TREE GROWTH COMPETITION INDICES FOR BIODIVERSITY CONSERVATION IN IITA FOREST IBADAN, NIGERIA

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Abstract
Studies on relative contributions of competition in forest tree growth is essential because it determine forest structure. There is dearth of information on forest growth using Competition Indices (CI) in International Institute of Tropical Agriculture (IITA), Ibadan Forest. Hence, this study assessed CI effects on stand growth in IITA towards improving its structure and biodiversity conservation. Data were collected using four systematic lines transect (270m each) at 200m apart for plot demarcation. Sixteen sample plots of 25m × 25m were alternately laid to collect growth data. Tree growth variable with Diameter at Breast Height (DBH) ≥ 10cm were estimated. Characterizing the joint influence of tree size and competition in each plot, overtopped trees were considered subject trees and 10m search radius was used in identification of competitor's tree for Distance Dependent (DD). Measurement of influence of neighbouring trees for Distance Independent (DI) was based on plot-centered. Eight CI (CI_1-CI_8) were assessed. Competition severity were assessed using Moran Coefficient (MC) and Geary Ratio (GR). Data were analyzed using descriptive statistic and correlation coefficient. The stand comprises of 389 stem ha^{-1}. The mean DBH and tree height were 25.12±1.023cm and 18.548±0.324m, respectively. It was observed that DD CI_6 gave better estimation (50.3021 ± 0.8775) of tree growth competition. Negative value of MC was observed on stand in plot 6, 11 and 15 (-9.52±0.821, -8.07±0.004 and -7.44±0.084, respectively). The GR was least (19.72±1.199) in plot 11 indicating a severe competition. Hence, DD CI assessed the growth predictability well compared to DI indices.

Keywords: Tree growth characteristics, inter-tree-competition, competition severity, IITA biodiversity

Introduction
Nigeria tropical rain forest has a large numbers of species, which are been represented by few tree and their growth pattern and rates varies (Aigbe *et al.,* 2013). Growth is an irreversible process which takes place in all living things. Tree growth simply means the increase in magnitude and quantity of the vegetative structures. As trees grow in the forest, competition sets in for photosynthesis, space and resources. Competition is an interaction between individual for survival for limited resources resulting to decrease for survivorship, reproduction and growth of the competing individual (Ige and Adesoye, 2017). However, it was asserted by Lo and Lin-(2012), that tree height and tree diameter within a forest will be constrained by the pressure of adjacent trees. Competition or growth rate in the forest often determines the shape and the structures of the forest stand (Coomes and Allen, 2007). Competition is also an essential environmental process that plays substantial roles in growth population, survival and replacement of species on forest composition and stand structure (Amiri and Naghdi, 2016; Ige, 2017). However, trees growing in a given population usually exhibit large variation in growth. Coomes and Allen (2007) emphasized on the need for understanding the different variation in growth which is the basis for forest structures and biomass and also noted that tree growth declined with altitude. It was ascertain by Pelemo *et al.* (2011) that some trees grow poorly in the forest not as a result of competition but due to the influence of some other disturbances such as floods, windstorms, fire and human inflicted damages which make the forest to be instable and make the tree less favorable to grow properly. Various attempt of predicting the tree growth as accurate and precisely basically brought out the study of competition on individual tree, two general method are widely used for tree growth competitor indices which are the Distance-independent or Non-Spatial indices and Distance-dependent or Spatial indices (Tome and Burkhart, 1989; Amiri and Naghdi, 2016). Non-spatial indices generally measures and portray the competition status of trees in the stand which requires not the trees coordinate or the relative location of the competitors trees (Tome and Burkhart, 1989; Contreras *et al.*, 2011). Obtaining Non-spatial indices variables are relatively easy and less time taking in terms of data computation and analysis. Spatial indices explain a tree's competitive position based on the direct conditions of their neighbouring tree (Contreras *et al.*, 2011). This generally measures the zones of influence of the neighbouring trees which best improve estimates of individual tree growth (Ige, 2017). In estimating the tree growth competition using Spatial and non-spatial indices, strong positive correlation has been proven to exist between tree growth and basal area. Basal areal basically deals with the average amount of an area occupied by tree stem, thus DBH a good predictors of forest dynamics which also improve the dependability of timber volume, growth and yield models (Brooks *et.al*. 1980; Onyekachi and Osho, 2018). In tropical natural forest, tree growth competition studies are rarely studied. Biodiversity loss in most cases have been linked with indiscriminate harvesting or deforestation without considering possible loss as a result of severe competition in the tropical ecosystem. Hence, this is was set out to provide a baseline information on assessment of tree growth competition using Spatial and Non-Spatial competition index in tropical forest of IITA, Ibadan.

Materials and Method
Study Area
This study was carried out in International Institute of Tropical Agriculture (IITA) Forest (Figure 1). IITA forest is geographically located in Akinyele Local Government Area of Oyo State Nigeria with latitudes of 7° 30' 5.1264" and 7° 28' 55.52" North and longitudes 3° 54' 47.50" and 3° 52' 44.49" East in the city of Ibadan. IITA forest has a humid tropical climate. The wet season starts from March to October and dry season that lasts from November to February, with a mean temperature of about 21°C to 23°C and the maximum temperature ranges from 28°C to 34°C. The forest used to experience bimodal rainfall pattern between 1300 – 1500mm between May and September. The mean daily relative humidity is between 64 -83% (Ariyo *et al*., 2012). The forest reserve has a low lying and gentle undulating topography with an elevation range between 243m to 292m. The parent rock materials of the soil are been formed through the underlying crystalline and gneiss. In the upland areas clay, quartz gravel and sand are

predominant soil types while the bottom of the valley has poorly drained clay and sandy soils (Oluyinka, 2020). Some part of IITA forest has a highly diverse plant species and could be classified as tropical semi-deciduous forest with diverse vegetation types (Osunsina *et al.*, 2012).

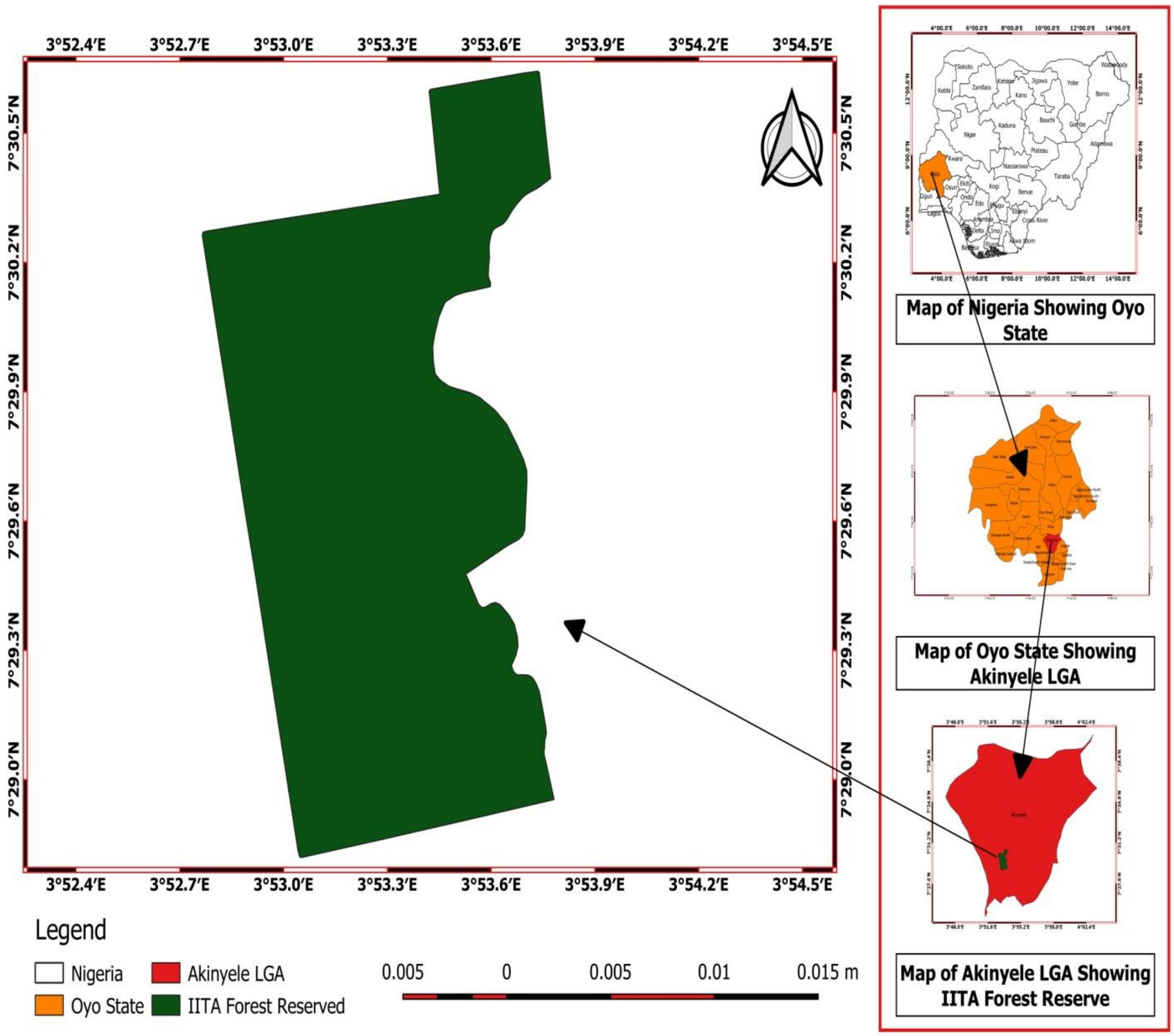

Figure 1: Map of IITA Forest Reserve.

Sampling Techniques and Data Collection

Reconnaissance was carried out so as to assess the forest stand and see the different changes that are currently taken place at the reserve. The survey carried out revealed that there was no evidence of logging in the forest, though the forest is a secondary forest that is currently undergoing reservation phase for biodiversity conservation. The sampling procedure used for the research work was adopted after the visitation to the study area. Simple systematic line transect was adopted for this study for plot laying and data collection. A total of 16 temporary sample plots were used for this research work. In laying of plots for data collection, simple systematic line transect as used by Adekunle *et al.* (2013) was adopted and modified for plot laying, four parallel transects of equal distance (270m) was delineated at 200m apart for this study. A total number of 4 sample plot of equal size (25m x 25m) were laid alternatively on each transect and 50m interval distance offset away from each sample plot was observed so as to decrease replication of tree species. To minimize the edge effect, 20m offset was measured at the beginning of each transect (Figure2).

Data Collection

On each sample plot, trees with DBH ≥ 10cm were identified and measured as done by Adekunle *et al.* (2013). To estimate volume per stand, the diameters at the base, middle and top; the total height of all the tree were measured using Spiegel relaskop Competitors tree was been identified by weighing the dimension of the subject tree and its neighbouring tree. All the relevant information for computational evaluation of the competition indices of each subject tree and its competitors within the search radius of 10 metres were measured and recorded.

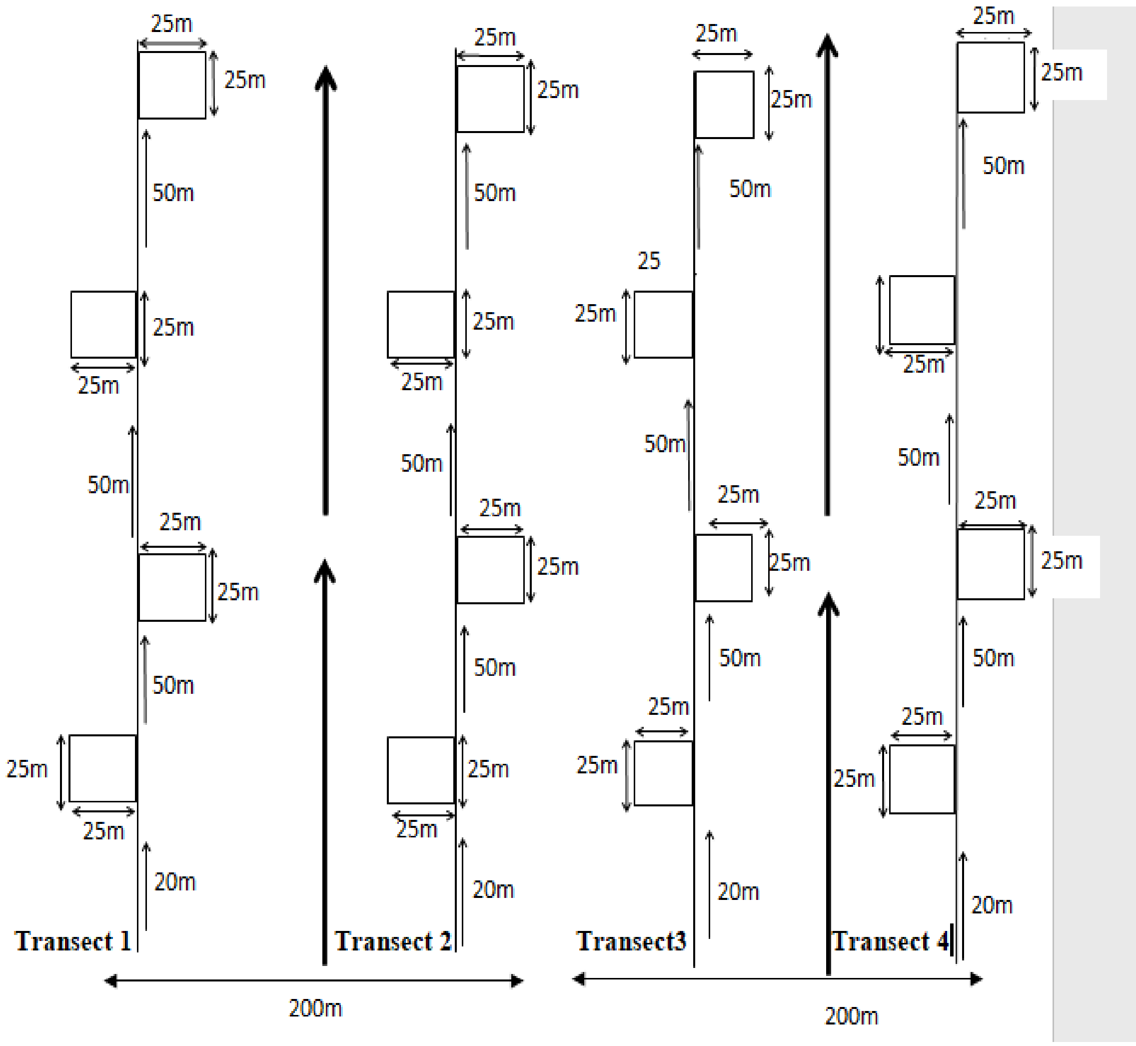

Figure 2: Systematic line transects sampling technique for Plot layout.

Tree Growth Competition Indices

All the tree growth variables were assessed. Spatial and Non-Spatial indices that are generally used were adopted.

Spatial or Distance Dependent Indices

Spatial indices were carried out by spatial location of the affected subject tree for their computations. Diverse method have been adopted to determine the pressure of the possible competitor trees over the subject tree such as crown-influence-zone overlap, DBH angle-gauge, fixed-radius and Height guage method (Ige, 2017). Height guage method was adopted and used. On the sample plot trees that are completely overtopped were considered as the subject tree and radius of 10m was used to measure the dimension of trees considered as neighbour trees ((Figures 2). The coordinates of all trees in the sample plot were been taken using Mapinr Software. The coordinate of the subject trees in each sample plot was been specified in the attribute table for further analysis. The coordinates collected were been transformed to distance as well as buffer of 10 meters created around the subject tree using ArcMap 10.8 software.

Non-Spatial or Distance Independent Indices

Measurements were based at the center of the plot against tree-centered neighborhood data used in spatial competition indices. Competition of each subject tree was quantified using four non-spatial competition indices (CI 1-4) and four Spatial competition indices (CI 5-9) as shown in Table 1 were used respectively for the competition indices. The indices used were carefully chosen from the literature, with the consideration of the availability of tree variables with their simplicity to describe the competition situation for this study.

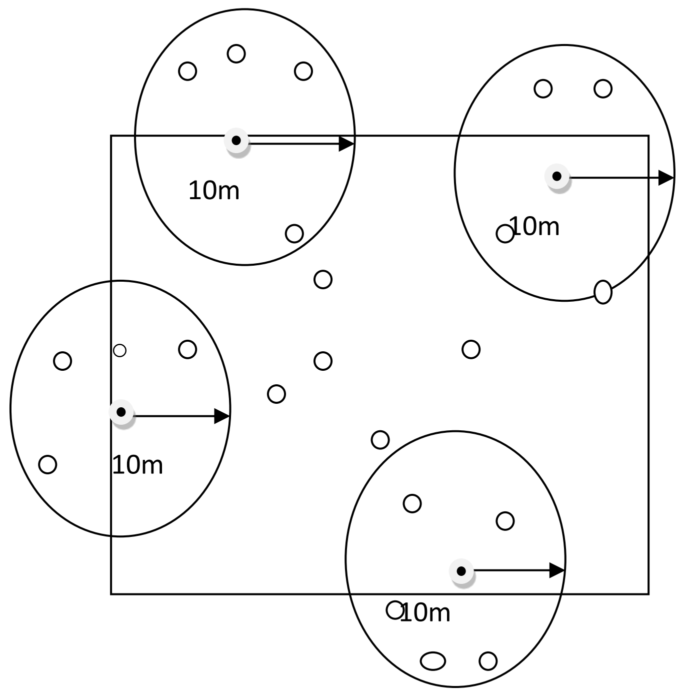

Figure 2: Spatial indices measurement techniques used in a sample plot of four subject trees (Thick dark dots) and competitor trees (open dots) using fixed-radius of 10m.

Table 1: Competition indices evaluated in this study

Equation No	CI	Source
Non-Spatial competition indices		
1	$\frac{\sum_{j=1}^{n} {d_j}^2}{{d_i}^2}$	Corona and Ferrara (1989)
2	$\frac{\left(1-\left[1-\left(\frac{BAL}{G}\right)\right]\right)}{RS}$	Schröder and Gadow (1999)
3	$\frac{\sum_{d_i<j\neq i}^{n}(g_j)}{S}$	Wykoff *et al.* (1982)
4	$\sum_{j\neq i}^{n}\left(g_{j;d_j>d_i}\right)/G$	Daniel *et al.* (1976)
Spatial competition indices		

5	$\sum_{i=1}^{n} h_i \, arctan\left(\frac{d_i}{dist_i}\right)$	Rouvinen and Kuuluvainen (1997)
6	$\sum_{i=1}^{n} h_i \left(\frac{h_j}{dist_i}\right)$	Braathe (1980)
7	$\sum_{i=1}^{n} \mathrm{d}_i \left(\frac{d_j}{dist_i}\right)$	Daniel *et al.* (1976)
8	$\sum_{j=1}^{n} \frac{d_j}{\mathrm{d}_i(\mathrm{l}_{ij}+1)}$	Daniel *et al.* (1976); Ige and Adesoye, (2017)

where n = quantity of neighbours within 10 m radius competition plot; BAL= basal area of neighbour trees larger than the subject tree (m^2h^{-1}); G is total basal area of the trees within plot (m^2h^{-1}); g_j = competitors tree basal area; $dist_i$ is the horizontal distance from ith neighbour tree to the subject tree (m); h_i height of the subject tree (m); h is height of the competitor tree (m); l_{ij}, distance amid subject (i) and competitor (j) tree (m) and, S = plot area.

Evaluation of Competition Severity

The relationships amid individual tree growth and size, and competition indices of trees in severe competition with adjacent trees were modeled using the local forms of Moran coefficient and the Geary ratio (Shi and Zhang, 2003). The Moran coefficient (*MC*) is defined as follows:

$$MC_i = (\mathrm{DBH_i} - \mathrm{meanDBH}) \sum_{j\varepsilon c_i} (DBH_j - \mathrm{meanDBH})$$

where mean*DBH* = plot average *DBH*. Positive *MC* value is an indicator of subject tree is in a cluster of similar size, whereas negative *MC* value indicates subject tree is in cluster of dissimilar size. Lower negative *MC* values indicate that both dominant and suppressed trees are in severe one-sided competition scenario.

The Geary ratio (*GR*) is defined as follows:

$$GR_i = \sum_{j\varepsilon c_i} (DBH_i - \mathrm{DBH_j})^2$$

The *GR* value indicates tree size variance within a cluster; a lower *GR* value means less variance of tree size and more severe competition among similar-sized trees.

Results

Tree Growth Characteristics

Table 2 shows the statistical summary of the growth characteristics obtained. The DBH ranges from 10 cm to 170 cm with mean value of 25.12±1.03 cm. The tree height ranges from 7.70 m to 38.10 m with mean value of 18.55±0.32 m. The numbers of tree per hectare in a sample plot varies from 96 to 704 with mean value of 442. The mean volume and basal area were1.04±0.14 m^3 and 0.08±0.01 m^2 respectively. The crown diameter had a mean value of 5.89±0.08 m with respective minimum and maximum values of 3 and 13.7 m. The crown length and crown ratio had respective mean value of 2.97±0.06 and 0.17±0.004 with their minimum and maximum values of 1 and 7.8m; and 0.05 and 0.51.

Table 2: Statistical summary of the tree growth characteristics

Stand Growth Variable	Mean	MIN	MAX
DBH (cm)	25.123 ± 1.026	10	170
THT (m)	18.548 ± 0.324	7.7	38.1
VOL (m^3)	1.035 ± 0.136	0.003	24.676
BA (m^2)	0.083 ± 0.010	0.007	2.270
CL (m)	2.9688 ± 0.059	1	7.8
CR (m)	0.174 ± 0.004	0.051	0.506
N/ha	442	96	704
CD(m)	5.894 ± 0.083	3	13.7

Where: DBH = Diameter at Breast Height, THT = Tree Total Height, VOL = Volume, BA = Basal Area, CL= Crown Length, CR= Crown Ratio, N/ha= Numbers of Tree per Hectare, CD= Crown Diameter

Table 3 shows correlation matrix amid Basal area and competition indices. There was a strong positive correlation between competition indices 3 (CI_3) and basal area, this was as a result of the similarities in the indices formulation and the association amid the input variables (the basal area in the CI_3) and the sample plot (S). All competition of each subject tree in the study area was quantified using four (4) spatial (dependent) and non-spatial (independent) indices. The results of the competition indices estimated in this study area are presented in table 4. The value of CI_1 ranges from 0.0203 ± 0.0183 to 1.4972±0.0183. Indices estimated with CI_2 ranges from 0.00006±0.0002 to 0.0435 ± 0.0002, CI_3had a value range of 0.1087 ± 0.1575 to 36.3215 ± 0.1575, $CI_4$and CI_5 had a range value 0.55726 ± 0.0058 to 0.9960 ± 0.0058 and 0.110604 ± 0.0044 to 0.4325 ± 0.0044 respectively. There was a change pattern in the estimate of competition indices 6 (CI_6) where the range value was higher compared to other competition indices the range value is between 22.425 ± 0.8775 to 87.7998 ± 0.8775 while CI_7 and CI_8had their values ranges from 0.002 ± 0.0039 to 0.3704 ± 0.0039 and 0.1075 ± 0.0393 to 2.7669 ± 0.0393 respectively. Individual tree growth and size relationship and competition indices of trees facing severe competition with adjacent trees were also assessed (Table 5) using MC and GR as indicators. A negative value of MC was observed on stand in plot 6, 11 and 15 (-9.52±0.821, -8.07±0.004 and -7.44±0.084, respectively) whereas stands in other plots were positive which ranges from 0.09±0.001 to 257.23±2.378. This implies that most of the trees in the negative MC stands are in a cluster of dissimilar sizes. The lower negative MC values is an indicator that both suppressed and the dominant trees are in severe one-sided competition scenario. The GR value indicates tree size variance within a cluster; a lower GR value means less tree size variance and more severe competition among similar-sized trees. Hence, for this study, trees in plot 11 are facing severe competition as its value was the least.

Table 3: Correlation matrix between Basal area increment and various competition indices

	DBH	*THt*	*BA*	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
DBH	1										
THt	0.595	1									
BA	0.926	0.441	1								
C1	0.108	0.072	0.081	1							
C2	0.826	0.460	0.828	-0.137	1						
C3	0.926	0.4409	1	0.081	0.828	1					
C4	0.210	0.024	0.149	0.510	0.076	0.149	1				
C5	0.139	0.131	0.055	-0.005	0.041	0.055	0.214	1			
C6	0.154	0.181	0.071	0.149	0.066	0.071	0.341	0.356	1		
C7	0.057	0.089	0.0372	-0.042	0.087	0.037	0.238	-0.104	0.553	1	
C8	0.101	0.005	0.075	0.616	-0.033	0.075	0.367	-0.104	0.328	-0.087	1

C1 – C4 are Distance independent competition indices (Non Spatial) while C5-C8 are Distance dependent competition indices (Spatial)

Table 4: Estimated mean for the competition indices

	Mean	Min	Max
CI_1	0.36867 ± 0.0183	0.0203 ± 0.0183	1.4972 ± 0.0183
CI_2	0.0017 ± 0 .0002	0.00006 ± 0 .0002	0.0435 ± 0 .0002
CI_3	1.3266 ± 0.1575	0.1087 ± 0.1575	36.3215 ± 0.1575
CI_4	0.8917 ± 0.0058	0.55726 ± 0.0058	0.9960 ± 0.0058
CI_5	0.2958 ± 0.0044	0.110604 ± 0.0044	0.4325 ± 0.0044
CI_6	50.3021 ± 0.8775	22.425 ± 0.8775	87.7998 ± 0.8775
CI_7	0.0334 ± 0.0039	0.002 ± 0.0039	0.3704 ± 0.0039
CI_8	0.7408 ± 0.0393	0.1075 ± 0.0393	2.7669 ± 0.0393

Where CI = competition indices, ± Standard error

Table 5: Assessment of competition severity

Plot	MC	GR
1	257.23±2.378	598.51±3.192
2	99.24±2.195	194.19±3.991
3	0.09±0.001	351.38±2.182
4	0.09±0.005	185.31±0.320
5	45.73±0.110	188.42±1.882
6	-9.52±0.821	163.57±2.229
7	61.75±1.631	181.06±1.934
8	31.91±1.092	381.46±2.118
9	11.70±0.887	27.91±1.094
10	9.55±0.101	191.07±3.001
11	-8.07±0.004	19.72±1.199
12	10.99±2.550	199.67±0.055
13	15.78±0.991	205.44±2.731
14	19.66±1.831	203.73±1.990
15	-7.44±0.084	212.27±2.992
16	28.99±0.711	210.34±0.921

±Standard deviation

Discussion

Model is now a daily routine used in forestry for predicting growth and yield, modeling diameter distributions, basal area model and tree crown model and many more (Ogana *et al*., 2015; Ureigho and Osho, 2017). Models are simply used for prediction and projection. Tree growth competition model was developed for this study in order to examine the competitive effect on each tree. One well studied Source of variation in individual tree growth is competition for resources. Studies of competitive neighbourhood synergy generally show that large, adjoining neighbours exert higher competitive stress than small distant neighbours (Wagner and Radosevich 1998; D'Amato and Puettmann 2004). Several studies had opined that decision of the management of the forest are often predetermined on information about current and future resources condition. As such, this study has made effort to obtain tree growth competition using spatial and non spatial indices and competition severity. The distance dependent involves spatially location of subject tree to competitors tree while the distance indepent examined the effect of the subject trees in relative to the stand measured at the center of the plot. Studied have shown that adding of competition indices to tree growth improves the predictability of the model due to inclussion of trees variables in the competition indices (Contreras *et al*., 2011; Maleki *et al.,* 2015 and Ige, 2017). For the study area, it was observed that distance dependent competition index C6 gave better estimation of tree growth competition and its effect on the growth of neighbouring trees. This study was in contrast with what was reported by Biging and Dobbertin (1996) that estimation of crown parameter improved the performance of distance dependent indices measure, because competition indices that performed best for this study only uses height and distance in its computational competition index. However, Fraver *et al*. (2014) noted that inter tree competition significantly affect growth rates as observed in better performance of model with competition indices when compared to models with no competition indices. The competition severity was assessed. Shi and Zhang, (2003) suggested that MC with a positive value indicates a subject tree is in a cluster of similar size, whereas MC with a negative value indicates a subject tree is in a cluster of dissimilar size. Hence in this study, a negative MC value was observed at stand plots 6, 11 and 15. This might be due to the topography of the stand which is generally undulating and sloppy with some out crop of rocks and irregular tree sizes. This mainly account for high competition rate in the study plots because trees that are on the same ground level are at the cluster of dissimilar size. Meanwhile, the GR value indicates variance of tree size within a cluster; a lower GR value means less variance of tree size and more severe competition among similar-sized trees. This further confirms the situation at stands in plot 11. Hence, the growth of stands in this plot is highly affected as compared to other plots.

Conclusions and Recommendations

The result of this study revealed the present assessment of stand growth characteristics and evaluation of tree growth competition indices in the study area. The study area has an estimated number of 389 stems per hectare which compares well with what has been observed in tropical forest ecosystem. Tree growth competition indices are not often address in many natural forests. Tree growth competition evaluated for this study involves using eight measures of tree competition index examined in terms of their effectiveness as growth predictor for the study area. This study demonstrated that one of the factors that influence forest processes and structure is competition. The inclusion of Spatial indices described the effects of tree neighbourhood maintained in the complex stand structure compared to distance independent indices in the study area. One major constraint to use of Spatial indices is the need to acquire tree attributes such as location and distance measurement which are time consuming and labour intensive, but with the use of MapinR and ArcMap techniques spatial indices for growth study could be effectively carried out. A positive strong correlation was found between two competition indices and tree growth variables, this is an indicator that competition exists between trees. There was more severe competition among similar-sized trees in plot 11 in the study area.

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