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Structure and Carbon Stock of an Urban Forest in a School Environment: Case of the Dan Dicko Dankoulodo University of Maradi, Niger

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SUMMARY

This study assessed the role of school urban forests, such as wood plantations on university campuses, in biodiversity conservation and climate change in Maradi. A forest inventory was carried out based on systematic random sampling according to transects following a fixed direction (South-North), which allowed us to install three parallel transects of ten plots of 2,500 m² each. Dendrometric parameters (diameter, height, and crown) were determined in each plot. The results show that the woody plantations in the surveyed area include 28 woody species belonging to 25 genera and 15 families, with Fabaceae as the dominant family (29%). The values of the calculated dendrometric parameters (mean height, mean diameter, average cover, density, and basal area) are respectively 3.57 m, 18.43 cm, 7.64%, 62.13 individuals/ha, and 12.43 m²/ha. The Shannon diversity and Piélou equitability indices are 2.58 and 0.77, respectively. The overall density of carbon and carbon dioxide is 2.84 t/ha and 10.42 t/ha, calculated on the 466 individuals recorded in.

Keywords: Structure and Carbon Stock, School Urban Forest, Green Campus

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INTRODUCTION

Urban and peri-urban forests are defined as "networks or systems that include all wooded areas, groups of trees, and individual trees within urban areas" (Salbitano et al., 2017). In particular, the school urban forest is a collection of woody species present in a school environment. According to Borelli and Conigliaro (2018), urban green spaces contribute to the quality of the living environment and the attractiveness of cities. They respond not only to social and ecological but also to economic challenges. There are many advantages associated with the presence of trees in the city. Among these benefits are reductions in air pollutants (Nowak et al., 2017), urban heat islands (Akbari, 2002), and carbon dioxide levels through the phenomenon of carbon sequestration (Arul Pragasan and Karthick, 2013; Moussa et al., 2019b); erosion control, land demarcation, and land marking (Yemmafouo, 2012). Trees in urban areas also address social, ecological, and economic issues (Wu et al., 2010) by providing shade and satisfying food, energy, and health needs.

In the school environment, trees play a very important role in the quality of education because the presence of woody trees promotes more social behavior in students and helps them regain their ability to concentrate more quickly while reducing stress (Li and Sullivan, 2016). The presence of greenery improves cognitive functions in terms of working memory and the ability to concentrate, which in turn enhances performance and education. Greenery has a positive impact on the overall health and well-being of pupils, students, and teachers. It improves students' ability to concentrate and perform and promotes a social climate. Everyone, including students and teachers, feels better in a green environment when it is hot (Klemm et al., 2015).

Indeed, changes in land use and the accelerated spatial expansion of cities are the main causes of change in the composition, structure, and function of urban forests, including school forests. For example, previous studies have shown that in most cities, native species have been replaced by the intentional planting of alien species or by ecological disturbances such as those due to urban sprawl (Elmqvist et al., 2016). According to Moussa et al. (2020), the woody urban flora of their study sites is dominated by exotic woody plants. Anthropization plays an important role in the fragmentation of species in urban centers (McKinney, 2002). In these centers, native species have given way to exotic species through intentional planting programs or through ecosystem imbalances caused by urban expansion (Elmqvist et al., 2016). Then, urbanization is one of the main causes of biodiversity erosion in West Africa, in addition to the role played by exotic species (Sené, 1993). Human activities have a serious impact on biodiversity and the ecosystem services that result from it (McDonald et al., 2013). For example, urban sprawl has an enormous impact on native species, leading to their reduction and subsequent disappearance through the fragmentation of their biotope (Bierwagen, 2007). In addition, urban expansion leads to biotic homogenization, which is a major challenge for the conservation of local biodiversity (McKinney, 2006). This phenomenon of urbanization biotically homogenizes the environment, thus threatening endemism through the introduction of exotic species (McKinney, 2006).

Despite its disadvantages, urbanization has advantages in terms of biodiversity conservation in urban green spaces, such as school green spaces that allow the preservation of wood plantations within campuses, thus playing an important role in the fight against climate change through the absorption of CO2. However, there is little information on urban forestry in schools, such as university campuses, in the literature, especially regarding small campuses from a spatial perspective. This absence of data on the role of the campus in biodiversity conservation considerably reduces the opportunity for school spaces to quickly acquire REDD+ mechanisms and to include university spaces in urban forest development programs and projects aimed at the development of green cities, especially for the wood plantation activities of August 3 in Niger at the level of the UDDM. In view of the above, it is therefore important to determine the structure and carbon stock of the school spaces in the case of the new UDDM site to fill the gap described above.

MATERIAL AND METHODS

STUDY AREA

This study was carried out at the new site of the UDDM (Dan Dicko Dan Koulodo University of Maradi), located east of the city of Maradi (Figure 1), specifically in Commune 3. The new UDDM site covers an area of 49 hectares (ha). It is an agro-forestry park that was allocated to the UDDM in 2012. The relief is flat, with dune soil on which there are some local species such as *Piliostigma reticulatum*, *Prosopis africana*, *Faidherbia albida*, and *Annona senegalensis*. The average annual rainfall is 550.8 mm (Daouda et al., 2025).

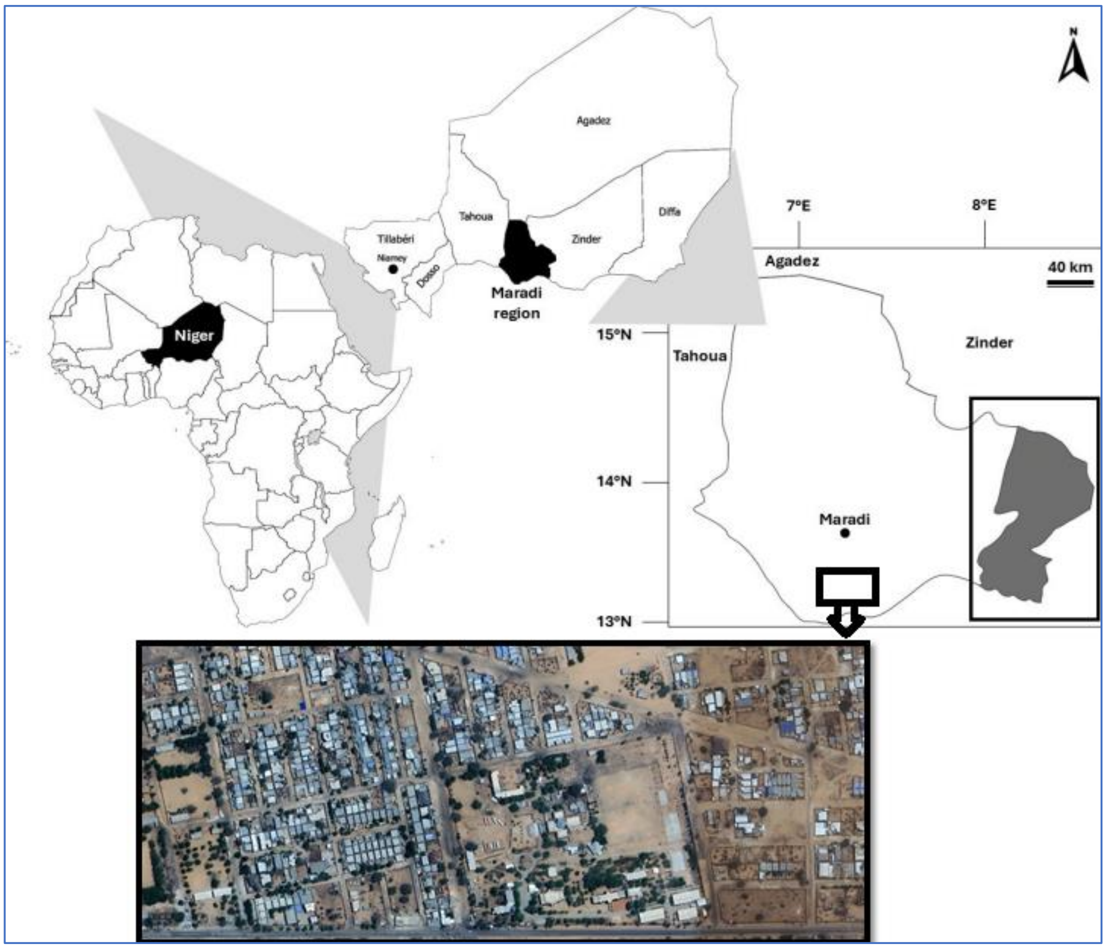

Figure 1: Map of the study area (Daouda et al., 2025).

DATA COLLECTION AND ANALYSIS

An inventory of woody biodiversity was carried out in plots of 2,500 m² (50 m x 50 m) (Kaboré, 2005). In addition, the sample size was determined with a margin of error of 15% according to the following Dagnelie formula d = [5-15%].

Sampling Procedure

During this study, systematic sampling was employed, with plots arranged at regular intervals in a fixed direction (south to north). This arrangement ensures that each plot

is connected to its neighbors, allowing the selection of one plot to systematically influence the choice of the others. Specifically, three parallel transects, each containing ten plots, were established with an equal distance of 20 meters between them.
Several parameters were then calculated, namely:

Overall density
D = N/S
N = total number of individuals
S = the sample area in hectares.

The average diameter
Dm = ∑di/N
Dm = average diameter (cm)
Di = diameter of the individual i
N = total number of individuals

The quadratic diameter

Mean Square Diameter(d) = $\sqrt{\sum_{i=1}^{w} ds_i^2}$
Where ds represents the diameters of different branches of the trunk.

Shannon-Weaver (1949) diversity index (H') and the Piélou index (1966)
H'= -∑Pi*ln pi or pi is the frequency of species i.
E = H'/Hmax with Hmax = ln(S).
Pi = (pi = ni/N) number of individuals ni of species i relative
Ni= number of individuals ni of species i relative
N= total number of individuals surveyed
H'= Shannon's index
E = Equitability Index
S = number of species

Estimation of woody biomass
Regarding the estimation of carbon stock, aboveground and underground biomass were determined according to the following formulas:
BA = 0.0673*($\rho_{(d)}$*D2*H) ^{0,976} where BA = above-ground biomass expressed in kg, $\rho_{(d)}$ = the density of the wood in g/cm3 (Chave et al., 2014);
BS = BA*0.26, with 0.26 the root biomass ratio (Cairns et al., 1997)
BS = underground biomass in kg
Carbon Stock (C) = Total Biomass*50%
50%= biomass of any plant species considered as carbon storage (Pearson et al., 2007)
Total biomass = BA+BS
$C0_2$= Carbon value*44/12 with 44/12 =3.67 (Pearson et al., 2007)

In addition, one-way analysis of variance (ANOVA) was used, along with the Tukey test, to compare the carbon stock among the first 10 species with a high rate of sequestration at the 1% threshold.

RESULTS

WOODY FLORISTIC COMPOSITION

The floristic inventory of the woody plantations at the new UDDM site allowed us to identify 28 species divided into 25 genera and 15 families, of which 18 are local (71.43%) and 10 are exotic (28.57%). The most represented families are Fabaceae (29%), Malvaceae (7%), Moringaceae (7%), and Myrtaceae (7%). Of the 28 species listed, 26 are fruit-bearing, resulting in a rate of 92.85%.

THE CARBON STOCK OF THE WOOD PLANTATIONS OF THE NEW UDDM SITE

The overall carbon stock of the species inventoried is 2.84 t/ha, of which 2.73 t/ha is for the first 10 species that sequester the most carbon (Table 1). The species *Faidherbia albida* has the highest carbon stock (0.86 t/ha) among the species inventoried, followed by *Borassus aethiopum*. On the other hand, the lowest values are observed in *Lannea microcarpa* (0.025 t/ha) and *Calotropis procera* (0.017 t/ha). In fact, the means having the same letters are not significantly different at the 1% level (Table 2). In addition, the results show that the class with a diameter D (1.30) >20 cm sequesters more carbon than the class with a diameter D (1.30) ≤ 20 cm (Table 3).

Table 1: Carbon and carbon dioxide stocks of the top 10 species

Names	Local names	Families	Carbon per species t/ha	CO_2 t/ha
Albizia chevalieri Chevalier's albizia	Kaska	Fabaceae	0.032	0.119
Balanites aegyptiaca Soapberry tree	Aduwa	Zygophyllaceae	0.153	0.56
Borassus aethiopum Palmyra palm	Giginya	Arecaceae	0.584	2.142
Calotropis procera Sodom's milkweed	Tumfafiya	Apocynaceae	0.017	0.056
Faidherbia albida Apple-ring acacia	Gawo	Fabaceae	0.864	3.17
Guiera senegalensis Senegal guiera	Sabara	Combretaceae	0.038	0.138
Hyphaene thebaica Doum palm	Goriba	Arecaceae	0.136	0.501
Lannea microcarpa African grape	Faro	Anacardiaceae	0.025	0.093
Piliostigma reticulatum Camel's foot	Kalgo	Caesalpinioideae	0.328	1.227
Prosopis africana African mesquite	Kiriya	Fabaceae	0.553	2.031
Total			**2.73**	**10.037**

Table 2: Comparison of the Means of the Top 10 Species per Individual

Species	**Carbon content (kg)**
Faidherbia albida	31.52b
Borassus aethiopum	41.21a
Prosopis Africana	45.5a
Piliostigma reticulatum	2.03d
Balanites aegyptiaca	14.9c
Hyphaene thebaica	3.56d
Guiera senegalensis	0.54d
Albizia chevalieri	0.34d
Lannea macrocarpa	1.27d
Calotropis procera	0.85d

Table 3: Above-ground biomass rate by diameter class

Diameter at chest height	Above-ground biomass rate (kg)	Proportions
$D_{(1.30)} \leq 20$ cm	6327.398	19%
$D_{(1.30)} > 20$ cm	27499.060	81%
Total	33826.458	100%

DISCUSSION

The results on the floristic composition highlighted a dominance of the Fabaceae family. In this family, the predominance of the species *Piliostigma reticulatum* has been noted and may be related to the fact that the study site is an agrosystem with sandy soil favorable to the development of the species (Arbonnier, 2002). This corroborates the work carried out by Moussa et al. (2016), who noted the predominance of Fabaceae in agroforestry parks in Niger. This predominance of Fabaceae may also be due to the high proportion of native species such as *Faidherbia albida*, *Prosopis africana*, and *Balanites aegyptiaca*, which are indicators of the nature of the site, which belongs to the southern Sahelian block describedby Saadou (1990). This dominance can also be explained by the ability of species in this family to adapt to harsh environmental conditions (Sreetheran et al., 2011). This predominance could also be explained by the resilience of these species to adapt to conditions. It is characteristic of a forest ecosystem with legumes involved in atmospheric nitrogen fixation (Chaer et al., 2011).

In addition to all this, it could be explained by the important ecosystem services provided by these species, hence their *conservation.* Furthermore, these species hold significant socio-economic value, offering benefits in food production, medicine, wood, shade, and *more.* The dominance of Fabaceae observed in our study is consistent with findings from the Vidyanagari educational campus (Avchar, 2022) and the Faculty of Agronomy at the University of Niamey (Issoufou and Yacine, 2021).

There is a fairly large proportion of local species compared to exotic species at the new UDDM site. This dominance may also be due to the fact that the new UDDM site is an agroforestry park that has become a protected school site, as well as due to assisted natural regeneration. However, the low proportion of exotic species at the site can be explained by the fact that few exotic species are planted in the inventoried area. The predominance of local species can serve as a habitat for local biodiversity. The floristic diversity of the site is moderately diverse, with a Shannon index and a Pielou equitability index of 2.58 and 0.77, respectively. This Shannon index is similar to those found by Moussa et al. (2019a), which are 2.48 and 2.30, respectively, on the floristic composition of cities such as Niamey and Maradi. This floristic richness can be linked to the introduction of several exotic species such as *Blighia sapida*, *Moringa oleifera*, and *Mangifera indica*. The Piélou index indicates that the distribution of species is regular. The specific diversity of the site is a major indicator of botanical diversity, as reportedby Yahara et al. (2013), which states that the diversity of legumes is an excellent marker of the botanical diversity of an environment.

As for the carbon stock, it is estimated at 2.84 t/ha for the 28 species identified. This result is comparable to the 2.85 t/ha and 2.40 t/ha reported respectively in the forest massif of the National School of Water and Forests of Dindereresso, Houet Province of Burkina Faso (Ouedraogo et al., 2019), and the agroforestry park in *Cordyla pinnata* in the southern groundnut basin of Senegal (Diatta et al., 2016). This carbon stock, although low, plays an important role in mitigating greenhouse gas (CO2) emissions responsible for climate change. Species with large diameters (D(1.30) > 20 cm) sequester more carbon than those with small diameters (D(1.30) ≤ 20 cm), as noted by Oulaïtar et al. (2017), which underlined that woody individuals of large diameters are inevitably the dominant element of above-ground biomass. The strong contribution of large diameter plants to total biomass stocks has been demonstrated by other studies (Joosten et al., 2004). This reflects a significant difference in carbon storage rates between species. This difference may be due to the growth and, therefore, to the age of the species, as revealed by Thompson et al. (2003), who stated that larger trees sequester more carbon.

CONCLUSION

This study made it possible to carry out an inventory and estimate of the carbon stock of the species in part of the site. A total of 28 species have been recorded in 25 genera and 15 families, with Fabaceae as the dominant family and a strong representation of native species. The overall carbon stock is estimated at 2.84 t/ha. This research, although not focused on the entire site, indicates that the site has a strong potential to contribute to national efforts to combat climate change, thanks to its rich and diverse floristic composition and its carbon sequestration capacity.

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