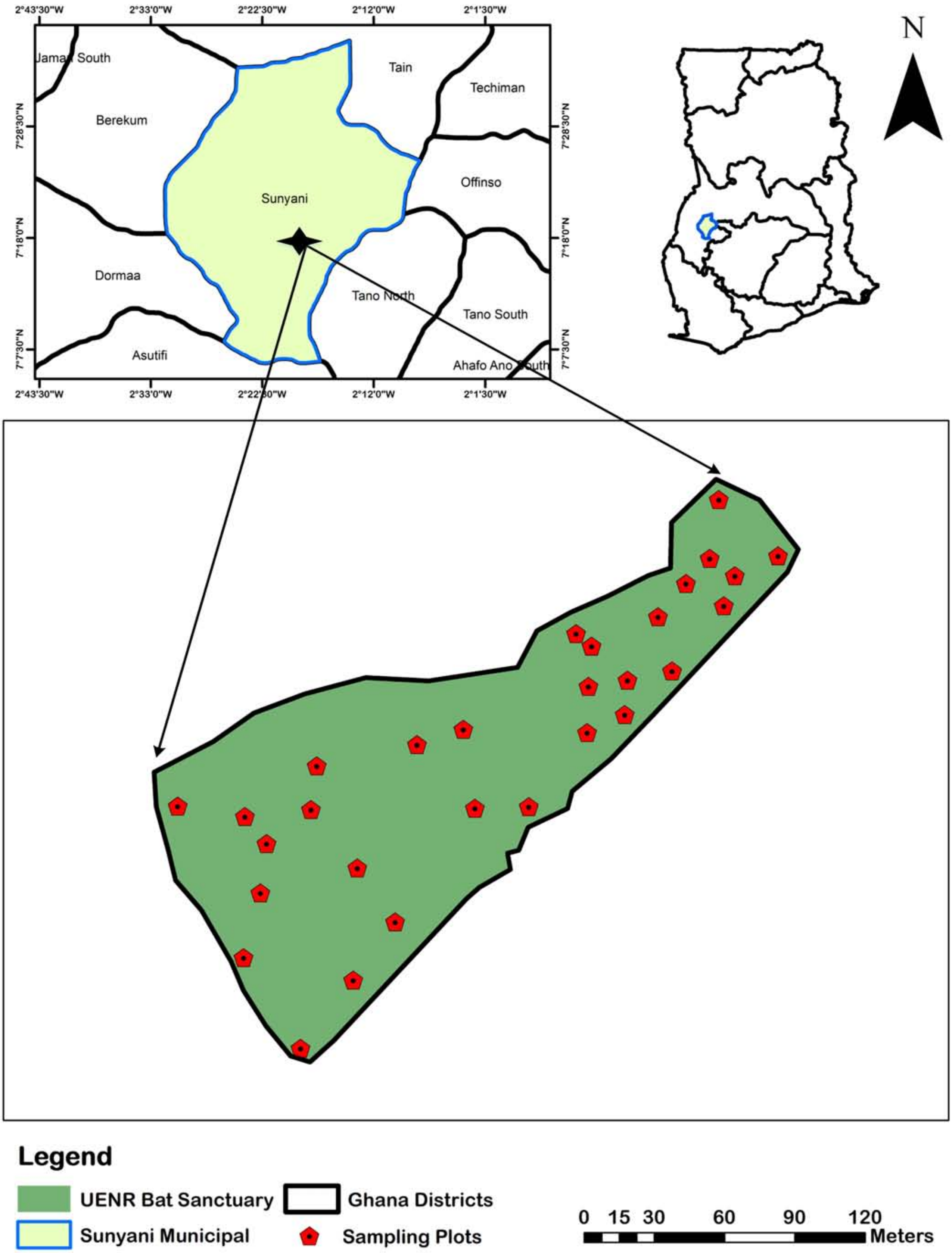

Figure 1: Map of Ghana showing Sunyani and location of the wildlife sanctuary

The Sunyani municipality is about 400 meters above sea level. The climate is characteristic of the tropical humid zone with two seasons, which include dry and wet seasons. The mean monthly temperature is between 23°C and 33°C. The lowest occurs around August, and the highest is observed around March and April. The relative humidity is high averaging between 75 and 80 percent during the rainy seasons and 70 and 80 percent during the dry seasons of the year, which is ideal for luxurious vegetative growth [18, 19]. Sunyani experiences a double maxima rainfall pattern which occurs in June-July and September-October with an annual average rainfall of about 1200mm, while the dry season occurs between December and February [20]. The seasonality offers farmers the opportunity to farm twice in a year. Thus, the main season and the minor season thereby boosting agricultural production in the municipality [18]. However, the rainfall pattern of the municipality might be changing over the years because of deforestation and depletion of water bodies resulting from human activities [20]. The area lies within the moist semi-deciduous forest type with some portions re-planted with *Tectona grandis*[17]. The dominant rock types underlying the area are the Precambrian Birimian formations, which have high mineral deposits. There is widespread masses of granite in the area. The soils, mainly Ochrosols, are fertile with high water holding capacity and support a wide range of crops [18].

b) Sampling design and data collection

The perimeters of the UENR Wildlife Sanctuary were mapped using a handheld GPS unit. Within the mapped Sanctuary, 29 sampling plots were randomly located using the "Create Random Points" algorithm in ArcGIS 10.4. A three-nest sampling plots of 10m x 10m, 5m x 5m and 1m x 1m were laid at the exact places located by the ArcGIS 10.4 software package (Figure 2). In the 10m x10m plot, Trees (individuals >10cm DBH) were sampled, Saplings (individuals ≥ 2cm and <10cm) were sampled from the 5m x 5m plots, while 1m x1m was used for the inventory of Seedlings (individuals <1m height or <2cm girth). Dead trees species were not considered due to difficulties in identifying them.

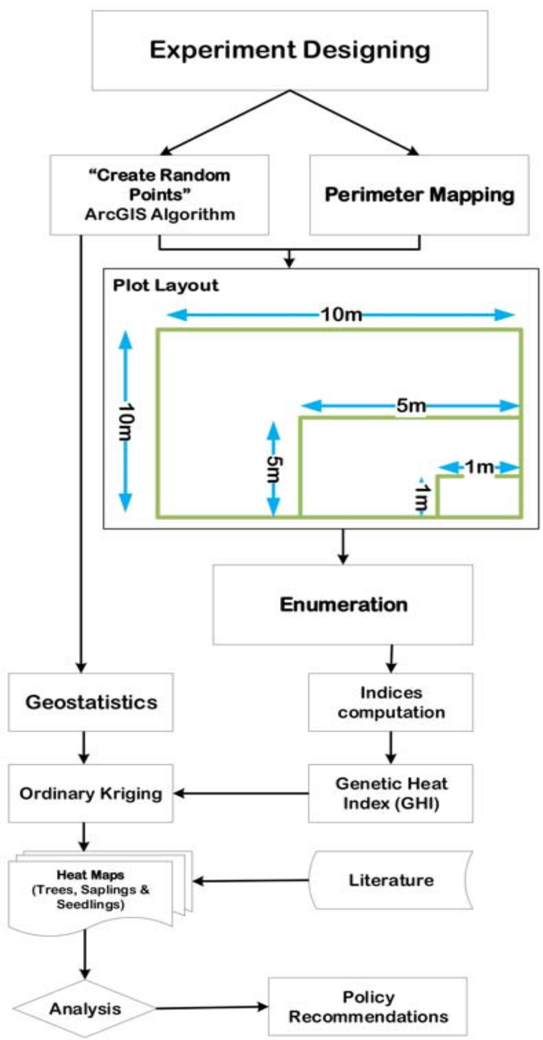

Figure 2: Experimental plot layout and analysis flowchart

c) Data analysis

The three indices were used to determine the species diversity are as follows;

a. Shannon Wiener's diversity index (H'):

$$H' = -\sum_{1=i}^{s} P_i In P_i \quad (1)$$

Where:

S is the number of species; Pi is the proportion of individuals or the abundance of the *ith* species expressed as a proportion of total cover; In = Log base n [21].

b. The Species Richness (S) was determined using the expression as follows:

$$S = \sum n \quad (2)$$

Where: n is the number of species in a community.

c. The Genetic Heat Index (GHI) of the wildlife sanctuary was determined as follows:

$$\frac{[(\mathrm{BK} * \mathrm{BK_{weight}}) + (\mathrm{GD} * \mathrm{GD_{weight}}) + (\mathrm{BU} * \mathrm{BU_{weight}}) + (\mathrm{RD} * \mathrm{RD_{weight}})]}{(\mathrm{BK} + \mathrm{GD} + \mathrm{GN} + \mathrm{RD})} * 100 \quad (3)$$

Where:

BK = number of black star species; GD = number of gold star species; BU = number of blue star species; GN = number of green star species; RD = number of red, scarlet and pink star species [22]. According to Hawthorne [22], Black Star species are rare internationally and uncommon in Ghana. Attention is being pursued to conserve the populations of these species. Gold Star species, on the other hand, are fairly rare internationally and locally. Blue Star species are also widespread internationally but are rare in Ghana or vice versa. Pink species are common and moderately exploited. They have a subgroup called promotable Pinks, where the government is encouraging their exploitation to reduce their numbers. Red, are common but are under pressure of exploitation.

The GPS points obtained during the study was exported to ArcGIS (v10.4). These data points were transformed from KMZ to shapefile. An attribute table was generated, and GHI data computed for each of the 29 plots points added. Ordinary kriging algorithm was used to interpolate GHI values calculated for each plot over the entire Wildlife sanctuary. Based on the Genetic Heat Index of floristic species, the conservation status of the wildlife sanctuary was ascertained and categorized [22]. The ArcGIS was used to categorized the spatial extent of the sanctuary into "very high conservation value" for GHI > 200; "high conservation value" (150 ≥ GHI < 200); "moderate conservation value" (100≥ GHI < 150); "low conservation value" (50 < GHI < 100) and "very low conservation value" (GHI < 50). The descriptive statistics such as mean and standard deviations of the data set were calculated.

III. Results

a) Star rating of trees, saplings, and seedlings

Figure 3 indicates the star ratings of species in the study area. Most (n = 18) of the Tree species identified and enumerated (58.1%) were Green star species, 29.0% species (n=9) had no known Star status, but three species (9.7%) were Blue star species. Only a Scarlet Star Tree species were identified. Similarly, a high proportion of the Saplings (n = 20; 66.7%) were identified as Green star species, 5 (16.7%) of the species had no known star status, and two Saplings (6.7%) were Blue star species. Only a species was of Pink star and Red star status, representing 3.3% each of the number of saplings identified. Moreover, a high proportion of the species (23) identified in the seedlings representing 76.7% were also Green star species, 3 (10.0%) were Blue species, and the rest had 1 (3.3%) species each. Generally, in each of the categories identified (i.e., trees, saplings, and seedlings), Green Star species were dominant in the sanctuary. Most of the Green Stars were of the Fabaceae, Lamiaceae and Meliaceae families. Compared to saplings and seedlings, a larger number of tree species were not identified as belonging any of the ratings.

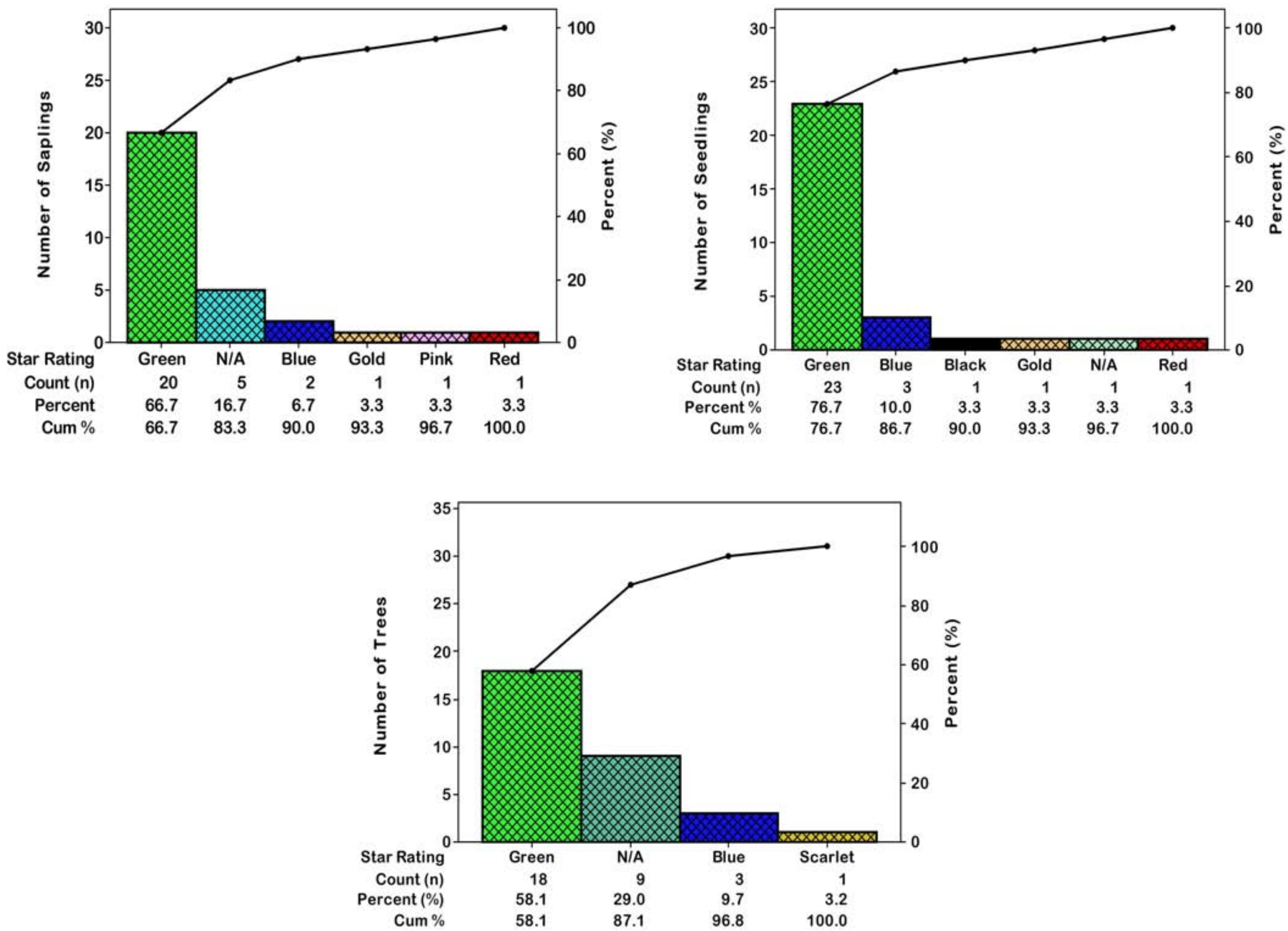

Figure 3: Pareto chart of Species Star rating of saplings. {A: Saplings (Individuals ≥ 2cm and <10cm DBH), B. seedlings (Individuals ≤1m height or <2cm DBH), and C: Trees (individuals > 10cm)} in the wildlife sanctuary

b) *Diversity of the floristic component*

The families of species and their frequencies are listed in Table 2. A total of 460 floral species were enumerated comprising 150 Trees, 112 Saplings, and 198 Seedlings. The individuals belonging to 58 species and 28 families. Fabaceae, Sapindaceae, Moraceae, Apocynaceae, and Rubiaceae were the most dominant families, representing about 15.7% (n = 14), 11.2% (n = 10), 8.9% (n = 8), 8.9% (n = 8) and 5.6% (n = 5) of the total families recorded. Concerning individual species, the first four (4) dominant Tree species were *Newbouldia laevis* (n = 37), *Holarrhena floribunda* (n = 16) and *Tectona grandis* (n = 11). *Newbouldia laevis* had the highest number of saplings (26 saplings) followed by *Milletia thonningii* (10 saplings). However, *Griffonia simpicifolia* (36) and *Selacia elegans* (34) were the most dominant Seedlings (Table 2).

Table 1 shows the Shannon Wiener's index (H'), Species Richness (S) and the mean Genetic Heat Index (GHI) for the three categories of species studied. Regarding Shannon diversity indices (H' ± Std Error), the Trees (1.05 ± 0.10) were more diverse compared to saplings (0.95 ± 0.10), and seedlings (1.03) within the study area. The species Richness (S) of 3.54 ± 0.3, 3.00 ± 0.30, and 3.66 ± 0.34 were obtained for Tree, Sapling, and Seedling, respectively.

Table 1: Shannon Wiener's diversity index, Species Richness, and Genetic Heat index of seedling, saplings, and trees

Stem group	Shannon Wiener's index (H')	Species Richness	Genetic Heat index (GHI)
Trees	1.05 ± 0.10	3.54 ± 0.30	8.13±2.0
Saplings	0.95 ± 0.10	3.00 ± 0.30	62.50 ± 22.5
Seedlings	1.03 ± 0.08	3.66 ± 0.34	269.38 ± 81.0

c) *The conservation status floristic components of the Wildlife sanctuary*

In the study, the Genetic Heat Index (GHI) was used as an indicator to assess the conversation status of the sanctuary. The mean Genetic Heat Index for Trees, Saplings, and Seedlings were 8.13, 62.50 and 269.38, respectively. Thus, the seedling of the area is of a "very high" conservative status compared to the Trees and Saplings. The genetic heat map (Figure 4) was produced to depict the spatial distribution of the conversation status (conservation hotspots) of trees, saplings, and seedlings, evident by their Genetic Heat Indices (GHI). For trees, the GHI ranges from "very low" conservation value to "moderate" conservation value. However, the "low" conservation spots for trees predominant (94.0%) and were mostly distributed throughout the entire sanctuary (Figure 4). Similarly, the GHI of Saplings ranges from "very low" conservation value to "very high" conservation value. Nevertheless, regarding the area coverage, the study observed that a relatively larger area of the sanctuary (60.1%) was of a "very low" conservation value compared to the areas of "very high" conservation value (6.8%; Table 3). Concerning seedlings, larger proportion (67.7%) of the sanctuary was of a high conservation status compared to a relatively a moderate conservation values.

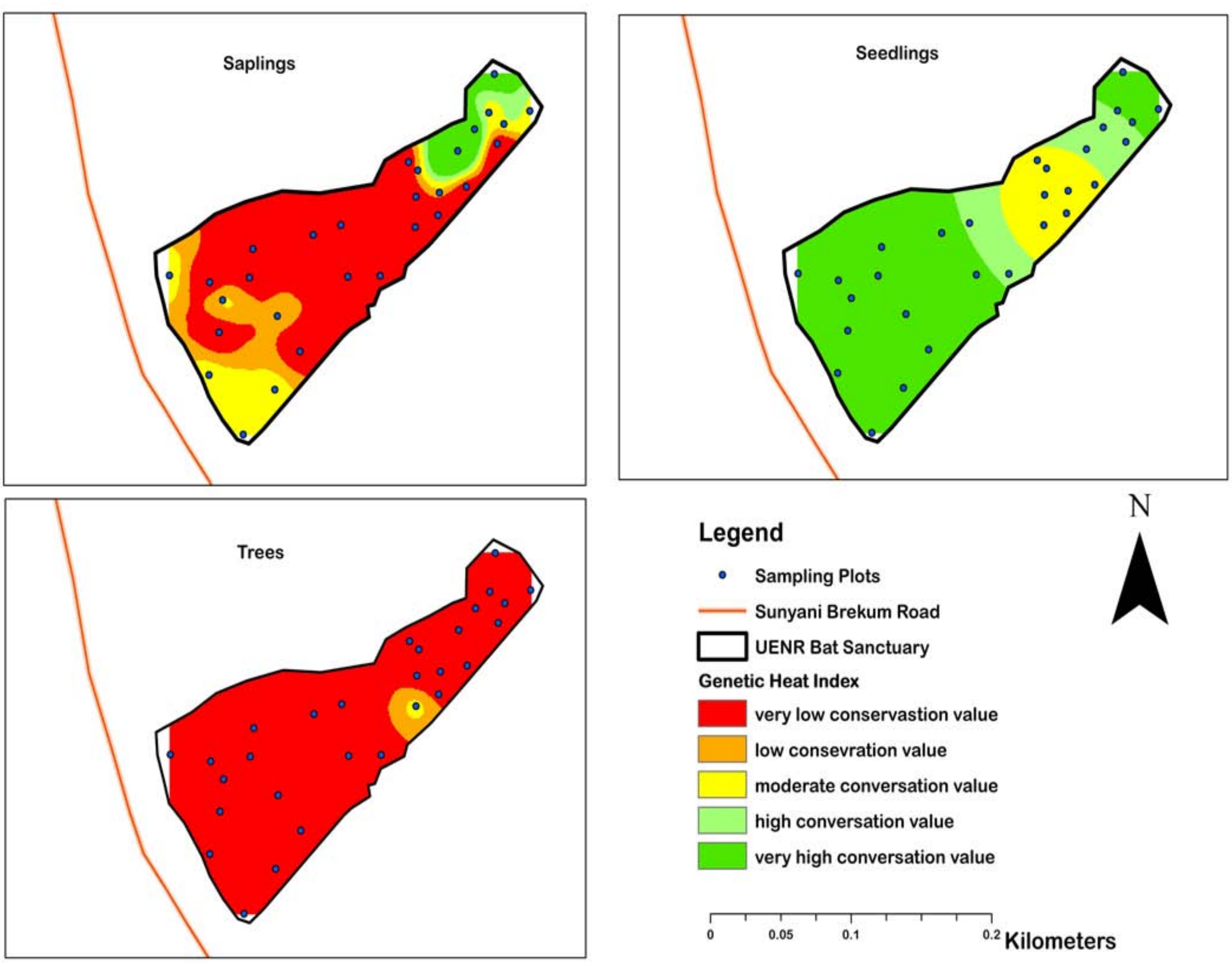

Figure 4: A heat map of flora diversity of the Wildlife Sanctuary

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Table 2: Families of species and their abundances

Saplings			Seedlings			Trees		
Family	Scientific name	n	Family	Scientific name	n	Family	Scientific name	n
Fabaceae	*Acacia pentagona*	1	Sapindaceae	*Blighia unijugata*	1	Fabaceae	*Albizia zygia*	1
	Albizia zygia	1		*Deinbollia grandifolia*	1		*Berlinia grandiflora*	3
	Baphia nitida	1		*Lecaniodiscus cupanioides*	1		*Delinox regia*	1
	Dalbergia saxatilis	1		*Paullinia pinnata*	1		*Leucaena leucocephala*	2
	Griffonia simplicifolia	9	Combretaceae	*Combretum racemosum*	1		*Lonchocarpus sericeus*	3
	Millettia thonningii	10		*Combretum smeathmannii*	1		*Millettia zechiana*	1
	Senna siamea	3		*Combretum zenkeri*	2		*Senna siamea*	21
Sapindaceae	*Allophylus africanus*	5	Rubiaceae	*Morinda morindoides*	1	Moraceae	*Ficus exasperate*	5
	Blighia sapida	10		*Psychotria ankasensis*	2		*Miliciaexcelsa*	1
	Blighia unijugata	6		*Psychotria ivorensis*	24		*Broussonetia papyrifera*	2
	Deinbollia grandifolia	1	Apocynaceae	*Holarrhena floribunda*	1	Apocynaceae	*Funtumia Africana*	2
	Lecaniodis cuscupanioides	4		*Voacanga africana*	1		*Holarrhena floribunda*	16
Moraceae	*Antiaris toxicaria*	3		*Motandra guineensis*	4		*Voacanga africana*	2
	Broussonetia papyrifera	1	Asclepiadaceae	*Gongronema latifolium*	1	Mimosaceae	*Albizia adianthifolia*	2
	Ficus exasperate	3		*Parquetina nigrescens*	4		*Albizia ferruginea*	3
Meliaceae	*Cedrela odorata*	1		*Secamone afzelii*	4	Malvaceae	*Bombax buonopozense*	1
	Ceiba pentandra	2	Mimosaceae	*Albizia adianthifolia*	8		*Cola caricifolia*	2
Bignoniaceae	*Newbouldia laevis*	26		*Albizia zygia*	1	Meliaceae	*Azadirachtaindica*	2
Celastraceae	*Salacia elegans*	4	Moraceae	*Antiaris toxicaria*	13		*Cedrelaodorata*	1
Euphorbiaceae	*Mallotus oppositifolius*	3		*Broussonetia papyrifera*	2	Sapindaceae	*Blighia sapida*	2
Apocynaceae	*Holarrhena floribunda*	3	Papilionaceae	*Baphia nitida*	1	Boraginaceae	*Cordia senegalensis*	7
Annonaceae	*Uvaria chamae*	3		*Millettia thonningii*	10	Irvingiaceae	*Klainedoxa gabonensis*	1
Rubiaceae	*Rothmannia longiflora*	2	Bignoniaceae	*Newbouldia laevis*	23	Anacardiaceae	*Lannea welwitschii*	1
Lamiaceae	*Tectona grandis*	2	Caesalpiniaceae	*Griffonia simplicifolia*	36	Phyllanthaceae	*Margaritaria discoidea*	2
Phyllanthaceae	*Margaritaria discoidea*	2	Euphorbiaceae	*Mallotus oppositifolius*	14	Leguminosae-Papilionoideae	*Millettia thonningii*	1
Sterculiaceae	*Cola caricifolia*	1	Clastraceae	*Salacia elegans*	34	Rubiaceae	*Morinda lucida*	10
Araliaceae	*Cussonia bancoensis*	1	Dilleniaceae	*Tetracera affinis*	1	Bignoniaceae	*Newbouldia laevis*	37
Apocynaceae	*Motandra guineensis*	1	Menispermacee	*Triclisia dictyophylla*	2	Sterculiaceae	*Sterculia tragacantha*	1
Asclepiadaceae	*Parquetina nigrescens*	1	Annonaceae	*Uvaria chamae*	1	Lamiaceae	*Tectona grandis*	16
Menispermaceae	*Triclisia dictyophylla*	1	Connaraceae	*Cnestis ferruginea*	2	Annonaceae	*Uvaria chamae*	1

IV. Discussion

The status of conversation area is important to ascertain. To understand explicitly the flora diversity, it was important to categorize them into Trees (>10cm DBH), Saplings (<2cm DBH and <10cm DBH), and Seedlings (≤1m height or <2cm DBH). Though the Tree species were more diverse compared to the Seedlings, the sanctuary was richer regarding seedlings compared to the trees. The reason may be the activities of the bats. They aid in the dispersal of different tree species by passing seeds of species through their digestive tract. Hamalainen et al. [23] iterated that secondary seed dispersal by carnivores could have important consequences for plant dispersal outcomes, with implications for ecosystem functioning under a changing climate and across disturbed landscapes where dispersal may be otherwise limited. However, due to competition for environmental factors and some things human disturbance, they are not able to the next phase of succession. Thus, the reason why most of the species in failed to appear within the sapling stage. For instance, none of the species such as *Griffonia simplicifolia* (family: Ceasalpiniaceae), the most abundant, was not able to migrate to Sapling and Tree stages. Under controlled conditions, Peltzer and Köchy[24] computed the competitive intensity and found the reduction in transplant growth by neighbors, was similar in both grass- and shrub-dominated habitats for transplants of Bouteloua, but was less intense in shrub-dominated habitats for the shrub Elaeagnus.

How rich a forest depends on the number and categories (usually defined as Star ratings) of species it has [25]. In this study, a star rating system developed by Hawthorne and Abu-Juam[25] and Hawthorne [22]was used to define the conservation status of each species recorded. In the study area, species enumerated were Green, Blue, Gold, Pink, Red and Black Stars. The Green star species dominated the three vegetation types (i.e., the Tree, Saplings, and Seedlings) with 58.1% of the total number of species in Trees, 66.7% of the total number of species in Saplings and 76.7% of the total number of species in Seedlings. The higher population of the Green Star species compared to other species star ratings in the sampling area could be because these species are dominant in Ghana and are of no conservation concern as described by Hawthorne and Gyakari[26]. A lesser number of Red Star and Scarlet species in both the Saplings and Seedlings reflects how uncommon red star species are in Ghana. Scarlet Star species used to be common, but they came under intense exploitation. Therefore, their exploitation is now restricted to control their extinction. Both the Trees and Seedlings had three (3) species each belonging to Blue Star whilst Saplings had none. Blue Star species though widespread internationally but it is a rarity in Ghana [26] and therefore need conservation concern. One (1) Pink Star species was found in the Saplings whileTrees and Seedlings had none. The Pink Star species are the tree species in Ghana that are common and moderately exploited as timber [25]. A Seedling a Black Star species (*Psychotria ankasensis*) was found. However, the mother tree could not be identified in the UENR's Wildlife Sanctuary. *Psychotria ankasensis* is a genus of flowering plants in the Rubiaceae family that is an endangered or facing extinction due to deforestation. Black Star species are species that are only found in Ghana (strictly endemic) or near endemic and thus urgent attention to conservation is needed [25]. Their presence within the UENR Wildlife Sanctuary could be due to the passage of their fruits through the digestive tract of the bats and resulted in their germination at the sanctuary. As a resukt of the activities of the bats,some species are being introduced that have "very high" conservation value into the area and attention must be directed towards strict conservation measures.

The Genetic Heat Index (GHI) for Trees, Saplings, and Seedlings were 8.13±2.0, 62.50 ± 22.5 and 269.38±81.0, respectively. The conservational classes defined by Hawthorne (1996) were used to classify the conservational values of each species recorded. The GHI of the tree species (8.125) ranges from "very low" conservation value to "moderate" conservation value as indicated. The GHI of saplings (62.50 ± 22.5) also ranged from very low conservation value to "very high" conservation value. The results of the study revealed that the conservation value of seedlings was very high. A GHI value of 269.38 ± 81 ranges from moderate conservation value to high conservation value. The high conservation value of seedlings might be due to favorable environmental conditions, which supports their growth.

V. Conclusions

The study assessed the floristic composition, diversity and conservation status of the UENR's wildlife Sanctuary using the Geostatistical tools and Genetic Heat Index. The findings from the Shannon diversity indices (H' ± Std Error) revealed that the Trees were more diverse (1.05 ± 0.10) compared to saplings (0.95 ± 0.10) and seedlings (1.03± 0.08) within the study area. The Seedlings had the highest Richness index (S=3.66 ± 0.34), followed Trees (S=3.54 ± 0.3), while the Saplings had the least Richness index (S=3.00 ± 0.30) among floristic components of the sanctuary.

Green star species were the dominant species in all the different diameter classes, representing 58%, 67%, and 77% of the total number of species of trees, saplings, and seedlings, respectively. Only a single black star seedling (*Psychotria ankasensis*) species was recorded. The families; including, Fabaceae, Sapindaceae, Moraceae, Apocynaceae, and Rubiaceae are the first five (5) most represented families in the study area. The least common species include Irvingiaceae, Anacardiaceae,Leguminosae-Papilionoi-deae, Bignoniaceae, Sterculiaceae, Caesalpiniaceae, Dilleniaceae, Menispermaceae, Connaraceae, Sterculia-ceae, Araliaceae Asclepiadaceae, Araliaceae, Menispermaceae, and Annonaceae. Trees had "very low" conservation value compared to saplings and seedlings. However, the seedlings were of a very high conservation status. The GHI of seedlings increased towards the southern part of the sanctuary whilst the spatial distribution of saplings was high in the northeastern part of the sanctuary.

On the whole, the study had demonstrated that land use conversions influence on floral species distribution could be analyzed successfully using geostatistical tools and GHI mapping. The study recommended that since the conservation value of the seedlings within the wildlife sanctuary was very high, strict protection and proper management of entire floristic components should be undertaken to promote the sustainable conservation of the remnant forest in the wildlife sanctuary.

VI. Patents

Acknowledgments

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Author Contributions

N.O.P. conceived and designed the experiments; E.F.A. and A.A. performed the experiment, analyzed the data and contributed analysis tools. All authors wrote and proofread the paper.

a) Conflicts of Interest

The authors declare no conflict of interest.

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