The Impact of Land-Use Change on Plant-Pollinator Interactions in Port Harcourt, Nigeria

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Abstract
Plant-pollinator interactions are among the most important processes in plant reproduction, conservation of biodiversity and restoration of ecosystems. However, anthropogenic activities such as land use changes have caused significant impacts on habitats and floral resources needed by pollinators. Land-use change is a major driver of pollinator decline, yet data on plant–pollinator interactions from tropical African cities remain scarce. This study compared plant-pollinator interactions across four land-use types in Port Harcourt, Nigeria: a recreational park, a university farm, a botanical garden and an urban residential area. The study also examined the composition of plant species, pollinators, and their visitation rates, interactions and characteristics. Using timed scan observations (10 min per focal plant, 09:00–11:00 h), plant pollinators on four focal plant species (Ixora coccinea, Sphagneticola trilobata, Coreopsis lanceolata and Aspilia sp.) were recorded and visitation rate, interaction richness and an adapted composite score, the Average Pollinator Network Index (APNI), based on min–max normalised performance metrics were calculated. Pollinators were mainly butterflying (notably Luthrodes pandava and Jamides sp.), with fewer bees and flies. The study concluded that land use types influence the interaction patterns of plant-pollinator networks in Port Harcourt, Nigeria. It demonstrates the differences among sites which tracked floral abundance and plant identity as much as land-use category. It also recommends that retaining abundant floral resources in urban and agricultural green space may support plant-pollinating insects and ensure biodiversity conservation.

Keywords: *plant–pollinator interactions, land-use change, visitation rate, urban ecology, environmental management, tropical Africa, Niger Delta*

1. Introduction

We call animals or insects that transfer pollen from plant to plant, "pollinators". Animal pollination supports most flowering plants and a large share of global crop types (Klein *et al.*, 2007; Ollerton *et al.*, 2011). Pollination is also among the ecosystem services reported as declining, with urbanisation, agricultural intensification and loss of floral resources identified as major drivers (Millennium Ecosystem Assessment, 2005; Potts *et al.*, 2016). Wild insect pollinators, which include native and introduced bees, flies, butterflies, moths and beetles, are not merely insects but providers of ecosystem services with measurable ecological and economic value. They contribute to the pollination of numerous leading global food crops (Klein *et al*., 2007; 2015; Garibaldi *et al*., 2020). Most evidence on how land use affects pollinators comes from temperate regions and from bees. Many animal-pollinated crops provide vitamins and minerals (e.g. vitamin C, antioxidants, and lycopene) essential for good

human and livestock health (Eilers *et al*., 2011; Chaplin-Kramer *et al*., 2014; Smith *et al*. 2015), even though some may comprise a small component of human diets. Land-use change is one of the greatest threats to biodiversity and is projected to increase in magnitude in the coming years, stressing the importance of better understanding how land-use change may affect vital ecosystem services such as pollination (Ganuza *et al.*, 2022).

The Niger Delta is located in southern Nigeria, covering about 70,000 km² across 9 states including Rivers, Bayelsa, Delta, Imo, Abia etc., where River Niger empties into the Atlantic Ocean. It is the largest wetland in Africa and third largest in the world (UNEP, 2011; Mmom & Arokoyu, 2010). Pollination is critical in the Niger Delta because most of its plants depend on animals, not wind. Most crops in the region depend on animal pollination (Eilers *et al*., 2011), with insects being the most important pollinators. Recent studies in Nigeria show pollinator abundance varies by season and vegetation zone (Eluyeba *et al*., 2025) and honeybees improve oil palm yield in the Niger Delta (Emuh & Ofuoku, 2011). Port Harcourt, in the Niger Delta, is experiencing rapid urban expansion, infrastructural development and vegetation loss. Land use change negatively affects plant-pollinator interactions through habitat loss, floral resource reduction, nesting site destruction, habitat fragmentation and reduced ecological connectivity leading to reduced plant diversity and pollination services (Thompson, 2024). Human activities are responsible for habitat loss and degradation, landscape simplification by large monocultures, and habitat fragmentation by roads and other infrastructure. Understanding the impact of land-use change on the functioning of ecosystems (such as pollination) requires considering the community of plant-pollinator interactions as a network across multiple sites, as change in land use is also known to impact the structure of these plant-pollinator interaction networks (Thompson, 2024). The impact of land use change on plant-pollinator interactions varies depending on the type and intensity of land use.

Land use type (e.g., natural habitat, agricultural landscapes, urban landscapes, recreational green spaces and conservation areas) is a significant predictor of pollinator community composition and diversity (Ganuza *et al.*, 2022). Responses depend on the group studied and on habitat quality: bee richness can be higher in diversified farmland than in simplified landscapes (Kennedy *et al.*, 2013), and urban green spaces with diverse flowers can support richer pollinator communities than heavily built areas (Baldock, 2020). They differ greatly in their ability to support pollinator communities. Little is known about which flowering plants and plant-pollinating insects persist across its land-use types, or how visitation differs among them. This study therefore aimed to describe plant-pollinator interactions on focal flowering plants across four land-use types in Port Harcourt. Specifically, the study documented the pollinator species recorded on each focal plant, compared visitation rates and interaction richness among sites; and explored a simple composite network performance index to summarise these measures.

2. Materials and Methods

2.1 Study Area

The study was carried out at four sites in Port Harcourt, Rivers State, representing different land-use types (Figure 1): Port Harcourt Pleasure Park (recreational), the Rivers State University School Farm (agricultural), the University of Port Harcourt Botanical Garden (conservational) and King Perekule Road, GRA (urban residential area). The area experiences a tropical climate with a mean annual rainfall of about 2,400 mm, mean temperature of 27°C and lies within the lowland rainforest/freshwater swamp vegetation zone of the Niger Delta.

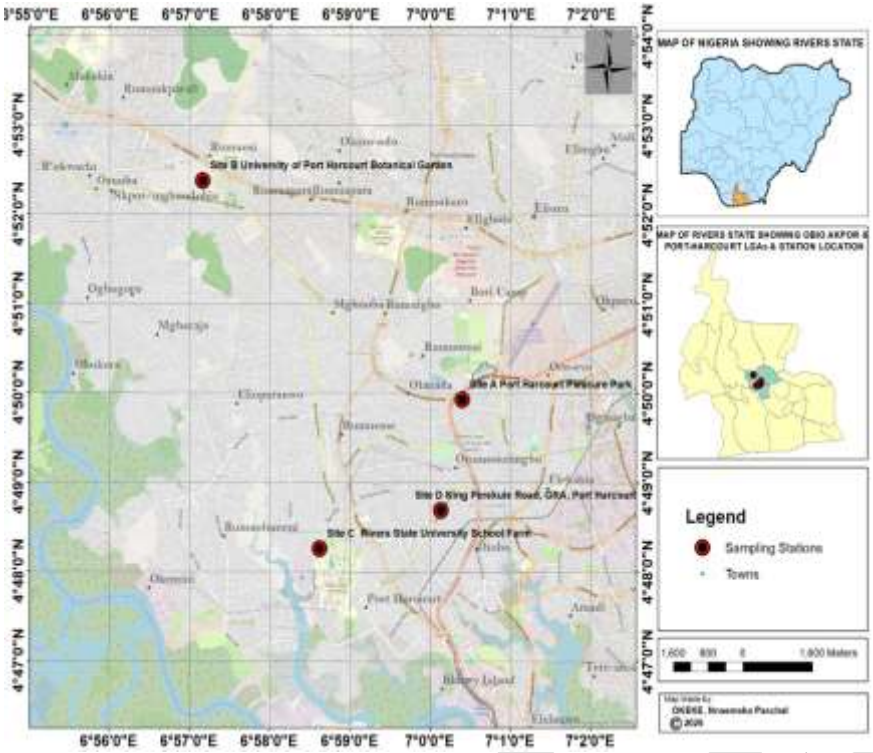


Figure 1. Map of Study Area showing the four different sample sites in Port Harcourt

2.2 Sampling design

Plant-pollinators were recorded by scan sampling (Altmann, 1974) between 09:00 and 11:00 am, the period of peak insect activity (Polatto *et al*., 2014). Each focal plant was observed for 10 minutes and visits by each pollinator species were counted (Arnold-Meeks & McGlone, 1986). Each study site was sampled six times over six months (two sessions weekly, per month) from January 2026 to June 2026. Identical flowering plant species were selected and observed across all sites to ensure comparability. Plant abundance and species richness were recorded to provide ecological context.

2.3 Field methods

Specimens were collected with sweep nets or by hand picking, killed in 70% ethanol, preserved in Eppendorf tubes and identified using morphological characters and taxonomic guides (Boorman, 1970, 1981) in the Animal and Environmental Biology laboratory. Photographs of pollinators and plants were taken for documentation. Temperature, humidity, grass height (Table 1); GPS Coordinates, time and date were recorded at each site. Floral abundance was recorded as the number of flowering clusters and flowering plant species.

2.4 Data analysis

For each focal plant, plant-pollinator species richness, interaction richness (number of distinct plant–pollinator links), interaction frequency (total number of visits), connectance (calculated following the standard formula for bipartite plant–pollinator networks, C = interaction richness / plant species × pollinator species; Jordano, 1987) and visitation rate (total visits divided by observation time, visits min^{-1}) were calculated (Kearns & Inouye, 1993). As fruit set, network specialisation (H2'), modularity and robustness could not be estimated from the available field data, an Average Pollinator Network Index (APNI) was adapted from the standard normalisation approach and developed for this study by integrating the field-measurable ecological network metric: plant species, pollinator species, interaction richness,

connectance and visitation rate forming a score of plant-pollinator network performance. APNI was calculated as the mean of min–max normalised values of plant-pollinator richness, interaction richness, connectance and visitation rate, with the minimum and maximum taken across the focal plants (Connectance + Interaction Richness + Visitation Rate + Plant Species + Pollinator Species) / 5). Each metric was first rescaled to a common 0–1 range using min–max normalisation, a standard technique for constructing composite indices from variables of different units and magnitudes (Nardo *et al.*, 2005): X = (X − Xmin) / (Xmax − Xmin) Where X is the observed value, Xmin is the minimum value across sites, and Xmax is the maximum value across sites. The plant–pollinator interaction data (Table 2) obtained from the four study sites were analysed using descriptive statistics and ecological network analysis. Plant–pollinator performance matrices (Table 3) were calculated from field observations to represent the occurrence of interactions between flowering plants and pollinating insects. Network complexity was evaluated using interaction richness, interaction richness, and connectance. Pollinator activity was assessed using visitation rate and interaction frequency.

3. Results

3.1 Plant species composition

Four flowering plant species from two families (Rubiaceae and Asteraceae) were studied. *Ixora coccinea* occurred at three sites and Pleasure Park had the most focal plant species (three). Flowering clusters of *Ixora coccinea* numbered 24 in the park and the botanical garden but only 12 on the urban residential area, where flower density was low. *Aspilia* sp. on the farm had 18 clusters and high flower density

Table 1: Plant Species Observed

Site	Plant Specie	Family	Number of flowering plants	Flower density	Grass height (mean value)
Pleasure Park	*Ixora coccinea*	Rubiaceae	24 clusters	High	0.7868m
	Sphagneticola trilobata	Asteraceae	10 clusters	Moderate	0.3234m
	Coreopsis lanceolata	Asteraceae	5 clusters	Low	0.2848m
RSU Farm	*Aspilia sp.*	Asteraceae	18 clusters	High	0.8785m
UNIPORT Botanical Garden	*Ixora coccinea*	Rubiaceae	24 clusters	High	1.5883m
King Perekule Road, GRA	*Ixora coccinea*	Rubiaceae	12 clusters	Moderate	0.3985m

3.2 Plant pollinators and visitation rates

Visitation rates differed among focal plants. The highest rate was recorded on *Ixora coccinea* in the botanical garden (12.5 visits min^{-1}; 125 visits from four species, 80 of them by *Luthrodes pandava*). *Aspilia* sp. on the farm received 89 visits (8.9 visits min^{-1}) from six species, the highest visitor richness, including *Apis* sp. (22 visits), *Jamides* sp. (36) and *Acraea* sp. (15). In Pleasure Park, *Ixora coccinea* and *Sphagneticola trilobata* received 70 and 44 visits (7.0 and 4.4 visits min^{-1}), mostly from butterflies, whereas *Coreopsis lanceolata*

received 8 visits (0.8 visits min^{-1}) from *Musca domestica*, *Eristalinus tabanoides* and *Apis mellifera*. *Ixora coccinea* on the urban residential area received 24 visits (2.4 visits min^{-1}) from three species. Butterflies, chiefly *Luthrodes pandava* and *Jamides* sp., dominated visits to *Ixora coccinea* at all sites. Bees (*Apis* spp.) were recorded on *Aspilia* sp., *Sphagneticola. trilobata* and *Coreopsis lanceolata* but not on *Ixora coccinea*.



Table 2: Plant–Pollinator Interaction Data

Site	Plant Species	Pollinator Species	Number of visits (frequency)	Observation time (min)	Pollinator Specie Richness	Interaction Richness	Connectance	Visitation Rate(visit/min)
Pleasure Park	*Ixora coccinea*	*Jamides sp.*	8	10	4	4	1	7
		Luthrodes pandava	54					
		Lerodea eufala	6					
		Zizula hylax	2					
	Sphagneticola trilobata	*Apis sp.*	2	10	4	4	1	4.4
		Jamides sp.	35					
		Zizula hylax	4					
		Luthrodes pandava	3					
	Coreopsis lanceolata	*Musca domestica*	1	10	3	3	1	0.8
		Apis mellifera	4					
		Eristalinus tabanoides	3					
RSU Farm	*Aspilia sp.*	*Apis sp.*	22	10	6	6	1	8.9
		Spoladea recurvalis	3					
		Jamides sp.,	36					
		Brenthia sp.	8					
		Junonia oenone	5					

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		Acraea sp.	15					
UNIPORT Botanical Garden	*Ixora coccinea*	*Papilio dardanus*	4	10	4	4	1	12.5
		Luthrodes pandava	80					
		Jamides sp.	35					
		Lerodea eufala	6					
King Perekule Road, GRA	*Ixora coccinea*	*Papilio demodocus*	1	10	3	3	1	2.4
		Luthrodes pandava	12					
		Jamides sp.	11					

3.3 Performance Indices

The Adapted Composite Performance Index**,** Average Pollinator Network Index (APNI) ranged from 0.516 (*C. lanceolata*, Pleasure Park) to 0.928 (*Aspilia* sp., RSU Farm) and connectance was 1.00 across every plant species sampled; Table 3). Differences were driven mainly by plant-pollinator richness and visitation rate.

Table 3: Adapted Composite Performance Index - Average Pollinator Network Index (APNI)

Site	Plant species richness (S_p)	Pollinator richness (S_a)	Interaction richness (I)	Connectance (C)	Visitation rate (V)	Normalized S_a	Normalized I	Normalized C	Normalized V	APNI	Network Performance
Pleasure Park	*Ixora coccinea*	4	4	1	7	0.667	0.667	1	0.56	0.724	High
Pleasure Park	*Sphagneticola trilobata*	4	4	1	4.4	0.667	0.667	1	0.352	0.672	Moderate
Pleasure Park	*Coreopsis lanceolata*	3	3	1	0.8	0.5	0.5	1	0.064	0.516	Moderate
RSU Farm	*Aspilia sp.*	6	6	1	8.9	1	1	1	0.712	0.928	Very High
UNIPORT Botanical Garden	*Ixora coccinea*	4	4	1	12.5	0.667	0.667	1	1	0.833	Very High
King Perekule Road, GRA	*Ixora coccinea*	3	3	1	2.4	0.5	0.5	1	0.192	0.548	Moderate

Key: S_p = Plant species richness, S_a = Pollinator species richness, I = Interaction richness, C = Connectance, V = Visitation rate, APNI = Average Pollinator Network Index.

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4. Discussion

The study was conducted across four sites representing different land-use types, these sites differed not only in their land-use characteristics but also in their dominant flowering vegetation, providing a suitable gradient for assessing plant–pollinator interactions. Pleasure Park was characterised by three flowering plant species *(Ixora coccinea, Sphagneticola trilobata, and Coreopsis lanceolata*), whereas RSU Farm was dominated by *Aspilia* sp., and both UNIPORT Botanical Garden and Perekule Road were dominated by *Ixora coccinea*. The variation in vegetation composition among the study sites is important because floral diversity is widely recognised as one of the main determinants of pollinator diversity, abundance, and foraging behaviour. Diverse floral resources provide pollinators with continuous nectar and pollen supplies, thereby supporting a wider range of pollinator taxa and enhancing the overall functioning of ecosystem. The findings indicate that recreational and conservation landscapes maintained comparatively richer floral resources than the urban site. Pleasure Park contained three flowering plant species from two botanical families, whereas the Botanical Garden preserved a naturally established population of *Ixora coccinea*. Such habitats are typically subjected to lower levels of habitat disturbance and intensive management compared to urban landscapes, thereby providing more suitable foraging and nesting opportunities for insect pollinators. This observation agrees with the findings of Hall *et al.* (2017), who reported that urban green spaces with diverse flowering vegetation supported significantly higher pollinator richness than heavily developed urban environments. Similarly, Wenzel *et al*., (2020) observed that habitat heterogeneity and floral diversity positively influenced insect community composition by enhancing both resource availability and habitat quality.

The clearest contrast was within a single plant species. *Ixora coccinea* received about five times more visits per minute in the botanical garden than on the urban residential area and the urban residential area plants also had half as many flowering clusters and low flower density. This is consistent with studies reporting that floral abundance is a key determinant of pollinator abundance (Nicholson *et al.*, 2021) and that urban sites with few flowers support fewer visitors (Baldock, 2020). However, land use, flower number and vegetation structure co-varied and each land-use type was represented by one site, so their effects cannot be separated. *Aspilia* sp. on the farm supported the most visitor species. Asteraceae with composite flower heads expose many florets at once and attract diverse insects (M'Gonigle *et al.*, 2022), and mass-flowering herbs in farmland can attract many visitors even where plant diversity is low (Grab *et al.*, 2019). The farm's pollinator richness therefore probably reflects the resource this plant offers rather than agricultural land use as such. *Coreopsis lanceolata* received the fewest visits. With few clusters (5) and low flower density, its low visitation may reflect limited floral display or flowering phenology during sampling, and should not be read as low ecological value (Ollerton, 2021). Butterflies dominated visits and bees were comparatively scarce. Because butterflies are often less effective pollen vectors than bees, our data describe flower visitation, not pollination effectiveness; we therefore use the term flower visitors and recommend that pollen-transport or seed-set data be added in future work. Average Pollinator Network Index offers a simple way to rank focal plants using field-measurable metrics, but it has not been validated against pollination outcomes, and its values depend on which plants are included in the normalization. The results are therefore a descriptive baseline.

5. Conclusion

This study looked at how different land uses in Port Harcourt affect the relationship between plants and pollinators. Plant-pollinator interactions differed among the four land-use types in Port Harcourt, with the highest visitation on *Ixora coccinea* in the botanical garden, the greatest pollinator richness on *Aspilia* sp. at the Rivers State University School farm, and the lowest visitation within *Ixora coccinea* on the King Perekule Road, GRA. *Ixora coccinea* was the most common flower across the sites, but the highest pollinator activity was on *Ixora coccinea* at UNIPORT Botanical Garden and on *Aspilia* at RSU Farm, which also had the best overall network performance. In summary, sites with more flowers and less disturbance like the botanical garden and the farm supported stronger plant-pollinator interactions than the urban residential area at GRA. The patterns were associated with floral abundance as well as land use. Maintaining abundant, continuously flowering plants in urban green space and farmland is a low-cost measure that may support flower-visiting insects.

Based on the findings of this study, the following recommendations are made:

a. **Conservation and maintenance of flowering plant diversity**

Urban planners, environmental managers, and landowners should encourage the maintenance and establishment of diverse flowering plant communities within urban and recreational landscapes. The presence of flowering plants such as *Ixora coccinea*, *Aspilia* sp., and other nectar-producing species can provide important resources for pollinators.

b. **Promotion of pollinator-friendly agricultural practices**

Agricultural landscapes should incorporate flowering vegetation and reduce practices that unnecessarily remove floral resources.

c. **Protection and expansion of urban green spaces**

Botanical gardens, parks, and other urban green spaces should be conserved and expanded because they can serve as important habitats for pollinating insects within highly modified landscapes.

d. **Reduction of excessive disturbance in urban landscapes**

Urban development activities should consider pollinator conservation by reducing unnecessary removal of flowering plants and maintaining vegetation structures that provide feeding resources for insects.

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