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Landscape Influence on Bee Abundance and Diversity: Conserving Pollinators for Increased Crop Production in the Forest Savannah Transition Zone of Ghana

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Abstact: The abundance and diversity of wild bees enhance the delivery of pollination services and the conservation of biodiversity. A study was carried out from June 2013 to April 2014 to assess the effect of landscape type on bee species abundance and diversity within the Forest Savannah Transition Zone (FSTZ) of Ghana. Three types of landscape namely agricultural land, natural vegetation and settlement fringes were selected from each of six communities and bees sampled from them using coloured pan traps (blue, white and yellow) and insect sweep net. A total of 706 bees comprising three families, 18 genera and 34 species were collected. The families were Apidae (18 species), Halictidae (11 species) and Megachilidae (5 species). Overall, bee species diversity varied significantly across the three landscape types ($F=11.64$, $P = 0.009$) but not abundance ($F= 0.13$, $P = 0.884$) at 5% probability level. Bees were more diverse in agricultural landscape and natural vegetation than in settlement fringes. Agricultural landscape and natural vegetation provided a wide range of floral resources to attract different foraging bees hence the diversity recorded. The 34 bee species pollinators recorded in this study is low and this may be a major reason why yields of bee pollinated crops in the FSTZ of Ghana have reduced in recent times.

Key words: Bees · Pollinators · Forest-Savannah Transition Zone · Natural Vegetation · Agricultural Landscape · Settlement Fringes

INTRODUCTION

Access to food is one fundamental right of humankind but hunger remains a global problem especially in Africa because many systems of food production in use are inefficient. Pollination is one ecosystem service that delivers food to our tables and contributes to improvement of livelihoods [1]. Production of most fruits and vegetables as well as regeneration of many forage crops used by livestock is mainly achieved through insect pollination [2]. It has been established that when the pollinator community consists of fewer species, yields of insect-pollinated crops are more unstable [3]. For more successful pollination services and maximum crop production, diverse communities of pollinators, mainly wild bees, are required [4, 5]. It is therefore important that nations across the world take steps to conserve pollination services and biodiversity in general.

Recent reports have pointed out that most pollinator populations have declined to levels that cannot maintain pollination services in both crop fields and natural habitats due to the increased disruption of habitats in both temperate [6] and tropical landscapes [7]. Drops in pollinator populations have occurred in several parts of the world including the USA, Mexico and Canada [8]. Loss of safe habitats [9] and corridors [10, 11] has been found to be the main threat to pollinators in fragmented landscapes. Habitat destruction through grazing, logging and agriculture [12, 13] reduces bee populations owing to loss of floral and nesting resources as well as mating and resting sites, especially since some oligolectic bees require specific flowers to survive [14, 15].

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In Ghana, many food and cash crops are grown in the Forest Savannah Transition Zone (FSTZ). In fact, the FSTZ is often referred to as the 'food basket' of Ghana. Among crops grown here are yam (*Discorea alata*), plantain (*Musa sapien*), maize (*Zea mays*), watermelon (*Citrullus lanatus*), tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena*), pepper (*Capsicum annum*), cucumber (*Cucumis sativus*), mango (*Mangifera indica*), cashew (*Anarcadium occidentale*) and several other fruits, vegetables and horticultural plants. Many of these crops including mango, cashew, cucumber, eggplant, tomato, pepper and water melon are pollinated by bees. Studies in central Europe and the US has shown that bee diversity and abundance are influenced by the nature of the surrounding landscape [16]. Widespread human activities including bush burning, logging, mining and agriculture currently prevail in the FSTZ. These activities have the tendency to alter the landscape and reduce bee populations. The threat posed to food security by human interference has resulted in countries embarking on various interventions to protect pollinators and increase food production. In the UK, the Biodiversity Action Plan (BAP) that was produced to protect species and habitats under threat included 17 species of bees (www.ubap.org.uk). Some developed countries like the US engage in commercial production of bees sorely for pollination purposes. This is not the case in Africa where subsistence agriculture is the order of the day. In Ghana, no information is currently available on how the different landscapes in the FSTZ relate to bee abundance and diversity. This situation is alarming considering the contribution of this region to crop production and livelihood sustenance. Agriculture is fundamental to Ghana's economy and is the highest employer of the labour force. Most small scale farmers in Ghana view insects as pests and not as important factor in the crop production system.

If it is known which landscapes or habitats support higher and diverse bee populations, then ways of manipulating these habitats to enhance the floral community and nesting opportunities could be pursued. This will ultimately results in higher pollination and hence increased food production within the transition zone. The principal objective of this study therefore was to investigate the influence of landscape type on bee species abundance and diversity within the FSTZ of Ghana.

MATERIALS AND METHODS

Study Area and Field Work: The bee collection was done on bi-monthly bases within the Forest Savannah Transition Zone of Ghana (Fig 1) from June 2013 to April 2014. The study area was divided into three subzones (Upper, middle and lower FSTZs) based on the proportion of grasses in relation to trees. Two communities were selected from each subzone for the study. The upper transition zone (Awisa and Subinso) constitutes the northern portion with the highest percentage grass cover whilst the lower transition zone (Nyameadom and Mankranso) forms the southern part and has the highest percentage tree cover. The middle transition zone (Kobedi and Yawhima) comprises the midsection with approximately equal proportions of grasses and trees. From each community, three landscape types namely agricultural land, settlement fringes and natural vegetation were identified giving a total of 18 sampling sites across the study area. The examined communities were at least 25 km apart and a minimum distance of 5 km was kept between transects. The subzones were at least 60 km apart. The study sites were conveniently and purposefully selected. Delineation into subzones was based on the relative proportions of trees in relation to grasses as well as nearness of site to motorable roads. On each site, a 500 m by 3 m fixed transect was constructed (Fig. 2).

Five sets of three 5.08 cm PVC pipes were erected at intervals of 100 m along each transect. The pipes were placed in a triangular form with each separated from the other by a metre distance and projecting one metre high above the surface of the ground.

Bee Sampling: Two complementary methods (Pan-trapping and netting) used by Potts *et al.* [17] and Munyuli [18] were adopted to sample bees from the study sites. Bee communities are best sampled when pan-trapping is used in conjunction with aerial netting [19]. It has been established that the pan trapping technique is easy to use by researchers with varying levels of entomological experience [20]. Westphal *et al.* [21] established that the pan trap method is the least biased and most successful technique for collecting bees. Three pan traps, each sprayed on the inside with either yellow, white or blue [22] fluorescent colour were filled with soapy water and placed on the PVC pipes between 7am and 10am each sampling day. The traps were removed between the same period the third day and any bee caught was transferred into vials containing 70% alcohol for preservation. In addition, a 30 minute walk was taken along each transect the second day and any bee found on flowers occurring within 2m radius on either side of each transect was netted. Temperature and relative humidity values were recorded on each sampling day using an Acurite digital weather instrument (Appendix). GPS readings of all sampling sites were documented. There were no weather restrictions during the entire study period (Cloudy or windy days were absent). After each sampling period, the samples collected were transported to the University of Cape Coast (UCC) Entomology Museum where the different bees collected were sorted out and pinned for identification. The species identified were counted, recorded and stored.

Data Analyses: EstimateS version 9.0 [23] was used to compute species abundance and Shannon's diversity index of bees collected from the three landscape types. SPSS version 21 was used to carry out analysis of variance (ANOVA) on the diversity and abundance figures among the pre-selected landscape types. Probability was set at 0.05% level of significance.

RESULTS

Bee Species Present in the FSTZ of Ghana: In all, 706 bees made up of three families, 18 genera and 34 species were identified (Table 1). The families were Apidae (18 species), Halictidae (11 species) and Megachilidae (5 species).

Variation Across Landscape Types: No significant variation in bee species abundance was found {F= 0.13, P = 0.884; Fig 3} across landscape types. Bee diversity however significantly varied (F=11.64, p = 0.009) across landscape types, with agricultural land recording the highest diversity whilst settlement fringes had the lowest (Fig 4).

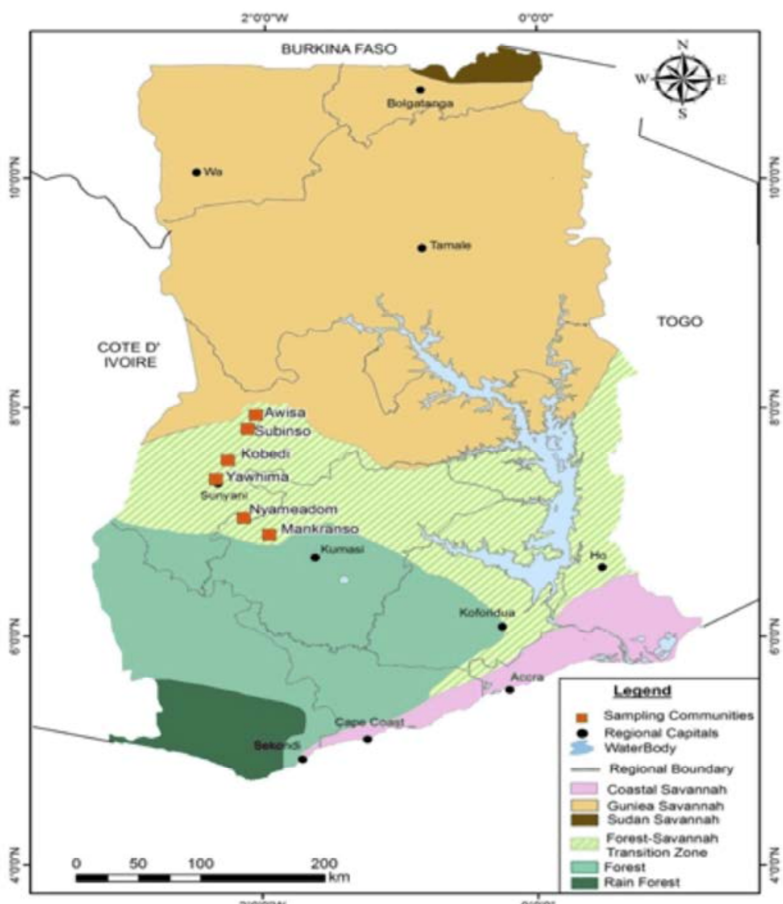

Fig. 1: Map of Ghana showing the study communities within the Forest Savannah Transition Zone

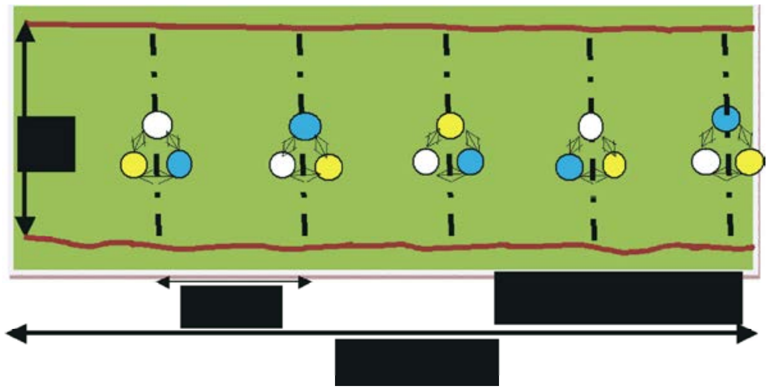

Fig. 2: Diagrammatic representation of the sampling protocol in each transect with white, blue and yellow colours representing the colours of the pan traps used whilst arrows represent the 1m distance between Polyvinyl Chloride (PVC) pipes.
Source: Field data

Table 1: List of Bees Collected from the FSTZ of Ghana from June 2013 to April 2014

No.	Family	Genus	Species
1	Apidae	*Apis*	*Apis mellifera* (Linnaeus, 1758)
2	,,	*Amegilla*	*Amegilla cingulata* (Fabricius, 1775)
3	,,	,,	*A.calens* (Lepeletier,1841*)*
4	,,	,,	*A. acraensis* (Fabricius,1793)
5	,,	,,	*A.albocaudata* (Dours,1869)
6	,,	,,	*A. nila* (Eardley,1994)
7	,,	*Meliponula*	*Meliopnula bocandei* (Spinola, 1853)
8	,,	*Compsomelissa*	*Compsomelissa nigrinervis* (Cameron, 1905).
9	,,	*Ceratina*	*Ceratina moerenhouti* (Vachal, 1903)
10	,,	*Thyreus*	*Thyreus nitidulus* (Fabricius, 1804)
11	,,	*Allodape*	*Allodape interrupta* (Vachal, 1903).
12	,,	*Braunsapis*	*Braunsapis leptozonia* (Vachal, 1909)
13	,,	*Xylocopa*	*Xylocopa imitator* (Smith, 1854)
14	,,	,,	*X. albiceps* (Fabricius, 1804)
15	,,	,,	*X. olivacea* (Fabricius, 1778)
16	,,	,,	*X. nigrita* (Fabricius, 1775)
17	,,	,,	*X.hottentota hottentota (*Smith, 1854*)*
18	,,	,,	*X. torrida (*Westwood, 1838*)*
19	Halictidae	*Lipotriches*	*Lipotriches orientalis* (Friese, 1909)
20	,,	,,	*L. natelensis* (Cockerell, 1916)
21	,,	,,	*L. nigrociliata* (Cockerell, 1932)
22	,,	,,	*L. tetraloniformis* (Strand, 1912)
23	,,	,,	*L. cirrita* (Vachal, 1903)
24	,,	,,	*L. guinensis (Strand, 1912)*
25	,,	*Pseudapis*	*Pseudapis amoenula* (Gerstacker, 1870).
26	,,	*Halictus*	*Halictus sp.*
27	,,	*Nomia*	*Nomia ivorensis* (Pauly, 1990)
28	,,	,,	*N. viridicincta* (Meade-Waldo, 1916)
29	,,	*Lasioglossum*	*Lasioglossum quebecensis* (Crawford, 1907)
30	Megachilidae	*Megachile*	*Megachile semierma* (Vachal, 1903)
31	,,	,,	*M. bituberculata* (Ritsema, 1880)
32	,,	*Chalicodoma*	*Chalicodoma cincta* (Fabricius, 1781)
33	,,	*Coelioxys*	*Coelioxys torrida* (Smith, 1854).
34	,,	*Lithurgus*	*Lithurgus sparganotes* (Schetterer, 1891)

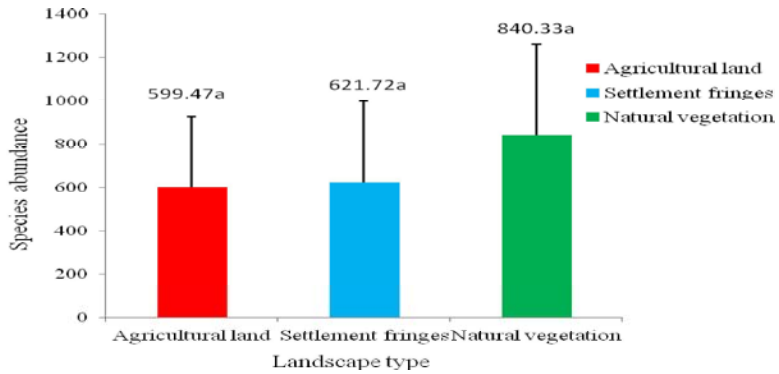

Fig. 3: Variation in bee species abundance across landscape types

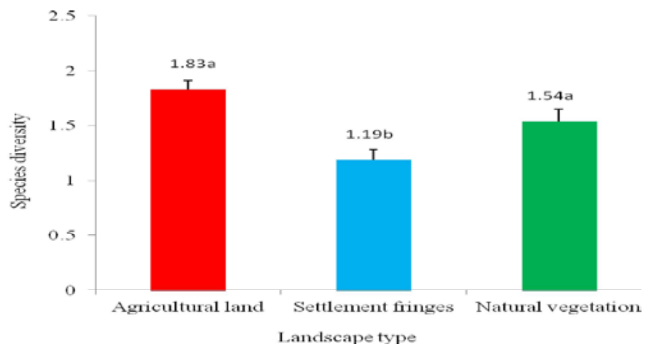

Fig. 4: Variation in bee species diversity across landscape types

DISCUSSIONS

General Variation Across Landscape Types: Several studies have established that floral and bee diversity and abundance are positively associated [24-26]. Similar to floral resources, the temporal and spatial distribution of nesting resources may determine the bee community composition in a given area [17, 27]. Thus the two principal factors which influence bee abundance and diversity are floral and nesting resources [28]. Consequently, the overall highest bee diversity recorded in agricultural land was probably in response to more diverse, healthy and abundant floral and nesting resources. Mono cropping may be common in the upper FSTZ but taking the study area as a whole, the mixed cropping system is more widespread. The mixed cropping system provides diverse floral resources for bees with different food requirements [29]. Pollinator diversity is enhanced by farmland variability because plant species provide complementary resources over time and space and insect species prefer different resource combinations [30, 31]. In fact, the loss of plant diversity and flower quantity arising out of habitat destruction and landscape fragmentation is believed to be the reason for the decline of many bee species [32]. In 2004, Fenster *et al.* [33] observed that increasing floral diversity provides a wider array of foraging niches for different functional groups of flower visitors.

Many scientific studies have revealed that the more semi-natural habitat areas there are on farms and within agricultural landscapes, the higher the diversity and abundance of native bees. Work in California by Kremen *et al.* [34] revealed that as the proportional area of wild habitat surrounding a farm increased, both native bee diversity and abundance equally increased significantly. Again, a study by Ricketts *et al.* [35] revealed that crop pollinators inhabit surrounding natural habitats and spill over into agricultural fields during crop bloom. Such places as wooded areas, hedgerows and herbaceous field margins are important for the conservation of wild bees as observed in this research. Natural and semi-natural habitats experience less disturbance and so help maintain overall bee biodiversity [36] by providing the relevant nesting and floral resources. Many wild bees that contribute to pollination need forage sources outside the crop season [37] and these are provided by surrounding natural areas. Many entomologists and ecologists have proven that the reduction of native bee diversity and abundance in crop fields is because these fields are far removed from critical floral and nesting resources [18]. When food crops are out of season, floral resources become scarce in agricultural land compelling bees to move to nearby natural areas to feed. Research shows that at the landscape scale, natural habitat is key to the survival of diverse crop pollinators while addition of floral resources may locally augment bee density and diversity at the field scale [38]. It is therefore logical to observe in this study that bee diversity in agricultural land did not significantly differ from that of natural vegetation. The two landscape types complement each other in terms of resources, mainly floral and nesting, at different times to support and maintain diverse bee populations. Studies conducted in east Africa by Gikungu [39] however showed that agricultural ecosystems support higher levels of bee diversity and abundance than natural or forested areas.

Bees exhibit extreme diversity in their nesting ecology and comprise a number of distinct guilds: miners, carpenters, masons, social nesters and cuckoos [40]. The diversity of nesting strategies and the specialization of guilds means that access to the correct quantity and quality of resources, both in space and time, is an important determinant of which species a landscape will support [41]. Thus the higher bee diversity observed in agricultural land and natural vegetation as compared to settlement fringes could mean the availability of the right quantity and quality of resources.

Unlike urban areas or cities, fringes of many rural settlements in Ghana lack the usual ornamental plants that provide forage resources for pollinators. During this study, animals such as cattle, sheep and goats were often observed moving and grazing freely in settlement areas. It was particularly widespread in the upper FSTZ where livestock production is the second most important occupation besides crop farming. Other factors that deprive settlement fringes of the needed floral and nesting resources and which may have played a role in the generally low bee species diversity observed in that landscape are indiscriminate waste disposal and wildfire. Although wild bees do benefit from some degree of disturbance, which promotes the growth of herbaceous plants and wildflowers, too much human-caused disturbance can have negative impacts [42].

CONCLUSION

Bee species diversity was significantly influenced by landscape type but not abundance. Much as the number of bee species recorded in this study cannot be compared with similar studies conducted elsewhere owing to possible differences in site characteristics, it is obvious that the numbers fall far short of the potential of the three landscape types studied. In the highlands of Jordan, a similar study conducted during the bloom period of stone fruits yielded 53 species consisting of five families from a total of 1461 specimens [43]. The need for a concerted approach towards conserving pollinators in Ghana, particularly bees, can therefore not be overemphasized. Maintaining diverse, healthy and abundant communities of wild bees within farmlands is crucial since Ghana's economy is largely dependent on agriculture. For example, encouraging the cultivation of ornamental plants in settlement areas and training crop farmers to adopt pollinator friendly farming practices are some of the measures that can be taken to ensure increased crop production within the FSTZ from its current levels.

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Appendix

Mean Bi-monthly Temperature and Relative Humidity values recorded in the FSTZ from June 2013 to April 2014

	Upper FSTZ		Middle FSTZ		Lower FSTZ	
Sampling month	Temp. (°C)	R. Hum. (%)	Temp. (°C)	R. Hum. (%)	Temp. (°C)	R. Hum. (%)
Jun. 2013	30.17	77.00	31.00	66.83	29.00	70.33
Aug. 2013	31.00	70.33	26.50	75.83	28.67	89.00
Oct. 2013	30.17	74.50	29.33	82.33	30.00	82.33
Dec. 2013	30.50	62.50	30.67	79.50	28.00	86.33
Feb. 2014	29.00	69.33	28.33	65.33	29.50	79.50
Apr. 2014	29.83	62.00	28.50	76.00	29.83	79.33
Annual means	30.11	69.28	29.06	74.30	29.17	81.41