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Research article

Urban land transformations and its implication on tree abundance distribution and richness in Kumasi, Ghana

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Abstract

Despite the rapid urban transformation in green space in most cities in Ghana, knowledge on urban tree diversity and the evidence of the consequences of built-up expansion on trees is scanty. This article provides a novel contribution to the current urban trees abundance and richness in Kumasi Metropolitan Area, Ghana. Post classification change detection technique was applied to quantify urban land use land cover (LULC) transformations (urban forest, agricultural, riparian vegetation and built-up) from 2007 to 2017. Species rank abundance distribution and richness were quantified using geometric series and individual-based rarefaction models. A total of 858 individual trees belonging to 76 taxa were recorded across the four LULC classes. Species abundance distributions in three LULC types varied substantially, with the exception of riparian LULC (slope $[k] = 0.086 \pm 0.12$, $\chi^2 P = 19.42$, $P = 0.15$). Land use pressure led to a 13.56 km^2 reduction in forest cover, while built-up and agricultural LULC increased by 31.13 and 1.85 km^2, respectively. These disturbances did not only affect indigenous tree dominance (41.3%) in favour of exotic species (58.7%) in the agricultural and built-up LULC types but also impacted on tree abundance ($n = 126$) and richness ($n = 28$) in agricultural land compared to abundance ($n = 280$) and richness ($n = 67.86$) in forest cover. Despite the contribution of LULC transformation to increase in tree diversity, there is the likelihood of future dominance of exotic species in the Metropolis if urban planners do not institute measures to conserve indigenous species.

Key words: species abundance distribution, urban species richness, geometric series, rarefaction, land use land cover

Introduction

The dramatic growth in human population accompanied by increasing urbanization implies an increase exploitation of resources, with a growing demand for residential space and a corresponding increase in industrial activities and agricultural intensity (Modica et al. 2012). This phenomenon of urban growth and sprawl had led to significant transformations of urban landscapes, which has affects ecosystem structure and functioning (Modica et al. 2012; Barrico and Castro 2016; Dupras et al. 2016).

Studies in several African countries had revealed that there is intense pressure on urban green spaces from human activities resulting in persistent deterioration of these spaces (Mensah 2014a). Urban green spaces in Ghana are fast disappearing and are being destructed at an alarming rate (Darkwah and Cobbinah 2014; Mensah et al. 2017). Mensah (2014b) in a study in Kumasi found out that the city, also known as the garden city, had lost most of its green vegetation to housing developments and commercial activities. Almost every part of the city has been concretized. This is reaching an alarming level especially when most of even the city's wetlands are being reclaimed for construction purposes. The same applies to others cities (Accra, Takoradi, Cape Coast, Tamale etc.) in Ghana. These are resulting in habitat losses, degradation, and fragmentation of urban greenery leading to loose of urban biodiversity and the alteration of species composition and diversity (Darkwah and Cobbinah 2017; Nero et al. 2017).

Urbanization and urban sprawl is therefore considered a major threat to biodiversity and has been shown to be one of the most damaging in terms of numbers of species lost or threatened and is responsible for species extinctions (McKinney 2002; Ricketts and Imhoff 2003; Buczkowski and Richmond 2012). Across major cities in the world, this phenomenon is a widely recognized land use management and planning issue (Dupras et al. 2016). It fragments forests and croplands, decreases native biodiversity and reclaims land for infrastructure. This alters the structure and functioning of natural ecosystems leading to further loss of biodiversity (Tratalos et al. 2007; Barrico and Castro 2016).

Despite these rapid urban transformations and changes in urban green space, knowledge on urban biodiversity and the evidence of the consequences of the built-up expansion on trees in cities in developing countries, for example Ghana is scanty (Aronson et al. 2014; Hackman 2014). However, biodiversity of urban landscapes is instrumental in meeting the Convention on Biological Diversity (CBD) biodiversity targets and the Sustainable Development Goals (SDG) (Nero et al. 2017). The presence of diverse tree species within urban landscapes provides resources that support urban environment and human wellbeing (Konijnendijk et al. 2006; Davies et al. 2017) and also serves as habitat for several life forms (Barbier et al. 2008). Urban trees help to compensate for the continuing loss of forest, by providing non-timber products (Gelens et al. 2010) and also contribute to mitigate climate change impacts via carbon sequestration (Nero et al. 2017).

To fill these gaps in knowledge in urban trees ecology in Ghana, some researches have been conducted in recent times (e.g. Mensah and Adzraku 2012; Nero et al. 2017; Uka and Belford 2016). These studies emphasized on street tree population and diversity (Uka and Belford 2016); evaluation of some indigenous tree species for street planting (Mensah and Adzraku 2012); and tree and trait diversity, species coexistence (Nero et al. 2017). None of these studies considered the spatio-temporal dynamics in built-up expansions and its role in urban tree diversity. This paper therefore aims to provide a novel contribution to the current status of urban trees diversity in Ghana, by assessing urban built-up expansion and its implication on tree diversity in Kumasi Metropolitan Area, Ghana. We hypothesized that urban transformation has not adversely impacted on the current tree diversity status in the Metropolis. This hypothesis aims to validate the intermediate disturbance theory proposed by Hutchinson (1953), which has shown to improve on species composition following disturbances (Veach et al. 2003).

Methods

Study area

Kumasi Metropolitan Area (KMA) is the largest metropolis in Ashanti Region of Ghana covering a total land area of 276 km^2. It is located on latitudes 6°38′N and 6°45′N and longitudes 1°41′05′ W and 1°32′W (Fig. 1). It is a fast-growing metropolis with an estimated population of 2 035 064 and an annual growth rate of 5.4% from 2000 to 2010 (Ghana Statistical Service 2013). Currently, there is a high rate of urban expansion, which has resulted to changes in land cover leading to depletion of forest and tree resources (Ghana Statistical Service (GSS) 2012).

The vegetation is typical semi-deciduous forest and characterized by diverse tree species like *Celtis adolfi-friderici*, *Triplochiton scleroxylon* and *Ceiba pentandra*, with some exotic species (Oteng-Amoako 2006). Average minimum temperature is 21.5°C and a maximum of 30.7°C, while annual precipitation is 2000 mm (Ghana Meteorological Service 2008). The metropolis is dominated by middle precambrian rock, with forest ochrosols as a predominant soil type, which is rich in nutrient and support agricultural activities in the periphery of Kumasi (GSS 2014). The topography is undulating and falls within the South-West physical region, ranging between 250 and 300 m above sea level (GSS 2014). Major River (Owabi) and streams such as Subin, Nsuben, Sisai, Aboabo and Wiwi drain the area.

Data collection approach

To quantify urban land cover changes within the last decade (between 2007 and 2017), two satellite images of 14 February 2004 and 20 January 2016 from the Enhanced Thematic Mapper Plus (ETM^{+}) sensor of Landsat-7 were obtained from the United States Geological Survey Earth Resources Observation and Science Data Centre (http://www.usgs.gov). Selection of this sensor was based on its availability and its wide use for studies on land use land cover (LULC) changes (Attua and Fisher 2011; Dadras et al. 2014; Misra and Balaji 2015). Google Earth image of was also used as a reference data where 200 points were digitized for the classification of 2004 Landsat image. A total of 207 ground truth data were randomly selected in the various LULC classes for the purpose of 2017 image classification.

Image pre-processing, classification and accuracy assessment

The two satellite images were pre-processed by stacking (bands 1, 2, 3, 4, 5 and 7) and projected into the Universal Transverse Mercator (UTM) projection system (zone: 30 N, datum: WGS-84). The boundary of the study was delineated using KMA boundary. The images were classified using Supervised Classification with Maximum Likelihood Classifier (Jensen 1996; Richards 1999; Lua et al. 2012). The usefulness of this classifier is that it takes into account the variability of the various classes and assign pixels to class of highest probability (Lillesand et al. 2004; Dedras et al. 2014). Using 70% (145 points) of the field data as training data, the images were classified into urban forest, riparian vegetation, agricultural land and built-up (Table 1). The accuracy assessment for the two images was done by using 30% of ground truth data for 2017 image and 30% of samples collected from Google image data (for 2007 image). Comparison of reference data and classification results was statistically analysed using error matrices. Kappa test (which measure the agreement between producer scores and user scores) was further carried out to measure the degree of accuracy of the classification since it accounts for all the elements in the confusion matrix (Cohen 1960).

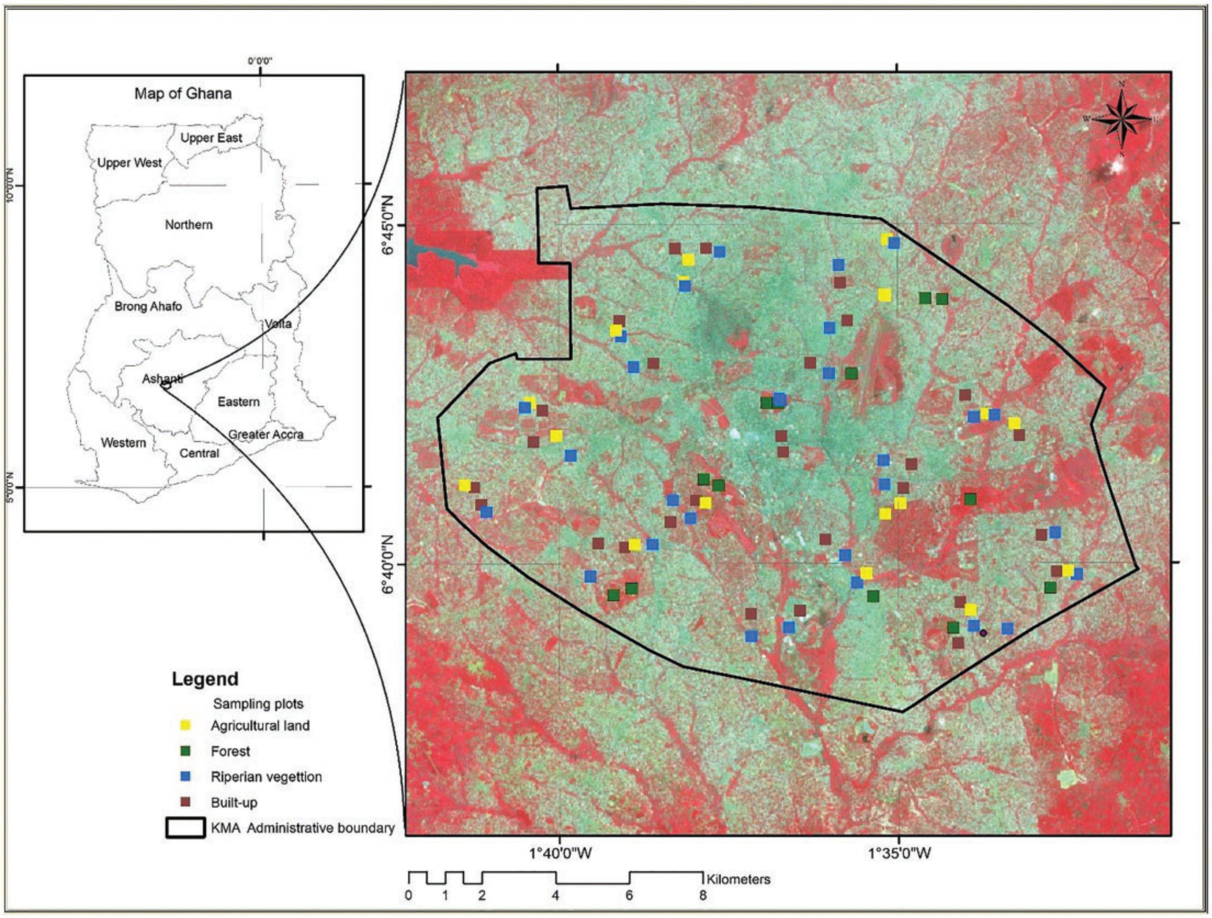

Figure 1: Map of Ghana, showing the location of the study area in the Ashanti Region. The yellow, blue, green and dark red colours, represented stratified random distribution of survey plots across the four land cover types

Table 1: Land cover classification scheme used to delineate biophysical features on Landsat images for the study

Land cover	Explanation
Forest	Tree dominated lands with a close canopy of 900 m^2/0.09 hectare and above or below 15% crown cover.
Agricultural land	Croplands, grassland, abandoned cropland, with scattered trees, shrubs and short vegetation.
Riparian vegetation	Vegetation along water bodies with trees, shrubs and other plants
Built-up	Lands with man-made infrastructure, paved/unpaved roads with scattered trees.

Change detection analysis of classified images

To detect the changes in the study area over the past 10 years, post classification change detection technique was used. Different change detection methods are available that include post classification, principal component analysis, image differencing and ratios (Chignell et al. 2015). However, the post classification change detection method has been the most extensively used technique. It has an advantage of operating on more than one independent classified image as an input data and the output is a change map and a change matrix (Chen 2002). The differences in transfer from one cover to another are seen and changes in percentage can also be calculated (Lillesand et al. 2004). This method has been proven to be the most effective and accurate tool in urban land cover change detection analysis (Afify 2011). The results of the change matrix were subsequently exported in excel to calculate the area of each cover type and that of the transfers in square kilometres.

Sampling procedure for tree species across the land cover types

Overall, 68 plots were laid and consisted of 19 plots in the built-up, 17 in agricultural land, 11 forest and 21 riparian vegetation land cover types, to sample tree species (Fig. 1). Plot sizes of 30 m × 30 m dimension were randomly laid in each land cover classes in selected changed areas (agricultural land, riparian vegetation and forest cover types). While in the built-up land cover type, 60 m × 60 m quadrats were laid. A 500-m interval among quadrats in each land cover type was assured in order to capture enough information about the inter- and intra-specific relationships between trees (Abd-El-Ghani 1998). Forest Trees guide developed by Hawthorne and Gyakari (2006) was used to aid in the identification of native and non-native tree species. Species that could not be identified on the field, specimen were taken and placed in plant press for identification at Parks and Gardens in KMA office.

Species abundance distribution analysis

Rank abundance model was applied to quantify tree abundance as a measure of diversity (e.g. Magurran and Ramnarine 2004). In each land cover type, the number of tree species say S_1 were listed and represented by one individual, the number of species, say S_K, represented by $_K$ individuals, where K denotes the abundance of the most abundant species and $S_1 + \ldots + S_K = S$ (Fattorini 2013). Thus, the sequence of relative frequencies $fr = Sr/S$ ($r = 1 \ldots K$) constitutes a frequency distribution for the number of individuals trees per species, which is usually referred to as the *species-abundance curve* (Fattorini 2013). We then fitted the geometric series (GS) model in the tree data (raw abundance), using the regression model approach (Fattorini 2005). With the GS, if a log scale is used for abundance, the species exactly fall along a straight line, according to the model equation $\log A = b_o + b_1 R$, where A is the species abundance, R is the respective rank, and b_0 and b_1 are optimized fitting parameters (Fattorini 2016). The linear slope of the GS model reflects a rapid decrease in species abundances by rank (Motomura 1932). The GS model was selected (as against log series) for tree diversity analysis, because it can be expressed by regression line in rank abundance plots, for the purposes of comparing habitats (Fattorini 2016). Second, this model approach was used in order to test against the null hypothesis (*Ho*) that tree abundance distribution was not evenly distributed in each of the land cover types.

All sampled tree species in each land cover class were ranked from the most to the least abundant on the rank abundant curve (Fattorini 2016). Each species rank was finally plotted on the x-axis, while the abundance was plotted on y-axis. Analysis of covariance (ANCOVA) was applied to test for the significant difference of the slope of the species abundance distributions (SADs) for the four LULC types, while Pearson's Chi-square test (χ^2) was applied to determine whether an observed distribution along the goodness of fit, statistically differed in the GS model. If significant differences were detected, we subjected data to multiple comparisons test. The SAD model is mostly used to measure the impact of disturbance on community structure (Gray and Mirza 1979), while the GS (a proposed SAD model) represents species distribution with lower evenness and provide a good fit to simple communities characterized by the high dominance of a few species (Magurran and Ramnarine 2004). The shape of tree distribution gives an insight into the diversity of the land use land cove types under study.

For species richness comparison across the four LULC types, we subjected the relative abundance data to individual-based rarefaction techniques (*rarefaction curves*) (Gotelli and Colwell 2011). Rarefaction curves are created by randomly re-sampling from the pool of N samples multiple times and then plotting the average number of species found in each sample ($1, 2 \ldots N$) (Gotelli and Colwell 2001). Therefore, rarefaction generates the expected number of species in a small collection of n individuals (or n samples) drawn at random from the large pool of N samples, and the curve, f_n is defined as:

$$f_n = E[X_n] = K - \binom{N}{n} -1 \sum_{i=1}^{k} \binom{N - Ni}{n} \ldots. \tag{1}$$

where $X_n =$ the number of groups still present in the subsample of 'n' less than K whenever at least one group is missing from this subsample, $N =$ total nummber of items, $K =$ total number of groups, $Ni =$ total number of items in group i $(i = 1, \ldots k)$ (Gotelli and Colwell 2001; Siegel 2004). Rarefaction methods (both sample-based and individual-based) allow for meaningful standardization and comparison of datasets (Gotelli and Colwell 2001) and have been used on plant species richness in different biogeographic regions (Koellner et al. 2004) and Natural Reserves (Chiarucci et al. 2009).

All analyses of tree abundance, richness and diversity ordering were performed using PAST ver. 3.06 software package (Hammer et al. 2001), which contains robust algorithm as indicated in Krebs et al. (1989).

A priori test for normality of data distribution was carried out, using Shapiro–Wilks test. This was to determine the appropriate statistical test to subject data to (i.e. parametric or non-parametric data analysis approach, Kent and Coker 1992). When sample data was shown to be normally distributed, and there was equal within-group variance across the LULC classes related with each mean in the test (i.e. homogeneity of variance), one-way ANOVA test was used to explore the differences in species abundance and diversity across the various LULC classes. A Tukey HSD post hoc test was then employed to determine which pairs of LULC classes significantly differed in tree diversity. The purpose of the Tukey HSD test was to adjust the level of significance to control the rate of type one error.

Results

Land use/cover changes

The results of the LULC map of KMA of years 2007 and 2017 are shown in Fig. 2. The overall classification accuracy for the 2007 image was 82.58% with a κ of 0.782, whereas the overall classification accuracy for the 2017 image was 86.70% with a κ of 0.8284. This implies that the classification agrees with above 80% of the reference data and therefore it is suitable to make comparison between the classified images (Yang 2007). From the results, riparian vegetation reduced from 23.41 to 22.98 km^2 and forest lands also reduced from 18.78 to 5.22 km^2. Built-up and agricultural lands however increased from 198.46 to 229.59 km^2 and 51.81 to 53.66 km^2, respectively, within the 10-year period (Fig. 2, Table 2).

The increase in built-ups resulted to a decrease in agricultural lands in the metropolis. Agricultural lands reduced from 32.6% to 25.5% and from the change detection results, conversion of agricultural lands to built-up constituted the major driver of LULC change (50.80 km^2) while a 7.5 km^2 area of riparian vegetation also converted into built-ups (Fig. 2, Table 2). The second land conversion was from forests to agricultural lands, which constituted an area of 20.0 km^2 with riparian vegetation to agricultural land being the third form of land conversion with an area of 7.8km^2.

SAD in the various LULC types in KMA

A total of 858 individual trees belonging to 76 taxa were recorded in all the four LULC types. Forest cover recorded the highest individuals ($n = 280$), while agricultural lands were the least individuals ($n = 126$) (Table 3). Tree taxa followed similar pattern in the four LULC classes (Fig. 3). Mean abundance ranged between 3.78 ± 0.91 and 1.70 ± 0.48 (Table 3). Indigenous and exotic species constituted 41.3% and 58.7%, respectively, of the total species sampled. SAD fitted well in the GS distribution model and were spatially varied in each of the four LULC types (Fig. 4, Table 3). There was a linear decrease in rank abundance of trees, indicated differences in tree abundance across LULC types. Overall, SADs among the LULC types did not differ

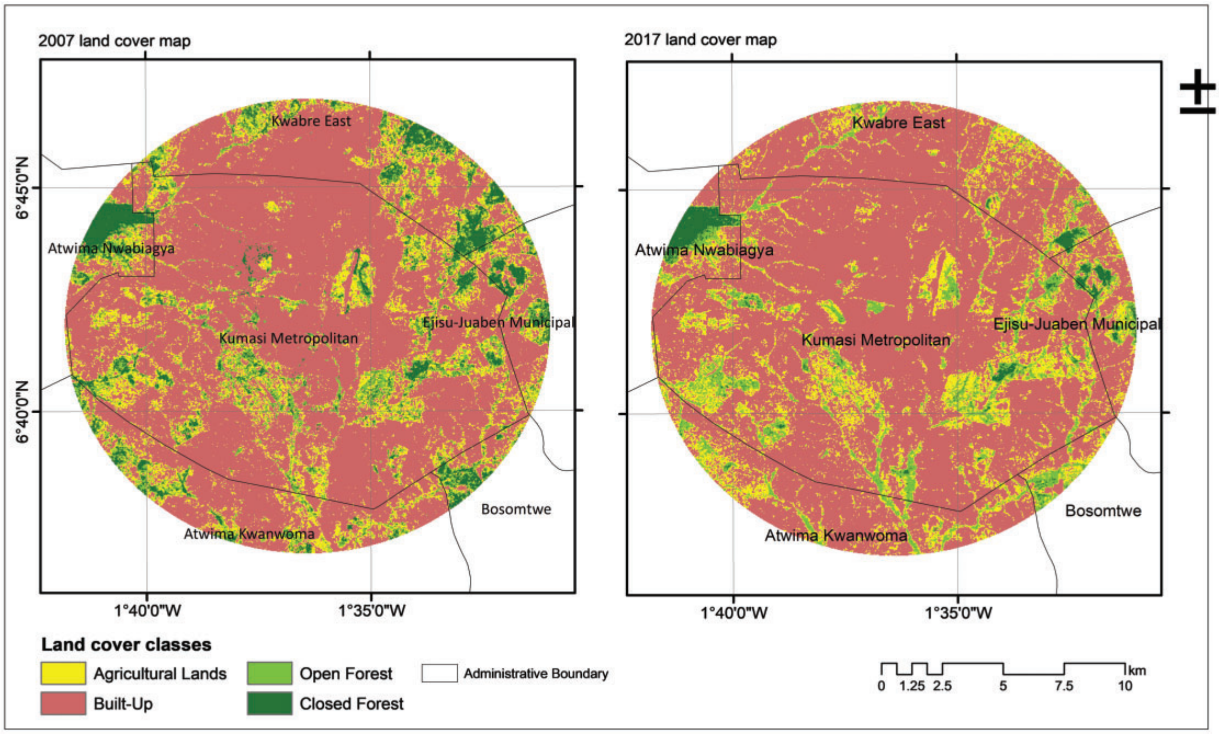

Figure 2: Classified Landsat images of 2007 and 2017, showing the various land cover classes, which indicated the expansion of built-ups into agricultural and forest lands in Kumasi Municipal Area

Table 2: Change detection matrix, showing areas of change in Km2 from 2007 to 2017

	Forest	Riparian vegetation	Agricultural land	Built-up	Total (2007)
Forest	4.26	5.89	4.81	3.83	18.78 (6.42
Riparian vegetation	0.59	7.06	9.28	6.49	23.41 (8.01%)
Agricultural land	0.32	7.80	21.54	22.14	51.81 (17.71%)
Built-up	0.05	2.24	1.03	197.13	198.45 (67.86%)
Total (2017)	5.22 (1.79%)	22.98 (7.17%)	36.66 (12.54%)	229.59 (78.51%)	292.45

significantly, as shown in the GS slopes of the regression lines ($F_{3,\,70}$= 0.001, P (regr): 0.97, ANCOVA interactions × species rank) across the four LULC types (Table 4), confirming our null hypothesis. But comparing individual slopes, we observed that only in the riverine area that species abundance and evenness distribution did not differ significantly (slope $[k] = 0.086 \pm 0.12$, $\chi^2P = 19.42$, $P = 0.15$), while the remaining three LULC types, namely; forest (slope $[k] = 0.077 \pm 0.11$, $\chi^2P = 28.52$, $P = 0.0007$), built-up (slope $[k] = 0.089 \pm 0.13$, $\chi^2P = 38.61$, $P = 0.0001$) and agricultural lands (slope $[k] = 0.102 \pm 0.14$, $\chi^2P = 21.8$, $P = 0.039$) exhibited significant difference in species distribution (Fig. 5, Table 4). Shallower declining slopes, as in the case of agricultural lands, reflected higher evenness in distribution and relative abundance of trees, while steeper slopes indicated less evenness in distribution, linked to their relative responses to different land use pressure and their ability at utilizing limited resources. Variations in the distribution patterns appeared to be influenced by the presence of high abundance of few tree species (e.g. *Dracenea fragrance*, *Cestrum nocturnum* and *Senna siamea*) and the near-absence of low abundance species like *Albizia ferruginea, Duranta* sp. and *Entandrophragma angloense*. These species were from the forest and built-up LULC types, while rarer species like *Persea americana*, *Alstonia boonei* and *Ceiba pentandra* were mostly found in the agricultural LULC class. The presence of these rarer species is evidenced of a possible successional process in which later colonists will require a far more suitable environmental condition, beyond which they may not survive. Comparison of SADs for the four LULC types allows for the distinguishing of their functional state, in relation to their influence on tree abundance in the metropolis.

Generally, individual-based rarefaction curves showed a pattern of increase in taxa richness, from the agricultural lands ($n = 28$) to the forest cover ($n = 46$) (Fig. 6). *Chao1* estimated richness showed similar trend increase from farmland ($n = 33.6$), riverine ($n = 43.75$), built-up ($n = 45.33$) and forest ($n = 67.86$) cover classes (Fig. 5). The dynamics in community richness followed similar trend in abundance distribution as shown in Fig. 4. This increasing pattern of species richness clearly revealed human-led disturbance gradient (from a severely disturbed to less disturbed LULC class) and which reflects in their tolerance level to disturbance regime. High tree richness in the forest site (typical pristine forest) was characteristically early colonialists, with similar functional traits and barely disturbed. While severely disturbed agricultural lands and built-up sites affected the richness of indigenous trees (41.3%), in favour of

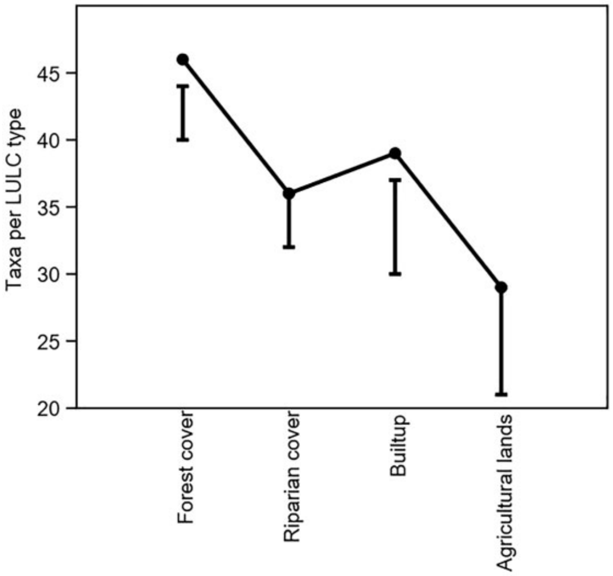

Figure 3: Variations in mean taxa of trees, across the land cover types. Notice that forest land cover type was highest in taxa composition

exotic species (58.7%), which thrived well under limited resource conditions (e.g. *Jatropha podagrica, Pithecellobium dulce* and *Senna siamea*) (Fig. 6, Table 4). These exotic species were much higher in the farmlands and built-up LULC types ($n = 41$) than in the riverine and forest LULC types ($n = 37$). Resilience of dominant rare species in farmlands LULC, following human-led disturbance, demonstrated their importance in contributing to increase in species richness.

Discussion

SAD in the various LULC types in KMA

Decrease in plant species richness and diversity has frequently occurred in urban centres (McKinney 2002). Despite the low tree abundance and richness in agricultural LULC type in the Kumasi Metropolitan Area, it was ranked by the Renyi order as the most diverse. This could be attributed to the spatially even distribution of species and rarity, compared to the remaining three LULC-type SADs. These differences in the relative SADs and the Renyi diversity profile of tree populations largely reflect their success rate at competing for limited resources (Magurran and Ramnarine 2004). Nero et al. (2017) found low species richness in grassland and croplands in Kumasi Metropolitan area, which was similar to our findings. Other studies found lower tree diversity and richness in agricultural and riverine LULC classes, to be linked to poor regeneration, recruitment (Veach et al. 2003) and high competition for nutrients, sun light and water (Davis et al. 1999; Veach et al. 2003). Although, inherent disturbances (like farming) in agricultural lands affect tree abundance, they tend to influence species heterogeneity and their even distribution, through the creation of spatial microhabitats for a suite of species specific. This appear to validate the intermediate disturbance theory proposed by Hutchinson (1953) and which has shown to improve on species composition (Veach et al. 2003). The distribution pattern of the trees at different microhabitat scale, across the four LULC classes, revealed the urban landscape diversity and their contribution to global diversity.

The presence of rarer species like *P. americana*, *A. boonei* and *C. pentandra*, found in the agricultural LULC class, suggests that later colonialists will probably require a suite of environmental conditions, without which their abundance and widespread distribution will be limited. Detection of less rare species was probably due to the less number of survey plots used in our study. Denslow (1995) and Chase and Knight (2013) argue that distribution of commonness and rarity of species in a community are affected by the rate of species accumulation with increasing sample effort (size and plot number). The authors concluded that more individuals must be sampled in order to encounter rarer species. Finding rare species in the field has often been identified as a very difficult task, requiring a large amount of plot survey and size, time and funding resources (Le Lay et al. 2010). Unfortunately, such problem is often worse in developing countries, which frequently host many biodiversity hotspots and threatened species needing conservation plans (Grenyer et al. 2006).

Ecological theory predicts the critical role of interrelationships between relative proportions of dominant to rare species in stabilizing a community, in which species colonized at a later stage (Magurran and Ramnarine 2004). Thus, to maintain a balanced heterogeneous tree community on urban landscape, will depend on not only evenness distribution, dominance and abundance but also the presence of species rarity and the type of LULC class in which they establish.

The least diversity observed in the forest LULC class, in spite of the taxa abundance and richness, was probably due to the low even distribution, as well as the near-absence of rarer species, which is an indicator of diversity. Because of the pristine nature of the forest LULC class and less disturbance, many of the colonialist species were well established in the prevailing microhabitat condition, and functionally distributed based on their trait similarities. The 'intermediate disturbance hypothesis' (Connell 1978) predicts maximum diversity at intermediate regimes of disturbance in an ecosystem. The statement from Connell (1978) suggests that disturbance do not only promote species heterogeneity but also create suitable habitat for rarer species occurrence; a phenomenon that was absent in the forest LULC class and which affected its diversity status. Grubb (1985) also suggested that the number of rare or infrequent species, which represent majority of species in a typical forest ecosystem, contribute in enhancing diversity. However, the absence of specific microhabitat (caused by disturbance) forest herbs in deciduous forest ecosystems is limited in their distribution, thus limiting their detection (Eriksson and Ehrlén 1992). Another factor that led to low species richness and abundance in the forest land cover was the less number of survey plots used in our study and this has the tendency to influence the spatial scale of sampling, with the ultimate effect on species diversity estimates. Measures of floristic richness and abundance have long been derived from an array of sampling designs, including number of plots, size and shape (Walker et al. 2016). Increased number of survey plots for instance (sampling effort) have a direct bearing on species richness and abundance (Gotelli and Colwell 2001). For instance, a study by Walker et al. (2016) on the effect of sampling size on diversity in a mixed grassland community found that species number increased with the number of plots sampled and concluded that properly measuring species diversity in mixed indigenous-exotic plant communities requires the use of sizeable plots and rarefaction rather than plot-averaging of statistics.

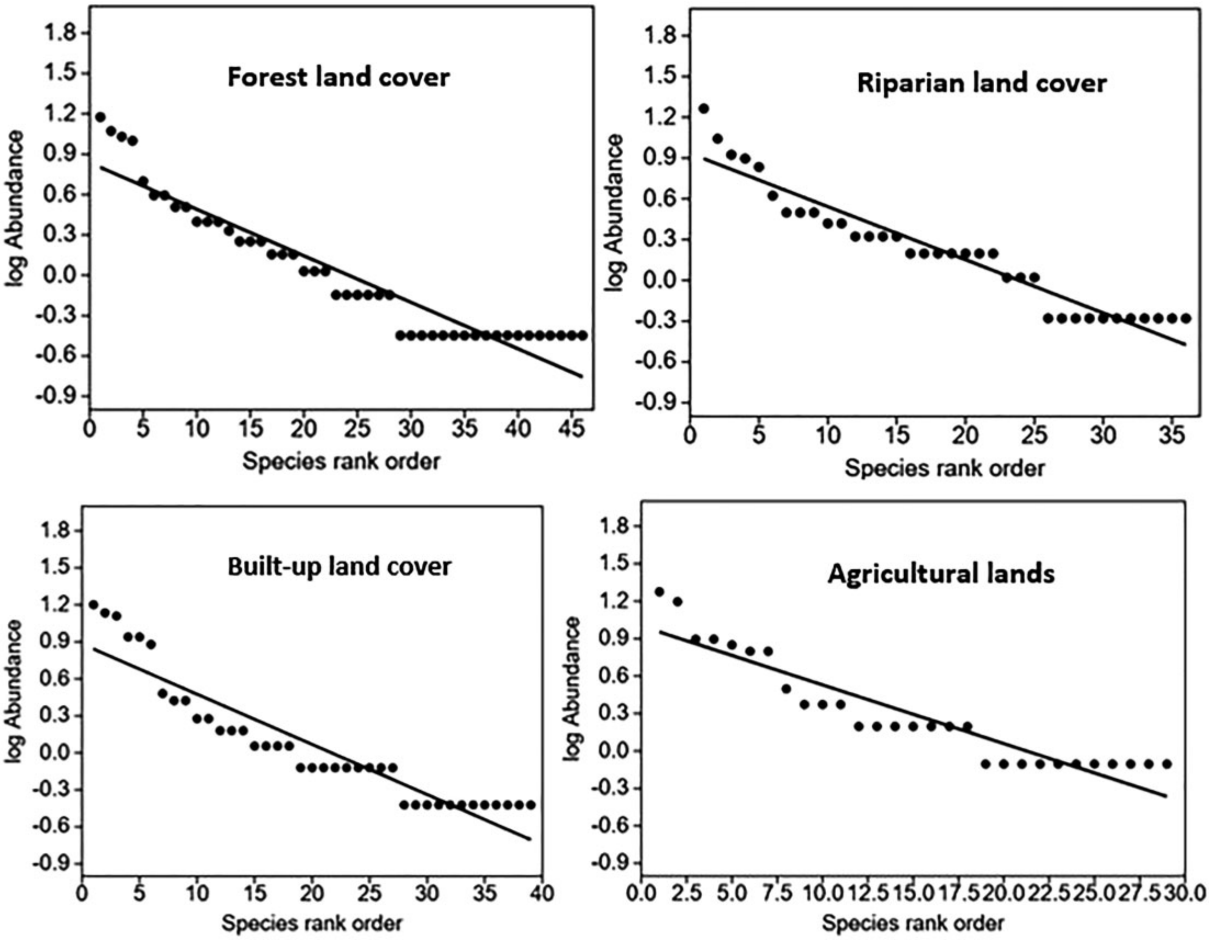

Figure 4: Geometric model for tree rank abundance distribution across the four LULC types in Kumasi Metropolitan area. Abundance is based on cumulative cover values per species per test site. Notice that SADs are ordered in decreasing magnitude and plotted against the corresponding rank in this order

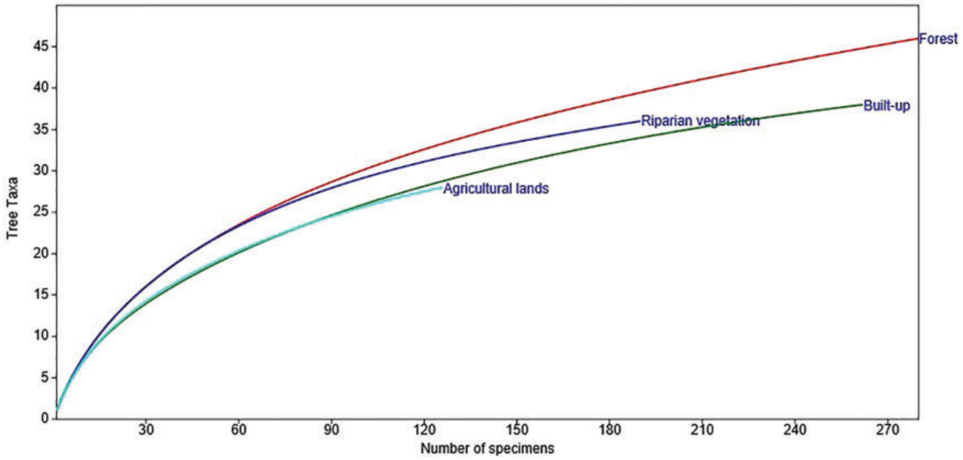

Figure 5: Standardized comparison of species richness for individual-based rarefaction curves. The data represent summary counts of trees that were recorded from the four LULC types in Kumasi Metropolitan area. The red, blue, green and turquoise lines are the rarefaction curves, calculated from Equation (1) (Gotelli and Colwell 2001). The vertical lines illustrate a species richness comparison standardized to 126 individuals, which was the observed tree abundance in the smallest (farmlands) of the four LULC types data set

Land cover transformations and its impact on tree diversity

Biodiversity spatial patterns have been studied among cities in Europe, North American and Australian (Niemelä et al. 2011; Aronson et al. 2014) in the face of growing human population and other anthropogenic activities. In spite of the valuable role of urban forest resources on human well-being (Konijnendijk et al. 2005), they have been subjected to human-led disturbances, which tend

Table 3: Results of the Geometric series model for tree abundance rank distribution of Kumasi Metropolitan area, calculated for forest, riverine, built-up and farmlands LULC

Sample	No. of individuals	Mean ± SE	Intercept ± S.E.	Slope ± S.E.	χ^2P	P
Forest	280	3.78 ± 0.91	1.26 ± 0.36	0.077 ± 0.11	28.52	0.0007^{a}
Riverine	190	2.57 ± 0.64	1.274 ± 0.38	0.086 ± 0.12	19.42	0.15
Built-up	262	3.54 ± 0.97	1.581 ± 0.41	0.089 ± 0.13	38.61	0.0001^{a}
Agricultural lands	126	1.70 ± 0.48	1.354 ± 0.43	0.102 ± 0.14	21.8	0.039^{a}

The linear slope (k) of the GS model, reflects a rapid decrease in species abundances by rank (Motomura 1932).

[a] Significance of the slope of SADs in LULC types. Slope of SADs: $F_{3,\ 70} = 0.0012$, P (regr): 0.97.

Table 4: List of tree species sampled across the four different LULC classes in the KMA

Forest	Built-up	Riparian vegetation	Agricultural land
Elaeis guineensis	_Elaeis guineensis_	_Elaeis guineensis_	_Elaeis guineensis_
Blighia sapida	_Blighia sapida_	_Blighia sapida_	_Blighia sapida_
_Bauhinia monandra_*	_Albizia lebbeck_	_Albizia lebbeck_	_Albizia lebbeck_
Xylopia spp	_Ficus exasperate_	_Ficus spp_	_Ficus spp_
_Sena apetabelis_*	_Citrus sinensis_*	_Citrus sinensis_*	_Citrus sinensis_*
_Senna siamea_*	_Albizia ferruginea_	_Bambusa vulgaris_*	_Senna siamea_*
_Cedrela odorata_*	_Anacardium occidentale_*	_Bauhinia monandra_*	_Cedrela odorata_*
Ceiba pentandra	_Senna siamea_*	_Bougainvilla alba_*	_Ceiba pentandra_
Chrysophyllum spp	_Theobroma cacao_*	_Callophylum innophyllum_	_Theobroma cacao_*
_Cinnamomum verum_*	_Codiaeum variegatum_*	_Ceiba pentandra_	_Celtis adolfi-friderici_
Piptadeniastrum africanum	_Piptadeniastrum africanum_	_Theobroma cacao_*	_Psidium guajava_*
Entandrophragma angolense	_Dracenea fragrance_	_Codiaeum variegatum_*	_Jatropha podagrica_*
Eucalyptus grandis	_Celtis adolfi-friderici_	_Duranta spp_*	_Moringa lucida_
_Delonix regia_*	_Ficus elastica_*	_Cola gigiantia_	_Cocos nucifera_*
_Gmelina arborea_*	_Plumeria rubra_*	_Delonix regia_*	_Antiaris toxicaria_
_Psidium guajava_*	_Gmelina arborea_*	_Gmelina arborea_*	_Pithecellobium dulce_*
Alchonea floribunda	_Psidium guajava_*	_Psidium guajava_*	_Terminalia mantaly_*
_Terminalia catappa_*	_Terminalia catappa_*	_Alchonea floribunda_	_Moringa oleifera_*
Moringa lucida	_Jatropha caucus_*	_Terminalia catappa_*	_Azadirachta indica_*
Nauclea diderrichii	_Moringa lucida_	_Jatropha podagrica_*	_Alstonia boonei_
_Lagerstroemia speciosa_*	_Cocos nucifera_*	_Moringa lucida_	_Ficus exasperate_
_Leuceana leucocephala_*	_Pithecellobium dulce_*	_Cocos nucifera_*	_Albizia zygia_
_Pithecellobium dulce_*	_Mangifera indica_*	_Leuceana leucocephala_*	_Vernonia spp_
_Mangifera indica_*	_Terminalia mantaly_*	_Pithecellobium dulce_*	_Mansonia altissima_
_Azadirachta indica_*	_Polyathia longifolia_*	_Mangifera indica_*	_Albizia adianthifolia_
Alstonia boonei	Moringa oleifera*	_Terminalia mantaly_*	_Persea Americana_*
Ficus exasperate	_Azadirachta indica_*	_Euphorbia tirucalli_*	_Roystonea regia_*
Musanga cecropioides	_Araucaria heterophylla_*	_Azadirachta indica_*	_Annona squamosal_*
Terminalia superba	_Alstonia boonei_	_Alstonia boonei_	_Garcinia kola_
Albizia zygia	_Albizia zygia_	_Ficus exasperate_	
Zanthoxylum gilletii	_Vernonia spp_	_Albizia zygia_	
Mansonia altissima	_Broussonetia papyrifera_*	_Zanthoxylum gilletii_	
Albizia adianthifolia	_Persea Americana_*	_Broussonetia papyrifera_*	
_Persea americana_*	_Cestrum nocturnum_*	_Persea Americana_*	
Margaritaria discoidea	_Roystonea regia_*	_Raphia spp_	
_Roystonea regia_*	_Newbuldia laevis_	_Newbuldia laevis_	
Newbuldia laevis	_Annona muricata_*	_Annona muricata_*	
Spathodia campanulata	_Annona squamosal_*	_Spathodia campanulata_	
_Tectona grandis_*	_Tectona grandis_*		
Millettia rhodantha	_Casuarina equisetifolia_*		
Entandrophragma utile			
Triplochiton scleroxylon			
Casuarina equisetifolia			

*Exotic species.

to affect plant diversity in urban centres like Helsinki and Northwestern Switzerland (Hamberg et al. 2008; Hegetschweiler et al. 2009). Our study found similar impacts of land cover transformation brought about farming activities on the low tree species diversity profile and richness in riparian vegetation. Encroachment of riverbanks for farming activities was widespread, as a result of population growth. This was evident in the change detection results, where 9.28 km^2 of riparian vegetation was converted into

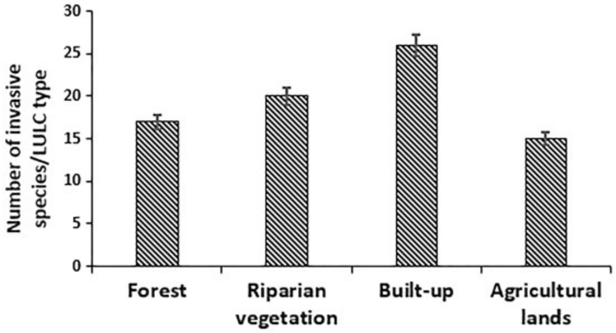

Figure 6: Variations in species invasive richness sampled across the four LULC types. Notice that built-up site had the highest invasive richness

agricultural lands. During farming and crop cultivation, trees are felled and replaced with annual cropping, which was observed during the study. We also observed houses constructed within 100-m radius, along the riverbanks, even though a minimum of 100 m from river banks were demarcated as 'restricted area for development' by the Ministry of Lands and Natural Resources (Water Resources Commission 2008). Campion (2012) indicated that about 34% of the wetlands within 100 m of the stream channel in the study area has been converted into settlements. This was confirmed by our findings, which revealed that 60% of trees in riparian vegetation was exotic species that have replaced indigenous species. In addition, reforestation activities, using exotic species on portions of riparian zone in the Kumasi Metropolitan Area, grew much faster than the local species (Mensah 2010). Urbanization has been reported to aid in the dispersal of exotic species (McKinney 2002) and which consequently lead to their increase (e.g. among Central European floras, Pyŝek 1998). We therefore conclude that indigenous plant communities tend to respond to the drivers of land transformation observed in KMA, compared with exotic species, and hence can used as indicators of the urban expansion.

Similarity of low diversity profile in riparian vegetation and built-up LULC classes may be due to disturbance at equal spatio-temporal scale. These disturbances included intensification of urban physical infrastructure, sand wining, dumping of refuse, cutting of trees for fuel load, farming close to the river bank and the reclamation of portions of the zone for infrastructure development. This phenomenon was largely linked to recent population increase within the Kumasi Metropolitan area, which stands at 1 730 249, and representing 36.2% of the total population in Ashanti region (Ghana Statistical Service 2013). Urbanization or growing cities in particular have been reported to modify land cover, reduce the area of natural habitats, affect ecosystem functioning and contribute to the loss of biodiversity (Elmqvist et al. 2013). With the priority of government to alleviating poverty and the provision of basic utilities for urban dwellers, it is highly likely that the quest for conservation of urban biodiversity, will be neglected, leading to further conversion of the remaining green spaces like recreational parks into built-ups.

High richness observed in the built-up LULC class was unexpected and contrasted some findings, which revealed urban expansion and its associated LULC changes to have caused a reduction in tree species abundance and richness, especially in built-up areas (Lambin et al. 2001; DeFries and Bounoua 2004). We attributed the high species richness in the built-up areas to the establishment of home gardens and planting of both indigenous and exotic trees for the provision of shade and wind breaks, by private individuals, resident in linear and nucleated settlements. For instance, indigenous trees such as *Albizia adianthifolia* and *Margaritaria discoidea* found in forest areas were equally found in the built-up areas; of which 45% can be described as remnant trees. Appiah et al. (2009) reported that high tree species richness in built-up areas was linked to the maintenance and protection of remnant trees that fall outside the boundary of buildings, during urban expansion process.

Although exotic species were found in all four LULC classes, their dominance in the built-up and riparian LULC classes explains the role play of humans in the introduction of these species in the urban environment of Kumasi. Mensah (2010) assessment of indigenous trees species in urban landscape of Kumasi Metropolitan Area revealed majority of the trees to be exotic species. Though this tend to increase richness, abundance and beautify the urban landscape, the presence of exotic species could potentially impact indigenous diversity and subsequently affect local gene pool. The forest LULC class also harboured pockets of invasive species, in spite of the near-absence of any form of disturbance. This was so because the forest system in the KMA is a typical semi-deciduous forest characterized by vegetation types that support invasive trees species (Oteng-Amoako 2006).

Based on the trends in LULC transformations observed in this study, there is a possibility that future urban tree diversity in the metropolis will increase but will be dominated by alien invasive species. This is because the alien invasive species were prominent in the Forest and Riparian land cover classes (see Table 4), which are supposed to be haven for the indigenous species. Even in the built-up where diversity was high, the species composition were largely alien invasive.

Conclusions

Urban expansion and its resultant LULC changes are an ongoing phenomenon in KMA. The findings revealed an increase in built-up areas from 198.46 (67.86%) to 229.59 km^2 (78.51%) while agricultural land, forest and riparian vegetation decreased over the last decade. While built-ups extended into agricultural land towards the exterior part of the municipality, there was a shift of agricultural lands into forest and riparian vegetation. This reflected in the change detection results with the highest conversion of 22.14 km^2 of agricultural lands into built-up. Forest patches also saw a 4.81 km^2 of its original size converted into agricultural lands. Riparian vegetation had $\sim$ 9.28 km^2 of its original size, transformed into agricultural lands and 6.49 km^2 to built-up. These LULC changes led to highest diversity in agricultural lands compared to the remaining three LULC, a phenomenon that appear to support the intermediate disturbances theory proposed by Hutchinson (1953). However, these disturbances tended to affect indigenous species tree richness (41.3%), in favour of invasive species (58.7%), which rather thrived well through a competitive advantage in limited resource utilization. Forest cover was the least diverse; an outcome that was far more than expected, given the relatively less disturbances observed. Given current state of tree composition in the face increasing urbanization, we predict that future indigenous tree composition in the Kumasi Metropolitan Area, will gradually be replaced by invasive species, if strict measures to curb urban growth and conservation of indigenous species are not enforced.

We therefore proposed the following conservation measures to revert the current trend:

- Appropriate land use planning such as EIA must be done for the forest and riparian vegetation before any commencement of developmental project.

- Education of general populace on the ecosystem services provided by trees as well as promotion of tree planting by individuals, government and non-government organization through a collaborative effort.
- Provision of incentives to local people who have maintained trees on the surroundings as well as those willing to plant new and assist in protecting the remnant trees.
- Government should take proper steps to restore the degraded forest and riparian vegetation and put on stringent measure to curb further degradation.
- Farmers should be educated and encouraged to practice of agroforestry.

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