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Diversity of Epiphytic Lichens in Urban, Peri-Urban and Adjoining Rural Areas of Benin City to Monitor the Ecosystem Health

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ABSTRACT: Lichens are widely used as biomonitors of environmental pollution, few lichen studies have been used to assess environmental quality in Nigeria. Managed and natural areas within Benin City metropolis and adjourning areas were investigated using lichen diversity to determine the ecosystem health status in four sites: Urban, Peri-urban, Rural and the Reference site. Lichen colonies obtained in triplicates per site from 10 mature trees (>60cm ghb) were collected and identified using standard keys and manuals. Based on the European Guideline procedure, Lichen Diversity Value (LDV) were estimated from lichen colony count obtained from a ladder grid (10cm x 10cm) at five levels placed perpendicularly at four aspects (North, South, East west) on each side of the tree at 100cm above ground level. Site disturbance statuses were deduced from the LDV position on the percentage environmental alteration scale. Growth form distribution were crustose 12 (85.71%) and foliose two (14.29%). Six lichen taxa was identified to generic levels. The estimated LDV which inferred environmental alterations for each site were: Urban (13.60), Rural (16.30), Peri-urban (19.70) and Reference site (33.77). These findings show high environmental alterations (stress) in the Urban and Rural areas with the reference site moderately altered with less external stress.

Keywords: Lichen diversity Value, Ecosystem health, Environmental quality, Crustose and Foliose

Introduction

Urban environments are towns and cities which have high population densities owing to the continuous immigration of individuals from rural environments in search for greener pastures (Okhakhu, 2016). It is also characterized by the numerous industrial, agricultural and transportation activities which has enhanced air pollution. Air pollution represent a serious threat to both the environment and the organisms living in the environment (Cansaran-duman *et al*., 2016) hence the need to bio-monitor with economically sustainable living organisms (Lichens). The stable self-supporting mutualistic relationship between an alga which is usually called the photobiont and a fungus (the mycobiont) metamorphosed to a single living organism called Lichen. In the association, the photobiont which is the photosynthetic partner provides food for the organism while the mycobiont provide a stable protective environment for its photobiont. Three most frequent genera of the photobiont are the *Trebouxia, Trentephohlia* and *Nostoc*. The vegetative body of the lichen is known as the thallus (Goward *et al*., 1994).
Lichen have a unique ability which is having remarkable tolerance to drying out (this ability is due to the high quantity of chloroxathone a metabolite that it produces when compared to that of higher plants) an advantage it has over higher plants. Lichen diversity can be classified based on their growth form; they exist in three growth forms

which are crustose, foliose and the fruticose and based on the substrate they colonise. Hence, classified into Terriculous, Saxiculous, Corticolous and Folicolous lichens (Wirth, 1995). These organisms are cosmopolitans and can tolerate all climatic conditions.

Lichens are among the most widely extensively used biomonitors of air pollutants in the terrestrial environment. They are used because of their high sensitivity to slight changes in the ecosystem which could affect their morphology, physiology, biodiversity and even have the ability to accumulate these pollutants (Nimis *et al*., 2002). Most studies on lichens in Nigeria has been concerned with the quantitative or active aspects of biomonitoring and its classification into different growth forms (Kapu, *et al*., 1991; Akinsoji, 1991; Obiakor and Ezeonyejiaku, 2013 and Aniefiok *et al*., 2014) with very few reported study on the diversity of lichens being used as biomonitors using the approach of the European guidelines which is a qualitative approach. Hence this study aims to investigate the efficacy of the European Guideline procedure in determining the ecosystem health status of four differentially impacted sites in Benin City, Nigeria using the biological diversity of lichens.

Materials and Methods

Sampling site: Four managed and natural areas within Benin City metropolis and adjoining areas comprising: Benin City (Urban), Ogba Zoo and Nature Park (Peri-urban), Udo town (Rural) and Okomu National Park (Pristine, Control) **(Figure 1)** were sampled for epiphytic lichens. Lichen colonies from random triplicates samples per site from 10 mature trees (>60 cm gbh) were collected, photographed and identified using standard keys and manuals.

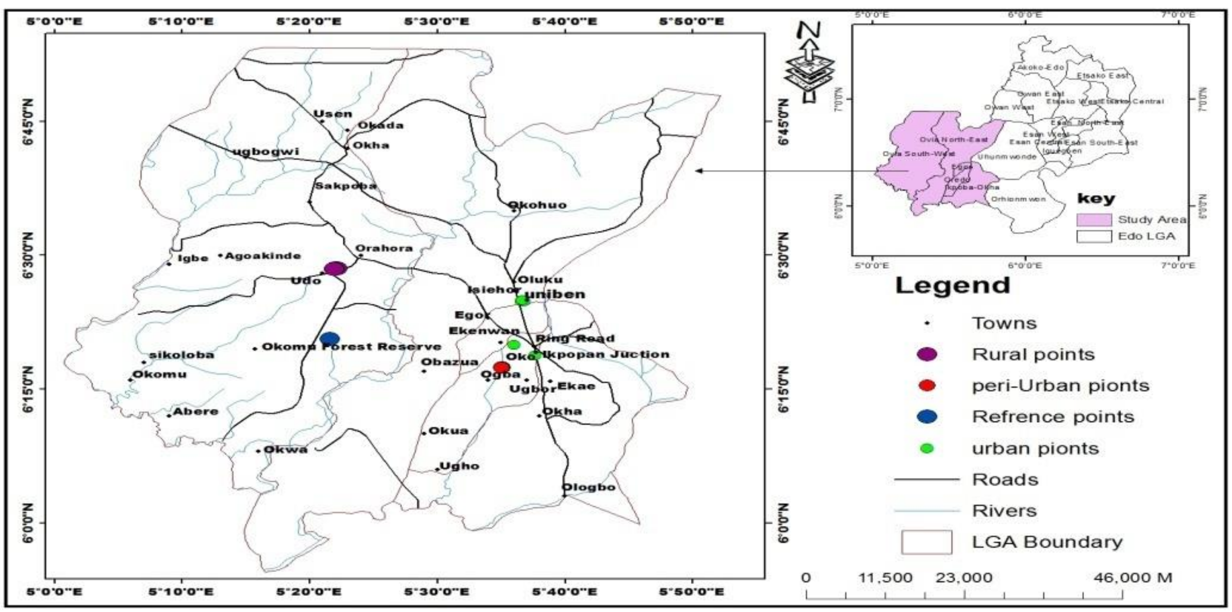

Figure 1: Map showing study areas with Edo State map (inset) showing region of interest (shaded).

Lichen Diversity Values (LDV) were estimated from colony counts from a ladder grid (10 cm x 10 cm) at five levels placed perpendicularly at four aspects (North, South, East and West) on each side of the tree at 100 cm above ground level **(**Figure 2**)**.

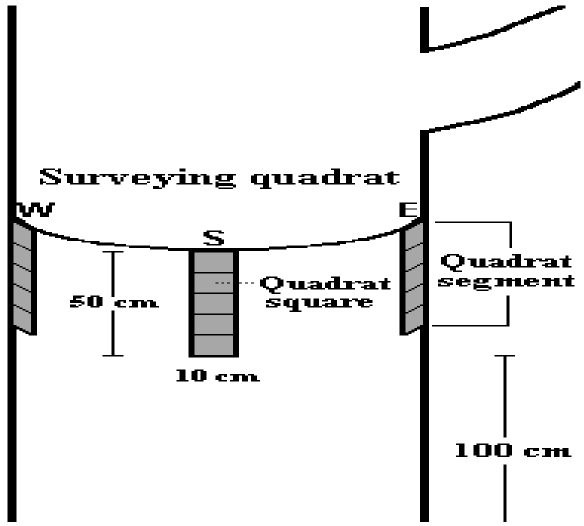

Figure 2: A model surveying quadrat showing location of ladder grid on the tree trunk

Site disturbance status were inferred from the LDV position on the percentage environmental alteration scale.

Calculation of lichen diversity values: The European guideline developed by Asta *et al.* (2002) with a few modifications was used to assess the lichen diversity in the different study sites. The European Guideline has been recently applied in a number of major studies to map lichen diversity in temperate and tropical countries (Davies *et al*. 2002; Pinho *et al*. 2004; Castello and Skert, 2005). LD value for each sample plot was calculated following the procedures of Asta *et al*. (2002). Within each sample plot; a sum of frequencies of all lichen species at each aspect on each tree (1) was calculated. Thus for each tree there were four Sums of Frequencies (SF1) on the North (SF1N), East (SF1E) South (SF1S) and West (SF1W) side of the trunk. Then the Mean of the Sums of Frequencies (MSF) for each aspect (North, East, South, and West) in each sample plot (j) was calculated according to the following equation:

$MSFNj = (SF1Nj + SF2Nj + SF3Nj + SF4Nj) / n$

where: $MSFNj$ = Mean of the sums of frequencies of all trees of sample plot j at a given aspect (e.g. North)

$SF1Nj$ = Sum of frequencies of all the species found at one aspect of tree 1 (e.g. North)

N, E, S, W = north, east, south, west.

n = number of trees surveyed in sample plot *j*

The Lichen Diversity Value (LDV) of a sample plot was then calculated as the sum of the MSFs of all aspects:

$LDVj = (MSFNj + MSFEj + MSFSj + MSFWj)$

where: $LDVj$ = Lichen Diversity Value of sample plot *j*.

Lichen identification: Morphological characters of thalli and fruiting bodies were examined using magnifying lenses (x10). Lichen identification was carried out according to lichen identification keys and pictorial guide proposed by Volkmar Wirth in The Lichens, A key to common lichens trees in England and the lichens of British Columbia (Nimis *et al*., 2009) and Key to the lichen genera of the Pacific Northwest (McCune, 2012). Pictures taken in the field were reconciled with the lichen catalogue in the British Lichenological Website.

Results

Epiphytic Lichen Distribution: A total of 14 lichen taxa were recorded on the trunks of 120 trees in the study sites. Of these, 12 (85.71%) were crustose and 02 (14.29 %) species were foliose (Table 1 and Plate 1). Fruticose lichens were not observed in any of the studied sites. Foliose lichens identified were *Flavoparmelia* sp. and *Canoparmelia* sp. while the identified crustose lichens were; *Phlyctis* sp., *Cryptothecia* sp., *Caloplaca* sp. and *Diploschistes* sp. while the remaining 08 lichens were unidentified (Table 1). The crustose lichen *Phlyctis* sp. was the most prevalent in this study.

Lichen Identification: Six (42.85%) of the lichen specimens were identified up to generic level using morphological characteristics to key them while the remaining eight (57.15%) were unidentified. (Plate 1 -7). Identification of species were based on their growth form (Table 1).

Table 1: Frequency of occurrence of different types and growth forms of lichen species recorded at the four study sites.

S/N	Species	Growth form	Ogba (Peri-urban)	Okomu (Reference site)	Udo (Rural)	Benin City (Urban)
1.	*Phlyctis sp.*	Crustose	21	21	90	41
2.	*Cryptothecia* sp.	Crustose	24	35	1	1
3.	*Caloplaca* sp.	Crustose	8	0	1	0
4.	*Diploschistes* sp.	Crustose	3	2	0	0
5.	*Flavoparmelia* sp.	Foliose	2	3	5	6
6.	*Canoparmelia* sp.	Foliose	0	0	0	9
7.	Unidentified sp. 1	Crustose	9	3	2	0
8.	Unidentified sp. 2	Crustose	31	45	24	39
9.	Unidentified sp. 3	Crustose	3	0	0	0
10.	Unidentified sp. 4	Crustose	2	0	0	0
11.	Unidentified sp. 5	Crustose	15	0	0	0
12.	Unidentified sp. 6	Crustose	3	2	0	0
13.	Unidentified sp. 7	Crustose	6	3	0	0
14	Unidentified sp. 8	Crustose	2	0	0	0

(a) *Phlyctis* sp. (Crustose)

(b) *Caloplaca* sp. (Crustose)

(c) *Diploschistes* sp. (Crustose)

(d) Unidentified sp.4. (Crustose)

(e) ***Cryptothecia*** **sp. (Crustose)**

(f) ***Flavoparmelia*** **sp. (Foliose)**

Plate 1: Photographs of some selected crustose (A, B, C, D, E) and foliose (F) lichens found at the study sites

Lichen Diversity Assessments: Lichen diversity value was recorded for each sampling plot (Table 2). The LDVs range between 15.00 to 24.80 in the peri-urban area. The LDV range was from 31.00 to 36.70 in the reference site. The LDV range from 10.60 to 21.00 in the rural area and from 9.20 to 16.80 in urban area.

The value 36.70 in the reference site was the highest LDV recorded while 9.20 in the urban area were the lowest LDV recorded across all the four study sites. The highest average LDV was recorded in the reference site (33.77), significantly lower in the peri-urban area (19.70) and rural area (16.53) but the lowest average LDV was recorded in the urban area (13.64)(table 2).

Table 2: Lichen Diversity Value (LDV) index from replicate sample plots in the four study sites

Study Plots	Okomu (Control)	Ogba (Peri-urban)	Udo (Rural)	Benin City (Urban)
1	31.00	24.80	10.60	16.80
2	33.60	19.30	21.00	9.20
3	36.70	15.00	18.00	15.00
Mean	**33.77**	**19.70**	**16.53**	**13.64**

Table 3: Environmental class and alteration profile inferred from the lichen diversity values (LDV) estimates per plot within each of the study sites

Class Environmental alteration (%)	LDV range	Location			
		Ogba (Peri-urban)	Okomu (Control)	Udo (Rural)	Benin City (Urban)
Naturality No (0)	>72	-	-	-	-
Semi-naturality Low (1-25)	48–72	-	-	-	-
Semi-alteration Moderate (26-50)	24–48	*	* * *	-	-
Alteration High (51-75)	1–24	* *	-	* * *	* * *
Lichen desert Very high (76-100)	0	-	-	-	-

(*) represents different plots.

Discussion

The number of lichens present in a particular habitat has been used in several studies to infer the health of that environment (McCune, 2000; Asta *et al*., 2002; Thormann, 2006; Giordani, 2007). In this study, the observed 14 species of lichens belong to two classes (crustose and foliose). This is consistent with the lichen diversity found in most tropical environment. Previous studies observed 19 lichen taxa belonging to two classes (crustose and foliose) in pine plantation and adjacent secondary forest in Peacock Hill Pusellawa, Sri Lanka. (Silva and Senanayake, 2015).

The absence of fruticose lichen from the study sites could be due to the high sensitivity of fruticose lichens to high irradiance which was relatively poor in the peri-urban and reference site and pollution (a call for concern in the urban areas). Wolseley and Pryor (1999) reported fruticose lichens to be light loving lichens usually present on tree trunks at appropriate light conditions and also signifies good air quality.

The part of the tree sampled which is the trunk could be a factor in the reduced number of foliose lichen recorded and lack of fruiticose lichens. It was observed that there were more foliose lichens at the twig and branches of the tree than the trunk, the twigs and branches receive higher precipitation as well as relatively greater availability of light (Siva and Senanayake, 2015). Hence I will recommend further studies to look into the twigs and branches of the national parks.

The lichen diversity number can be used to estimate the quality of the environment and the amount of stress that the area is experiencing. High LDV suggests relatively good environmental quality with low stress while low LDV assumes poor environmental quality with high stress (Asta *et al*., 2002).

The scale of environmental alterations established for this study (Table 3) suggests that none of the study plots fell into the very high environmental alteration class. This indicates that the environmental conditions were favourable for the epiphytic lichen growth and development in the study areas, in addition, no sample plot was recorded as being free from environmental alterations not even the control which indicates that all sampled plots were found to have some degree of environmental alterations. High environmental alterations were recorded in majority of the plots (table 3). Moderate environmental alterations were recorded in about three plots. The environmental alteration results were in agreement with the LD results. In the assessments, the recorded frequency of lichen species played an important role in generating LDVs and was found influencing the degree of environmental alteration of the sampled plots. Plots with high LDVs were recorded with low environmental alteration and with high frequency of lichens while plots with low LDV were identified with high environmental alterations and low frequency of lichen species. This indicates that environmental alteration assessment identifies area which have favourable environmental conditions for species and those areas which are poor in lichen species frequencies.

Conclusion

The result showed that moderate LD scores were recorded in the reference site while the rural, peri-urban and urban areas fell into the low and very low LD. The decreasing LDV estimates was directly proportional to the degree of human habitation and environmental influence. The least and most polluted sites were the reference site and the urban area. Highest lichen diversity in the reference site (control) indicates that there were low environmental stress enabling the lichens present to be able to colonize the substrate rapidly while low LD recorded in the other sites (ubran, peri-urban and rural) indicates the high level of stress encountered by these habitats. This research has been able to provide a suitable platform for monitoring of the atmospheric environment using lichen diversity for futuristic purposes.

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