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# Predicted Aboveground Vegetation Carbon Stocks in the Diouroup and Ndiago Communes, Senegal

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**Abstract**

The MBOW et al. (2013)'s predictive non-destructive-allometric equation accuracy allowed us to find Above-Ground vegetation Carbon stocks in the communes of Diouroup and Ndiago. The great variation in the Carbon Accumulation Levels is due to principally the soil salt in Diouroup and the vegetation clearance in Ndiago. We used a systematic stratified inventory to assess the vegetation floristic composition and the dendrometric parameters. The Adapted Endogenous Allometric Equation, that is the MBOW et al. (2013)'s one underwent, to be tested, a multiple linear regression using other tropical allometric equation models. We also developed a new parameter, the Local carbon Storage Performance Index, to compare species Carbon storage performance. The data statistical analyses and the multiple linear regression confirm the consistency of the MBOW et al. (2013)'s equation use. The great Carbon density variation allows the following results in the different strata mean values: 2.21 ± 0.00027 tC.ha-1 (Diouroup shrub); 38.7 ± 0.0046 tC.ha-1 (Diouroup tree); 8.53 ± 0.001 tC.ha-1 (Ndiago shrub); 16.2 ± 0.0019 tC.ha-1 (Ndiago tree). Whatmore, generally the Ndiago's vegetation stores Carbon 8 times more than the Diouroup's. These Carbon differences are attributed to soil salt and clearance. Despite this, the Local carbon Storage Performance Index analysis designates Balanites aegyptiaca, Combretum glutinosum and Faidherbia albida as the most performant species in both communes, which are recommended for future reforestations.

**Keywords:** Allometry, predicted biomass, predicted carbon stocks, Senegal, tree diameter, vegetation diversity, vegetation structure, West Africa

## Introduction

Climate change mitigation is often based on Above-Ground vegetation Carbon (AGC) storage. This first requires to know the baseline Carbon (C) stock potential. Contrary to the foresters' former volume estimation, the new approach uses allometric equations that take into account the whole plant Biomass (B) or C and not only the log's one as in the past (MBOW, 2009). For instance, more than one billion dry tonnes of wood are annually used by human beings for firewood, essentially comprising branches (WEST P., 2015). It's necessary to take into account this part in the global C balance. There are two ways to assess AGC: the destructive method (that destroys sample plants) and the non-destructive method. Under similar ecobiogeographical conditions, a previous area A destructive-allometric equation can be used as current area B non-destructive-allometric equation. The hugest challenge in any Carbon Stocks prediction estimations is the accuracy of results. To address it, in the case of a non-destructive-allometric equation use, one must prefer the endogenous (inside-country-made or native destructive) rather than the exogenous (foreign-made destructive) allometric equation (Jagodzinski, 2020; Kauffman, 2020; MBOW, 2009). Whatmore, recently, satellite imagery exploitation helps a lot with the improvement of the C stocks' classification, stratification, space analysis, etc. and in accuracy (Suratman, 2022). Up until now, AGC has been assessed in various vegetation types (BASTIAS, et al., 2021; Derdouri, Wang, Murayama, & Osaragi, 2023; Liu, Zhang, Lan, Cui, & Li, 2025; Sasmito, 2020), in different continents (Pearson, Brown, & Casarim, 2014; Suratman, 2022), in above-ground and below-ground levels (Omali & Akpata, 2025). The research purposes range from academic and cognitive (Pearson, Brown Sandra L., & Birdsey, 2007; Pearson, Brown, & Casarim, 2014), to agroecological or C credits (Brown, 2004; Liu, Zhang, Lan, Cui, & Li, 2025; Mbow, Verstraete, Sambou, Diaw, & Neufeldt, 2013; Pearson, Brown, & Casarim, 2014; Sambou, 2017).

To the local scale, we run this study in two communes, Diouroup and Ndiago, belonging to a greater space named the Groundnut Basin, in West-central Senegal. This area is traditionally devoted to the agriculture of principally groundnut but also, bean, maize, millet, sorghum, etc. Diouroup and Ndiago are respectively more subject to salinisation by the expansion of tannes, that are saline soils (Lebigre & Marius, 1984) and the vegetation clearance.

While many previous studies focus on protected reserves, classified or non-classified vegetations, this topic deals with the predicted AGC stocks of two atypic areas. Diouroup and Ndiago correspond to localities where live poor populations whose survival and financial incomes depend principally on agriculture and logging activities inside the non-classified vegetation. Besides, the presence of salt in Diouroup accentuates the degradation of the agricultural soil quality. All these factors contribute to increase deforestation and forest degradation in the Land Use, Land-Use Change, and Forestry (LULUCF) activities which are reported to be « responsible for about 25% of all greenhouse gas emissions » in the world (Sharma, Chand, Rai, & Prasad, 2017). We used in this study the Mbow, *et al., (2013)*'s model as a non-allometric equation to compute the AGC.

The main aim of this study is to assess the predicted AGC and its variations inside the different Accumulation Levels (AL), *i.e.* the vegetation strata of Diouroup and Ndiago. To be more precise, we compared the distribution of Diouroup and Ndiago Biomass stocks after having statistically tested Mbow *et al. (2013)* model ; we also intended to show the impact of soil salt and of the vegetation clearing and logging that are the Land Use, Land Use Change and Forestry (LULUCF) respectively in Diouroup and in Ndiago Biomass variability; and finally, we developed the Local carbon

Storage Performance Index (LSPI) to classify the Diouroup and Ndiago species C storage performance.

The guiding hypothesis of this study is that the overall spatial AGC stock densities decrease because the smaller Diameters at breast height (Dbh) expose the younger vegetation individuals to higher impacts of soil salt and LULUCF.

## Material and Method

### Study areas

Our two study communes Diouroup and Ndiago are just 49 Km apart. Then, they share the same geographic regional vector. Indeed, except the terrain elevation lower in Diouroup (1 to 6 m) than in Ndiago (16 to 39 m), both communes share the same Sudano-sahelian climatic zone (DIOP, et al., 2023; GERAD, 2010; LY, 2009; Service Régional de la Statistique et de la Démographie de Fatick, 2021; SOW & BATHIERY, 2022). They also are covered by the same dominant unweathered ferruginous soils common to the Groundnut Basin (ANSD, 2023) and influenced by the same geological detrital deposits from the Secondary and Tertiary periods, covered by the Quaternary sediments (LY, 2009) and some locally sparse Continental Terminal layers (ANSD, 2023). The commune of Diouroup is located in the district of Tattaguine, department of Fatick, region of Fatick. The commune of Ndiago is located in the district of Mbadakhoune, department of Guinguinéo, region of Kaolack. The two communes are located in the Center-west of Senegal, in the Groundnut Basin. The semi-arid climate shows a rainy period from July to October and a long non-rainy season from November to June. The annual mean rainfall is respectively 594 and 622 mm for Diouroup and Ndiago. The Diouroup commune, with 226 $km^2$, has a population of around 17,000 inhabitants, that is a density of 75.2 Inhabitants/$Km^2$. People are mainly of the Serer ethnic group. They specialise in various economic activities, mainly in order of importance, agriculture (millet, groundnuts, rice, fruits and vegetables), livestock breeding and fishing. The commune of Ndiago covers 184 $km^2$, with a population of 13,316 inhabitants, that is a density of 72.4 Inhabitants/$Km^2$. The majority of the population are Serer. Among the constraints in both communes, we can mention: climate change; combined poor agricultural practices; lack of natural resource management; strong demographic pressure; degradation of ecosystems; degradation of plant cover by intensive vegetation cutting; accentuation of soil exhaustion; conflicts between breeders and farmers, etc. (ENDA PRONAT, 2021; GERAD, 2010). In Diouroup, salinisation of land ends up in tannes or (saline soil) which now occupy a great space of the commune.

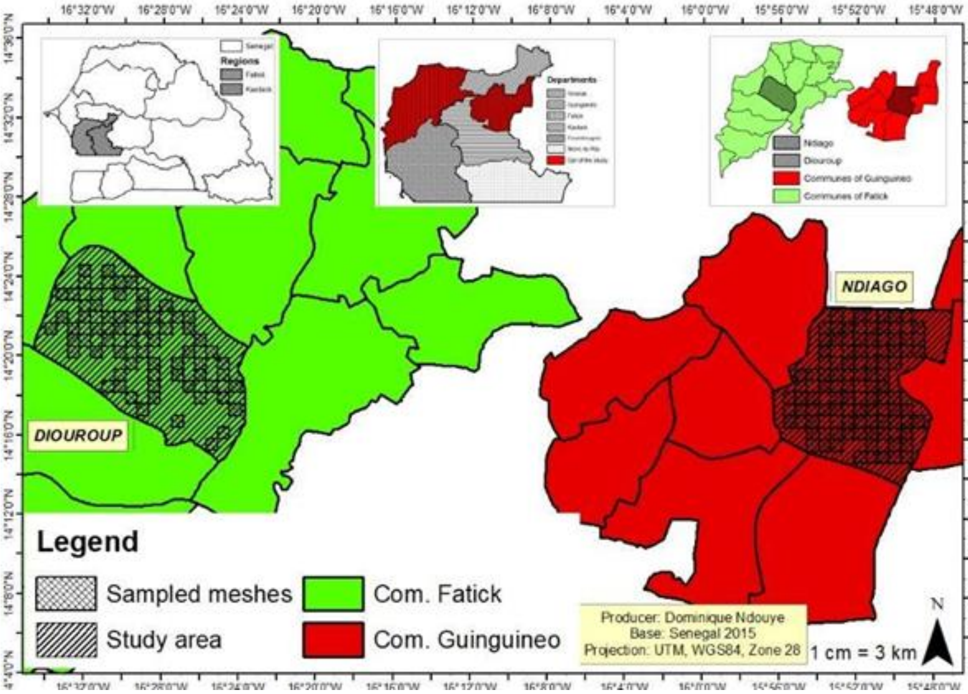



**Figure 1:** Study areas and inventoried meshes

## Material

### Field research tools

It consists of the following tools a GPS device used to delineate surfaces and to mark centroids or objects position shown in the maps, a metric stick more than 6 m high used to measure short shrub plants or boles height, a clinometer used to measure high shrubs and trees height, a metric roller 1.5 m long used to measure the plant's trunk Dbh and diameter at 0.3 m from the ground, a metric roller 30 m long used to delineate plot borders on the field

### Information Technologies Tools

They are the following programmes: ArcMap 10.8: to create maps, Envi 5.1: to exploit satellite images, to create colour composition maps, Microsoft Excel 2019: to solve statistical operations and to prepare input files for the other geomatics and statistics programmes (ArcMap 10.8, R.4.4.1, SPSS 24, Stata 13,...), XLSTAT 2025 (Microsoft Excel Add-in) to run the models linear regression processes, Stata.13: to make it easier to run the correlation between variables, SPSS.24 to create graphs and other statistics figures, Winrock SamplePlot Calculator 2014 to calculate the distribution of plots inside the sample.

**Sampling Method**
**Satellite Imagery**

It consists of an one-scene Landsat generation 8 image, with a resolution of 30/30 meters, captured in the period between May 5th and 15th, 2017: LC08_L1TP_205050_20170505_20170515_01_T1.

With its Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Landsat 8 is able to produce “true color synthesized images” (Cheng, Yifei, Li, & Iqbal, 2023; Voskanian, Thome, Wenny, Tahersima, & Yarahmadi, 2023).

With ENVI 5.1 and ArcGis 10.8, we used the Landsat 8 satellite image to create a colour composition and to realise the area classification in order to stratify and analyse the vegetation. We also located, delineated and determined the strata area and represented the plots’ centroids and the meshes grid of our study communes Diouroup and Ndiago.

**Distribution of Plots**

"Winrock SamplePlot Calculator 2014" was used to calculate the distribution of plots in the communes of Diouroup and Ndiago. We set up a systematic stratified inventory sampling of 1 km-side square meshes. Inside the mesh, we had inventoried one or two 50-m-side square plots, oriented North/South. This choice is based on the physiognomy (structure) and density of the vegetation according to the Verified Carbon Standard’ methodology (The Earth Partners LLC, 2012). If the vegetation inside the mesh is dense and/or homogeneous, we use 1 plot instead of 2; this was too much the case in Diouroup, hence the decrease in the total number of plots. On the contrary, when the vegetation is sparse and/or heterogeneous, we used 2 plots instead of 1; this was often the case in Ndiago, hence the increase in the total number of plots

We planned to inventory 163 plots in each commune, according to the vegetation strata representativity. In Diouroup, the savannah zone would receive 148 plots while the “tannes” would have 15. In Ndiago, the plots would be distributed as follows: 1 in Tree to Shrub Savannah; 19 in the Tree Savannah; 6 in the Shrub Savannah; 137 in the Shrub and Tree Savannah.

Inside the plot, we considered as woody, adult, worthy plant, the individuals with a Diameter at breast height (1.3 m from the ground) superior or equal to 5 cm. We considered as of regeneration individuals with a trunk diameter strictly inferior to 5 cm. For each adult individual, we recorded the total Height (H), the Dbh for the trees and the Diameter at 0.3 m from the ground ($D_{0.3}$), the Diameter of the East/West and North/South crown, the number of Stems.

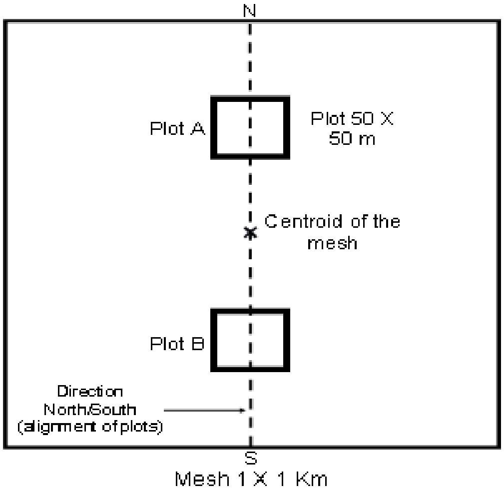



**Figure 2:** Mesh plots layout

## Vegetation stratification

Stratification consists in vertically structuring vegetation depending on the height of its individuals. That is also a way of C stocks potential Accumulation Levels (AL) differentiation. Individuals included in the same height interval share the same stratum. The basis of our stratification refers to the work of Jean Louis Deniveau in 1995 (MAHAMANE, 1997). We thus distinguished 4 strata. "These are: the Low Shrub stratum, 2 to 4m; the High Shrub stratum, 4 to 8m; the Lower Tree stratum, from 8 to 16m; and the High Tree stratum, from 16 to 32m".

However, given the high number of individuals concerned, we had to reduce the lower limit of the Low Shrub stratum to 1.5 m instead of 2 m. In addition, it happened that, for practical reasons, due to the low number of individuals in certain strata, these ones were grouped so as to have 2 for each commune: the Shrub stratum, from 1.5 to 8 m; the Tree stratum, from 8 to 32 m.

## Variables Studied

The choice of parameters is inspired by the work of MBOW, *et al., (2013)*, SAMBOU *(2017)*, BAKHOUM *(2013)*, NGOM *(2008)* and ATSRI, *et al. (2020)*. These are: the Height of the trees (H) to establish the vertical structure of the stand; the Diameter at breast height (Dbh) of the trunk at 1.3 m from the ground in order to establish the horizontal structure of the woody stand; the Diameter to the base of the trunk at 0.3 m ($D_{0,3}$) to estimate the basal area which allows the vegetation's footprint assessment; the number of tree Stems; the number of individuals per species and per plot to determine densities.

**Methods Used in the Carbon Assessment**

**Method of the Stored Carbon Potential Prediction**

We used a generic (concerning many species at the same time instead of one species) allometric equation that was developed by *MBOW et al. (2013)* for the dry savannahs in southern Senegal. We then call it an Adapted Endogenous Allometric Equation (AEAE). Its performance ensures a Coefficient of determination ($R^2$) of 0.934 and reduces the error margin (bias or residuals) to only 0.012% (MBOW, VERSTRAETE, SAMBOU, DIAW, & NEUFELDT, 2013). It is expressed as follows:

$$y = 1.929x + 0.116x^2 + 0.013x^3$$

Where:

x is the explanatory or independent variable, representing the Dbh;

y is the explained or dependent variable, representing the Biomass.

To build this equation, *MBOW, et al., (2013)* sampled 101 individuals from the 3 dominant High Storage Potential (HSP) species.

To determine the Biomass per unit (plant individual, plot, …), y, we entered the Dbh value, x in a Microsoft Excel 2019 file and computed the result with the *MBOW, et al., (2013)*'s allometric equation. Thus, from the unit, we could extend the AL of Carbon stored by the vegetation (sample, stratum, study area, etc.) using the Biomass Expansion Factors or BEF (number, density, area, etc.). Finally, the “aboveground biomass is converted into Carbon stock using an overall conversion factor of 0.5” (SKOLE, SAMEK, DIENG, & MBOW, 2021).

However, the use of an AEAE, must be justified by the sharing of many parameter values between the current study area (ours) and the origine area (*MBOW, et al., (2013)*'s). We consider the following correspondences, validated in our approach: Regional Vector Correspondence ; Specific correspondence; Diametral correspondence.

**Method to determine the Local carbon Storage Performance Index (LSPI):**

We developed the Local carbon Storage Performance Index (LSPI) to be able to effectively compare the relative Carbon storage potential of various tree species. For cause, a species that is rare but possesses extreme dendrometric characteristics may exhibit high Carbon density without, however, contributing significantly to the overall stock on the ground. This composite index takes into account several Phytogeographic variables related to the Biomass productivity such as Abundance (%), Basal area ($m^2.ha^{-1}$), Canopy cover ($m^2.ha^{-1}$), Carbon density ($t.ha^{-1}$), Election, HSP, Observed density (Ind./ha), Occurrence rate (Ind./ha), Quadratic Mean, Specific Regeneration Rate (%). The status of Selected species is based on the Dbh Quadratic mean (Q), and the Carbon High Storage Potential (HSP) quality

(SAMBOU, 2011) is related to the plant's Biomass Wood Density (MBOW, 2009). We used the chart below to determine the (LSPI) by attributing scores to each species (Table 1). The LSPI is an unitless and unlimited statistics parameter.

**Table 1:** Scores Chart to Determine the LSPI

| Terms | Scores (Points) | Assigned symbol/ colour | Rank |
|---|---|---|---|
| Selection by the Quadratic Mean (Q) | 3 | X | |
| HSP Status | 4 | X | |
| First maximum | 4 | | 1st |
| Second maximum | 3 | | 2nd |
| Third maximum | 2 | | 3d |
| Forth maximum | 1 | | 4th |

## Values Kriging

ArcMap 10.8 automatically excluded the excessive values, to mean the outliers (Table 11). That was to ensure the best possible data homogenisation respecting at the same time their hierarchical rank and structure.

## Statistical Tests

Beside the areas match clues, we used XLSTAT 2025 to proceed with a multiple linear regression test confronting the *MBOW, et al., (2013)* AEAE model to some other native and foreign ones, that are called regressors. This purpose was to increase the confidence in the *MBOW, et al., (2013)* AEAE use by comparing its influence on the Biomass prediction to the other models' one. This multiple linear regression used as the dependent variable *MBOW, et al., (2013)* model and as the independent variables the following tropical-originated models: *BROWN, (1997)* designed for the tropical zone; *FAO (http://www.globallometree.org/)* made in India; *HENRY, et al., (2011)* made in Senegal; *KUYAH, et al., (2012)* made in Kenya. To do this, we first computed with the same plots x (Dbh) values the corresponding plots y (Biomass) values for each equation. After, we use the obtained Biomass values to run the multiple linear regression.

Plus, for all the vegetation strata of Diouroup and Ndiago, the Shapiro-Wilk normality test of the B data was carried out with the R.4.4.1 software. It showed everywhere an abnormality of values with a probability, $p < 0.05$. Consequently, we went to other tests.

## Results

### Imagery treatment results

The classification gave 6 classes in Diouroup (Bare ground, Grassy Savannah, Habitat, Mangrove, Shrub Savannah, Tree Savannah) and 5 classes in Ndiago (Bare/Agricultural ground, Grassy Savannah, Habitat, Shrub Savannah, Tree Savannah) (Maps 2 & 3).

**Figure 3:**

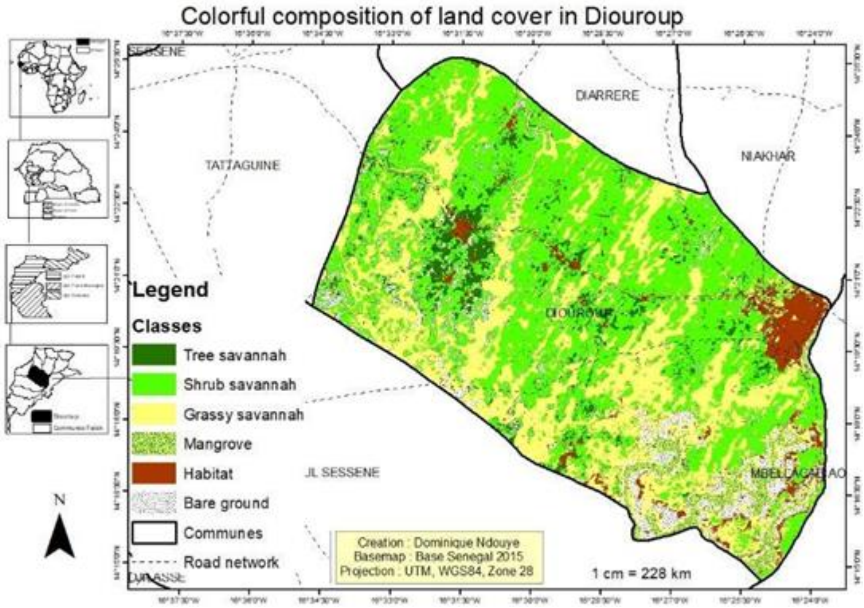
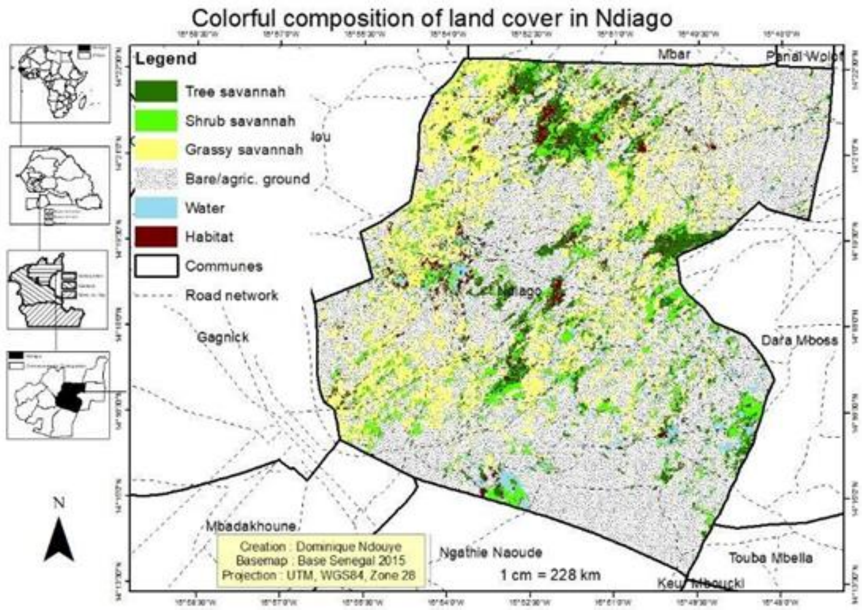



**Figure 4:**



The classification was more successful in Diouroup than in Ndiago with respectively an Overall Accuracy (OA) value of 94.4% and 79.2% and a Kappa Coefficient (KC) of 0.9251 and 0.7041.

In Diouroup, the vastest class is Shrub Savannah (46.3%), followed by the Grassy Savannah (32.7%) and the Bare ground (6.62%). In Ndiago, the vastest class is Bare/Agricultural ground (62.9%), followed by the Grassy Savannah (18.1%) and the Shrub Savannah (8.2%) (*Figure 6*).

About the classification margin of error, the greatest one in Diouroup occurred in the Shrub Savannah (35%) followed by the Grassy Savannah (30.4%) and the Mangrove (12.6%). The greatest margin of error in Ndiago occurred in the Tree savannah (40.4%) followed by Shrub Savannah (30.4%) and the Grassy Savannah (13.7%) (*Figure 5*).

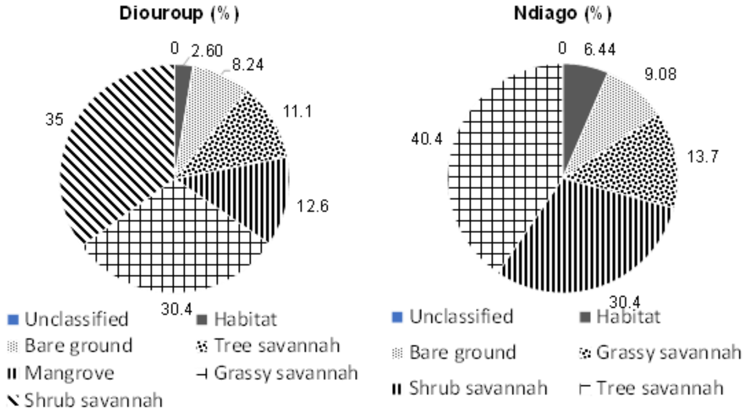



**Figure 5:** Classification Margin of Error

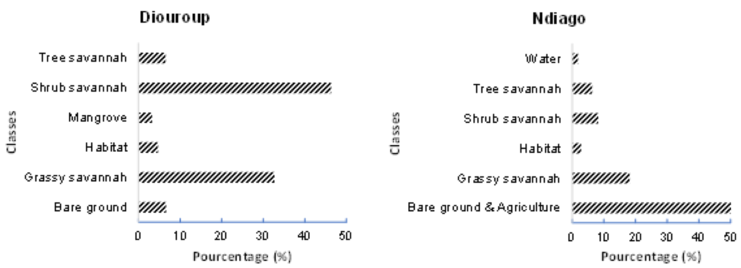



**Figure 6:** Classes areas

## Study Areas Consistency

The following correspondences were noticed between our study area and the *MBOW, et al., (2013)'s*:

1. Regional Vector Correspondence: as showed earlier (p.), our study sites and the MBOW, *et al., (2013)*'s one belong to the same Groundnut basin. Then, they both belong to the Soudano-sahelian zone, share the same geological sedimentary basin, the same soil with a slightly different altitude (p.).

2. Specific correspondence: this concerns the existence of similar dominant species between the two areas *(Table 4)*;
3. Diametral correspondence: this is the correspondence of the Dbh classes of the dominant species with HSP between the two areas. The Dbh range values taken into account by the *MBOW, et al. (2013)* equation goes from 5.1 to 41.5 cm. This corresponds perfectly to the values of the dominant species Dbh classes in Diouroup and Ndiago.

**Statistical Analyses**

**MBOW, *et al.*, *(2013)* AEAE test analysis:**

The multiple linear regression of *Mbow, et al., (2013)* by *BROWN, (1997), FAO (http://www.globallometree.org/), Henry, et al., (2011) and KUYAH, et al., (2012)* showed the following results (Table 5).

The Analysis Of Variance (ANOVA) gave a $p < 0.5$ in Diouroup and Ndiago. In addition, the Standardised coefficients (Sc) were calculated. These ones constitute a powerful means of comparing the effect of many Independent variables on the same Dependent variable in the context of multiple regression. The calculation formula of the Sc is as follows:

$$Sc = \frac{Stand.deviation\ of\ the\ Independent\ variable}{Stand.deviation\ of\ the\ Dependent\ variable}$$

Sc is an unitless statistics parameter.

We were able to more appreciate the *MBOW, et al., (2013)* confidence through its relationship with the other tropical-originated, in other terms, third-part allometric equations (*Figure 7* & 8).

The higher the Sc absolute value is, the greater the impact of the Independent variable (third-part allometric equations) on the Dependent variable *(MBOW, et al., (2013))* is.

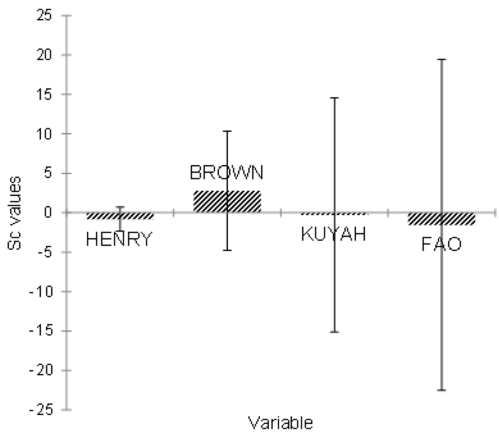



**Figure 7:** MBOW / BROWN, FAO, HENRY and KUYAH Standardised coefficients (Conf. Interv. 95%), Diouroup

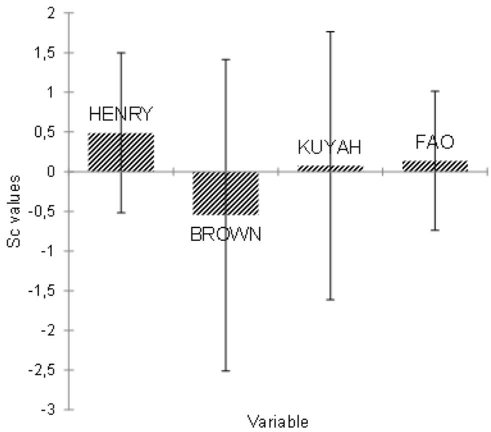



**Figure 8:** MBOW / BROWN, FAO, HENRY and KUYAH Standardised coefficients (Conf. Interv. 95%), Ndiago.

**Table 2:** Standardised coefficients at Diouroup

| Source | Value | Standard Error | t | p > \|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| HENRY | -0.83 | 0.76 | -1.09 | 0.28 | -2.35 | 0.69 |
| BROWN | 2.79 | 3.77 | 0.74 | 0.46 | -4.77 | 10.3 |
| KUYAH | -0.29 | 7.40 | -0.04 | 0.97 | -15.1 | 14.5 |
| FAO | -1.54 | 10.5 | -0.15 | 0.88 | -22.5 | 19.4 |

*t: Student test value* *p: probability-value*

**Table 3:** Standardised coefficients at Ndiago

| Source | Value | Standard Error | t | p > \|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| HENRY | 0.49 | 0.51 | 0.96 | 0.34 | -0.52 | 1.50 |
| BROWN | -0.55 | 0.99 | -0.55 | 0.58 | -2.51 | 1.41 |
| KUYAH | 0.07 | 0.85 | 0.09 | 0.93 | -1.62 | 1.76 |
| FAO | 0.14 | 0.44 | 0.31 | 0.76 | -0.74 | 1.01 |

*t: Student test value* *p: probability -value*

More detailed statistical parameters permitted us to deepen the analysis (Table 6). About the third-part models, we distinguished 3 groups: the Similar model (HENRY, PICARD, TROTTA, & VALENTINI, 2011), the Intermediate model (BROWN, Estimating Biomass and Biomass Change of Tropical Forests: A Primer; Forestry Paper 134, 1997) and the Extreme models *(FAO, http://www.globallometree.org/ ; KUYAH, et al., 2012)*. For instance, in Diouroup, the mean Bd ($t.ha^{-1}$) produced by MBOW, HENRY, BROWN, KUYAH and FAO is respectively 19.2 ± 0.0023; 19.1; 2.28; 387; 156, while in Ndiago it is 20.5 ± 0.0025; 19; 1.75; 94.4; 322. So that, when we divide the Bd mean values of HENRY, BROWN, KUYAH and FAO by the Bd mean value of MBOW, we respectively get in Diouroup 1; 0.12; 20.2;

.12 and in Ndiago, 0.93; 0.09; 4.62; 15.7. Between the two communes, only the extreme models (KUYAH and FAO) Bd values vary a lot.

**Table 4:** Species with High Storage Potential (HSP) of Diouroup, Ndiago and Patako (MBOW, 2009; SAMBOU, 2011). In yellow, common species

| N° | DIOUROUP | NDIAGO | MBOW (2009) | SAMBOU (2011) |
|---|---|---|---|---|
| 1 | *Acacia nilotica* | *Acacia nilotica* | *Acacia macrostachya* | *Adansonia digitata* |
| 2 | *Acacia senegal* | *Acacia seyal* | *Acacia seyal* | *Cola cordifolia* |
| 3 | *Adansonia digitata* | *Adansonia digitata* | *Balanites aegyptiaca* | *Combretum glutinosum* |
| 4 | *Anogeissus leiocarpus* | *Albizia chevalieri* | *Bombax costatum* | *Cordyla pinnata* |
| 5 | *Azadirachta indica* | *Anogeissus leiocarpus* | *Combretum glutinosum* | *Daniellia oliveri* |
| 6 | *Balanites aegyptiaca* | *Balanites aegyptiaca* | *Combretum nigricans* | *Detarium microcarpum* |
| 7 | *Bauhinia rufescens* | *Combretum glutinosum* | *Cordyla pinnata* | *Detarium senegalense* |
| 8 | *Combretum glutinosum* | *Cordyla pinnata* | *Crossopterix febrifuga* | *Faidherbia albida* |
| 9 | *Detarium senegalense* | *Diospyros mespiloformis* | *Daniellia oliveri* | *Khaya senegalensis* |
| 10 | *Diospyros mespiloformis* | *Faidherbia albida* | *Pterocarpus erinaceus* | *Neocarya macrophylla* |
| 11 | *Faidherbia albida* | *Gardenia triacantha* | *Sterculia setigera* | *Parkia biglobosa* |
| 12 | *Ficus gnaphalocarpa* | *Grewia bicolor* | *Terminalia macroptera* | *Prosopis africana* |
| 13 | *Lannea acida* | *Guiera senegalensis* | *Ximenia americana* | *Pterocarpus erinaceus* |
| 14 | *Mangifera indica* | *Piliostigma reticulatum* | | *Saba senegalensis* |
| 15 | *Neocarya macrophylla* | *Pterocarpus erinaceus* | | *Tamarindus indica* |
| 16 | *Piliostigma reticulatum* | *Sclerocarya birrea* | | *Terminalia macroptera* |
| 17 | *Prosopis juliflora* | *Ziziphus mauritiana* | | *Ziziphus mauritiana* |
| 18 | *Sclerocarya birrea* | | | |
| 19 | *Tamarindus indica* | | | |
| 20 | *Tamarix senegalensis* | | | |
| 21 | *Ziziphus mauritiana* | | | |

**Table 5:** Multiple linear regression test allometric models

| Allometric model | Regression equation | $R^2$ | Bioclimatic zone | Source |
|---|---|---|---|---|
| Polynomial | $Y(t.ha^{-1}) = 1.929Dbh + 0.116 \times Dbh^2 + 0.013 \times Dbh^3$ | 0.93 | Sudanese and Sudano-Guinean dry savannahs (Senegal) | MBOW, et al., 2013 |
| Polynomial | $Y(t.ha^{-1}) = -0.0091 + 0.2535 \times Dbh^2 \times H$ | 0.94 | Dry tropical forest (India) | FAO, http://www.globallometree.org/ |
| Exponential | $Y(Kg.ha^{-1}) = 33{,}338\left(1 - e^{\left(-2 \times 2245 \times \frac{Dbh}{33{,}338}\right)}\right)^2$ | — | Dry tropical forest (Senegal) | HENRY, et al., 2011 |
| Exponential | $Y(t.ha^{-1}) = e^{(-1.996 + 2.32 \times \ln(Dbh))}$ | > 0.80 | Tropical zone | BROWN, 1997 |
| Polynomial | $Y(t.ha^{-1}) = 0.091 \times Dbh^{2.472}$ | > 0.80 | Tropical forest (Kenya) | KUYAH, et al., 2012 |

**Table 6:** Summary of the analysis of the MBOW, et al. (2013)'s model multiple linear regression. Bd: Biomass density; Stand. dev.: Standard deviation; RSDM: Rate of the Standard Deviation relative to the Mean; RMSE: Root Mean Square Error.

| Study areas | Strata | Parameters | | Allometric models parameters values | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | MBOW | HENRY | BROWN | KUYAH | FAO |
| Diouroup | | Bd (t.ha$^{-1}$) | — | 19.2 ± 0.0023 | 19.1 | 2.28 | 387 | 156 |
| | Tree | Area (ha) | 1,471 | — | — | — | — | — |
| | | Stock (t) | — | 28,218 ± 3.39 | 28,165 | 3,360 | 568,756 | 229,261 |
| | Shrub | Area (ha) | 10,462 | — | — | — | — | — |
| | | Stock (t) | — | 200,693 ± 24.1 | 200,314 | 23,894 | 4,045,091 | 1,630,544 |
| | | Stock total (t) | — | 228,912 ± 27.5 | 228,480 | 27,253 | 4,613,848 | 1,859,805 |
| | | Stand. dev. (t.ha$^{-1}$) | — | 58.2 ± 0.007 | 8.80 | 2.62 | 1,546 | 474 |
| | | RSDM (%) | — | 279 | 42.1 | 12.5 | 7,397 | 2,269 |
| | | Mean X / Mean MBOW | — | 1 | 1 | 0.12 | 20.2 | 8.12 |
| | | RMSE (t.ha$^{-1}$) | — | 47.5 ± 0.0057 | — | — | — | — |
| | | Perc. RMSE/Mean (%) | — | 248 | — | — | — | — |
| | | P-value | — | 0.00003 | — | — | — | — |
| Ndiago | | Bd (t.ha$^{-1}$) | — | 20.5 ± 0.003 | 19 | 1.75 | 94.4 | 322 |
| | Tree | Area (ha) | 1,158 | — | — | — | — | |
| | | Stock (t) | — | 23,681 ± 2.84 | 21,960 | 2,022 | 109,365 | 372,973 |
| | Shrub | Area (ha) | 1,514 | — | — | — | — | |
| | | Stock (t) | — | 30,962 ± 3.72 | 28,711 | 2,644 | 142,987 | 487,635 |
| | | Stock total (t) | — | 54,643 ± 6.56 | 50,671 | 4,666 | 252,351 | 860,607 |
| | | Stand. dev. (t.ha$^{-1}$) | — | 37.3 ± 0.0045 | 7.40 | 1.19 | 215 | 821 |
| | | RSDM (%) | — | 345 | 68.4 | 11.0 | 1,986 | 7,589 |
| | | Mean X / Mean MBOW | — | 1 | 0.93 | 0.09 | 4.62 | 15.7 |
| | | RMSE (t.ha$^{-1}$) | — | 37.4 ± 0.0045 | — | — | — | — |

## Data statistical analyses

After the Shapiro-Wilk test proved the abnormality of the Dbh data, we proceeded with the other statistical tests. The Kruskal-Wallis test with STATA 13 showed a resemblance in the Dbh values distribution between the Shrub and Tree strata in Diouroup with a probability greater than 0.05; i.e. $p = 0.7728$. The opposite is observed in Ndiago where the distribution of Dbh is differentiated in the two Shrub and Tree strata with $p < 0.05$. We then carried out the Mann-Whitney-Wilcoxon test with SPSS 24. This proved a differentiated distribution of Dbh within the Shrub and Tree strata of Diouroup and Ndiago with a $p < 0.05$.

**Stand Data Analysis**

After the field inventory, the number of plots decreased from 163 to 89 in Diouroup because of vegetation density and/or homogeneity and it increased in Ndiago from 163 to 196 because of vegetation sparseness and/or heterogeneity. There are nearly twenty of the most dominant species in Diouroup and Ndiago. Apart from the Tree stratum of Diouroup where a legume dominates (*Faidherbia albida*, 42.6%), in the rest of the Strata, we notice the supremacy of *Combretaceae*: *Combretum glutinosum* (54.6% of the Shrub stratum of Diouroup and 16.7% of the Tree stratum of Ndiago), and *Guiera senegalensis* (82.5% of the Shrub stratum of Ndiago). *Combretum glutinosum* and *Faidherbia albida* are included in the list of species with High Storage Potential (HSP) (SAMBOU, Estimation du stock de carbone pour l'établissement du scénario de référence du projet Arlomom dans la forêt classée de Patako et ses alentours (Centre-ouest du Sénégal), 2011) *(Table 9)*. Even about the Observed density, the both communes' highest scores, are found in *Acacia seyal*, *Combretum glutinosum* and *Guiera senegalensis*; for the Specific Regeneration Density, in *Guiera senegalensis, Tamarix senegalensis, Combretum glutinosum*; for the Canopy cover, in *Faidherbia albida*, *Combretum glutinosum, Balanites aegyptiaca*.; for Occurrence rate, in *Guiera senegalensis, Combretum glutinosum, Acacia seyal (Figure 9).*

Even though the various strata's dendrometric (Dbh mean and H mean) and diversity (Shannon index and Richness of species) parameters values are almost equal, the ones related to the Biomass productivity are different (Table 8). For instance, respectively, for the Shrub and Tree strata, Ndiago's Basal area value is 2.78 and 5.59 times the Diouroup's one. As well, with the same comparison about Stems density we found 5.06 and 3.77. Finally, the Local carbon Storage Performance Index (LSPI) showed us the most performant species in the C storage in both Diouroup and Ndiago (Table 7). We have listed the 10 first species, giving into brackets the LSPI values respectively of Diouroup and Ndiago, as follows: *Combretum glutinosum* (38/41, Shrub, Selected, HSP), *Balanites aegyptiaca* (33/32, Tree, Selected, HSP), *Guiera senegalensis* (24/23, Shrub, Selected), *Adansonia digitata* (18/18,Tree, Selected, HSP), *Faidherbia albida* (18/18, Tree, Selected, HSP), *Tamarix senegalensis* (16/17, Shrub, Selected), *Ziziphus mauritiana* (14/14, Tree, Selected), *Acacia seyal* (14/12, Tree, Selected), *Anogeissus leiocarpus* (11/12, Tree, Selected), *Cordyla pinnata* (10/12, Tree, Selected, HSP). There are 7 among these ones, that are *Acacia seyal, Balanites aegyptiaca, Combretum glutinosum, Faidherbia albida, Guiera senegalensis, Tamarix senegalensis, Ziziphus mauritiana* which belong to the 10 most abundant species.

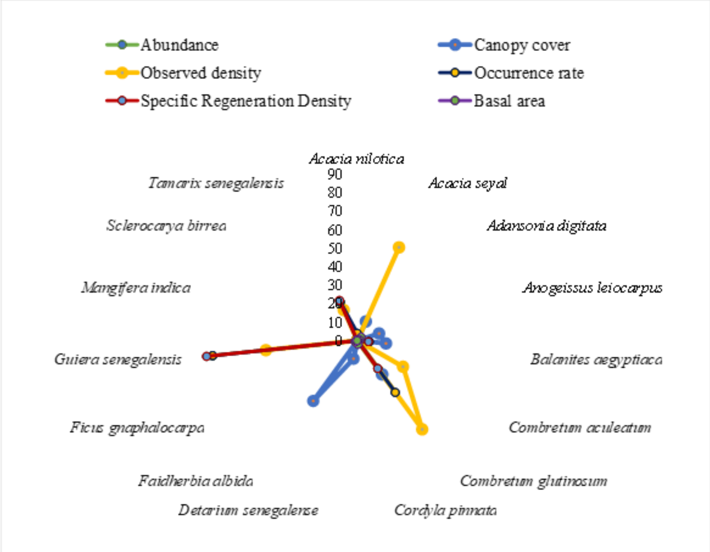



**Figure 9:** Distribution of phytogeographic parameter values by species in Diouroup and Ndiago

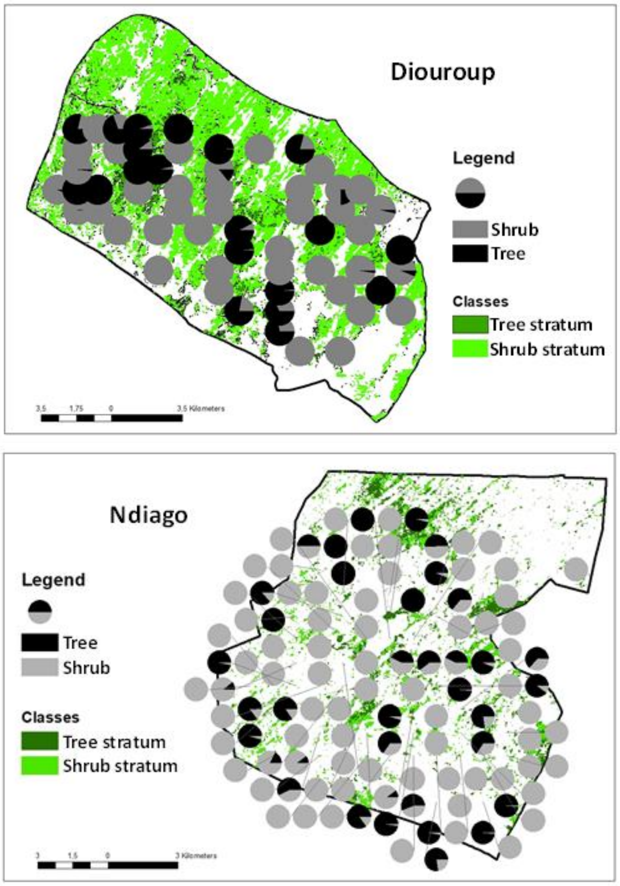



**Figure 10:** Distribution of Biomass density (Bd) in the grids

**Table 7:** Summary table of the LSPI and phytogeographical parameters, including Biomass density (Bd)

| N° | SPECIES OF INTEREST FOR CARBON SEQUESTRATION | | DIOUROUP | | | | | | | | | | | | NDIAGO | | | | | | | | | | | | LOCAL CARBON STORAGE PERFORMANCE INDEX, LSPI (Points) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name | Strata | Characteristics: Election / Quadrat. mean | Characteristics: HSP | Carbon density (t/ha) | Abundance (%) | Canopy cover (m2.ha-1) | Basal area (m2.ha-1) | Observed density (Ind./ha) | Occurrence rate (Ind./ha) | Shannon index | Plant Species Regularity Index | Stand Regeneration Rate (%) | Specific Regeneration Rate (%) | Characteristics: Election / Quadrat. mean | Characteristics: HSP | Carbon density (t/ha) | Abundance (%) | Canopy cover (m2.ha-1) | Basal area (m2.ha-1) | Observed density (Ind./ha) | Occurrence rate (Ind./ha) | Shannon index | Plant Species Regularity Index | Stand Regeneration Rate (%) | Specific Regeneration Rate (%) | |
| 1 | *Acacia adansonii* | Tree | | | | | | | | | | | | | | | 0.11 | | | 0.06 | 6.4 | | | | | | |
| 2 | *Acacia macrostachya* | Shrub | | | | | | | | | | | | | | | 1.05 | | | | 46 | | | | | | |
| 3 | *Acacia nilotica* | Tree | X | | 0.21 | | | | 5.6 | | | | | | X | | 2.07 | 1.34 | 11.0 | 0.39 | 42.1 | 3.9 | | | | 1.12 | 9 |
| 4 | *Acacia seyal* | Tree | | | 0.07 | 1.32 | | | 15.2 | 1.32 | | | | 1.41 | X | X | 3.49 | 2.5 | 11.3 | 0.77 | 167 | 2.5 | | | | 2.01 | 12 |
| 5 | *Adansonia digitata* | Tree | X | X | 0.25 | | | | 5.14 | | | | | | X | X | 13.3 | | 1.91 | 2.68 | 14.2 | | | | | | 18 |
| 6 | *Albizia chevalieri* | Tree | | | | | | | | | | | | | X | | 5.75 | | | 0.38 | 14 | | | | | | 3 |
| 7 | *Anacardium occidentale* | Tree | | | | | | | 5.33 | | | | | | | | | | | | | | | | | | |
| 8.00 | *Anogeissus leiocarpus* | Tree | X | | 1.12 | | 1.52 | | | | | | | | X | | 13.4 | | 12.3 | 1.17 | 9.1 | 12 | | | | | 12 |
| 9 | *Asparagus africanus* | Shrub | | | | | | | 8.00 | | | | | | | | | | | | | | | | | | |
| 10 | *Avicennia africana* | Tree | | | 1.02 | | | | 32 | | | | | | | | | | | | | | | | | | |
| 11 | *Azadirachta indica* | Tree | X | | 0.22 | | 1.93 | | 8.4 | 8.71 | | | | | | | 0.09 | | | 0.06 | | | | | | | 3 |
| 12 | *Balanites aegyptiaca* | Tree | X | X | 1.12 | 9.2 | 2.3 | 0.2 | 53 | 9.2 | | | | 9.41 | X | X | 3.17 | 3.9 | 15.5 | 0.69 | 35.6 | 3.9 | | | | 2.6 | 32 |
| 13 | *Bauhinia rufescens* | Shrub | X | | 0.08 | | | 0.062 | 7 | | | | | | | | 0.35 | | | 0.01 | 7 | | | | | | 3 |
| 14 | *Borassus aethiopum* | Tree | | | 0.06 | | | | 22.7 | 0.66 | | | | | | | | | | | | | | | | | |
| 15 | *Chloris prieurii* | Herbaceous | | | | | | | 8.00 | | | | | | | | | | | | | | | | | | |
| 16 | *Combretum aculeatum* | Shrub | | | 0.12 | 3.33 | | | 50.9 | 3.33 | | | | 2.59 | | | 1.74 | | | | 86 | | | | | | 2 |
| 17 | *Combretum glutinosum* | Shrub | X | X | 3.11 | 34.8 | 22.7 | 0.09 | 180 | 34.8 | | | | 33.8 | X | X | 3.09 | 3.55 | | 0.36 | 59.5 | 3.56 | | | | 3.51 | 41 |
| 18 | *Combretum micranthum* | Shrub | | | | | | | | | | | | | | | 0.17 | | | 0.02 | | | | | | | |
| 19 | *Combretum nigricans* | Shrub | | | | | | | | | | | | | | | 4.09 | | 7.03 | | 80 | | | | | | 3 |
| 20 | *Commiphora africana* | Shrub | | | 0.06 | | | | | | | | | | | | 0.07 | | | 0.04 | | | | | | | |
| 21 | *Cordyla pinnata* | Tree | | | | | | | | | | | | | X | X | 14.6 | | | 1.96 | | | | | | | 12 |
| 22 | *Cyperus limbelatus* | Herbaceous | | | | | | | 12 | | | | | | | | | | | | | | | | | | |
| 23 | *Detarium senegalense* | Tree | X | X | | | 10.1 | | | | | | | | | | | | | | | | | | | | 9 |
| 24 | *Dichrostachys glomerata* | Shrub | | | 0.47 | | | | | | 3.11 | 0.5015 | 93.6 | | | | 0.09 | | | | 82 | | 1.53 | 0.278 | 95.9 | | |
| 25 | *Diospyros mespiliformis* | Tree | | | | | | | | | | | | | X | | 46.8 | | 6.7 | | 80 | | | | | | 7 |
| 26 | *Echinochloa colona* | Herbaceous | | | | | | | 8.00 | | | | | | | | | | | | | | | | | | |
| 27 | *Eragrostis ciliaris* | Herbaceous | | | | | | | 8.00 | | | | | | | | | | | | | | | | | | |
| 28 | *Euphorbia balsamifera* | Shrub | | | 0.19 | | | 0.071 | 10 | | | | | | | | | | | | | | | | | | |
| 29 | *Faidherbia albida* | Tree | X | X | 0.57 | 8.64 | 40.4 | 0.053 | 34.2 | 8.64 | | | | 8.33 | X | X | 2.68 | 1.77 | 8.37 | 0.72 | 11 | 1.8 | | | | 1.72 | 18 |
| 30 | *Feretia apodanthera* | Tree | | | | | | | | | | | | | X | X | 0.98 | 1.86 | | 0.02 | 30.3 | 1.87 | | | | | 7 |
| 31 | *Ficus gnaphalocarpa* | Tree | X | | 2.34 | | 3.63 | 1.21 | 8.00 | | | | | | | | | | | | | | | | | | 10 |
| 32 | *Grewia bicolor* | Shrub | | | 0.06 | | | 0.062 | | | | | | | | | 1.19 | | | 0.18 | 20.4 | | | | | | |
| 33 | *Guiera senegalensis* | Shrub | | | 0.95 | 8.83 | | | 60 | 8.83 | | | | 9.41 | X | | 9.08 | 78.4 | 1.26 | 0.15 | 240 | 78.4 | | | | 81.6 | 23 |
| 34 | *Leptadenia hastata* | Herbaceous | | | | | | | | 0.52 | | | | | | | | 1.13 | | 0.03 | 11.7 | 1.13 | | | | 1.18 | |
| 35 | *Mangifera indica* | Tree | X | | 0.14 | | 2.5 | 0.53 | | | | | | | | | | | | | | | | | | | 7 |
| 36 | *Maytenus senegalensis* | Shrub | | | 0.06 | 1.46 | | | 33.6 | 1.46 | | | | 1.56 | | | | | | | 80 | | | | | | |
| 37 | *Moringa oleifera* | Tree | | | 0.05 | | | 0.015 | | | | | | | | | 0.26 | | | 0.17 | | | | | | | |
| 38 | *Neocarya macrophylla* | Tree | X | X | | | 2.23 | | | | | | | | | | | | | | | | | | | | 7 |
| 39 | *Nepenthes macrophylla* | Tree | | | | | | | 8.00 | | | | | | | | | | | | | | | | | | |
| 40 | *Piliostigma reticulatum* | Shrub | X | | 0.51 | 1.39 | 1.57 | | 10 | 1.39 | | | | 1.37 | X | | 3.73 | 2.19 | 10.2 | 0.27 | 11 | 2.18 | | | | 1.94 | 6 |
| 41 | *Prosopis juliflora* | Tree | | | 0.1 | | | | 13 | | | | | | | | | | | | | | | | | | |
| 42 | *Sclerocarya birrea* | Tree | X | | 1.97 | | 2.42 | 0.38 | 5.33 | | | | | | | | 4.09 | | | | | | | | | | 7 |
| 43 | *Securidaca longepedunculata* | Tree | | | | | | | | | | | | | | | 1.23 | | | | 46 | | | | | | |
| 44 | *Spermacoce verticillata* | Shrub | | | | | | | 12 | | | | | | | | | | | | | | | | | | |
| 45 | *Tamarindus indica* | Tree | X | X | 1.03 | | 4.1 | | 10 | | | | | | | | 2.34 | | | 1.13 | | | | | | | 7 |
| 46 | *Tamarix senegalensis* | Shrub | X | | 1.87 | 22.3 | | 0.018 | 54.6 | 22.9 | | | | 23.8 | | | | | | | | | | | | | 17 |
| 47 | *Ziziphus mauritiana* | Tree | X | X | 0.18 | | | 0.02 | 8.89 | 0.69 | | | | | X | X | 0.38 | 1.08 | 3.06 | 0.13 | 18.9 | 1.12 | | | | | 14 |
| 48 | *Others* | | | | | 8.71 | | | | | | | | | | | | 2.08 | | | | | | | | | |

LEGEND

*Election / Quadrat. mean : Selection of the species after determining that the mean square root, Q, of the DBH class of its individuals has been reaHSP : High Storage Potential XHSP : 4 points X Election / Quadrat. mean : 3 points* 1st 4 points 2nd 3 points 3rd 2 points 4th 1 point

**Table 8:** Main characteristic parameters of the study sites

| Strata | Ba ($m^2.ha^{-1}$) | Sd (Stems.ha-1) | Dbh mean (cm) | H mean (m) | Shannon Ind. (H) | Rspe (Spe.ha-1) | Cd (t.ha-1) |
|---|---|---|---|---|---|---|---|
| Diouroup shrub savannah | 17.3 ± 0.0021 | 631 | 9.05 | 2.64 | 0.07 | 8.76 | 2.29 ± 0.00028 |
| Diouroup tree savannah | 6.33 ± 0.00076 | 10.1 | 38.8 | 13.2 | 0.20 | 5.03 | 27.5 ± 0.0033 |
| Ndiago shrub savannah | 48.2 ± 0.0058 | 3197 | 8.74 | 2.24 | 0.04 | 9.21 | 8.85 ± 0.0011 |
| Ndiago tree savannah | 35.4 ± 0.0042 | 38.1 | 38.5 | 12 | 0.20 | 6 | 15.4 ± 0.0018 |

*Ba : Basal area ; Sd: Stems density ; Dbh : Diameter at breast height ; H : Height of the trunk ; Shannon Ind. (H) : Shannon Index ; Resp : Richness of species ; Bd: Biomass density*

**Biomass Analysis**

It clearly appeared that in our two communes, the Tree and Shrub strata do not have the same extent, even if they both are larger in Diouroup than in Ndiago (*Figure 6*). Naturally, the Shrub area is everywhere larger than the Tree one. Nevertheless, inside the majority of the Accumulation Levels (AL) of grids, the Tree B productivity (Bd) is higher than the Shrub one (Figure 3 & 4).

However, we noticed a Bd decrease in the Dbh classes [5 ; 10 [, [10 ; 15 [, [15 ; 20 [, [ 20 ; 25 [ for all strata. Especially for Diouroup Shrub, Diouroup Tree and Ndiago Tree Bd values are low (*Figure 11*).

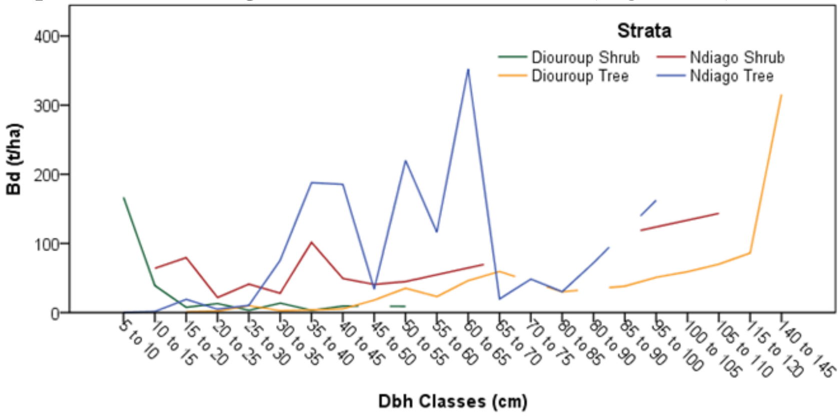



**Figure 11:** Distribution of Bd in Dbh classes

In Diouroup Tree, there is no productivity for the Dbh$_{[5\ \text{to}\ 10[}$ and Dbh$_{[10\ \text{to}\ 15[}$ classes (*Figure 12*).

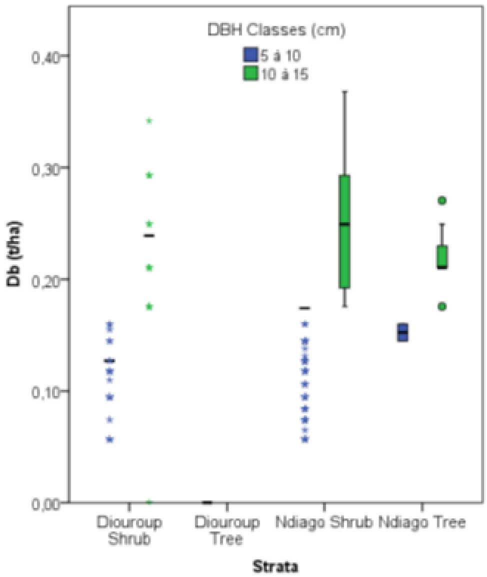



**Figure 12:** Distribution of Biomass density Dbh[5 to 10[ and Dbh[10 to 15[ classes

Among the most productive species, we selected 15 that correspond, in other words, that exist in both of the communes. In Diouroup, among the 8 first ones, only *Anogeissus leiocarpus*, *Sclerocarya birrea* and *Tamarindus indica* do not have a great Abundance whereas in Ndiago, they are *Anogeissus leiocarpus* and *Sclerocarya birrea*. We notice *Balanites aegyptiaca, Combretum glutinosum and Faidherbia albida* are species of a High Storage Potential and a high Local Storage Potential Index (LSPI). For all 15 species, the Ndiago productivity equals many times the Diouroup productivity except for *Azadirachta indica, Combretum glutinosum, Dichrostachys glomerata*. For example, with the following species we found the highest Bd Multiplier Factor (BdMF) from Diouroup towards Ndiago: *Acacia seyal* (47.0), *Combretum aculeatum* (14.6), *Anogeissus leiocarpus* (12.0), *Acacia nilotica* (10.1), *Guiera senegalensis* (9.53). For the most abundant and performant (highest LSPI) in both communes *Combretum glutinosum* and *Faidherbia albida*, we respectively found 0.99 and 4.70. On average, the Ndiago productivity of the 15 corresponding species is 8 times higher than in Diouroup.

In the kriging, ArcMap 10.8 has excluded more outliers in Ndiago than in Diouroup (Table 11). In each commune, we distinguished three Zones of B productivity. Due to the wide variability of the data, we used gradients that were double or triple the values shown in the legend in order to better distinguish the B distribution areas (*Figure 13* & 14). The Zone 1 (red colour) corresponds to the low productivity area, the Zone 2 (yellow colour) constitutes the intermediate productivity area and the Zone 3 (green colour) is the high-productivity area. The surface values (in ha) of these Zones increase in inverse proportion to their productivity ones.

After the outliers exclusion, kriging reveals a spatial horizontal Bd data distribution more homogenous and more structured in Diouroup than in Ndiago (*Figure 13* & 14). We can notice a high intermingling of all the Zones in Ndiago. Plus, about the Zone 1, the main vegetation pressure factors are significant human settlement impact and tannes salinity for Diouroup and clearing and timber harvesting for Ndiago. In the Zone 2, it is the clearing and timber harvesting for Diouroup and Ndiago while the Zone 3 seems to be safe in the both communes.

**Table 9:** Comparison of the Biomass productivity (Bd) between Diouroup and Ndiago. Highlighted in yellow, the dominant species in Abundance (%). LSPI: Local carbon Storage Performance Index. HSP: High Storage Potential

| N° | Species | Strata | Bd (t/ha) | | Bd Multiplier Factor from | Bd Multiplier Factor from |
|---|---|---|---|---|---|---|
| | | | Diouroup | Ndiago | | |
| 1 | *Acacia seyal* | Tree | 0.15 ± 0.000018 | 6.97 ± 0.0008364 | 0.02 | 47.0 |
| 2 | *Combretum aculeatum* | Shrub | 0.24 ± 0.0000288 | 3.48 ± 0.0004176 | 0.07 | 14.6 |
| 3 | *Anogeissus leiocarpus* | Tree | 2.23 ± 0.0002676 | 26.8 ± 0.003216 | 0.08 | 12.0 |
| 4 | *Acacia nilotica* | Tree | 0.41 ± 0.0000492 | 4.15 ± 0.000498 | 0.10 | 10.1 |
| 5 | *Guiera senegalensis* | Shrub | 1.89 ± 0.0002268 | 18.1 ± 0.002172 | 0.10 | 9.53 |
| 6 | *Piliostigma reticulatum* | Shrub | 1.02 ± 0.0001224 | 7.46 ± 0.0008952 | 0.14 | 7.28 |
| 7 | *Faidherbia albida* [LSPI/HSP] | Tree | 1.14 ± 0.0001368 | 5.35 ± 0.000642 | 0.21 | 4.70 |
| 8 | *Bauhinia rufescens* | Shrub | 0.17 ± 0.0000204 | 0.7 ± 0.000084 | 0.24 | 4.11 |
| 9 | *Balanites aegyptiaca* [LSPI/HSP] | Tree | 2.23 ± 0.0002676 | 6.34 ± 0.0007608 | 0.35 | 2.84 |
| 10 | *Tamarindus indica* | Tree | 2.05 ± 0.000246 | 4.68 ± 0.0005616 | 0.44 | 2.28 |
| 11 | *Sclerocarya birrea* | Tree | 3.95 ± 0.000474 | 8.17 ± 0.0009804 | 0.48 | 2.07 |
| 12 | *Ziziphus mauritiana* | Tree | 0.37 ± 0.0000444 | 0.68 ± 0.0000816 | 0.54 | 1.84 |
| 13 | *Combretum glutinosum* [LSPI/HSP] | Shrub | 6.22 ± 0.0007464 | 6.18 ± 0.0007416 | 1.01 | 0.99 |
| 14 | *Azadirachta indica* | Tree | 0.43 ± 0.0000516 | 0.18 ± 0.0000216 | 2.39 | 0.42 |
| 15 | *Dichrostachys glomerata* | Shrub | 0.97 ± 0.0001164 | 0.17 ± 0.0000204 | 5.71 | 0.18 |
| | Mean | | 1.56 ± 0.0001872 | 6.63 ± 0.0007956 | 0.79 | 8.00 |

**Table 10:** Bd distribution in the productivity Zones

| Productivity Areas | Area characteristics | Diouroup | Ndiago |
|---|---|---|---|
| Zone 1 | Bd ($t.ha^{-1}$) | 0 – 50 | 0 – 25 |
| | Location | South-central / West | North-central / South |
| | Strata | Shrub | Trees / Shrub clumps |
| | Main vegetation pressure factors | Significant human settlement impact, tannes salinity | Clearing and timber harvesting |
| Zone 2 | Bd ($t.ha^{-1}$) | 50 – 150 | 25 – 50 |
| | Location | North-central / South-central | North to South, surrounded by Zone 1, patch within the Southern part of Zone 1 |
| | Strata | Tree / Shrub | Heavily Tree wooded farmland |
| | Main vegetation pressure factors | Clearing and timber harvesting | Agricultural fields |
| Zone 3 | Bd ($t.ha^{-1}$) | 150 – 300 | 50 – 110 |
| | Location | North | West / East / South-central, surrounds Zone 2 in the middle of the southern part of which it contains a patch. |
| | Strata | Tree forest | Clumps Tree Forest |
| | Main vegetation pressure factors | ------ | ------ |

**Table 11:** Kriging outliers

| Diouroup | | Ndiago | |
|---|---|---|---|
| Plot | Db outlier ($t.ha^{-1}$) | Plot | Db outliers ($t.ha^{-1}$) |
| 108 | 845 | 35 | 490 |
| | | 95 | 184 |
| | | 104 | 178 |
| | | 73 | 165 |
| | | 28 | 148 |

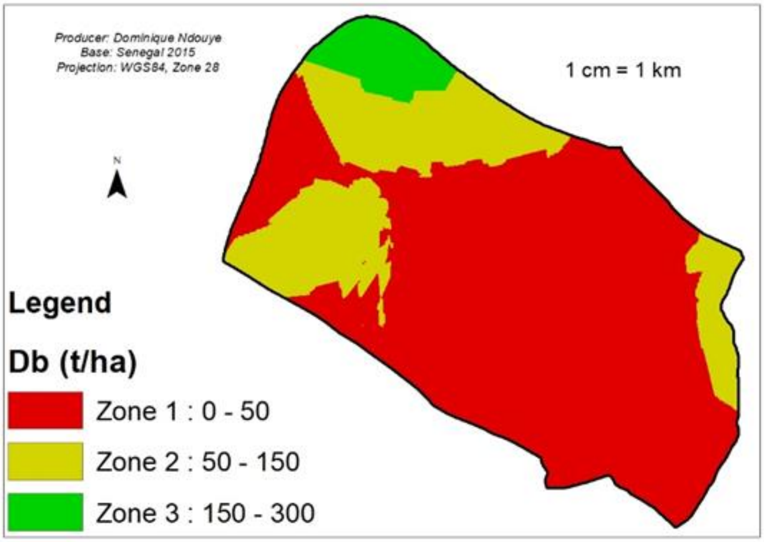



**Figure 13:** Horizontal distribution of Biomass in Diouroup

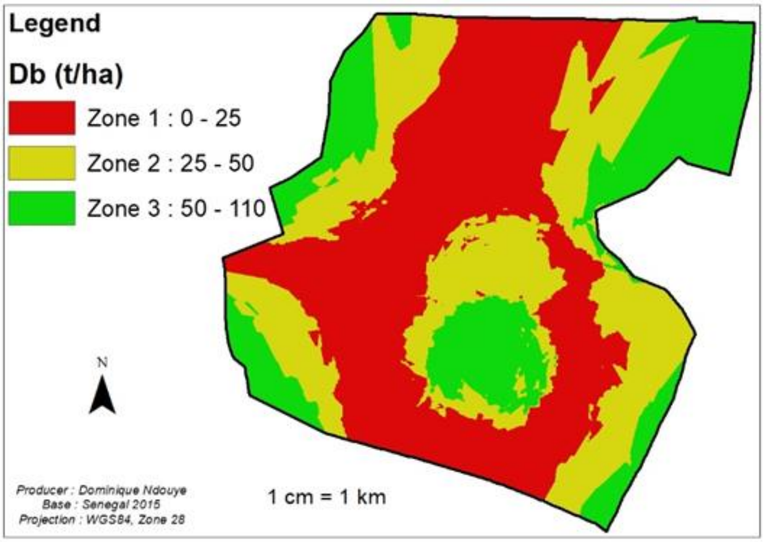



**Figure 14:** Horizontal distribution of Biomass in Ndiago

**Carbon Densities (Cd) Distribution**

Even if the general study areas Carbon density (Cd) mean is 16.4 ± 0.002 tC.ha$^{-1}$, the strata Cd stocks analysis reveals many variabilities. Tree strata Cd is generally higher than the Shrub Strata's *(Table 12)*. The Diouroup Shrub Stratum stores a third as much as the Ndiago Shrub Stratum whereas the Diouroup Tree Stratum Cd is twice as much as the Ndiago Tree Stratum's *(Table 12)*. The Rate of the Standard Deviation relative to the Mean (RSDM) shows high values in the Diouroup Shrub (264 %) and Tree (232 %) Strata and the Ndiago Shrub (171 %) and Tree (225 %) Strata.

The variance (and the covariance) of Cd increases exponentially in the two communes when one goes from Shrub (34 ± 0.00408 and 211 ± 0.02532 tC.ha$^{-1}$) Tree Strata (8,078 ± 0.96936 and 1,334 ± 0.16008 tC.ha$^{-1}$).

**Table 12:** Carbon Storage by stratum

| Carbon density (tC.ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|
| Strata | Shrub | | Tree | | Mean |
| Commune | Diouroup | Ndiago | Diouroup | Ndiago | |
| Mean | 2.21 ± 0.00027 | 8.53 ± 0.001 | 38.7 ± 0.0046 | 16.2 ± 0.0019 | 16.4 ± 0.002 |
| Maximum | 33 ± 0.004 | 92 ± 0.011 | 422 ± 0.051 | 228 ± 0.027 | 194 ± 0.023 |
| Minimum | 0.06 ± 0.0000072 | 0.07 ± 0.0000084 | 0.23 ± 0.000028 | 0.11 ± 0.000013 | 0.12 ± 0.000014 |
| Standard deviation | 5.83 ± 0.0007 | 14.5 ± 0.0017 | 89.9 ± 0.011 | 36.5 ± 0.0044 | 36.7 ± 0.0044 |
| RSDM (%) | 264 | 170 | 233 | 225 | 223 |
| Variance | 34 ± 0.004 | 211 ± 0.025 | 8.08 ± 0.00097 | 1.33 ± 0.00016 | 63.6 ± 0.0076 |
| Covariance | 93.8 ± 0.011 | | 780 ± 0.094 | | 218 ± 0.026 |
| Area (ha) | 10,462 | 1,514 | 1,471 | 1,158 | 3,651 |
| Stock (t) | 23.1 ± 0.0028 | 12.9 ± 0.0015 | 56.9 ± 0.0068 | 18.8 ± 0.0023 | 27.9 ± 0.0034 |

In Diouroup and Ndiago area, the Shrub stratum is larger than the Tree's one, making our plants community essentially a Shrub Savannah one *(Figure 10)*.

Being just 49 Km apart, the two communes share the same geographic regional vector (p.). Normally, the results found between them should be too close *(Table 6)*. In fact, they are not so different in the overall means but in the various ALs' values. Indeed, the ANOVA test has proved the allometric model *MBOW, et al., (2013)* fits our study area's data (p.). In addition, Biomass values produced by the Similar Model (Henry, Picard, Trotta, & Valentini, 2011) and the Intermediate Model (BROWN, Estimating Biomass and Biomass Change of Tropical Forests: A Primer; Forestry Paper 134, 1997) results are closer the *MBOW, et al., (2013)*'s ones. This is because of the similarity in the original phytogeographical developing conditions of MBOW (Senegal), Henry (Senegal) and somehow Brown (Tropical zone) *(Table 5)*. The overall mean Carbon density (16.4 ± 0.002 tC.ha$^{-1}$) is close to that found at Sokone, a neighbouring site, 14 tC.ha$^{-1}$ (Skole, Samek, Dieng, & Mbow, 2021). This value also corresponds to the default average density recommended by the IPCC for when we assess aboveground biomass in Senegal. On the contrary, the great differences in the phytogeographical conditions between our study areas and the ones of the extreme models *(FAO, http://www.globallometree.org/ ; KUYAH, et al., 2012)* increase the deviation of the compared results *(Table VI)*.

In the Biomass density (Bd) kriging, we counted 6 outliers for Ndiago against 1 for Diouroup *(Table 11)*. This is symbolic of the that the unit (plant individual, plot, …) variable (Ba, Sd,…) values are higher in Ndiago than in Diouroup *(Table 8)*, whereas large space (Stratum) variable (Zone Bd) values are higher in Diouroup than in Ndiago *(Table 10)*. Thus, there was a great variability in the Bd between Diouroup and Ndiago *(Table 8)*.

This variability is mainly exacerbated by a natural factor in Diouroup, the salt and an anthropic factor in Ndiago, the LULUCF. The Tree and Shrub covers are both larger in Diouroup than in Ndiago. Plus, the vastest class in Diouroup is Shrub Savannah with 46.3% of the area and in Ndiago, the Bare/Agricultural ground with 62.9% (*Figure 6*). This suggests that clearing/logging is more impactful in Ndiago than salt is in Diouroup. The salt impact is so large as it contributes to keep too many plants at the Shrub stage whereas in Ndiago the clearing/logging has the greatest land use impact. In fact, too much salt in the plant's sap causes an osmotic imbalance. So, to reduce the loss of sap's water due to this osmotic imbalance, the plant closes its stomata to prevent from an additional loss by evapotranspiration. At the same time, this action prevents also from $CO_2$ (Carbon dioxide) entry through stomata for the photosynthesis to produce the plant Biomass and to grow (Borsai, et al., 2021). Diouroup and Ndiago correspond to localities where live poor populations whose survival and financial incomes depend principally on agriculture and logging activities inside the non-classified vegetation; hence, they exert a pressure on vegetation land cover (p.).

When we compare the 15 most productive species common to Diouroup and Ndiago, some like *Acacia seyal*, *Combretum aculeatum*, *Anogeissus leiocarpus*, are respectively 47.0, 14.6, and 12.0 times more productive in Ndiago than in Diouroup, with a general BdMF of 8. What factor can produce such a massive, systematic and non-discriminatory phenomenon on similar species between two close areas? – A natural one, salt (*Table 9*). Nevertheless, we notice some inverse BdMF values concerning *Azadirachta indica, Combretum glutinosum, Dichrostachys glomerata*. These are species adapted to stress conditions like salty one (Abu-Elala, Et Al., 2023; Amani, Ichaou, Karim, & Mahamane, 2021; Asif, Naseer, Turabi, Khan, & Maryam, 2023; Hausenblas, Lynch, Befus, Braverman, & Hooper, 2024; Kassambara, Et Al., 2025; Lapo, Ingambire, & Moussa, 2025; Singh, Kumar, Rajkumar, Sheoran, & Yadav, Effects of sodic water irrigation on growth, physiological relations and ion uptake in two Ziziphus rootstocks in Indian Journal of Agricultural Sciences, 2018).

Considering some dendrometric data, such as Basal area (Ba), Stems density (Sd) that are higher in Ndiago, one could imagine the vegetation thrives there more than in Diouroup. In addition, the Dbh, the variable most strongly correlated with the Carbon (Atsri, Kokou, Abotsi, Kokutse, & Cuni-Sanchez, 2020) shows Strata mean values almost equal between Diouroup and Ndiago. Nevertheless, we saw that Diouroup Tree Savannah Strata's Cd ($27.5 \pm 0.0033$ $t.ha^{-1}$) is higher than the Ndiago Tree Savannah Strata's ($15.4 \pm 0.001848$ $t.ha^{-1}$) but the opposite occurs between Diouroup Shrub Savannah ($2.29 \pm 0.0002748$ $t.ha^{-1}$) and Ndiago Shrub Savannah ($8.85 \pm 0.001062$ $t.ha^{-1}$). We attribute this inconsistency to salt and clearing/logging that cause a great values variability between the Carbon ALs of Diouroup and Ndiago (*Table 8).*

To the AL of Bd classes [ 5 ; 10 [, [ 10 ; 15 [, [ 15 ; 20 [, [ 20 ; 25 [, the abnormality of the Diouroup Shrub's low values becomes all the more understandable when we compare them to Ndiago ones (*Figure 11*). This must be because salt lowers the growth of younger plants *(Figure 12).*

The Bd kriging maps demonstrate the natural, coherent, structured effect of salt in Diouroup contrary to the anthropic, discriminatory effect of clearing/logging on Bd productivity distribution in Ndiago. Whatmore, salt reduces unit Biomass density in Diouroup and LULUCF reduces Stratum Biomass density in Ndiago *(Table 8).*

Some 9 phytogeographic variables including Abundance were taken into account in the LSPI calculation (p.). In spite of these numerous variables, we counted the 7 mosvalidity *(Table 7)*. The cross-analysis of LSPI and the BdMF allowed interesting comments. *Balanites aegyptiaca*, *Combretum glutinosum* and *Faidherbia albida*, the most abundant and performant in C storage (LSPI) in Diouroup and Ndiago, show a respective Bd Multiplier Factor (BdMF) from Diouroup towards Ndiago of 2.84, 0.99 and 4.70. This difference illustrates enough the role of salt in Carbon Storage. The species genetics probably also influences the adaptability of the *Combretum glutinosum* that permits its storage performance to be almost even between Diouroup and Ndiago *(Table 9).*

Definitely, *Combretum glutinosum, Balanites aegyptiaca, Guiera senegalensis, Adansonia digitata, Faidherbia albida,* are the LSPI top-5 species that are strongly recommended for future Carbon sequestration projects.

## Conclusion

This study has assessed the predicted Above-Ground Carbon stocks vegetation in Diouroup and Ndiago. The variation inside the Accumulation Levels of Carbon is mainly increased by the presence of salt in Diouroup and by the Land Use, Land Use Change and Forestry activities in Ndiago. These factors deeply effect the structure and physiognomy of the plants community hence, especially the distribution of their Carbon stocks and their variability. Even between many of the most productive similar species between Diouroup and Ndiago, there is a great difference in the Carbon density values. We developed the Local carbon Storage Performance Index to identify the most performant species in Carbon storage. This parameter takes into account not only the Carbon density but also other variables related to the Biomass productivity. This allows the comparison between different endemic species, thus, to be able to select the most performant ones for future LULUCF afforestation and reforestation projects.

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