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Woody species in the urban schoolyards in West Africa Sahel cities in Niger: diversity and benefits for green schools

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Abstract
Urban schoolyards are essential in biodiversity conservation; they provide numerous ecosystem services to students, school managers, and the city where the schools are located. However, limited or no studies have explored the role of urban schoolyards in both biodiversity conservation and carbon sequestration. This study, therefore, assessed the structure and values of urban schoolyards forest in the cities of Niamey and Maradi in the Niger Republic. A total of 60 schools was selected purposively from Maradi and Niamey (30 schools in each city), where the data were collected through a face-to-face survey. Additionally, a forest inventory and participatory observations were conducted to gather the dendrometric data and animal biodiversity. The findings revealed that, a total of 97 different tree species belonging to 35 families and 81 genera. In addition, neem tree and Fabaceae (22 species) were found to be the dominant tree species and botanical family respectively in the schoolyards of both cities. The similarity index was 64% indicating high similarity between the floras of the schoolyards in the two cities. The biomass value equals about 48.91 t/ha and 27.49 t/ha carbon stock in the primary schools of Niamey and Maradi respectively. Furthermore, the analysis of the structure of the urban schoolyard forests showed high values of structural parameters indicating the vitality/health/integrity of the forest. The ability of students to name plants, animals, and ecosystem services of their schoolyards is significantly low. This study recommends the use of multipurpose woody plant species in urban greening school initiatives for quality education. Furthermore, the study recommends a further investigation of the effects of the school urban forest structure on the students' academic performance and the allergenic potential of woody species found in urban schools.

Keywords Schoolyard biodiversity · Niger republic · Urban trees · Ecological literacy · Forest finance

1 Introduction

The loss of woody biodiversity is caused by anthropic and natural activities resulting in serious environmental issues. For example, urbanization through the expansion of urban infrastructure development leads to the destruction of tree species, habitat loss, and the extinction of urban forests [1, 2]. These anthropic activities lead to biodiversity loss, soil erosion,

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the emergence of various diseases, influencing the impacts of climate change and associated environmental problems. However, many studies reported the importance and use of trees in urban areas [3, 4]. For instance, the urban forest is the source of food production [5], contributes to the mitigation of urban air pollution [6], climate change mitigation [3], and the enhancement of the urban population's well-being [7, 8]. In addition, urban trees in school areas improve air quality, regulates school temperatures, heighten the beauty of the schools, thereby improving students' academic performance [9] and urban food production [10] which make a city green and sustainable as highlighted by the United Nations Sustainable Development Goals (SDGs) 11 and Paris Agreement which calls for more climate solutions such as green city solutions like tree planting programs in urban areas.

Additionally, schoolyards' trees reduce conflict and physical violence in urban areas [11], and their presence in urban spaces also contributes to the smooth running of physical activities [12]. Despite the various importance urban forest brings to bear; only a few studies have investigated the role of trees in the urban schoolyards and the services they provide, with previous studies focusing on only the role of trees on campuses. For instance, the campuses have been reported to be sites of biodiversity conservation [13, 14]. Furthermore, [15] discovered that the University of Sumatera Utara, Campus of Medan in Indonesia has 121 tree species from 37 families and also provides numerous services such as wood and latex production as well as absorption of polluted air. Additionally, [16] also indicated that the public primary schools represent 10% of tree cover in Kenya.

Moreover, studying the students' perception of plant and animal species in their schoolyards is also rare in the West Africa Sahel region. This has necessitated the need to assess the students' perception of plant and animal species in their schools. This can be achieved by the formation of student groups such as green students, which [17] underlined that the concept of eco-literacy as botanical knowledge is necessary for sustainable natural resources management. For example, woody plants have been used for school greening purposes in Niger since the colonial period [18]. The schoolyards in the cities of Niamey and Maradi are an important educational hub in terms of the number of schools and students in Niger. The trees in the schoolyards of these two cities have been characterized slightly as urban forest types in Niamey and Maradi cities [19] with natural forest patches and artificial tree plantations (Fig. 1). These urban green spaces provide a suitable, healthier, and peaceful learning environment. In addition, most of the schools in Niger are now working to meet Sustainable Development Goals (SDGs) by creating urban green infrastructure in their schoolyards, the trees in schoolyards contribute to quality education through the forest biodiversity for environmental education and urban forest in schools (SDG4) and also enhance the academic performance of student and schools' employees' productivity [9]. Consequently, the trees in schoolyards promote the city's sustainability (SDG11), climate actions (SDG13), and the conservation of terrestrial biodiversity (SDG15). The tree diversity in the schoolyards of Maradi and Niamey is shown in Fig. 1.

Previous studies on urban schoolyards have highlighted numerous contributions of schoolyards biodiversity in mitigating climate change, regulating the microclimate of the schools as well as in improving the performance of the student and the beauty of the cities. However, these studies did not investigate the diversity and values of woody species at different educational levels (primary, secondary and tertiary schools) and students' perception of plant and animal species in their schools. Similarly, there is no study, which explored the determinants of the botanical knowledge of tree species of the students with regard to the schoolyards of their studying areas, the role of urban schoolyards in biodiversity conservation, and carbon storage, especially in the West African context. This study attempts to close this gap by investigating the woody species richness in the urban schoolyards forest in the cities of Maradi and Niamey in the Niger Republic. By doing so, the study provides a baseline reference situation from Maradi and Niamey two cities of the Niger republic with contrasting urban school environments. Therefore, this study attempts to fill this gap by (1) investigating the woody species richness and carbon sequestration potential in the urban schoolyards forest in the cities of Maradi and Niamey in the Niger Republic and (2) highlighting the perception of schoolyard vegetation. Specifically, this study seeks to answer the following questions: (1) Could urban schoolyards' biodiversity contribute to the reduction in the loss of woody species in the Sahel region? (2) What is the carbon sequestration potential of woody species in the schoolyards of these cities? (3) What socio-economic and ecological benefits are provided by these urban schools' woody plants? (4) How do the students and school managers perceive the schoolyard's trees?

2 Materials and methods

2.1 Study area

This study was conducted in Maradi and Niamey, which are two Sahel cities in the Niger Republic. Niamey is the political capital of the Niger republic located between 13.5116° N, and 2.1254° E and accounts for a population of 1,203,766

Photo A Secondary school in Niamey

Photo B tertiary school in Niamey

Photo C Secondary School Maradi

Photo D Primary school Maradi

Fig. 1 Tree species diversity in the schoolyards of Maradi and Niamey (source Moussa Soulé)

inhabitants [20]. The second city Maradi is a city located between 13.5010° N, and 7.1036° E and accounts for approximately 326,804 inhabitants in 2021. The choice of the two cities in this study is explained by their differences in socio-economic, political characteristics, and agroecological structures. For instance, the average maximum temperature in Niamey is about 35.9 °C and the average minimum temperature is 19.90 °C, with Maradi is having an average maximum temperature of 36.7 °C and an average minimum is about 24 °C [20]. Additionally, the urban forestry activities in the two cities are made up of trees planted in public and private spaces and preserving historical woody vegetation [19]. Figure 2 provides an overview of the geographical location of the two cities and the schoolyards' woody species in primary, secondary, and tertiary schools across Maradi and Niamey cities.

2.2 Data collection

This study used urban forestry inventory, based on quota and purposive sampling approach. Accordingly, three educational levels (primary schools, secondary schools, and tertiary schools) were considered and two types of schools (private and public) were included. The study sample consisted of 30 schools in both two cities (Maradi and Niamey). From each school, dendrometric data were collected from a plot of 50 m × 50 m as recommended for the agroforestry systems in West Africa [21]. In each plot of 2500 m^2, parameters such as tree diameter at 1.30 m, total woody plant height, crown diameters, and name of the species were collected. In addition, the centre of the plot was recorded by a means of GPS (Garmin GPSMAP 64x, Handheld GPS, and Garmin GPSMAP 64 Worldwide with High-Sensitivity GPS and GLONASS Receiver). The wood density for biomass estimation was performed using [22] and an ethnobotanical survey was used to collect data from the students, school managers, and their perception of the existence of trees in their schools. The book called Trees, Shrubs, and Lianas of West African Dry Zones, was used to identify tree species [23]. The tools for data collection for this study were the forest inventory sheet used for forest data collection, individual questionnaires (individual interviews) for the ethnobotany data collection, and observations such as taking pictures with our phone's cameras. The questionnaires and inventory sheet were in the French language.

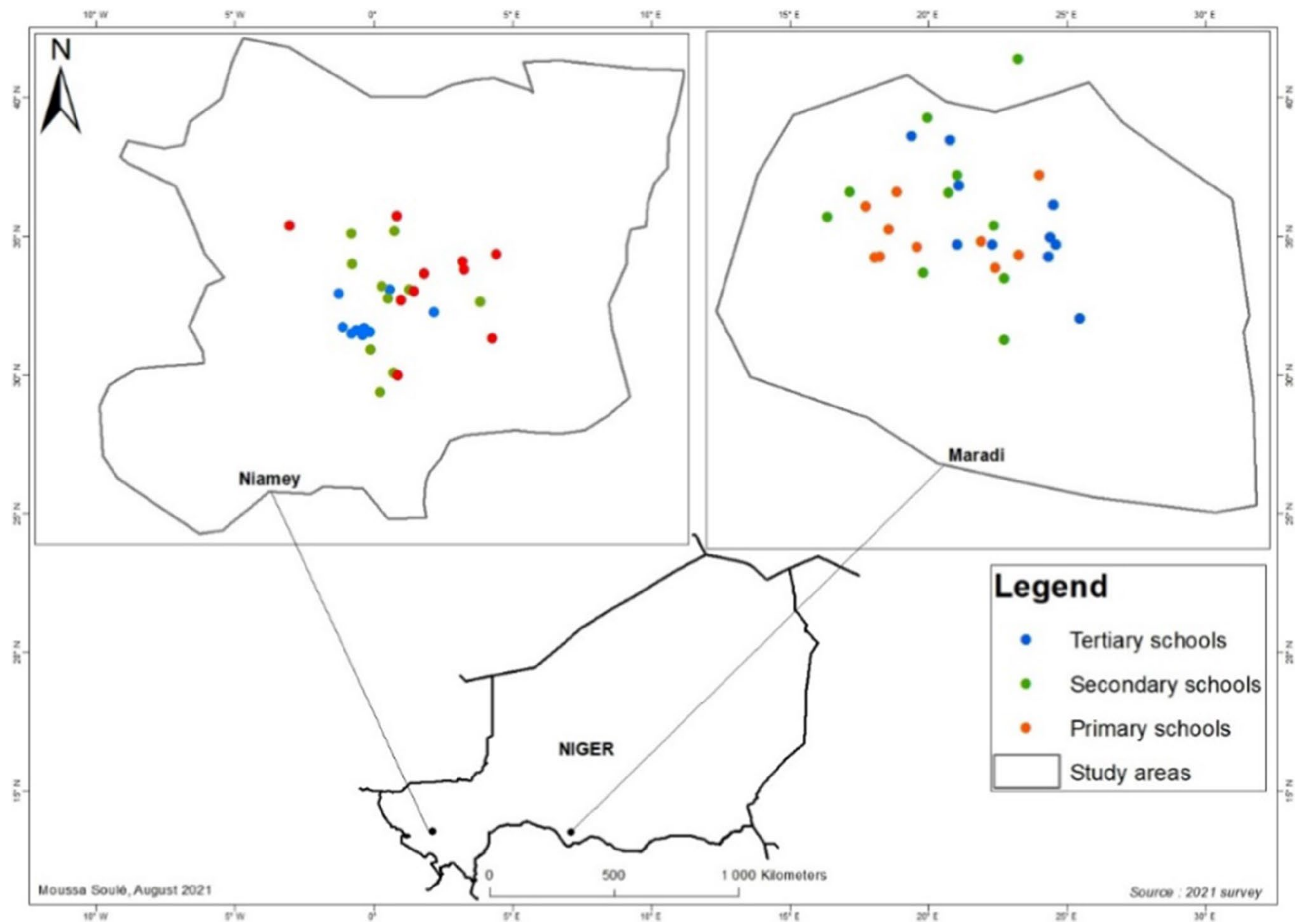

Fig. 2 Study area

2.3 Data analysis

2.3.1 Determination of ecological indicator

Descriptive statistics such as frequency, percentage and inferential statistics were used to draw the systematic composition such as tree species richness, families, and genera, species origins (native or exotic) across the two urban schoolyards strata. Accordingly, the following ecological indicators were determined.

a. Percentage of the planted or preserved stem in schoolyards: it corresponds to the total number of stems counted in a given school divided by the total number of the stem recorded in the primary, secondary and tertiary schools. For this indicator, the dominance was calculated based on the percentage by inferring the percentage.
b. Stem density (Stem/ha): it refers to the total number of individual stems of a given species per unit area (ha);
c. Crown area (Ca, m^2) was calculated assuming an elliptical crown shape using (Ca) (m^2) = $\pi((d_1/2)x(d_2/2)$, Where d_1 is the largest crown diameter (m) and (d_2) is the diameter perpendicular to the larger crown diameter (m).
d. Tree cover (%) was calculated as = Ca (m^2) (100)/Plot size (m^2);
e. Basal area, Basal area was calculated as BD (m^2) = D^2 * (π/4), where π is *pi* = 3.14, and D is diameter of 1.3 m.
f. Shannon–Wiener diversity index: H′= − ∑ [(*ni*/*N*)**ln* (*ni*/*N*)], where *ni* is the number of individuals of species *i*, *N* is the total number of individuals in per land-use unit and *ln* is the natural logarithm.
g. Pielou's evenness (J′): $J = H'/H'_{max}$, where H' is the Shannon diversity index and H'_{max} is the maximum possible value of H'.

h. Sorensen index was calculated to compare the similarity between the Niamey and Maradi using the formula described in (Thiombiano et al., 2017): K = 2C/(2C + A + B), where A is the number of species in one area (e.g. Niamey), B is the number of species in another area (e.g. Maradi) and *C* is the number of species common to the study sites. Excel was used for some calculations, tabulation and drawing graphs.

2.3.2 Estimation of schoolyards carbon stock

The above ground biomass (AGB) was used to estimate the carbon stock by using the general allometric model developed by [24]. For tropical vegetation, the above-ground biomass $AGB = 0.0673(\rho D^2 H)^{0.976}$ where AGB = refers to the above-ground biomass in kg, ρ = wood density (gcm^{-3}), D = diameter in cm at breast height (1.3 m), H = total trees height (m). The below-ground biomass was estimated using of root shoot ratio of 0.25 developed by [25] for the tropical vegetation and the carbon conversion factor of 0.47 [22].

2.3.3 Determinants of the students' botanical knowledge of the schoolyards trees species

A regression analysis was conducted to determine the factors affecting the students' botanical knowledge of the tree species in the schoolyard. In this study, the number of tree species known by the student was considered as a dependent variable (Y) and other selected factors such as age and sex of the students, the types of the schools, the type of ecosystem services obtained by the students from the trees in the schoolyards, the number of vertebrate in the schoolyards, the number of invertebrate hosted by the trees in the schoolyards, the school education level and the location of the schools were considered the independent variables of the model. The dependent variable of the model is a continuous variable and refers to the number of trees species known by the student (Y). The explanatory variables were the age of the student (X_1), the number of vertebrates hosted by the trees the (X_2) and the number of invertebrates hosted by the trees of the trees of schoolyards (X_3). Other explanatory variables were included X_4 is a categorical representing the type of school; it scores 1 if the school is public and 2 otherwise, X_5 the location of the schools, which scores 1 if the school is located in Niamey and 2 if it is located in Maradi, X_6 refers to the school educational levels, which the value 1 if the educational level is a primary school, 2 if it is a secondary school and 3 if the educational level in tertiary school. Likewise, X_7 represents the type of ecosystem service perceived by the students from the trees of the schoolyards, which scores 1 if intangible ecosystem services, 2 if tangible ecosystem services, and take 3 if they perceive both tangible and non-tangibles ecosystem services. The regression model used to determine the factors affecting the students' botanical knowledge of the tree species in the schoolyard is as follow:

$$Y = a_0 + \sum_{n=1}^{n} Xn$$

where the dependent variables (Y) represents students' botanical knowledge of the tree species in the schoolyard in term of number of trees species and Xn other selected explanatory variables of the regression model such as age and sex of the students, the type of school, school educational level, the location of the school.

The laboratories of the University of Maradi and Abdou Moumouni University were used to identify unknown species by the means of tree species photos. The tree species classification and nomenclature were conducted by the mean of Angiosperm Phylogeny Group IV botanical classification system [26]. Furthermore, a taxonomically comprehensive phylogeny was used for the legume tree species, the new subfamily classification of the Leguminosae [27] and the animal species were identified with the support from specialists using photos taken during the collection of the data on the field.

Prior to the statistical analysis, the Ryan-Joiner test and Levene' test were used to check the normality and homogeneity of the data in order to use the parametric analysis. Kruskal Wallis test was used to the difference in the number of tree species across the school level at alpha 0.05 level of significance.

3 Results

3.1 Sociodemographic characteristics of the respondents

The sociodemographic characteristics of the respondents are presented in Table 1. The most respondents were male (52.00%), aged between 16–23 years (49.00%) and studied in public school (63.17%) (Table 1).

3.2 Structure of the urban forests in the urban schoolyards

3.2.1 Floristic composition of the urban schoolyards in the two cities

There are 62 woody species classified into 31 families in the schoolyards of Niamey, with Fabaceae being the dominant botanical family (15 species) (Annex 1). In addition, the neem tree (*Azadirachta indica* A. Juss.) accounted for 58.40% of the total stem recorded in the schoolyards (Table 2), with about 53% of the total plant species (33 species) of exotic origin, and 26 species (42%) were food trees in the schoolyards of Niamey. Furthermore, the number of tree species varied significantly according to the types in Niamey (public, private) (H = 5.77 DF = 2, P = 0.056). The overall Shannon index was 2.17 ± 0.79 and the overall evenness of 0.58 ± 0.10 as. A similar trend was observed in the schoolyards at Maradi, where about 82 woody species belong to 29 families with 33% of woody plants species being of exotic origin (Table 2 and Annex 2). The number of planted stems accounted for 88% and 74% in Niamey and Maradi city respectively with an overall Shannon index of 2.40 ± 0.63 and 0.58 ± 0.18 as overall evenness. The similarity index was 64% indicating high similarity between the floras of the schoolyards in the two cities.

3.2.2 Parameters of the structure of urban forests in the schoolyards

The results showed that the tree cover was higher in Maradi primary school (49.71%) than in Niamey primary school (38.40%) (Table 3). Additionally, in Niamey, primary schools had the highest values for the basal area (16.92 m^2/ha) and the highest carbon density (48.91 t/ha), whilst Maradi primary schools had the highest stem density (135 stem/ha) (Table 3). The basal area varied significantly between the two cities across the school types (H = 3.86 DF = 1; P = 0.050), however, there are no significant differences in the tree cover, stem density and carbon density across the schools in Maradi and Niamey schools.

3.2.3 Students' knowledge of the tree biodiversity and zoological diversity in their schoolyards

The students' knowledge of their schoolyard's biodiversity (Botanical and zoological knowledge) and ecosystem services rendered by the tree species in their schools are summarized in the Table 4. It showed that most of students (85.50%) knew between 0 and 5 different tree species, 74% of them knew between 0 and 2 vertebrae. In addition, 93.67% of the students knew between 0 and 2 invertebrates, 57.00% of them were aware of intangible ecosystem services provided by the schoolyard trees.

3.2.4 Relations between schools, schoolyards trees biodiversity ecosystem services and hosted animals

Pearson's correlation test was conducted to examine the relationship between the type of schools, the educational level, the number of tree species, vertebrates and invertebrates in the schoolyards and the type of ecosystem services provided by the trees in the schoolyard across the two cities. Table 3 showed that there were negative, weak but significant relationships between the type of schools (public/private) and the number of tree species in the schoolyards (r = -0.1244**), the

Table 1 Sociodemographic characteristics of the students (n = 600)

Variables		Frequency (n)	Percentage (%)
Age of the students	8–15 years	228	38.00
	16–23 years	294	49.00
	More than 23 years	78	13.00
Sex of the students	Male	312	52.00
	Female	288	48.00
Type of the schools	Public	379	63.17
	Private	221	36.83
Education level of the schools	Primary	200	33.33
	Secondary	200	33.33
	Tertiary	200	33.33

Table 2 Tree biodiversity urban forest in the schoolyards

Ecological indicators	School educational level					
	Niamey			Maradi		
	Primary school (n = 10)	Secondary school (n = 10)	Tertiary school (n = 10)	Primary school (n = 10)	Secondary school (n = 10)	Tertiary school (n = 10)
Total number of tree species	38	29	54	35	29	77
Total number of native tree species	14	14	30	17	14	45
Total number of exotic tree species	24	15	25	18	15	32
Total number of fruit species	18	14	12	16	13	31
Total number of the stems accounted	527	3175	861	1116	1901	6978
Dominant species with high number of stems	*Azadirachta indica* A. Juss (N = 219), *Mangifera indica* L (N = 66)	*Azadirachta indica* (N = 2166), *Eucalyptus camaldulensis* Dehnh (N = 418)	*Azadirachta indica* (N = 281), *Mangifera indica* L (N = 67)	*Azadirachta indica* A. Juss (N = 333), *Moringa oleifera* Lam (N = 157)	*Azadirachta indica* (N = 1103), *Acacia senegal* (L.) Willd (N = 203)	*Piliostigma reticulatum (DC.)* Hochst. (N = 1230), *Azadirachta indica* A. Juss. (N = 997)
Number of families	24	17	28	18	18	
Dominant families	*Fabaceae* (8 species)	*Fabaceae* (8 species)	*Fabaceae* (15 species)	*Fabaceae* (9 species)	*Fabaceae* (7 species)	*Fabaceae* (16 species)
Shannon Index	2.38	1.30	2.83	2.50	1.71	2.96
Evenness	0.65	0.38	0.71	0.70	0.51	0.68
Total number of planted stems	467	2865	705	1005	1725	4668
Total number of natural stems preserved in the schools	60	310	156	111	176	2310

Table 3 Parameters of the structure of urban forest in the schoolyards of Maradi and Niamey

Parameters	Educational level of the schools					
	Primary school		Secondary school		Tertiary school	
	Niamey	Maradi	Niamey	Maradi	Niamey	Maradi
Tree cover (%)	38.40	49.71	21.70	31.95	23.80	14.97
Basal area (m^2/ha)	16.92	12.14	7.71	4.10	2.98	3.60
Carbon density (t/ha)	48.91	27.49	18.91	19.07	8.30	2.09
Stem density (stem/ha)	79	135	44	106	63	35
Number of the plot (2500 m^2)	10	10	10	10	10	10
Land area (ha)	2.50	2.50	2.50	2.50	2.50	2.50

Table 4 Students' knowledge of the tree species and zoological diversity in their schoolyards (n = 600)

Variables		Frequency (n)	Percentage (%)
Number of tree species	0–5 species	513	85.50
	6–10 species	84	14.00
	More than 10 species	3	0.50
Number of vertebrates	0–2	444	74.00
	3–5	152	25.33
	More than 5	4	0.67
Number of invertebrates	0–2 species	562	93.67
	More than 2 species	38	6.33
Tree ecosystem services	None	6	1.00
	Tangible ecosystem services	1	0.17
	Intangible ecosystem services	342	57.00
	Both tangible and intangible ecosystem services	251	41.83

type of schools and the number of vertebrates (r = -0.1129**), the number of vertebrates and invertebrates (r = -0.1283**) on the trees of the schoolyards.

Moreover, the results showed that there were weak, positive but significant relationships between the types of schools and the number of invertebrates (r = 0.1011000*) in the schoolyards, the number of tree species and the number of vertebrates in the schoolyards (r = 0.1320), the number of tree species in schoolyards and the number of invertebrates in the schoolyards (r = 0.1776**), the number of tree species in schoolyards and the trees benefits obtained by the students (r = 0.2700**). Furthermore, Table 5 it showed that there was a week, positive and significant relationships between the number of vertebrates and the location of the school (r = 0.2662**).

3.3 Determinants of the students' botanical knowledge of the schoolyards tree species

The results showed that the p-value for the regression model is equal to 0.0000 while its correctness equals to is 0.2059 and the Chi-square equals 22.05%. These values indicate that although the value of the Chi-square of the model is low, its variables had a significance value of 0.0000. It can therefore be concluded that the model is efficient to determine the determinants of student botanical knowledge of trees species in the schoolyard. Accordingly, the regression equation expressing the determinants of the students' knowledge of tree species in their schoolyards is as follows:

$$\mathrm{NTS} = -0.66385 + 0.3236992\mathrm{X2} + 0.4114956\mathrm{X3} - 0.4014161\mathrm{X4} + 2.578733\mathrm{X7(1)} + 3.51309\mathrm{X7(2)}$$

A positive sign implies that the associated variables affect positively the students' botanical knowledge of tree species in their schoolyard whereas a negative sign indicates the associated variables affect negatively the students' botanical knowledge of tree species in their schoolyards. The results of the regression analysis showed that the number of vertebrates in the schoolyard trees and the number of invertebrates existing in the schoolyards trees and the type of benefits

Table 5 Relationship between schools, tree biodiversity and hosted animals and city (n = 600)

	TS	SEL	NTS	NV	NI	BT	Cities
TS	1.0000000						
SEL	0.0846000 0.0382000	1.0000000					
NTS	– 0.1244** 0.0023000	0.1762** 0.0000000	1.0000000				
NV	– 0.1129* 0.0056000	– 0.1708** 0.0000000	0.1320** 0.0012000	1.0000000			
NI	0.1011000* 0.0132000	0.0967000 0.0178000	0.1776** 0.0000000	– 0.1283** 0.0016000	1.0000000		
BT	0.0516000 0.2065000	0.0756000 0.0643000	0.2700** 0.0000000	– 0.0948000 0.0203000	0.0350000 0.3923000	1.0000000	
Cities	0.1417** 0.0005000	0.0000000 1.0000000	– 0.0170000 0.6782000	0.2662** 0.0000000	0.0549000 0.1790000	– 0.0250000 0.5408000	1.0000000

** and * refers to 1% and 5% respectively. In addition, TS, SEL, NTS, NV, NI and BT state for types of schools, school education level, number of trees species in schoolyards, number of vertebrae hosted by trees, number of invertebrates hosted by trees species and benefits that students obtained by the existence of the trees in schoolyards respectively

obtained by students from the trees in their schoolyards affected positively and significantly the botanical knowledge of tree species of the schoolyard. In addition, the type of schools (public/private) and their locations affected negatively and significantly the students' botanical knowledge of the tree species in their schoolyards.

With regard to public students, being a student in private schools decreases the students' knowledge of the number of the tree species of the schoolyard by -0.40. This implies that the student of public school had better botanical knowledge of tree species of the schoolyards than those in private schools.

An increase by 1 unit of the students' knowledge of intangible ecosystem services provided by schoolyards trees by 1 unit increases their knowledge of trees species by 2.578733 (Table 6) whilst an increase by a unit of the students' knowledge of tangible and benefits provided by the trees species of the schoolyard increases tree species by 3.5 (Ceteris paribus).

On the other hand, with reference to Niamey the location of school in Maradi decreases the students' botanical knowledge of the tree species of the schoolyards by 0.2891124 (Ceteris Paribus). Accordingly, the students studying in Niamey had better botanical knowledge of the tree species of schoolyard than those studying in Maradi. schools. Then, an increase in the number of vertebrates and invertebrates known by one unit increases the students' botanical knowledge of the tree species of the schoolyards by 0.3236992 and 0.4114956 respectively (Table 6).

4 Discussion

The overall Shannon indices in Niamey and Maradi showed that the schoolyards of these two cities have high woody species diversity. Previously, [28] noted that overall Shannon indices with values greater than 2 indicate medium–high diversity. Similarly, [29] stated that such Shannon values show commonly low spatial competition among tree species within a given site. The high woody species diversity in these schoolyards could result from the natural regeneration of the fruit consumed by the students and the dissemination of tree seeds by the birds. In this context, [30] noted that bats are key agents in dispersing the seeds of *Azadirachta indica* trees. Additionally, tree species like *Azadirachta indica* have high germinative capacity and might be utilized for various purposes. For example, [31] mentioned that *Azadirachta indica* is a high seed production capacity and germinative capacity tree, which was is to reduce the air pollution. Also, the dominance of *Azadirachta indica* trees in the two cities' schoolyards resulted from programs such as Green Sahel National tree plantation days in the Niger republic, which promoted the planting of these trees during that period. [32] stated that the city's climate conditions are favourable for the growth and propagation of *Azadirachta indica* trees. Additionally, the schoolyard's tree biodiversity possessed both native and exotic floras, which makes them an important reserve of tree species. For instance, in Niamey, the schoolyards accounted for 62 woody species grouped into 31 families in the schoolyards of Niamey with Fabaceae being the dominant botanical family (15 species) (Annex 1) 53% of the total plant species (33 species) with the exotic origin, and 26 species (42%) being food trees. A similar trend was observed in Maradi,

Table 6 Determinants of the students' botanical knowledge of the tree species of the schoolyards

NTS	Coef	Std. Err	t	P > t
Type of schools (reference: public school)				
Private school	− 0.4014161	0.151062	− 2.66	0.008**
Educational level of the schools (reference. primary school)				
Secondary school	− 0.3929068	0.260213	− 1.51	0.132
Tertiary school	0.2905389	0.407658	0.71	0.476
Perception of ecosystem services				
Intangible ecosystem services	2.578733	0.698758	3.69	0.0000**
Tangible ecosystem services	2.46413	1.806893	1.36	0.173
Both intangible and intangible	3.51309	0.699749	5.02	0.0000**
Location of the school (reference: Niamey)				
Maradi	− 0.2891124	0.144801	− 2.00	0.046*
Number of Vertebrae	0.3236992	0.056302	5.75	0.000**
Number of invertebrates	*0.4114956*	*0.072614*	*5.67*	*0.000***
Age of the students	0.0446896	0.033182	1.35	0.179
Sex of the students (reference: male)				
Female	0.2054623	0.139929	1.47	0.143
Intercept	− 0.6638498	0.811489	− 0.82	0.414

which accounted for 82 woody species belonging to 29 families while 33% of woody plant species were of exotic origin (Table 2). Similarly, [19, 33] indicated that the urban areas are important sources of tree species diversity and contain both native and exotic species. These tree floristic compositions in the schoolyards of Niamey and Maradi could enhance the academic performance of the students. [34] reported that the schoolyards' tree species and trees' composition affected the academic performance of primary school students.

Additionally, the study showed that Fabaceae was the most dominant botanical family in the schoolyards. Some of the tree species belonging to this family such as *Tamarindus indica*, *Dialium guineense*, and some gum species are multipurpose trees. In addition, the dominance of Fabaceae in these schoolyards indicates the Sudano-Sahelian vegetation. Similarly, [35] and [36] highlighted that Fabaceae spreads in large soil and climate ecological drylands, which indicates the diversity of angiosperm in the area. Also, [14] reported that Fabaceae is the most dominant family in the forest of the campus of Sambalpur university.

On the other hand, the study showed that the students perceived only the intangible ecosystem services rendered by the tree species in the schools. This is due to fact that the schoolyard's trees are used as shades during break time and hot weather and also for student's basic learned lessons from school. This observation has been made by [37] which could be explained by the major service perceived by the students is shade in both cities. Similarly, [38–40] reported that urban trees played a key role in carbon sequestration. Similarly, [41] emphasized that protecting the trees from destruction slows down the impacts of climate change which is a key to meeting the SDG 13 (climate action).

With regards to the students' botanical knowledge of the schoolyard's tree species and animals existing in the schoolyards, the study revealed that most of the students knew few tree species. This is an indication that the students were botanically illiterate about their schoolyard's tree biodiversity, which could affect the promotion of green education. In addition, this low botanical knowledge of the students might be due to the fact that the tree floras of the schoolyards are mostly made up of exotic tree species. This could be also due to the lack of interest in plants as reported [42] which is a leading factor in botanical illiteracy. Previously, [17] noted that it is crucial for to school authority to initiate tree conservation for sustainable natural resource management. The school authorities need to use the school tree vegetation for teaching purposes such as teaching the local environment components with a focus on tree species in the schoolyards for a botanical education such as teaching the importance of tree species to the students and naming the tree species to their schools via ecological excursion. There is also a need to involve the students in the tree planting in their schools and allow them to put the names of each tree species in their schools.

Furthermore, the findings of our study showed that the student had low zoological knowledge of the animals (vertebrates and invertebrates) living in their schoolyards. The low knowledge of the student regarding the zoological diversity of their schoolyards could result from the absence of the animals during the day as well as the extinction of some animals due to students' noise. There is to promote zoological education via the ecological excursion in the schoolyards, to visit the Zoos. The school managers can also construct the school' botanical garden with some animals for ecological education which is key to sustainability education.

The study showed that the number of vertebrates and of invertebrates existing in the schoolyards and the ecosystem services provided by these schoolyard's trees to the students affected positively and significantly the student botanical knowledge of tree species. Accordingly, these factors contribute to enhancing the student knowledge of the schoolyards tree species and therefore increase the students' botanical literacy as noted by [43, 44]. Since the study revealed that most students had low botanical knowledge of the tree species existing in their schoolyards, this might pose a serious hindrance to the students' discussion about tree species, which can affect negatively the student's observational skills and conceptual learning as noted by [45, 46]. Furthermore, poor botanical knowledge could augment the risk of the students consuming toxic fruits [47].

In addition, the type of school (public/private) and the location of the school affected negatively and significantly the student botanical knowledge of tree species. With regard to private schools in the two cities (Maradi and Niamey), the students had low botanical knowledge of tree species existing in their schoolyards. This could be due to the fact that the teachers in private schools did not carry out few outdoor activities in their school forests. This result corroborates that of [48–50] who reported that the students have low botanical knowledge in the nearby environment. In addition, the students studying in Niamey had better botanical knowledge of the tree species of their schoolyards than those in Maradi schools. This might be explained by that the accessibility of the student to NTIC and other information channels (TY & radio) in Niamey could be better than in Maradi. There is a need to use the tree in their schoolyards for teaching purposes in order to increase green awareness and environmental education in schools.

Our findings revealed the use of exotic food tree species such as mango tree, *Annona squamosa*, *Carica papaya*, Moringa species etc. which is key to food security and nutrition for the students. This also highlights the urban food forestry in the schoolyards in the two cities such as the existence of school food forests like the campus mango forest at the University of Niamey and other schools which is key to promoting the school sustainability key for quality education. In addition to that our results show the use of indigenous food tree species such as *Balanites aegyptiaca*, *Lannea microcarpa, Sclerocarya birrea*, etc. in the school urban forest which can help to conserve biodiversity like native birds [51] and their fruits constitute a great source of minerals and vitamins which can help to fight food insecurity and malnutrition in the schools. In short, our study demonstrates the role of urban schoolyards in biodiversity conservation and the carbon sequestration potential of the trees in the schoolyards which are key to meeting the SDGs for sustainable cities.

4.1 The study implications with the Sustainable Development Goals (SDGs)

Forests in urban schoolyards are central to meeting the Sustainable Development Goals. Accordingly, the results of the current study demonstrate that some cultivation of the food trees such as Moringa species, (Fig. 1, photo B) the layer of urban food forests such as canopy layer (large fruit and nut trees) which is composed of *Carica papaya*, *Moringa oleifera* and mango trees. The second layer is an herbaceous layer composed of vegetable plants such as lettuce (*Lactuca sativa*). The two layers are part of seven layers of the urban forest garden, which is central element of urban food forestry [52] which constitutes a means of promoting to the zero poverty (SGD 1) and zero hunger (SDG 2). Additionally, the leaves and the fruits of fodder tree species such as the fruits of *Faidherbia albida* in the schoolyards could contribute the raise funds through a sale that improve the quality of the education (SDG 4) and food security for promoting a Smart City Model. Our study reported the diversity of the food tree species (Annex 1 and 2) used in the schoolyards in the urban areas which can rise the urban food forestry practices in the schoolyards as means of promoting Smart cities, where people are allowed to harvest nuts, root, fruits, leaves and vegetables that can contribute the urban climate change adaptation (SDG 13).

Furthermore, the results of the regression analysis showed the existence of strong relationship between the number of trees species and intangible ecosystem services rendered by the schoolyard's forest. One of the key implications of this relationship is the regulation of microclimate through the lowing of the temperature of the school and beyond of the city. Therefore, it contributes to climate change mitigation (SDG 13) especially during the hot periods in dryland zones like the West Africa Sahel cities. This role of urban forests in regulating the urban temperature plays a key role in promoting good health and well-being (SDG 3) for sustainable and heathier cities (SDG 11) as the urban forests are solutions to the urban island heat [53] for urbanite' well-being. This relationship highlights also the urban forest in the schoolyard of the two cities present an opportunity for urban air pollution removal, which improve the health and wellbeing of the urban citizens. This service could be confirmed due the dominance of the neem trees in the urban schoolyards in the two cities as neem tree has been pointed out that neem tree is a good natural air filter (air pollution removal central to the urban heath) and, absorber of CO_2 (climate change mitigation), Oxygen producer (urban health) and used for soil restoration [31].

The use of food plants in the schoolyards as income generating activity is an opportunity for green job creation (SDG 8) for fighting poverty and enhance the resilience of urban areas. For instance, the harvest of fruit, leaves, nut and vegetables in the urban areas can boost the food market and provide jobs to the young people and women as the two cities the sale of leaves, fruits, nut and some vegetables are gender oriented commercial activities. This can promote the gender empowerment (SDG 5) and fix young people from joining the terrorist and other serene of urban delinquency for promoting peaceful cohesion (SDG 16) in the urban areas which is paramount to the urban sustainability mostly in the cities like Niamey and Maradi where urbanites are facing security challenges. The use of native tree species in the urban forestry has been highlighted to provide many services such as carbon sequestration, beauty of city, cultural services and enhancer of biodiversity conservation (SDG 14 and 15) due to the fact that local plants are habitat to the local living things. For instance, the local tree species are used as cultural services such as in manning some neighbourhoods of the cities in Niamey and Maradi. For exemple, the local name of *Faidherbia albida* is Gao in Hausa language, which is used for names of some neighbourhoods in Niamey and Maradi such as Dan Gao (which means the son of *Faidherbia albida*). This highlights the use of local tree as spatial identifier. The presence of the local trees in the schoolyards can educate the urban students about the local name of the tree species which is central to botanical education.

5 Conclusions

This study documented the taxonomy, the diversity, and the relevance of tree's existence as green infrastructure elements in the school (primary, secondary, and tertiary). Our study has characterized the structure of unforgotten urban forest types, which is a collection of trees in urban schoolyards. The study identified three school forest types in the urban educational system, which are primary school urban forest, secondary school urban forest, and tertiary urban school forest with their different structural and compositional values. Our findings highlighted that school urban forests had high structural values, which are mostly high woody species richness with myriad of ecosystem services across school types in Niamey and Maradi. The results have demonstrated the role of urban schoolyards in tree biodiversity conservation, which has to be considered in the urban forestry analysis. Our study recommends the use of multipurpose woody plant species in urban greening school initiatives for quality education. Furthermore, the study recommends a further investigation, which will look at the effects of the school urban forest structure on the students' academic performance and the allergenic potential of woody species found in urban schools. Our study has demonstrated planting trees and conserving natural forests in schoolyards is a double win for biodiversity conservation and trapping carbon. However, increasing demand for new academic buildings, parking places and other developmental processes within the schoolyards in the two cities are some menaces associated with these urban forest types. Hence, the present work can act as baseline information regarding the importance of schoolyards in tree biodiversity and carbon conservation, which can help in making appropriate management strategies for the conservation of these urban school forests. Our study complements the international efforts of proposing city green solutions as nature-based solutions to fight climate change and make healthier and sustainable urban areas. Finally, our study recommends that the school authorities incorporate multipurpose tree planting in your school's environmental plans and the use of Rainwater Harvesting Systems for the school urban forestry in two cities.

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Author contributions MS collected the data and drafted the manuscript with the supervision of CN. MS did the tree biodiversity and carbon estimation analyses. HTA conducted the regression analysis and interpreted its results. All authors contributed to drafting the article based upon their expertise and perspectives, read and approved the final manuscript before the submission to the journal.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The research was approved by the Department of Civil Engineering at Koforidua Technical University, Ghana in a letter dated 18.01.2021. All users of the questionnaires agreed for their data to be used for the purposes of research.

Consent for publication All authors give full consent for publication.

Competing interests The authors declare no competing interests.

Annex 1: List of species recorded in the schoolyards in Niamey city

No.	Number of species	Families	Food and other resources provided by the species	Primary	Secondary	Tertiary	City
1	*Adansonia digitata* L	Bombacaceae	Fruit + leaves	Yes	Yes	Yes	Niamey
2	*Albizia lebbeck* (L.) Benth	Fabaceae		Yes	Yes	Yes	Niamey
3	*Anacardium occidentale* L	Anacardiaceae	Fruit	Yes	Yes	Yes	Niamey
4	*Annona squamosa* L	Annonaceae	Fruit	Yes	Yes	Yes	Niamey
5	*Azadirachta indica* A. Juss	Meliaceae		Yes	Yes	Yes	Niamey
6	*Balanites aegyptiaca* (L.) Del	Balanitaceae	Fruit	Yes	Yes	Yes	Niamey
7	*Bauhinia rufescens* Lam	Fabaceae	Fruit (Forage)		Yes	Yes	Niamey
8	*Borassus aethiopum* Mart	Arecaceae	Fruit	Yes	Yes	Yes	Niamey
9	*Calotropis procera* (Ait.) Ait. f	Asclepiadaceae		Yes	Yes	Yes	Niamey
10	*Carica papaya* L	Caricaceae	Fruit	Yes	Yes	Yes	Niamey
11	*Casuarina equisetifolia* L	Casuarinaceae		Yes	Yes		Niamey
12	*Ceiba pentandra* (L.) Gaertn	Bombacaceae		Yes		Yes	Niamey
13	*Citrus limon* (L.) Burm. f	Rutaceae	Fruit	Yes	Yes	Yes	Niamey
14	*Crescentia cujete* L	Bignoniaceae	Fruit			Yes	Niamey
15	*Dalbergia sissoo* Roxb	Fabaceae				Yes	Niamey
16	*Delonix regia* (Boj.) Raf	Fabaceae	Fruit	Yes	Yes	Yes	Niamey
17	*Dialium guineense* Willd	Fabaceae	Fruit		Yes		Niamey
18	*Diospyros mespiliformis* Hochst. ex A. Rich	Ebenaceae	Fruit		Yes	Yes	Niamey
19	*Eucalyptus camaldulensis* Dehnh	Myrtaceae		Yes	Yes	Yes	Niamey
20	*Euphorbia kamerunica* Pax	Euphorbiaceae				Yes	Niamey
21	*Faidherbia albida* (Del.) Chev	Fabaceae	Fruit (Forage)	Yes	Yes	Yes	Niamey
22	*Ficus platyphylla* Del	Moraceae	Fruit	Yes	Yes		Niamey
23	*Vitis vinifera* L	Vitaceae	Fruit	Yes			Niamey
24	*Fragaria vesca* L	Rosaceae	Fruit	Yes			Niamey
25	*Gmelina arborea* Roxb	Verbenaceae		Yes	Yes	Yes	Niamey
26	*Grewia villosa* Willd	Tilliaceae	Fruit			Yes	Niamey
27	*Hyphaene thebaica* (L.) Mart	Arecaceae	Fruit	Yes	Yes	Yes	Niamey
28	*Jatropha curcas* L	Euphorbiaceae		Yes			Niamey
29	*Jatropha gossypiifolia* L	Euphorbiaceae	Leaves	Yes			Niamey
30	*Khaya senegalensis* (Desr.) A. Juss	Meliaceae		Yes	Yes	Yes	Niamey
31	*Kigelia africana* (Lam.) Benth	Bignoniaceae	Fruit	Yes		Yes	Niamey
32	*Lannea microcarpa* Engl. & K. Krause	Anacardiaceae	Fruit			Yes	Niamey

No.	Number of species	Families	Food and other resources provided by the species	Primary	Secondary	Tertiary	City
33	*Lawsonia inermis* L	Lythraceae	Leaves used for henna	Yes		Yes	Niamey
34	*Maerua crassifolia* Forssk	Capparaceae	Fruit (Forage)			Yes	Niamey
35	*Mangifera indica* L	Anacardiaceae	Fruit	Yes	Yes	Yes	Niamey
36	*Manihot esculenta* Crantz	Euphorbiaceae	Leaves + root	Yes			Niamey
37	*Moringa oleifera* Lam	Moringaceae	Fruit + Leaves	Yes		Yes	Niamey
38	*Musa acuminata* Colla	Musaceae	Fruit	Yes	Yes	Yes	Niamey
39	*Nerium oleander* L	Apocynaceae		Yes			Niamey
40	*Phoenix dactylifera* L	Arecaceae	Fruit	Yes	Yes	Yes	Niamey
41	*Phyllostachys edulis* (Carrière) J.Houz	Poaceae				Yes	Niamey
42	*Piliostigma reticulatum* (DC.) Hochst	Fabaceae	Fruit		Yes	Yes	Niamey
43	*Pithecellobium dulce* (Roxb.) Benth	Fabaceae				Yes	Niamey
44	*Prosopis juliflora* (Sw.) DC	Fabaceae	Fruit	Yes		Yes	Niamey
45	*Psidium guajava* L	Myrtaceae	Fruit			Yes	Niamey
46	*Punica granatum* L	Punicaceae	Fruit	Yes			Niamey
47	*Sclerocarya birrea* (A. Rich.) Hochst	Anacardiaceae	Fruit			Yes	Niamey
48	*Senegalia senegal* (L.) Britton	Fabaceae				Yes	Niamey
49	*Senna siamea* (Lam.) Irwin & Barneby	Fabaceae		Yes	Yes	Yes	Niamey
50	*Tamarindus indica* L	Fabaceae	Fruit + leaves	Yes	Yes	Yes	Niamey
51	*Tectona grandis* L. f	Verbenaceae				Yes	Niamey
52	*Terminalia catappa* L	Combretaceae	Fruit		Yes	Yes	Niamey
53	*Terminalia mantaly* H. Perrier	Combretaceae		Yes	Yes	Yes	Niamey
54	*Thevetia neriifolia* Juss	Apocynaceae				Yes	Niamey
55	*Thuja occidentalis* L	Cupressaceae				Yes	Niamey
56	*Vachellia nilotica* subsp. *nilotica*	Fabaceae	Fruit	Yes	Yes	Yes	Niamey
57	*Vachellia seyal* (Delile) P.J.H.Hurter	Fabaceae	Gum	Yes	Yes	Yes	Niamey
58	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Fabaceae	Fruit (Forage)			Yes	Niamey
59	*Vitellaria paradoxa* Gaertn. f	Sapotaceae	Fruit			Yes	Niamey
60	*Vitex doniana* Sweet	Verbenaceae	Fruit	Yes		Yes	Niamey
61	*Ziziphus mauritiana* Lam	Rhamnaceae	Fruit	Yes	Yes	Yes	Niamey
62	*Ziziphus spina-christi* (L.) Desf	Rhamnaceae	Fruit			Yes	Niamey

Annex 2: List of species recorded in the schoolyards in Maradi city

No.	Number of species	Families	Food and other resources provided by the species	Primary	Secondary	Tertiary	City
1	*Lannea microcarpa* Engl. & K. Krause	Anacardiaceae	Fruit			Yes	Maradi
2	*Sclerocarya birrea* (A. Rich.) Hochst	Anacardiaceae	Fruit			Yes	Maradi
3	*Anacardium occidentale* L	Anacardiaceae	Fruit	Yes		Yes	Maradi
4	*Mangifera indica* L	Anacardiaceae	Fruit	Yes	Yes	Yes	Maradi
5	*Annona senegalensis* Pers	Annonaceae	Fruit			Yes	Maradi
6	*Annona squamosa* L	Annonaceae	Fruit		Yes	Yes	Maradi
7	*Polyalthia longifolia*. Sonn	Annonaceae				Yes	Maradi
8	*Borassus aethiopum* Mart	Arecaceae	Fruit	Yes	Yes	Yes	Maradi
9	*Hyphaene thebaica* (L.) Mart	Arecaceae	Fruit		Yes	Yes	Maradi
10	*Phoenix dactylifera* L	Arecaceae	Fruit	Yes	Yes	Yes	Maradi
11	*Calotropis procera* (Ait.) Ait. f	Asclepiadaceae		Yes	Yes	Yes	Maradi

No.	Number of species	Families	Food and other resources provided by the species	Primary	Secondary	Tertiary	City
12	*Euphorbia balsamifera* Ait	Euphorbiaceae			Yes	Yes	Maradi
13	*Leptadenia hastata* (Pers.) Decne	Asclepiadaceae	Fruit + leaves			Yes	Maradi
14	*Leptadenia pyrotechnica* (Forssk.) Decne	Asclepiadaceae				Yes	Maradi
15	*Saba senegalensis* (A. DC.) Pichon	Asclepiadaceae	Fruit			Yes	Maradi
16	*Vernonia amygdalina* Del	Asteraceae	Leaves			Yes	Maradi
17	*Balanites aegyptiaca* L	Balanitaceae	Fruit	Yes	Yes	Yes	Maradi
18	*Kigelia africana* (Lam.) Benth	Bignoniaceae	Fruit			Yes	Maradi
19	*Stereospermum kunthianum* Cham	Bignoniaceae				Yes	Maradi
20	*Newbouldia laevis* (P. Beauv.) Seem	Bignoniaceae				Yes	Maradi
21	*Adansonia digitata* L	Bombacaceae	Fruit + leaves	Yes	Yes	Yes	Maradi
22	*Bombax costatum* Pellegr. & Vuillet	Bombacaceae				Yes	Maradi
23	*Ceiba pentandra* (L.) Gaertn	Bombacaceae				Yes	Maradi
24	*Boswellia papyrifera* (Del.) A. Rich	Burseraceae				Yes	Maradi
25	*Commiphora africana* (A. Rich.) Engl	Burseraceae	Fruit (Forage)			Yes	Maradi
26	Cactus Sp	Cactaceae		Yes			Maradi
27	*Boscia salicifolia* Oliv	Capparaceae				Yes	Maradi
28	*Crateva adansonii* DC	Capparaceae	Fruit			Yes	Maradi
29	*Maerua angolensis* DC	Capparaceae				Yes	Maradi
30	*Maerua crassifolia* Forssk	Capparaceae	Fruit (forage)			Yes	Maradi
31	*Carica papaya* L	Caricaceae	Fruit	Yes	Yes	Yes	Maradi
32	*Casuariana equisefolia* Forst	Casuarianaceae				Yes	Maradi
33	*Combretum glutinosum* Perr. ex DC	Combretaceae				Yes	Maradi
34	*Guiera senegalensis* J.F. Gmel	Combretaceae				Yes	Maradi
35	*Terminalia avicennioides* Guill. & Perr	Combretaceae				Yes	Maradi
36	*Terminalia catappa* L	Combretaceae	Fruit	Yes	Yes	Yes	Maradi
37	*Terminalia mantaly* H. Perrier	Combretaceae		Yes	Yes	Yes	Maradi
38	*Diospyros mespiliformis* Hochst. ex A. Rich	Ebenaceae	Fruit			Yes	Maradi
39	*Manihot esculenta* Crantz	Euphorbiaceae	Root + leaves	Yes	Yes	Yes	Maradi
40	Ricinus communis L	Euphorbiaceae		Yes	Yes		Maradi
41	*Jatropha curcas* L	Euphorbiaceae		Yes		Yes	Maradi
42	*Acacia senegal* (L.) Willd	Fabaceae	Gum	Yes	Yes	Yes	Maradi
43	*Albizia chevalieri* Harms	Fabaceae				Yes	Maradi
44	*Albizia lebbeck* (L.) Benth	Fabaceae		Yes		Yes	Maradi
45	*Bauhinia rufescens* Lam	Fabaceae	Fruit (forage)	Yes		Yes	Maradi
46	*Delonix regia* (Boj.) Raf	Fabaceae	Fruit	Yes			Maradi
47	*Detarium microcarpum* Guill. & Perr	Fabaceae	Fruit			Yes	Maradi
48	*Faidherbia albida* (Del.) Chev	Fabaceae	Fruit (forage)	Yes	Yes	Yes	Maradi
49	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don	Fabaceae	Fruit	Yes		Yes	Maradi
50	*Parkinsonia aculeata* L	Fabaceae	Fruit			Yes	Maradi
51	*Piliostigma reticulatum* (DC.) Hochst	Fabaceae	Fruit		Yes	Yes	Maradi
52	*Prosopis africana* (Guill. & Perr.) Taub	Fabaceae				Yes	Maradi
53	*Prosopis juliflora* (Sw.) DC	Fabaceae	Fruit	Yes	Yes	Yes	Maradi
54	*Pterocarpus erinaceus* Poir	Fabaceae				Yes	Maradi
55	*Senna siamea* (Lam.) Irwin & Barneby	Fabaceae			Yes	Yes	Maradi
56	*Tamarindus indica* L	Fabaceae	Fruit + leaves	Yes		Yes	Maradi
57	*Vachellia nilotica* subsp. *nilotica*	Fabaceae	Fruit	Yes	Yes	Yes	Maradi
58	*Vachellia seyal* (Delile) P.J.H.Hurter	Fabaceae	Gum			Yes	Maradi
59	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Fabaceae	Fruit (Forage)		Yes		Maradi
60	*Lawsonia inermis* L	Lythraceae	Leaves		Yes		Maradi

No.	Number of species	Families	Food and other resources provided by the species	Primary	Secondary	Tertiary	City
61	*Punica granatum* L	Punicaceae	Fruit			Yes	Maradi
62	Gossipuim *herbaceum* L	Malvaceae	Fruit	Yes		Yes	Maradi
63	*Jatropha gossypiifolia* L	Malvaceae	Leaves			Yes	Maradi
64	*Azadirachta indica* A. Juss	Meliaceae		Yes	Yes	Yes	Maradi
65	*Khaya senegalensis* (Desr.) A. Juss	Meliaceae				Yes	Maradi
66	*Melia azedarach* L	Meliaceae				Yes	Maradi
67	*Ficus platyphylla* Del	Moraceae	Fruit	Yes		Yes	Maradi
68	*Ficus sycomorus* ssp. *gnaphalocarpa* (Miq.) C.C. Berg	Moraceae	Fruit	Yes		Yes	Maradi
69	*Ficus thonningii* Blume	Moraceae		Yes		Yes	Maradi
70	*Moringa oleifera* Lam	Moringaceae	Fruit + leaves	Yes	Yes	Yes	Maradi
71	*Moringa stenopetala* Baker f	Moringaceae	Fruit + leaves	Yes		Yes	Maradi
72	*Musa acuminata* Colla	Musaceae	Fruit	Yes	Yes	Yes	Maradi
73	*Eucalyptus camaldulensis* Dehnh	Myrtaceae		Yes	Yes	Yes	Maradi
74	*Psidium guajava* L	Myrtaceae	Fruit	Yes		Yes	Maradi
75	*Syzygium guineense* (Willd.) DC	Myrtaceae			Yes	Yes	Maradi
76	*Ziziphus mauritiana* Lam	Rhamnaceae	Fruit	Yes	Yes	Yes	Maradi
77	*Ziziphus spina-christi* (L.) Desf	Rhamnaceae	Fruit			Yes	Maradi
78	*Citrus limon* (L.) Burm. f	Rutaceae	Fruit	Yes	Yes	Yes	Maradi
79	*Citrus sinensis* (L.) Osbeck	Rutaceae	Fruit			Yes	Maradi
80	*Blighia sapida* Koenig	Sapindaceae	Fruit			Yes	Maradi
81	*Vitex doniana* Sweet	Verbenaceae	Fruit			Yes	Maradi
82	*Vitex simplicifolia* Oliv	Verbenaceae	Fruit			Yes	Maradi

Yes means the presence of the species was recorded in the given school types in Niamey and Maradi cities.

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