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Cluster Analysis and Tree Crown Characteristic Index of Some Selected Tree Species for Shade And Shelter

Alabi J.O.[1]; Oladele, F.A.[2]; AbdulRahaman, A.A.[2]

[1] Department of Plant and Environmental Biology, Kwara State University, Malete.

[2]Department of PlantBiology, University of Ilorin, Ilorin, Nigeria

Corresponding Author: john.alabi@kwasu.edu.ng
Phone no: 07030535488

ABSTRACT

The study investigated the tree crown characteristic index and cluster analysis of some selected tree species for shade and shelter at University of Ilorin Botanical Garden. Attempt was made to relate tree crown characteristic index to the foliage feature benefits of tree species studied at the University of Ilorin Botanical garden and environs as shade or shelter plant towards good ecosystem services. The study area was divided into 30 plots using transect lines of 10m X 10m for tree species. Samples were collected from each plot. Cluster analysis of the tree species and tree crown characteristic indices were performed by assigning code 1 – 6 to taxonomic characters in ascending order according to the observation and measurement. The study revealed that, cluster analysis of tree species in the gardens and environs gave percentage clusters of 63%, outliers 37% and tree crown characteristics indices in the heat-map ranged from 4.33 to 6 and 1 to 2.67 for shelter and shade respectively; The study concluded that, tree crown characteristics: shape of crown, shape of leaf, leaf type, leaf arrangement, petiole, stem height, leaf area, crown diameter, area of canopy and density of leaves were good candidates for ecosystem services such as: shading, shelter and landscape productivity

Keywords: Tree species, crown characteristics, heat-map, ecosystem services

INTRODUCTION

Plant canopy or tree crown serve as an index of shade or shelter, because this gives room for much penetration or reduction in penetration of sun rays and rain drops. This is to say that a plant with many branches but loosely arranged leaves will not be considered as a shade plant but rather a shelter plant. A plant that can serve effectively as a shade plant must possess many branches arising from a trunk, particularly there must be dense leaves known as tree crown.

Shade provided by trees on paved surfaces and parked cars decreases evaporative hydrocarbon emissions and ozone formation. It is a fact, however, that trees can also impact negatively on air quality through the emission of volatile organic compound (VOC) and from emissions resulting from tree management activities. Deciduous trees are known to emit great amounts of the compound 'isoperene' during a hot day; coniferous trees emit the VOCs 'pinene' day and light, and such VOCs emitted can add to ozone formation in the atmosphere (Chameides and Lindsay, 1988). However cumulative studies involving urban tree impacts on ozone have shown that increased urban canopy cover, particularly with low VOC emitting species, leads to net reduced Ozone concentrations in cities (Nowak and Dwyer, 2007).

One way to mitigate extreme summer temperatures in the urban areas is the adoption of 'cool cities' strategy. According to Kjelgren and Montague (1998) a 'cool cities' strategy aims to reduce the urban heat island effect by (a) promoting tree planting to shade buildings and to cool the ambient environment through evapotranspiration by foliage and (b) using reflective roof and paving surfaces to reduce heat accumulation due to solar radiation. The surfaces of pavements and buildings can reach very high temperatures unless shaded. By shading ground surfaces, trees can decrease the amount of radiation being absorbed by and then being re-radiated from paved surfaces (Roberts and Jackson, 2006).

Trees can seize the majority of the sun's energy, and while some of it is reflected, most is absorbed and used in photosynthesis. Research shows that tree canopies can reduce the temperatures of the surfaces they shade by as much as 10-25^{o}C (Akbari and Pomerantz, 2001). Shading effects of different tree species vary according to their Leaf Area Index (LAI) a ratio of leaf area per unit of ground surface area. It is also known that shading by tree is more efficient than shading by non-natural materials such as tarpaulin (Georgi and Dimitriou, 2010). Research in the USA shows that increasing the amount of leaf area in urban or suburban area can have a significant effect on surface temperatures (Hardin and Jensen, 2007). Recent research in Melbourne supports these outcomes, with inner city areas and the western suburbs experiencing higher temperatures than the more leafy eastern or southern suburbs (Loughnan and Nicholls, 2010). It seemed to these authors that leafy suburbs could be 2-3 degrees cooler than new tree- less suburbs. A study by Taha (1996) found out that the addition of a large number of trees to the public realm should result in an air temperature reduction of 1-3^{o}C in the hottest areas.

Information on the performance of specific plants for green buildings is limited. In terms of living walls, Cameron *et al.* (2014) found that plant species differed in their cooling capacity as well as their mechanisms for cooling. *Hedera helix* and the silver-leaved, semi-herbaceous *stachcys lanata* accomplished the best for wall cooling. *Prunus avium* also provided significant air-temperature cooling but was less efficient in its surface-temperature cooling when compared to *stachys lanata* and *hedera helix*. When assessed on a per leaf area basis, however, other species revealed greater cooling potential with *Fuchia triphylla*, *Jasmium sambac* and *Lonicera japonica* out-performing others. *Fuchsia triphylla* promoted evapotranspirative cooling, whereas shade cooling was more important in *Jasminum sambac* and *Lonicera japonica* (Zupancic, 2015). In terms of providing thermal comfort in a hot, humid park setting, compact multilayered plants were suggested over large grassy areas for cooling (Cao *et al*., 2010).

When comparing trees and grass, the surface composition of grass has been shown to have little effect on globe temperatures whereas tree shading was found to decrease globe temperatures by 5 to 7^{o}C as they provide the greatest reduction of heat stress from their shade (Froehlich and Matzarakis, 2013). This suggests that while both grass and trees may help to reduce urban heat island, trees are more efficient in providing relief to metropolitan residents from heat stress. Where possible, trees are suggested over shrubs and grass for cooling as correlation analysis shows stronger correlation coefficients between their pattern metrics and urban cool islands, especially in warm seasons (Chen *et al*., 2014; Zupancic, 2015). In terms of tree types, deciduous trees have been known as most important for providing thermal comfort in parks because of the provision of shade in hot months but do not block needed warmth from the sun in cold months (Lin *et al*., 2010; Hwang *et al*., 2011). During summer, both deciduous and evergreen trees provided similar cooling effects, but in winter the evergreen tree park was much cooler and below the 'neutral' comfort conditions (Cohen *et al*., 2012; Zupancic, 2015).

A study conducted by Meier and Scherer (2012) found that species with a lower canopy temperature like *Populus nigra*, or *Tiliacordata* are especially suitable for reducing local air temperatures; however, some species such as *Quercus robur* and several species of *Populus acerifolia* as well as *Populus acerifolia* should be avoided due to their high emissions of biogenic volatile organic compound (BVOC) and potential contribution to ground-level ozone formation (Meier and Scherer, 2012). A comparison of small trees that grow in warm temperate climates with dry winters found that *Eucalyptus sp.* had significantly higher cooling effects. The species with the least effect on temperature were *Grevillea robusta* and *Cupressus sempervirens* (Feyisa *et al*., 2014; Zupancic, 2015). Attempt was made to relate tree crown characteristic index to the foliage feature of tree species studied in the University of Ilorin Botanical Garden and environs as shade or shelter plant towards good ecosystem services.

MATERIALS AND METHODS

Description of Experimental Location

The study was conducted at Botanical Gardens of University of Ilorin and environs, located in Sudano-Guinea Savanna Region of Nigeria between the periods of 2012 and 2018, the area is characterized by various floras with flat land terrain, and it is located between latitude 8.469406^{0}N and longitude 4.660905^{0}E. The presence of derived savanna has been observed which is manmade, through the effects of grazing, farming and fire burning, which occur at different time of the season.

Collection of Plant Specimens

For this study 10m X 10m line transects was used and total enumeration of the tree species in each location was recorded (Olajide *et al*., 2006). Taxonomic studies of the foliage features were assessed (Tables 2 and 3). Fresh leaves were collected from mature stands of trees at sites of studied fields (Table 1). The leaf specimens were identified at the Herbarium for confirmation of their identity. Voucher specimens of all plants were deposited at the Herbarium of Department Plant Biology, University of Ilorin, Nigeria.

Table 1: Informations on Tree species at University of Ilorin Botanical Garden and Environs

	Scientific Names	Common Names	Local Names	Families
1.	*Plumera rubra* L	Frangipani	Usibaka	Apocynaceae
2.	*Vitellaria paradoxa* Gaertn. F.	Shea butter	Emi	Sapotaceae
3.	*Gliricidium sepium* (Jacq) Kunth	Quick stick	Agunmaniye	Fabaceae
4.	*Polyalthia longifolia* Sonn	Azoka tree	Igunnu	Annonaceae
5.	*Casuarina equisetifolia* L	Whisthing pine	Iu Jeki	Casuarinaceae
6.	*Tectonia grandis* L	Teak	Tikii	Verbenaceae
7.	*Terminalia catappa* L	Almond tree	Igi furutu	Combretaceae
8.	*Parkia biglobossa* (Jacq) R. Br. Ex Don	Locust bean tree	Igbaa	Mimosaceae
9.	*Daniellia olieveri* (Rolfe) Hutch and Dalz	Balsam tree	Iya	Caesalpiniaceae
10.	*Prosopis africana* (Guill and Perr.)Taub	Iron wood	Kirya	Mimosaceae
11.	*Delonix regia* (Hook) Raf	Flamboyant tree	Seke-seke	Caesalpinaceae
12.	*Gmelina arborea* Roxb	Melina	Igi-melina	Verbenaceae
13.	*Plumera alba* L	Frangipani	Usibaka	Apocynaceae
14.	*Azadirachita indica* A Juss	Neem	Dongo yaro	Meliaceae
15.	*Anacardium occidentale* Linn De Wild	Cashew	Kasu	Anacardiaceae
16.	*Citrus sinensis* Osbeck	Sweet Orange	Orombo didun	Rutaceae
17.	*Bridelia ferruginea* Benth	Pyrexia	Ira	Euphorbiaceae
18.	*Blighia sapida* K. Koenig	Akee apple	Ishin	Sapindaceae
19.	*Annona senegalensis* Pers.	Curstard apple	Abo	Annonaceae
20.	*Lophira lanceolata* Tiegh.ex Keay	Chewstick	Ipawhaw	Ochnaceae
21.	*Burkea africana* Hook	Wild seriga	Apasa	Caesalpiniaceae
22.	*Albizza lebbeck* (Linn) Benth	Silk flower	Igbagbo	Fabaceae
23.	*Eucalyptus citrodora* Labii	Lemon scented	Igi-Rosia	Myrtaceae
24.	*Hildagardia barterii* Roxb	Hildagadia	Okurugbedu	Malvaceae
25.	*Eucalyptus cinerea* F.Muell. ex Benth	Eucalyptus	Igi-Rosia	Myrtaceae
26.	*Acacia moniliformis* Griseb	Acacia	Kasia eleti	Mimosaceae
27.	*Ficus diversifolia* L	Fig	Odan	Moraceae
28.	*Mangifera indica* L	Mango	Mangoro	Anacardiaceae
29.	*Lonchocarpus cyanenscens* Perkin	WestAfrica indigo	Elu	Fabaceae
30.	*Adansonia digitata* A.L	Baobab	Ku'uka	Bombacaceae

Shade and Shelter Characteristics of Tree Crowns

The tree crown characteristics for shade and shelter were determined using the method of Tandy (1981). The following parameters were determined: (i) Qualitative characters of tree crown or canopy foliage features and (ii) Quantitative characters of the tree crown or canopy feature.

Cluster Analysis of the Foliage Features

Codes (1, 2, 3, 4, 5, and 6) were assigned to the character states (qualitative and quantitative) in accordance to the observation, measurement and range of variation of these characters among the operational taxonomic unit (Tables 2 and 3). The formula according to Hill (1980) was used to determine the character states for the quantitative features only.

$$K = 1.0+3.332 \log n$$

Where K = Number of States

n = Number of species (OTU'S)

The formula helps in the determination of number of states, which could be in range of two or three states called character values which is the transformation of quantitative characters to qualitative characters for the generation of the dendrogram by cluster analysis. The converted numerical code is represented as 1- represent short, small or low value, 2- represent medium value and 3- represent large, long, tall, narrow or high value.

Statistical Analysis:

The data obtained were subjected to cluster analysis using Paleontological Statistical Software Application Packages 3.14 (Hammer *et al*., 2001; Hammer and Harper, 2006). Cluster analysis was performed by agglomerative technique using the Un-weighted Pair Group Method with Arithmetic Mean (UPGMA) method. Relationships between the tree species were graphically represented in the heat map and analysed taxonomically in form of dendogram, based on ward's method, neighbour joining and single linkage.

RESULTS

Trees Species Matrix Plots

Heat map is a common method of visualizing or display data. It may also be combined with clustering methods which group samples together based on the similarity of their taxonomic characters expression pattern. This can be useful for identifying plant species that are common for shade and shelter or biological diversity associated with a particular condition such as an environmental condition or air pollution related diseases. In heat map the data is displayed in a grid where each row represents a particular plant and each column represents a particular taxonomic character. The colour and intensity of the boxes are used to represent changes in taxonomic character of the plants. For example low values might tend towards cool blue tones while higher value tends to hotter orange and red tones. The colour key ranges from minimum data value to maximum data values.

Table 2: Description of Qualitative Tree Crown Foliage Features

	Coded Character States					
Qualitative Characters	1	2	3	4	5	6
1. Shape of Crown	Globular	Conical	Cylindrical	Spreading		
2. Shape of leaf	linear	Lanceolate	Oblanceolate	Oval	Ovate	Obovate
3. Leaf Type	Simple Compound	Pinnate Compound	Bipinnate Compound	Bilobate		
4. Leaf Texture	Thin	Thick	Leathery			
5. Leaf Surface	Glaborous	Pubescent	Floccose	Scabrid	Sericeous	
6. Leaf Apex	Acute	Acuminate	Obtuse	Truncate	Bristle tipped	Apiculate
7. Leaf Margin	Smooth	Serrated	Cuneate	Entire	Undulate	Dentate
8. Leaf Base	Cuneate	Obtuse	Cordate	Oblique	Truncate	Auriculate
9. Petiole	Winged	Puberulous	Glabrous	Cylinderical	Stout	Tomentose
10. Fruit Type	Berry	Drupe	Follicule	Legume	Nut	Capsule
11. Flower Type	Perfect	Imperfect	Bilateral Symmetry	Radial Symmetry		
12. Leaf Form	Narrowleaf	Fascicle	Conifer	Broadleaf		
13. Leaf Arrang.	Opposite	Alternate	Whorled			
14. Anatomy of twigs	Present	Absent	I don't know			
15. Leaf Colour	Parrot Green	Lime Peel	Deep Mist	Alfalfa	Cadenza	Siamese

The colour key (1 – 6) in the matrix plot (heat map) ranges from minimum data value as outliers (cool blue) to maximum data value as clusters (hotter orange and red tones). Hence the landscape status of equal rows and columns which could be of either trees species or taxonomic variables within the operational taxonomic unit (OTU's) was a fair representation of these points interrelationship (Figs. 1 - 4).

Accordingly, the landscape status of the tree species gave 13 clusters namely: 23, 26; 1, 13; 12, 27; 7, 6; 27, 24; 15, 28, 18; 16, 14; 8, 10; 21, 9; 5, 22; 30, 20; 17, 19; 29 and outlier namely: 2, and 25. Tree species 25 occurred as outliers but with some affinity or relationship with the cluster 26, 23. Likewise tree species 4 and 11 occurred as outliers with some affinity or relationship with clusters 18, 28 respectively and were fair representation of these points' interrelationships (Fig. 1)

Table 3: Description of Quantitative Tree Crown Foliage Features

	Coded Character State						
Quantitative Characters	1	2	3	4	5	6	Instrument
1. Leaf Length	Short	Medium	Long				Measurement Tape
2. Leaf Width	Small	Medium	Narrow	wide			
3. Stem Height	Short	Medium	Tall				Swedish Stem guage
4. Plant Height	Short	Medium	Tall				Altimeter
5. Freq. Distrn	Small	Medium	Large				Quadrat
6. Blade Length	Short	Medium	Long				
7. Petiole Length	Short	Medium	Long				
8. Leaf Area	Small	Medium	Large				Leaf Area meter- 211
9. Blade Width	Small	Medium	Narrow	Wide			
10. Crown diameter	Short	Medium	Long				Spiegel Relaskope
11. Area of Canopy	Small	Medium	Large				Densiometer- model C
12. Diameter of Trunk	Short	Medium	Long				Diameter Calliper
13. Freq. of Lichens	Small	Medium	Large	Absent			
14. Density of Lichens	Low	Medium	High	Absent	Rare	Occassional	
15. Density of Leaves	Low	Medium	High				

The cluster heat map is well known in the natural sciences and is one of the most widely used graphs in the biological sciences. For visualization, by far the most popular graphical representation has been the clustered heat map. In the case of taxonomic characters of trees species, the colour assigned to a point in the heat map grid indicates how much of a particular tree or foliage features is expressed in a given sample. The expression level is generally indicated by red for high expression and either light blue or deep blue for low expression. The different colours may indicate functional relationship of either shade or shelter among the trees species and the foliage features (Fig. 2)

Fig 3 shows the correlation co-efficient between the trees species and the crown or canopy characteristic features. Results show that tree species was positively and significantly correlated with the crown characteristics at all foliage features level. Similarly tree species was positively related to the shape of the crown, shape of the leaf and leaf type in the qualitative foliage features likewise, in the quantitative foliage features tree species was positively related to leaf length, leaf width, leaf area, blade length, blade width and density of leaf. The relationship was however not significant for tree species at foliage features qualitative characteristic level of leaf texture.

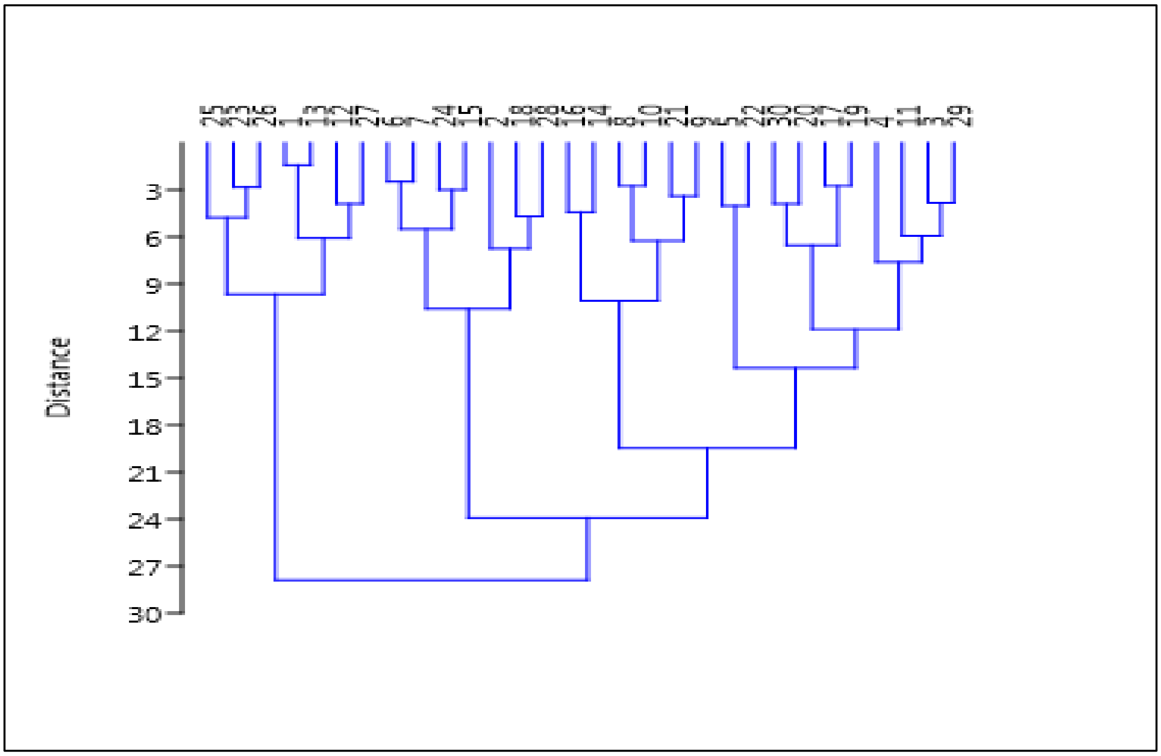

Fig.1: Ward's Linkage Dendrogram Hierarchical Clustering of Trees Species at University of Ilorin Botanical Garden and Environs.

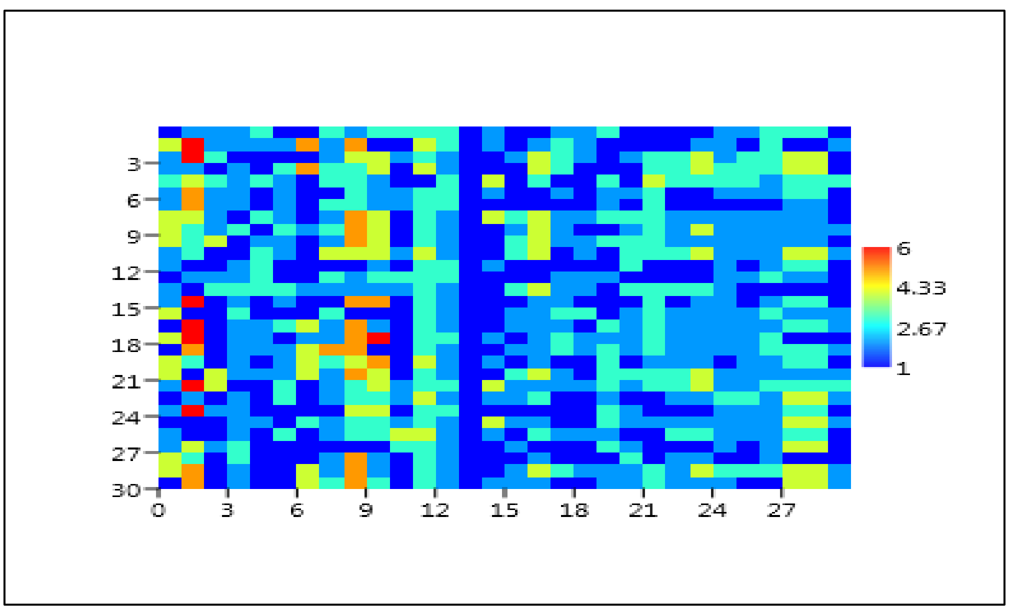

Fig. 2: Heat Map Showing the Significant Effect of Taxonomic Characters of each Trees species at the University of Ilorin Botanical Garden and Environs

Table 4: Linear Correlation Co-efficient of Tree Crown Shape and Crown Foliage Parameters

S/N	Crown Shape	Correlation Co-efficient (r)
1	Shape of leaf	0.009172
2	Leaf type	0.19677
3	Leave texture	0.098216
4	Leaf surface	-0.096507
5	Leaf apex	-0.060724
6	Leaf margin	0.090162
7	Leaf base	-0.10081
8	Petiole	0.35887
9	Fruit type	0.17569
10	Flower type	-0.49167
11	Leaf forms	-0.043743
12	Leaf arrangement	-0.10024
13	Twigs anatomy	0
14	Leaf colour	-0.022569
15	Leaf length	0.12309
16	Leaf width	0.38232
17	Stem height	0.25515
18	Plant height	0.20153
19	Frequency distribution	-0.13062
20	Blade length	0.28121
21	Petiole length	0.20534
22	Leaf area	0.1307
23	Blade width	0.27254
24	Crown diameter	-0.14513
25	Canopy area	0.01743
26	Trunk diameter	0.1259
27	Lichens density	-0.53683
28	Lichens frequency	-0.53683
29	Leave density	0

Fig 4 shows the effect of crown characteristic on the trees species. The shape of crown, shape of leaf, leaf base, petiole and leaf form are slightly longer than leaf type, leaf texture and structure in the qualitative crown characteristics of the foliage features likewise, leaf length, leaf width, blade length and leaf area are slightly longer than stem height and density of leaf in the quantitative crown characteristic of the foliage features.

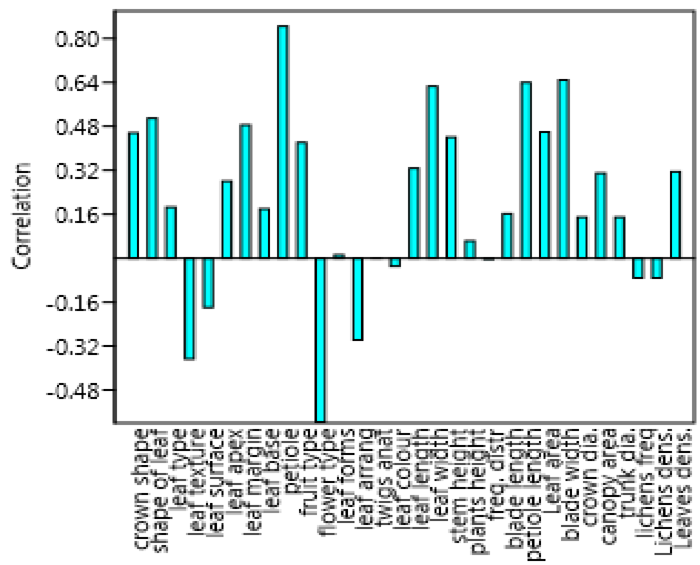

Fig 3: Linear Correlation Co-efficient of Trees Species and Some Crown Characteristics

Qualitative and Quantitative foliage features

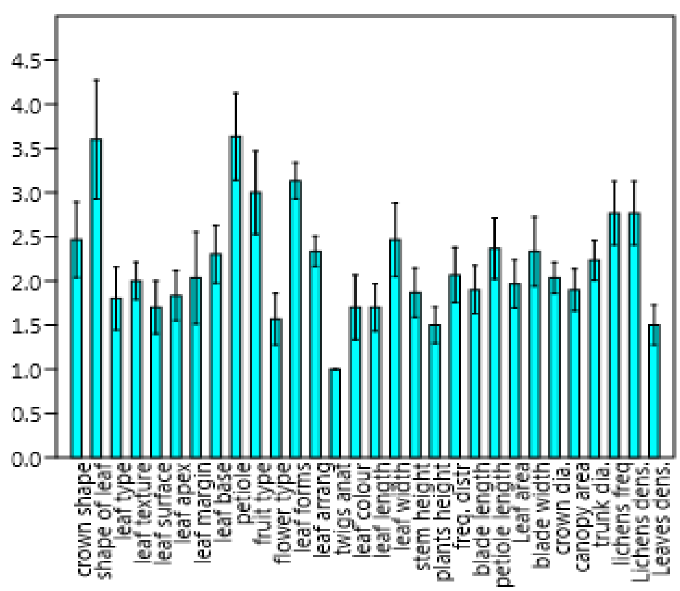

Fig 4: Functional relationship of trees species as affected by crown characteristics

DISCUSSION

Dendrograms are made up of clades and leaves, the arrangement of the clades tells us which leaves are most similar to each other. The height of the branch points indicates how similar or different they are from each other. Accordingly, the landscape status of the tree species gave 13 clusters namely: *Eucalyptus citrodora, Acacia moniliformis; Plumera rubra, Plumera alba; Gmelina arborea, Ficus diversifolia; Tectonia grandis, Terminalia catappa; Hildagardia barterii, Anacardium occidentale; Mangifera indica, Blighia sapida; Citrus sinensis, Azadirachita indica; Parkia biglobossa, Prosopis africana; Burkea Africana, Daniellia olieveri; Casuarina equisetifolia, Albizza lebbeck; Adansonia digitata, Lophira lanceolata; Bridelia ferruginea, Annona senegalensis; Gliricidium sepium, Lonchocarpus cyanenscens.* Tree species *Eucalyptus cinerea, Vitellaria paradoxa* occurred as outliers but with some affinity or relationship with the cluster *Eucalyptus citrodora, Acacia moniliformis and Blighia sapida, Mangifera indica* respectively. Likewise tree species *Polyalthia longifolia and Delonix regia* occurred as outliers with some affinity or relationship with clusters *Gliricidium sepium, Lonchocarpus cyanenscens* respectively. The greater the height, the greater the difference and this play a significant effect on shade or shelter functional benefits of foliage or tree crown characteristics index of tree species in the botanical garden and environs. Heat-map is a common method of visualizing or display data (Weinstein, 2008). It may also be combined with clustering methods which group samples together based on the similarity of their crown characters expression pattern. The expression level was indicated as red for high expression (clusters) and either light blue or deep blue for low expression (outliers). This can be useful for identifying plant species that are commonly for shade (high expression) or shelter (low expression) and tree crown characteristics indices ranged from 4.33 to 6 and 1 to 2.67 for shade and shelter respectively in the botanical garden and environs of the studied site. Application of Dendrogram and heat-map generated from the cluster analysis also showed a significant effect of economic importance of botanical garden. The grouping of the trees species in the garden studied into shade or shelter have been shown to be proportional to the ecosystem services provided by the garden which was in line with the findings of Manes *et al.* (2012) on the economic benefits of the botanical garden.

A high correlation, meaning one that is closer to the value of one, means that the variables are very strongly related to each other (Table 4). Confirmation for this observation was found in this study with a significant positive correlation co-efficient between crown shape and some crown foliage parameters such as shape of leaf, leaf type, leaf length, leaf width, blade length, blade width, canopy area and plant height and can be of good characteristics that may thus serve as indices for selecting each of the plant species as either shade or shelter depend on the interest of the users in the landscape.

However, earlier report showed that shading effects of different trees species vary according to their crown or canopy forms, branching configuration and leaf area index, a ratio of leaf area per unit of ground surface area (Tandy, 1981). This was also supported by the results of the present study of cluster analysis generated from taxonomic variables (qualitative and quantitative). It was also known that shading by tree is more operational and effective than shading by non-natural material (Georgi and Dimitriou, 2010). Other workers have also reported that trees provided soil improvement, shade and shelter (Muoghalu and Awokunle, 1994).

Conclusion

Observation from the studies makes it possible that the tree crown characteristics index of the trees species that occurred within the line transects at the botanical garden and environ of the study area serve as indices for selecting each of the trees species as either shade or shelter purposes, which could be of help to mitigate harsh weather condition. The study concluded that, tree crown characteristics: shape of crown, shape of leaf, leaf type, leaf arrangement, petiole, stem height, leaf area, and crown diameter, area of canopy and density of leaves were good candidates for ecosystem services such as shading, shelter and landscape productivity.

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