



Quantification of Phytomass and Carbon Storage of Woody Vegetation in Logone Valley (Far North, Cameroon)

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Abstract: The degradation of the vegetation through anthropogenic or natural phenomena leads to the release of more carbon into the atmosphere than that occurs during photosynthesis. This constitutes a great burden to world. In order to assess the contribution of the Logone Valley vegetation to climate change mitigation, the present study aims to estimate the phytomass and carbon stock. Woody carbon was quantified using the non-destructive Brown equation in 500 x 20 m transects for each vegetation formation. The species and families with the highest phytomass were *Balanites aegyptiaca* (3 16.35 t/ha) and Balanitaceae family (316.35 t/ha). The quantities of carbon sequestered in the plant formations were 373.06 tC/ha in the woody savannah, 237.23 tC/ha in the shrub savannah, 45.82 tC/ha in the grassy savannah and 71.31 tC/ha in the cultivated zone. Hence, this study add knowledge of the contribution of each plant formation to carbon sequestration. Actions to strengthen the woody potential are required to minimise the long-term degradation of this site and to make it a sustainable source of carbon sequestration.

Keywords: Phytomass, Carbon stock, Climate change, Logone Valley, Cameroon

Woody flora play a crucial role in the well-being of the world population by providing various goods and services, including biodiversity conservation, economic climate regulation, air and water purification and recreation (Ezekiel and Bhoke 2024). It also produces fruits, seeds, tubers, flowers, sap and other edible products that are used for human and animal consumption, traditional medicine, handicrafts and to heat timber, moreover, contributes directly to the diet (Popoola 2001). Despite its importance, the management of the woody vegetation is highly leading to degradation. However, the degradation of the vegetation through anthropogenic or natural phenomena, leads to the release of more carbon into the atmosphere than that occurs during photosynthesis (Brown 2002). The deforestation disrupts the natural carbon cycle by reducing greenhouse gas emissions (Swarnkar et al., 2025). The vegetation plays a key role in mitigating climate change by absorbing and storing atmospheric carbon (Arianasari et al., 2021). The loss of plant cover reduces carbon reserves, resulting in the accumulation of carbon in the atmosphere. The carbon absorbed by the plant is converted into organic matter and stored in the phytomass (Fadillah et al., 2023). In Cameroon, and more specifically in the Sudano-Sahelian zone, climate change, the result of deforestation and the degradation of vegetation cover is increasing at an alarming rate (Agbanou et al., 2018). Given the recognised importance of vegetation in the climate change process, this degradation is continuing

and poses a real threat to the populations living in the Logone Valley, Far North region, Cameroon. The present study seeks to quantify carbon stock in woody vegetation of the Logone Valley, addressing a critical data gap in the region. More specifically, our study aimed to assess the living above-ground and below-ground phytomass in order to deduce the quantity of sequestered carbon.

MATERIAL AND METHODS

Study area: The study area is located in Logone et Chari Sub Division from Far North Region of Cameroon between 12° North latitude, 15° East longitude. The present study was carried out in four (04) divisions namely Kousseri, Goulfey, Waza and Logone-Birni (Fig. 1). The site was chosen because of the pressure of human activities, due to the advancing desert, global warming, the drop in rainfall, the population's exposure to poverty, the anarchic and illicit exploitation of non-timber forest products and timber forest products by the population to meet their needs and the expansion of agriculture, as well as the agropastoral conflict which oppose regularly the Arabs and Musgoum tribes.

Floristic inventory: The sampling technique used to carry out the floristic inventories mentioned by Tchobsala (2011). In each subdivision, according to the orientation of the local population, we chose the place where plant formations exist with a dominance of anthropogenic activities. The experimental design is a split-plot with two factors. The first

factor is the different subdivisions (main treatments), the second factor is the types of plant formations (secondary treatments) and the transects chosen in each type of plant formation constitute the repetitions. The inventory of plant species was carried out on a transect of 10,000 m² (500m x 20m), 5 layons 4 metres wide and 500m long. In each transect, all the trees were surveyed and the following dendrometric parameters were measured for all individuals with a height of one and a half metres (1.30 m): height, crown diameter and circumference at the base of the trunk at 1.30 cm from the ground (Arbonnier 2000). Samples of species not identified in the field were taken and identified at the Plant Biology Laboratory of the University of Maroua and through the identification key for sahelian woody plants.

Floristic surveys were carried out in four (04) districts, taking into account four (04) plant formations (cultivated area, shrub savannah, tree savannah and herbaceous savannah), so that twelve (12) surveys per district with four (04) per plant formation. A total of 48 transects were placed throughout the sub division.

Quantification of carbon stock: This is carried out in the 500m x 20m transect. The diameters at breast height (1.30 m from the ground) and the heights of all the trees in the transects are measured using a tape measure and a graduated pole respectively. This phytomass is estimated by the indirect method, using a mathematical model that takes into account the diameter at breast height and the height of the trees. Brown's (1997) and Tchobsala (2014), mentod was used. Coefficient of determination is highly significant (R²= 0.987). It was also developed in the Sahelian climate.

$$Ba = \exp [-3.114 + 0.9719 \ln (D2H)]$$

where Ba is the above-ground phytomass of the tree in kg,

DBH is the diameter at breast height in m and H is the height of the tree in m.

Root phytomass: Measuring roots is difficult and expensive, but root phytomass can be estimated indirectly and accurately using an equation used by Cairns et al. (1997).

$$Br (kg) = \exp [-1.0587 + 0.8836 \times \ln (Ba)]$$

Where Br = root phytomass, Bt= total phytomass above ground from the total above-ground phytomass of each type of plant formation, the root phytomass was calculated. It was also expressed in tonnes per hectare.

Estimating the amount of carbon in above-ground phytomass: The carbon in the various components is generally assessed by evaluating the phytomass present in the transects. Following the recommendations of the IPCC (2003), the majority of studies use an average carbon concentration value of 50% for vegetation when more precise data is not available. This consists of assessing the quantity of carbon from the phytomass present in several components (above and below ground). The carbon quantities were obtained as per method of Ibrahima et al. (2002) and Tchobsala et al. (2014).

$$QCv = Ba \times Cv,$$

Where: QCv = vegetation carbon (t/ha), Ba = above-ground phytomass (t/ha), Cv = vegetation carbon concentration (0.5)

Estimating the amount of carbon in root phytomass: To determine the final carbon values, the root phytomass below the soil surface was added. The amount of carbon is obtained as per Ibrahima et al. (2002) and Saïdou et al. (2012).

$$QCr = Br \times Cv$$

With: QCr = root carbon (tC/ha), Br = root biomass (t/ha), Cv = vegetation carbon concentration (0.5)

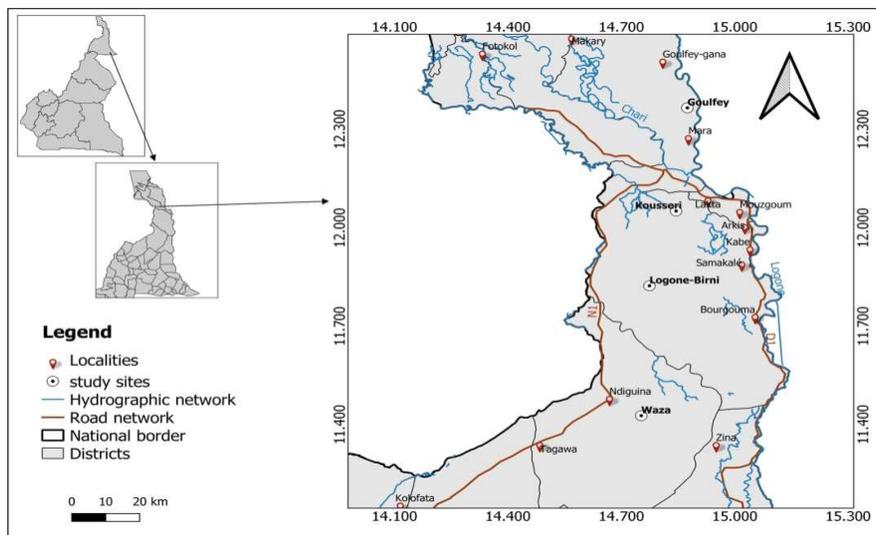


Fig. 1. Study site

Estimation of the total quantity of carbon in each type of plant formation: This was simply obtained by summing the quantities of carbon in all the components (aerial and root) of each type of plant formation. In other words, it is the sum of aerial carbon and root carbon.

$$QC \text{ total} = QC \text{ arien} + QC \text{ racinaire}$$

Calculating CO₂ emissions

The quantity of carbon dioxide (CO₂) that is emitted into the atmosphere was calculated as per Woods Hole Research Center (2011) in Mali.

$$C02 = AGBP * PMC02 / PMC \text{ where:}$$

AGBP is the total above-ground biomass of the sample plot;

PWC02 is the molecular weight of carbon dioxide (44);

PMC is the molecular weight of carbon (12).

Statistical analysis of the data: The data collected during this study were recorded in an Excel sheet and analysed using i-Xlstat where anova one-way was used to bring out the difference between plant formations and boroughs.

RESULTS AND DISCUSSION

Total biomass by plant formations and sites: Phytomass increases with higher DBH and species density. This wooded savannah has the highest phytomass production with 234.78 t, 207.19, 177.35 and 174.47 t/ha respectively in Waza, Goulfey, Kousseri, and Logone-Birni (Table 1). The lowest phytomass yields were in the grassy savannah (51.30 and 21.45 t/ha) and the cultivated zone (39.65, 33.68, 27.78 and 17.51 t/ha) in the subdivisions of Waza, Goulfey, Kousseri and Logone-Birni respectively.

Phytomass distribution by species: The estimated phytomass of each species as a function of the diameter at breast height and the density of the species in the study area (Table 2). The species with the highest phytomass are *Sclerocarya birrea* (75.20 t/ha) followed by *Combretum glutinosum* (61.63 t/ha) in the Waza site. In the Logone-Birni district, *Acacia nilotica* (82.87 t/ha) followed by *Balanites aegyptiaca* (64.64 t/ha). The species *Balanites aegyptiaca* (104.82 t/ha) and *Acacia seyal* (61.82 t/ha) have a high phytomass rate in the Kousseri site. In the Goulfey area, *Acacia seyal* (96.60 t/ha) and *Balanites aegyptiaca* (95.63 t/ha) sequester more phytomass than the other species on the site. The species *Balanites aegyptiaca* (316.35 t/ha), followed by *Acacia nilotica* (227.85 t/ha) and *Acacia seyal* (224.38 t/ha) sequester more phytomass than the other species on the site.

Contribution to phytomass by plant family : Mimosaceae families (187.93, 172.06 and 147.18 t/ha), followed by the Balanitaceae family (95.63, 64.64, and 104.43 t/ha) in the arrondissements of Goulfey, Logone-Birni and Kousseri respectively; In the arrondissement of Waza, the

Combretaceae (94.99 t/ha) and Anacardiaceae (75.20 t/ha) families had the highest phytomass at this site. For the site as a whole, the Mimosaceae family (577.56 t/ha), followed by the Balanitaceae (316.35 t/ha) and Rhamnaceae (108.96 t/ha) have more phytomass than the other families on the site.

Carbon stock estimation: The largest carbon stocks per hectare are located in wooded savannahs with carbon stocks of 110.34, 97.37, 82.35 and 82.00 tC/ha respectively in Waza, Goulfey, Kousseri and Logone-Birni; followed by shrub savannas at 65.43 tC/ha in Waza, 62.91 tC/ha in Goulfey, 56.37 tC/ha in Logone-Birni and 52.52 tC/ha in Kousseri. Low carbon sequestration in the cultivation zone of 23.8 tC/ha in Logone-Birni, 18.63 tC/ha in Waza, 15.83 tC/ha in Goulfey and 13.05 tC/ha in Kousseri (Table 4).

Potential CO₂ equivalent: This table shows that wooded savannahs release the greatest quantities of carbon into the environment, maximum 404.60 tCO₂/ha in Waza, and minimum 20.50 tCO₂/ha to Logone-Birni (Table 5).

The phytomass results obtained from the sites and plant formations are similar to those obtained in the peri-urban savannahs of Ngaoundéré by Tchobsala et al. (2014), who showed that tree savannahs sequester much more carbon than other plant formations. The low phytomass production in the grassy savannah can be justified by the fact that it is devoid of woody species, and in the cultivated zone this can be explained by the strong human action observed in these formations. Uncontrolled felling by the local population for a variety of reasons (fodder, firewood, food, NTFPs) leads to a reduction in phytomass. The low phytomass in the cultivation zone is due to low densities, which can be explained by the spacing of trees chosen by local people for cultivation. Phytomass production at different sites shows that Waza has the highest phytomass. This phytomass performance in this locality is justified by the existence of a park consisting of denser vegetation where anthropogenic activity is controlled. These results do not corroborate those of Zapfack (2005) in the Yaoundé forest region, where the cultivated areas showed low phytomass production (1.91 t/ha). This

Table 1. Phytomass in the different plant formations and sites (t/ha)

Arrondissement/PF	SA	SAR	SH	ZC
Waza	234.78 ^b	139.22 ^h	51.30 ^e	39.65 ^{de}
Log-Birni	174.47 ⁱ	119.94 ^g	11.90 ^a	17.51 ^{ab}
Goulfey	207.19 ⁱ	133.85 ^{gh}	21.45 ^{abc}	3.68 ^{cd}
Kousseri	177.35 ⁱ	111.72 ^f	12.87 ^a	27.78 ^{bcd}

Numbers with the same letters are not significantly different at the 5% level. P= 0.05, n= 03.

SA= Wooded Savannah, SAR= Shrubby savannah, SH= Grassy savannah, ZC= Growing area, PF= Plant Formation

Table 2. Estimated species phytomass (t/ha)

Names of species	Waza	Log-Birni	Kousseri	Goulfey	PT
<i>Acacia albida</i>	9.55	15.04	2.75	9.94	37.28
<i>Acacia ataxacantha</i>	/	0.41	/	/	0.41
<i>Acacia gerrardii</i>	/	0.55	/	/	0.55
<i>Acacia hockii</i>	0.59	3.95	6.14	/	10.68
<i>Acacia nilotica</i>	24.62	82.87	57.94	62.42	227.85
<i>Acacia polyacantha</i>	0.49	2.92	2.13	/	5.54
<i>Acacia senegal</i>	/	1,68	/	/	1,68
<i>Acacia seyal</i>	23.37	42.58	61.82	96.60	224.38
<i>Acacia sieberiana</i>	11.23	22.07	16.39	18.96	68.66
<i>Annona senegalensis</i>	1.18	/	/	/	1.18
<i>Anogeissus leiocarpus</i>	5.35	/	0.71	/	6.06
<i>Azadirachta indica</i>	4.87	16.56	6.10	1.13	28.66
<i>Balanites aegyptiaca</i>	51.65	64.64	104.43	95.63	316.35
<i>Bauhinia rufescens</i>	2.99	3.10	2.98	8.30	17.37
<i>Borassus aethiopum</i>	/	1.40	0,4	/	1.84
<i>Boscia angustifolia</i>	5.66	1.77	20.04	42.74	70.21
<i>Calotropis procera</i>	47.78	6.73	8.87	18.08	81.45
<i>Celtis integrigolia</i>	2.32	/	/	/	2.32
<i>Combretum aculeatum</i>	/	0.95	/	0.35	1.30
<i>Combretum adenogonium</i>	0.87	/	/	/	0.87
<i>Combretum glutinosum</i>	61.63	/	/	/	61.63
<i>Commiphora africana</i>	0.86	/	/	/	0.86
<i>Dalbergia melanoxylon</i>	1.35	0.32	/	/	1.67
<i>Dichrostachys cinerea</i>	0.54	/	/	/	0.54
<i>Diospyros mespiliformis</i>	/	2.44	/	/	2.44
<i>Gardenia aqualla</i>	0.73	/	/	/	0.73
<i>Guiera senegalensis</i>	27.14	/	/	/	27.14
<i>Hyphaene thebaica</i>	/	12.35	13.97	/	26.32
<i>Khaya senegalensis</i>	/	8.27	/	/	8.27
<i>Mangifera indica</i>	/	1.04	/	/	1.04
<i>Mitragyna inermis</i>	8.68	/	3.97	7.92	20.57
<i>Moringa oleifera</i>	/	/	2.95	/	2.95
<i>Parkinsonia aculeata</i>	/	/	0.99	/	0.99
<i>Phoenix dactylifera</i>	/	/	2.31	/	2.31
<i>Piliostigma thonningii</i>	10.13	5.51	/	/	15.65
<i>Sclerocarya birrea</i>	75.20	/	/	/	75.20
<i>Stereospermum kunthianum</i>	4.77	0.41	/	/	5.17
<i>Strychnos innocua</i>	/	/	0.70	/	0.70
<i>Tamarindus indica</i>	5.35	1.89	2.95	8.63	18.82
<i>Ziziphus mauritiana</i>	47.97	21.65	8.65	25.46	103.73
<i>Ziziphus mucronata</i>	/	2.74	2.49	/	5.24

PT= Total Phytomass, /= No data

difference is due to the ecological environments, the survey methodology used and the density of species in the different sites and plant formations. The statistical test showed a highly significant difference between the biomass values of the different plant formations and sites at the 5% threshold ($P < 0.001$).

With regard to the biomass of the species, those that have a significant quantity of biomass, have a strong power of very rapid regeneration, their densities are high and have a characteristic affinity for the zone and are recognised in the region for their multiple use value. These results are superior to those obtained by Il-Mataï *et al.* (2020) on vegetation dynamics in reforestation sites in the Sudan-Sahelian zone of Cameroon, where they found the highest values of total phytomass of species observed in *Balanites aegyptiaca* (108.64 t/ha), *Azadirachta indica* (121.02 t/ha) and *Acacia nilotica* (95.17 t/ha). The lower phytomass observed may be explained by the rarity of certain species in the area.

The large amount of phytomass following certain families can be explained by the fact that these families have a very rapid capacity to adapt in the study area. These results differ from those of Aboubakar, (2022) who found high phytomasses of Combretaceae in the southern part of the Benoué in northern Cameroon. This difference is due to the density of species in the different sites and plant formations,

the methodology applied and anthropic action.

The carbon stock is proportional to the quantity of phytomass produced. These differences in results are

Table 4. Quantity of carbon sequestered by plant formations (tc/ha)

Sites/PF	SA	SAR	SH	ZC
Waza	110.348 ^k	65.43 ^h	24.11 ^e	18.63 ^{de}
Logone-Birni	82.00 ⁱ	56.37 ^g	5.59 ^a	23.8 ^{ab}
Goulfey	97.37 ^j	62.9 ^h	10.08 ^{abc}	15.83 ^{cd}
Kousseri	83.35 ⁱ	52.52 ^f	6.04 ^a	13.05 ^{bcd}

Numbers with the same letters are not significantly different at the 5% level. $P = 0.05$, $n = 03$.

SA= Wooded Savannah, SAR= Shrubby savannah, SH= Grassy savannah, ZC= Growing area and PF = Plant formations.

Table 5. Potential CO₂ equivalent by plant formations and site (tCO₂/ha)

Sites/PF	SA	SAR	SH	ZC
Waza	404.60 ^t	239.92 ^h	88.41 ^e	68.33 ^{de}
Logone-Birni	300.67 ^j	206.70 ^g	20.50 ^a	30.18 ^{ab}
Goulfey	357.05 ⁱ	230.66 ^{gh}	36.96 ^{abc}	58.04 ^{abc}
Kousseri	305.63 ^j	192.53 ^f	22.18 ^a	47.87 ^{bcd}

Numbers with the same letters are not significantly different at the 5% level. $P = 0.05$, $n = 03$.

SA= Wooded Savannah, SAR= Shrubby savannah, SH= Grassy savannah, ZC= Growing area and PF = Plant formations.

Table 3. Estimated phytomass of families

Families	Waza	Log-Birni	Kousseri	Goulfey	PT
Anacardiaceae	75.20	1.04	/	/	76.24
Annonaceae	1.18	/	/	/	1.18
Arecaceae	/	13.75	16.71	/	30.46
Asclepiadaceae	47.78	6.73	8.87	18.08	81.45
Balanitaceae	51.65	64.64	104.43	95.63	316.35
Bignoniaceae	4.77	/	/	/	5.17
Burseraceae	0.86	/	/	/	0.86
Caesalpiniaceae	18.48	10.50	6.92	16.93	52.83
Capparaceae	5.66	1.77	20.04	42.74	70.21
Combretaceae	94.99	0.95	0.71	0.35	96.98
Ebenaceae	/	2.44	/	/	2.44
Fabaceae	1.35	0.32	/	/	1.67
Loganiaceae	/	/	0.70	/	0.70
Meliaceae	4.87	24.83	6.10	1.13	36.93
Mimosaceae	70.39	172.06	147.18	187.93	577.56
Moringaceae	/	/	2.95	/	2.95
Rhamnaceae	47.97	24.39	11.14	25.46	108.96
Rubiaceae	9.40	/	3.97	7.92	21.29
Ulmaceae	2.32	/	/	/	2.32

PB= Total phytomass, /= No data

justified by the fact that the capacity of a savannah to store carbon depends mainly on the species composition of the flora and the diameter classes of the trees present. The methodological approach for estimating carbon stock also differs from one study to another. These results are similar to those of Tsoumou et al. (2016) in the Dimonika model forest in the south-east of the Republic of Congo, where they found a value of 129 tC/ha. The statistical test shows that there is a highly significant difference between the sequestered carbon values of the different plant formations and sites at the 5% threshold ($P < 0.001$).

Potential CO₂ equivalent in the wooded savannah can be explained by the high phytomass production observed in wooded savannahs. These results differ from those obtained by Firdaus et al. (2010), who found a similar average carbon rate between formations. The differences observed between the studies can be explained by the varying climatic conditions and anthropogenic activities between the study areas, on the one hand, and by the existence of a park at Waza, a reserve at Kousseri and a protected area at Goulfey, on the other. The statistical test showed a highly significant difference between the values of the different plant formations and the sites at the 5% threshold ($P < 0.001$).

CONCLUSION

The present study showed that the phytomass per hectare by species varied between sites and the highest was *Sclerocarya birrea* (Waza), *Acacia nilotica*, (Logone-Birni), *Balanites aegyptiaca* (Kousseri) and *Acacia seyal* (Goulfey) and also depends on the plant formations while, the tree savannah had the highest phytomass. The greatest amount of carbon sequestration was recorded in the tree savannah. These differences were also significant. The results showed that the tree savannah has a higher carbon sequestration potential than the other plant formations. The results of these findings can serve as a baseline for possible future payments for ecosystem services. Based on studies it is recommended to avoid late fire, limit abusive cutting of fresh wood, Encourage local populations to reforest with endogenous species, promote improved stoves and other energy sources to reduce demand for wood.

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