*J. Appl. Environ. Biol. Sci.*, 2(7)271-280, 2012



ISSN 2090-4274
Journal of Applied Environmental and Biological Sciences
*www.textroad.com*

# Natural Regeneration of Woody Stands in the Groundnut Basin Lands in the Sudano-Sahelian Zone (Region of Kaffrine, Senegal)

**Charles Bakhoum[1]*, Babou Ndour[2], Leonard Elie Akpo[3]**

[1]Department of operations, World Vision Senegal, B.P. 3731 RP, Dakar, Senegal
[2]Institut Sénégalais de Recherches Agricoles (ISRA) du Sénégal, Centre National de Recherches Agronomiques (CNRA) de Bambey, B.P. 53 Bambey
[3]Laboratoire d'Ecologie végétale et d'Ecohydrologie, Faculté des Sciences et Techniques, Université Cheikh Anta DIOP, Sénégal, B.P. 5005 Dakar (Sénégal)

## ABSTRACT

The assessment of woody regeneration capacity in Sudano-Sahelian zone in Senegal was determined from the woods inventory and counting. To assess the regenerative potential of the species, an inventory of juvenile plants (basal diameter was less than 3.5 cm) was made. Only the diameter and the height of the highest seedling were measured. Other seedlings supposedly belonging to the same strain were systematically counted. The natural regeneration was strongly dominated by the family of Combretaceae (*Combretum glutinosum* and *Guiera senegalensis*), followed by the Caesalpiniaceae (*Piliostigma reticulatum*). Regeneration capacities varied depending on the lands under the influence of topography gradients and recovery according to a factorial correspondence analysis (soils x species matrix) which allowed the identification of the main groups of lands and to characterize the heterogeneity of the woody stand. There was a variability of the natural regeneration by size and a positive correlation between the height and the basal diameter of seedlings.
**Keywords**: seedlings – species – regenerative capacity – topography – recovery.

## INTRODUCTION

In semi-arid, harsh climatic conditions are among the limiting factor in the balance of ecosystems. The distribution of wood is strongly related to human pressures that threaten regeneration ([1]; [2]; [3]). In the Sahel, the decline of rainfall, land clearance for expansion of cultivation areas; have contributed to environmental degradation ([4]; [5]). In Senegal enormous changes to forests, farmlands, waterways, and air are being driven by the need to provide food, fiber, water, and shelter to rapid growing population. Croplands, pastures, plantations, and urban areas have strongly expanded in recent 20 years, accompanied by large increases in energy, water and fertilizer consumption ([6]; [7]).The level of reduction is especially important in Senegal that many species are located in the Sahelian climate conditions ([8]; [9]).

It is important to study the capacity of natural regeneration of woody species in the Groundnut Basin, heavily agricultural area where the woody is threatened by the factors listed above in order to better preserve the potentiality of the remained natural vegetation.

The restoration and / or the rehabilitation of ecosystems advocated as a solution needed to be based on native species ([10] [11]) and in particular on their capacity for regeneration [12]. An actual knowledge of the potential for natural regeneration of woody species and environmental constraints can better assess the influence of various factors on density and height of seedlings ([13]; [14]) and to help the identification and the species selection for regeneration purpose. It provides to development projects some tools to establish a sustainable strategy of intervention with respect to the environment ([15]; [16]).

The present research aimed to evaluate the regenerative capacity of woody species in the lands of South-eastern of the Groundnut Basin in Senegal.

## 2. MATERIAL AND METHODS

### 2.1. Site Location

The study was conducted in the Groundnut Basin in Senegal, precisely in Koungheul and Kaffrine departments located between 15 ° 86' W and 14 ° 58' E longitudes and 14 ° 74' N and 13 ° 74' S latitudes (Figure 1). The climate is Sudano-Sahelian with a rainy season of short duration ranging from June to July to October and a long dry season from 8 to 9 months. The monthly average temperatures minimum and maximum are respectively 18.2 ° C in January and 40.7 ° C in April. The average annual temperature is 29.6 ° C. Theanalysis of rainfall series 1958-2008 showed that the interannual averagerainfall was 640 ± 171 mm. The coefficient of variation was 27%.

***Corresponding Author:** Charles Bakhoum, Department of operations, World Vision Senegal, B.P. 3731 RP, Dakar

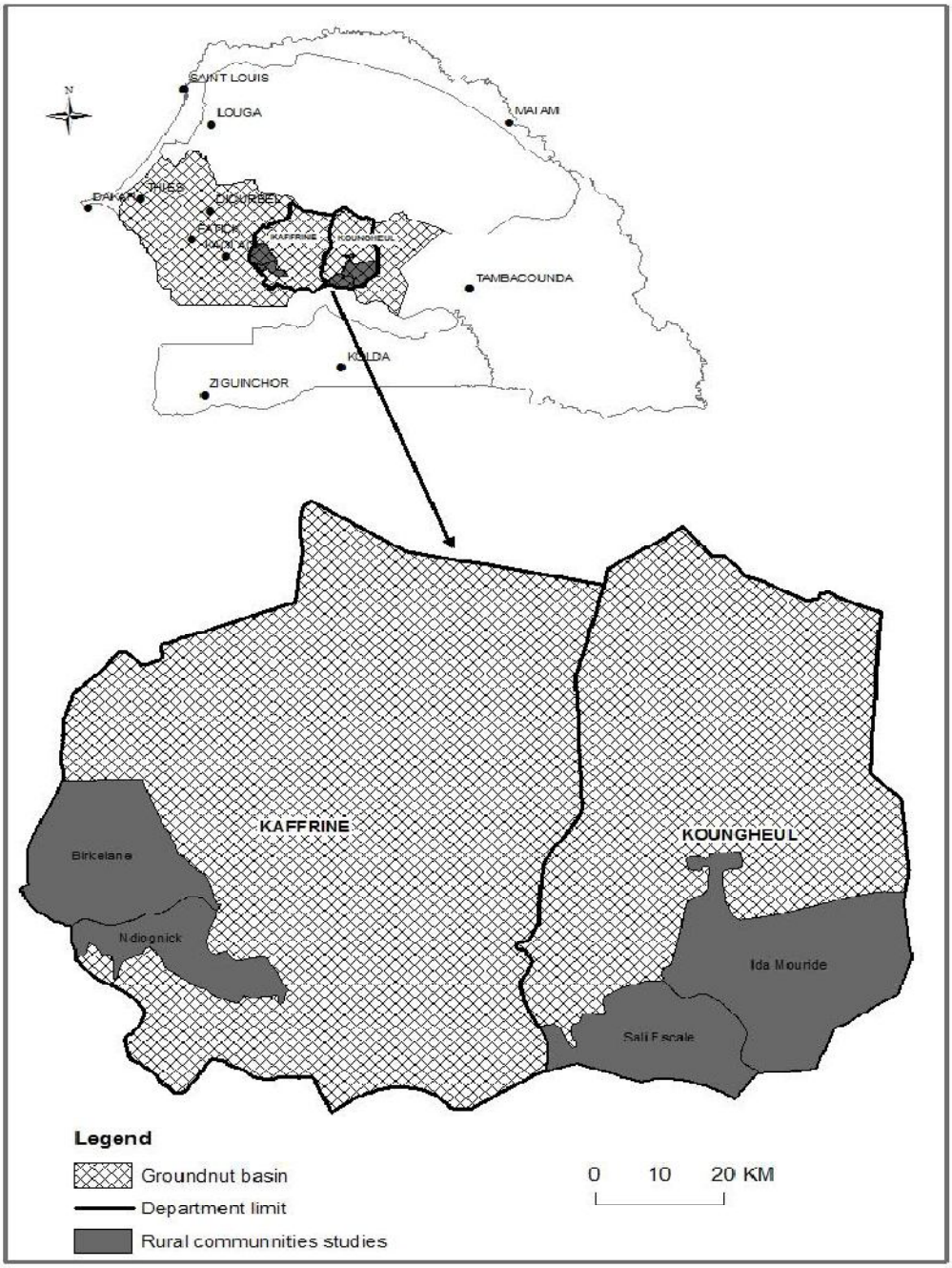



**Figure 1.** Location of the site (DEFCCS/CSE, 1996)

## 2.2. Methods

A total of 25 groups of villages in the studied area, were determined according to some cultural practices criterion (intensity of agricultural activity, diversification, mechanization level, presence or absence of fallow, trees density in fields). In each group, equidistant transects of 500 m oriented East-West were laid down. Therefore, every 500 m, plots of 50 m x 50 m were delineated in fields, in fallows and in forests plots of 30 m x 30 m were installed. Fifty plots were ultimately laid out in each land.

The complete enumeration of the woody stand was then performed in a total of 1143 plots of 262 ha [6] and the seedlings were identified and counted. Only the diameter and the height of the highest seedling were measured. Other seedlings supposedly belonging to the same strain were systematically counted.

### 2.3. Data analysis

To establish the regeneration of woody species, we defined by "seedling," any plant which trunk basal diameter is less than 3.5 cm (10 cm of circumference) **[11]**.

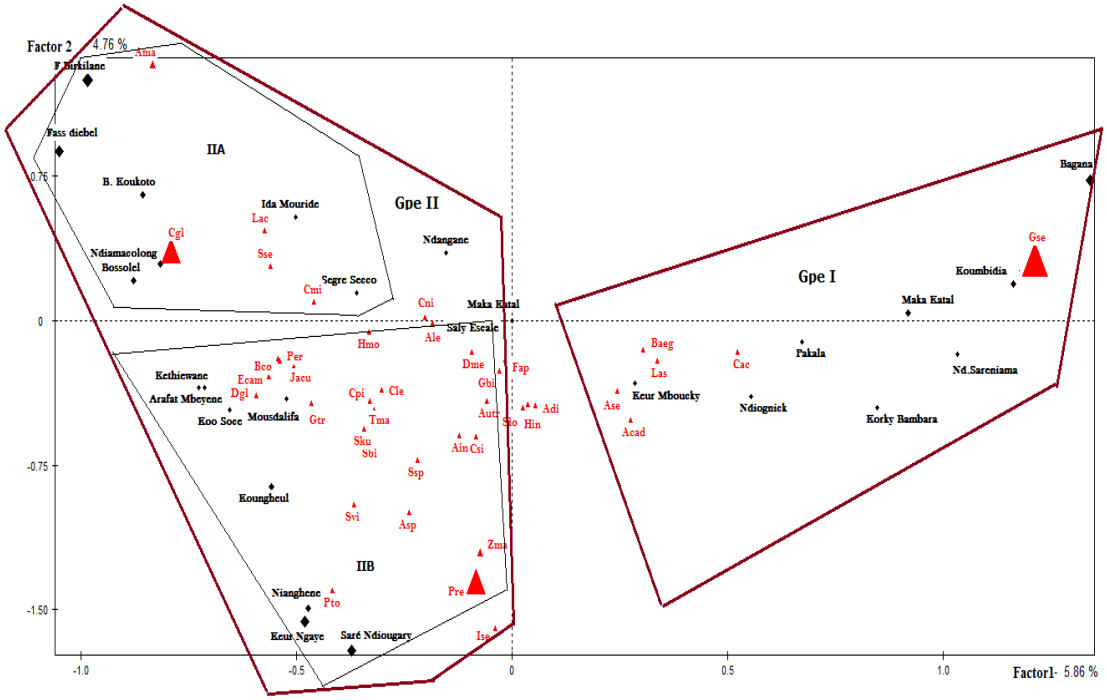
The factorial analysis of correspondence (Lands x species matrix) was used to define the main groups of land and to characterize the heterogeneity of the woody stand.

The composition and the structure of the woody stand were studied. The ecological importance of species allowed the identification of the woody stand.

## 3. RESULTS

### 3.1 Typology of the woody stand

The typology of the woody stand has allowed to identify four groups of lands of *Piliostigma reticulatum* and *Combretum glutinosum* and lands of *Guiera senegalensis* and *Combretum glutinosum.* These lands are subdivided into lands of *Guiera senegalensis* and *Combretum glutinosum* **[6]**.




Δ : species
◊: Lands

Figure2. Definition of land groups using factorial analysis of correspondence (FAC)

### 3.2 Characteristics of seedlings

#### 3.2.1. Variability among families

The woody stand of 33 families with 59 genera and 75 species was strongly dominated by the family of Combretaceae which included 72.5% of seedlings, followed by the Cesalpiniaceae with 15.2%. Only five other families, Mimosaceae (3.2%), Rhamnaceae (2.1%), Anacardiaceae (1.5%), Icacinacées (1.2%) and Rubiaceae (1.1%) had higher frequencies 1% (Figure 3). These results showed that although there was a diversity of families (33), young plants were concentrated in Combretaceae and Cesalpiniaceae. The best represented species in these two families seemed to find favorable conditions enough or an adaptation strategy in the area of study.

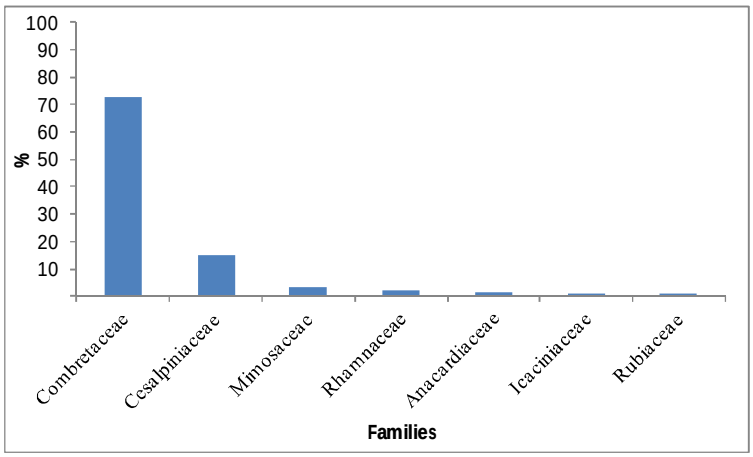



**Figure 3.**Frequencies of the most represented families

### 3.2.1.1 Renewal of species

The regeneration rate of species varied among families. *Combretum glutinosum* and *Guiera senegalensis* (Combretaceae) and *Piliostigma reticulatum* (Cesalpiniaceae) were distinguished by their higher regeneration rate with respectively 36.3%, 29.4% and 13.6%. In the lands, each of these species indicated minimum regeneration rate in the lands of *Piliostigma reticulatum* and *Combretum glutinosum*, 9.4% for *Combretum glutinosum*, 7.9% for *Guiera senegalensis* and 4.3% for *Piliostigma reticulatum*. The maximum rate of *Guiera senegalensis* (17.4%) and *Piliostigma reticulatum* (5.7%) was found in the lands of *Guiera senegalensis* and *Combretum glutinosum* (16.6%) in the same lands. *Acacia macrostachya* and *Cordyla pinnata*, two of the five most represented adult species [6] indicated rates below 1% (Figure 4). Three species (*Lannea acida*, *Euphorbia balsamifera*, *Crataeva religiosa*) showed no seedlings.

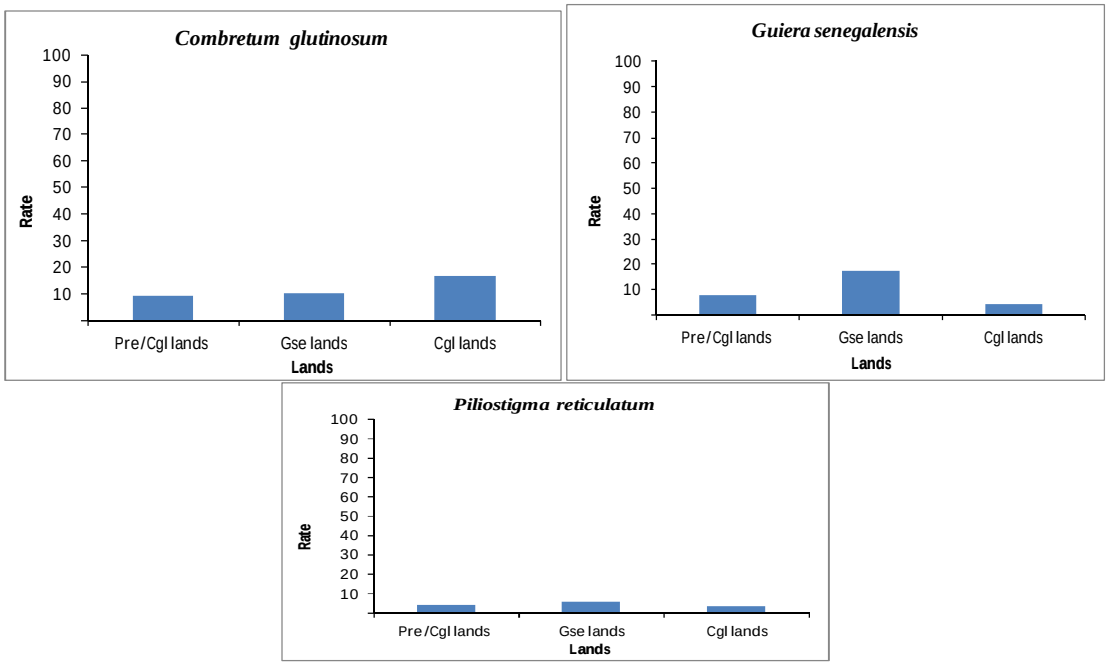



**Figure 4**. Regeneration rate of the most represented species
(Cgl = *Combretum glutinosum* Pre = *Piliostigma reticulatum* ; Gse = *Guiera senegalensis*)

### 3.2.2 Structure of seedlings

### 3.2.2.1 Distribution according to diameter

The distribution of seedlings by diameter class showed that the class from 0.5 to 1 cm was the most represented with a frequency of 36.1%. This was followed by classes 1.5 to 2 cm (18.1%), 1 to 1.5 cm (17.2%) and less than or equal to 0.5 cm (12.1%). Other classes had their frequencies below 10% (Figure 5). Results on

the distribution of basal diameter indicated that the seedlings of the woody stand were concentrated in the first classes. Discharges which were numerous in fields but cut annually in the pre winter preparing and promptly released could explain it.

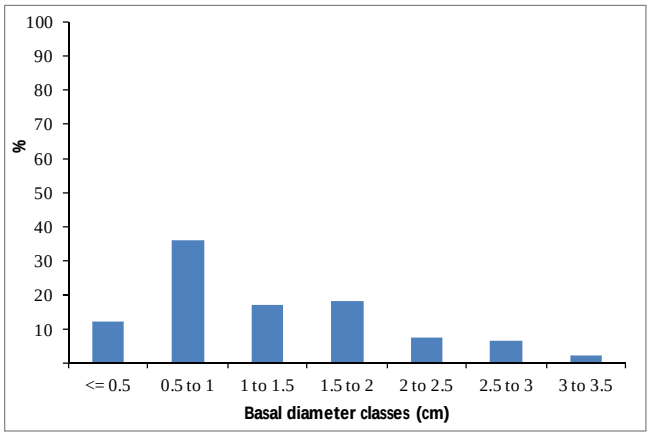



**Figure 5**. Distribution of seedlings according to basal diameter

### 3.2.2.2 Distribution according to height

It was also the second class (0.6 to 1.1 m) which contained more individuals with a frequency of 31.7%, followed by classes from 1.1 to 1.6 m (24, 6%) and 0.1 to 0.6 m (24.4%). These first three classes concentrated together 80.7% of young plants whereas the last three classes included 19.4% (Figure 6). The Pearson correlation test showed that the relationship between height and basal diameter of young plants was strong and significant.

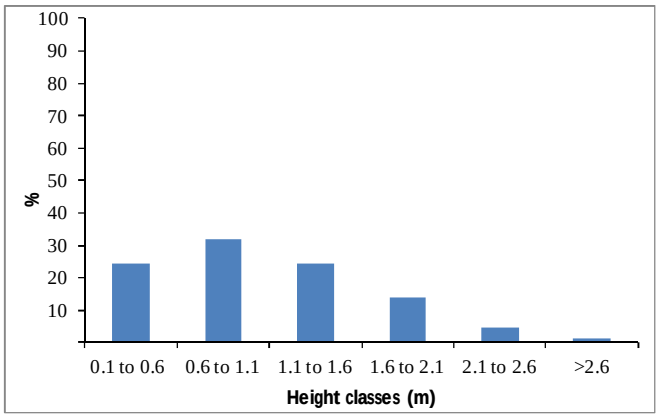



**Figure 6**. Distribution of seedlings according to height

### 3.2.3. Distribution in the lands

### 3.2.3.1 Frequency

All seedlings, in lands of *Piliostigma reticulatum* and *Combretum glutinosum* contained 27.9% of individuals covering 92 ha. The lands of *Guiera senegalensis* indicated 43.8% of seedlings occupying 100 ha and those of *Combretum glutinosum* counted 28.3% on 70 ha. For measured individuals 28% were counted in the lands of *Piliostigma reticulatum* and *Combretum glutinosum*. The lands of *Guiera senegalensis* and those of *Combretum glutinosum* contained respectively 42.2% and 29.8% of individuals (Figure 7). These results showed that the lands of *Guiera senegalensis* and *Combretum glutinosum* contained 72% of seedlings recorded in the woody stand. The topography and the recovery which allowed the determination of the respective lands seemed to play a role. If for seedlings, the lands of *Guiera senegalensis* presented more individuals (42.2%), adult individuals were dominant in lands of *Combretum glutinosum* (61.6%) [6].

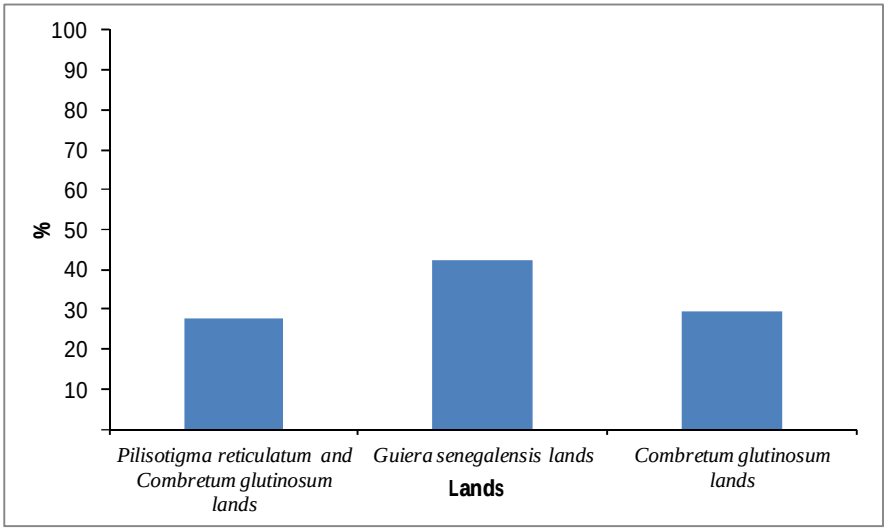



**Figure 7**. Frequency of seedlings of vegetation in the lands

### 3.2.3.2 Distribution according to basal diameter and height

The distribution of seedlings according to the basal diameter depending on lands indicated that the second, third and fourth classes contained most of the seedlings. These three classes had a frequency of 74.3% in the lands of *Piliostigma reticulatum* and *Combretum glutinosum*, 67.7% in the lands of *Guiera senegalensis* and 74% in those of *Combretum glutinosum* (Figure 8).

The distribution of juvenile plants by basal diameter class was unimodal in lands of *Piliostigma reticulatum* and *Combretum glutinosum* and those of *Guiera senegalensis* with a peak for the class 0.5 to 1 cm.

In contrast, this distribution was bimodal in the lands of *Combretum glutinosum*, with a first peak for the class 0.5 to 1 cm (41.7%) and the second peak, less important was the class from 1.5 to 2 cm (20.1%). The first class (less than or equal to 0.5 cm) was relatively weakly represented. The frequency of seedlings in the lands from the fifth class was less than 10%.

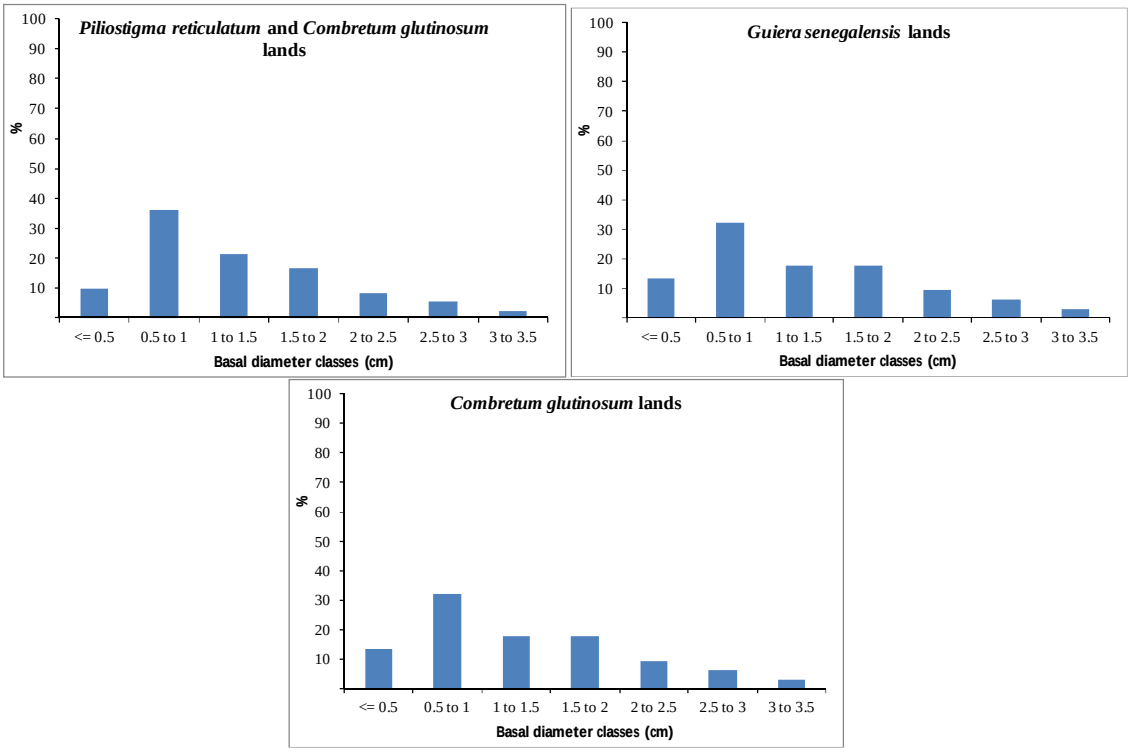



**Figure 8**. Distribution of seedlings according to basal diameter in the lands

The distribution of juvenile plants according to height showed that the first three classes were strongly represented in seedlings. Their frequency was 84.6% in the lands of *Piliostigma reticulatum* and *Combretum glutinosum*, 76.1% in those of *Guiera senegalensis* and 83.4% of Combretum glutinosum. The first class from 0.1 to 0.6 m had more seedlings in the lands of *Combretum glutinosum* (31.9%) than in those of *Piliostigma reticulatum* and *Combretum glutinosum* (21.7%) and *Guiera senegalensis* (20, 8%) (Figure 9). For the last two classes (2.1 to 2.6 m and above 2.6 m), the number of seedlings recorded was low (below 10%) including 3% in the lands of *Piliostigma reticulatum* and *Combretum glutinosum* , 8.3% in those of *Guiera senegalensis* and 4.8% in lands of *Combretum glutinosum*. Comparing the overall distribution of seedlings according to size (basal diameter and height) with that in the lands of *Piliostigma reticulatum* and *Combretum glutinosum*, lands of *Guiera senegalensis* and *Combretum glutinosum*, it was as if the distribution was carried by the lands of *Guiera senegalensis* which was more densely populated in seedlings.
The Pearson correlation test is strong and significant at 5% in the lands between basal diameter and height.

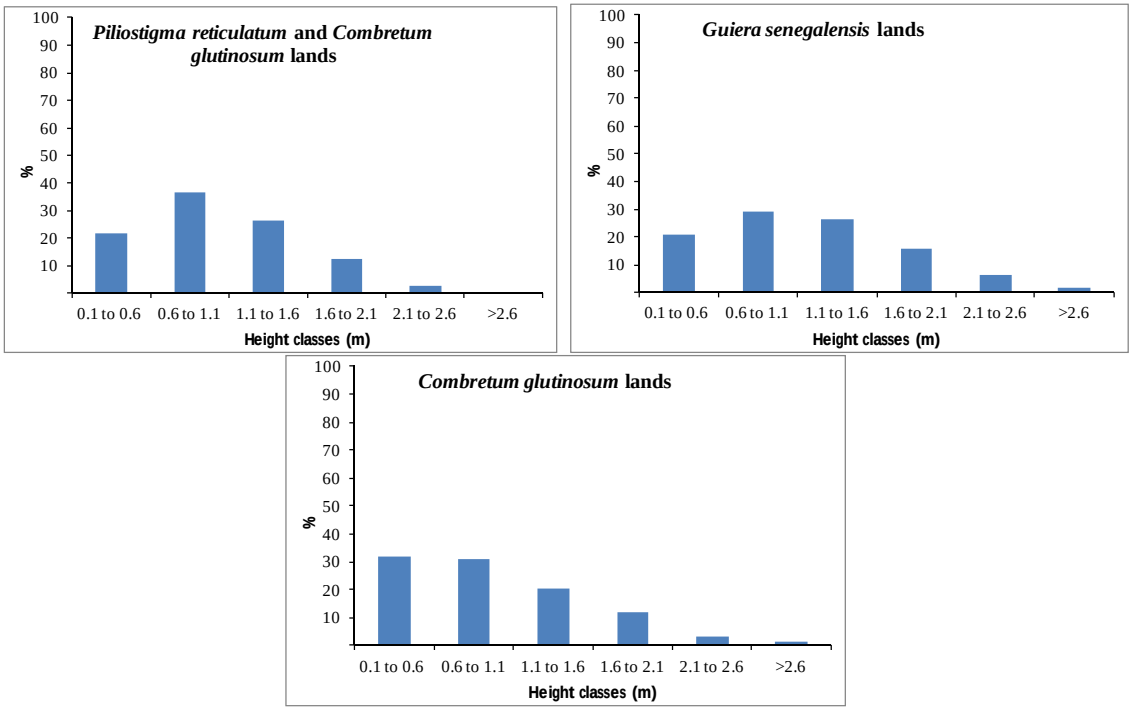



**Figure 9**. Distribution of seedlings according to height in the lands

## 4. DISCUSSION

In the study area, it was sometimes difficult to know whether several emerging seedlings belong to the same strain for species such as *Combretum glutinosum* , *Guiera senegalensis* ,*Piliostigma reticulatum*. There was also considerable uncertainty by assuming that each of the many seedlings counted could become a shrub. Many authors who worked in semi-arid raised this difficulty ([17]; [18]; [19]). Thus, to avoid an overestimation of the natural potential regeneration, seedlings measured were used in data. The comparison showed that the lands of *Guiera senegalensis* and *Combretum glutinosum* were respectively fitted in more seedlings than lands of *Piliostigma reticulatum* and *Combretum glutinosum*. This is partly due to the topography factor ([3]; [20]). The lands of *Piliostigma reticulatum* and *Combretum glutinosum* were characterized by an irregular relief (top and bottoms) which promoted water erosion might be a constraint for the release and survival of natural seedlings. As for the land of *Guiera senegalensis* and *Combretum glutinosum*, they were marked by a regular relief (flat), the middle could be favorable to the development of seedlings due to its stability that would promote water infiltration into the soil. In the Sahel, the topography factor has been identified as involved in generating the heterogeneity of population ([21]; [3]). In lands of *Piliostigma reticulatum* and *Combretum glutinosum*, it was found a more intense agricultural activity compared to those of *Guiera senegalensis* and *Combretum glutinosum*. Almost all arable land was planted which did not favor the recovery of the vegetation through natural regeneration ([22]). The human pressure was a determinant of natural regeneration ([8]; [23]; [24]). One of the main causes of vegetation change is the gradual occupation of the land by crops ([25]; [19]; [26]). Only shrubs that are able to regenerate relatively quickly lead to a change in vegetation structure and composition ([27]; [28]).

The separation of lands of *Guiera senegalensis* and *Combretum glutinosum* made on the basis of recovery, demonstrated the importance of natural regeneration and was positively correlated with the importance of recovery by species. This result confirms the conclusion of [11] Akpo and Grouzis (1996a) that cover favors the regeneration of woody species.Tree improves edapho-climatic conditions in arid and semi-arid Africa ([29]; [30]). It acts favorably on microclimatic factors, improving the stock of water, and soil fertility, reduces evapotranspiration ([31]; [32]; [5]; [33]).

Certain works indicated a dominance of seedlings that means a mode of reproduction essentially asexual (vegetative) [19]; [6]. It is as if there were difficulties of regeneration by sexual reproduction. In other semi-arid environments, studies have shown that vegetative regeneration is often known as an adaptation strategy against disturbances and climatic changes of sexual species ([34]; [5]). However this mode of reproduction, as a result of genetic erosion, is not favorable to the preservation and maintenance of plant populations. Also asexual regeneration does not guarantee the spatial propagation of species at a comparable scale that would match that of seeds [35]. The vegetative reproduction seems to reflect a pressure on the woody through various factors (drought, predators, wildfires and other anthropogenic activities) [36].

*Combretum glutinosum*, *Guiera senegalensis* and *Piliostigma reticulatum* most represented adult species [6], showed the highest regeneration rates with an essentially vegetative mode of reproduction. This regenerative potential is related to several factors:

• existing species frequently abundant sprouting in the fields of culture, are cut each year during the clearing ([37]; [38]) but regenerate quickly [29];
• these species are not killed by farmers because of their multiple uses [39];
• although they are palatable to livestock [40], they are not their main forage in the study area;
• the comparison of changes in rainfall marked by a deficit ([41]; [42]; [43]) with the changes in the structure of seedlings, showed that *Combretum gluinosum*, *Guiera senegalensis* and *Piliostigma reticulatum*, developped the best strategies for adaptation to climate change.

*Acacia macrostachya* and *Cordyla pinnata* among the five most represented adult species are threatened of disappearance. The natural regeneration of *Cordyla pinnata* is annihilated by the mechanization of agriculture and early harvesting of fruit by populations [44]. *Acacia macrostachya* is often eliminated in the fields because of its thorns and small branches curved towards the bottom that can impede agricultural mechanization. The three species (*Combretum glutinosum*, *Guiera senegalensis* and *Piliostigma reticulatum*) that best regenerate did not constitute the favorite fodder of animals so they are normally growing. It could confirm a study in the Sahel region, which indicated the existence of a negative correlation between the distribution of diameter and height for *Maerua crassifolia* (very palatable to livestock) related to grazing of seedlings [10]. The typology allowed us to find three groups of homogeneous lands showing that the ecological subdivision did not match administrative one (four rural communities).

## CONCLUSION

The regeneration of the woody stand presented variability depending on the family, the size and lands. *Combretum glutinosum*, *Guiera senegalensis* and *Piliostigma reticulatum* were species with good regeneration potential. Their regeneration rates were significant. This natural regeneration was stimulated by their resilience to disturbance and climatic factors (vegetative reproduction) and their management in the fields by farmers. *Cordyla pinnata* and *Acacia macrostachya* among the five represented woody species in the environment were facing regeneration difficulties. Action must be taken to preserve the species through: a) the promotion of natural regeneration in fallow fields and b) the implementation of a participatory management strategy of classified forests of Koungheul and Birkelane and the protected domain of Mousdalifa c) the development of production of nursery of *Cordyla pinnata*.

Investigations should be prosecuted for a better understanding of different modes of regeneration and dynamics of the three most represented species in seedlings.

## ACKNOWLEDGMENT

This work was performed under the project "farmers managed natural regeneration" of World Vision Senegal. It received financial support from the Australian Government (AUSAID) and technical.

## REFERENCES

[1] Boussim J., Gampine D., Ilboudo J.B., 1998. Etude des contraintes à la régénération naturelle de neuf espèces ligneuses du Burkina Faso. In : Ba A.T., Madsen J., Sambou B., eds. Végétation et biodiversité au Sahel. Danida: Aarhus (39) : 289-301.

[2] Gijsbers H.J.M., Kessler J.J., Knevel M.K., 1994. Dynamic and natural regeneration of woody species in farmed parklands in the Sahelian region (Province of Passore, Burkina Faso). For Ecol Manage, 64: 1-12.

[3] Vincke C., Diedhiou I., Grouzis M., 2010. Long term dynamics and structure of woody vegetation in the Ferlo (Senegal). Journal of Arid Environments 74: 268–276.

[4] Akpo L. E., I. Coly, D. Sarr, Ngom et S. Ndao, 2004. Modes d'utilisation des terres et diversité floristique dans le terroir de la Néma en zone Semi-aride (Sénégal, Afrique de l'Ouest). Journal of agriculture and environment for international development, Vol. 98, No. ¾.

[5] Kizito F., Sene M., Dragila M.I., Lufafa A., Diedhiou I., Dossa E., Cuenca R., J. Selker J., Dick R.P., 2007. Soil water balance of annual crop–native shrub systems in Senegal's Peanut Basin: The missing link. Agricultural water management 90: 137 – 148.

[6] Bakhoum C., Ndour B., Akpo L.E., 2012. Typology of woody stands in Senegal: case of the Groundnut Basin. International Journal of Science and Advanced Technology (ISSN 2221-8386,) Volume 2 No 2 February, http://www.ijsat.com, pp. 26-35.

[7] Paeth, 2006. The climate of tropical and northern Africa-a statistical – dynamical analysis of the key factors in climate variability and the role of human activity in future climate change. In bonner Meterologische Abhandlungen, 61, 340 S.

[8] Touré A., 2002. Contribution à l'étude de l'évolution des réservoirs de carbone en zone nord soudanienne au Sénégal, Thèse N° 2585, Faculté Environnement Naturel, Architectural et Construit (ENAC), Ecole Polytechnique Fédérale de Lausanne (EPFL), pp I-3-11, II-4 p.

[9] Diouf, A., Lambin, E.F., 2001. Monitoring land-cover changes in semi-arid regions: remote sensing data and field observations in the Ferlo, Senegal. Journal of Arid Environments 48, 129–148.

[10] Diatta S., Douma S., Houmey V. K., Banoin M.et Akpo L. E., 2007. Potential de régénération naturelle d'un ligneux fourrager (Maerua crassifolia Forsk.) en zone sahélienne, Revue Africaine de Santé et de Productions Animales, E.I.S.M.V. de Dakar, 5(1-2) : 23-28.

[11] Akpo L. E., & Grouzis, M., 1996a. Influence du couvert sur la régénération de quelques espèces ligneuses sahéliennes (Nord-Sénégal, Afrique occidentale). Webbia 50 (2): 247-263.

[12] Reij C., Tappan G., 2011. Initiatives de Reverdissement en Afrique, Mise à jour, no4.

[13] Samba A.N.S., Sène A., Thomas I., 2000. Régénération des ligneux dans la parc à Acacia albida, CNRF, ISRA, Sénégal, 4p.

[14] Diouf B., 2001. Etude de la Régénération Naturelle Assistée des espèces associées aux cultures annuelles dans les parcelles agroforestières du projet GERT (Gestion de l'Espace et des Ressources Naturelles du Terroir). Mémoire de fin d'étude pour l'obtention du diplôme d'ingénieur des travaux agricoles, Département des Productions Végétales, Ecole Nationales des Cadres Ruraux de Bambey (ENCR), Sénégal, pp. 27-31.

[15] Reij C., Tappan G., Smale M., 2009. Agroenvironmental Transformation in the Sahel, Another Kind of "Green Revolution", The International Food Policy Research Institute (IFPRI).

[16] Larwanou M. et Saadou, 2006. Evaluation de la flore et de la végétation dans les sites traités et non dans les régions de Tahoua, Maradi et Tillabéry. Centre Régional d'Enseignement Spécialisé en Agriculture (CRESA), Niamey, Etude Sahélienne.

[17] Lawesson E.J., 1990. Sahelian woody vegetation in Senegal. Vegetation 86 : 161-174.

[18] Nouvellet Y., 1992. Evolution d'un taillis de formation naturelle en zone soudanienne du Burkina Faso (fascicule 1). Thèse Doc. Sci. Bot. Trop., Université Paris VI, France, pp. 209.

[19] Diatta M., Grouzis M., Faye E., 1998. Typologie de la végétation ligneuse en zone soudanienne. Bois et forets des tropiques, N° 257 (3).

[20] Poupon, H., Bille, J.C., 1974. Recherches écologiques sur une savane sahélienne du Ferlo septentrional, Sénégal: influence de la sécheresse de l'année 1972–1973 sur la strate ligneuse. La Terre et la Vie 28 : 49–75.

[21] Douma S., Diatta S., Banoin M., Kaboret-Zoungrana C. et Akpo L.E. 2007. Caractérisation des terres de parcours sahéliennes : typologie du peuplement ligneux de la Station expérimentale sahélienne de Toukounouss au Niger ; *J. Sci. Vol.* 7, N° 4 :14-16.

[22] Wezel, A., 2000. Scattered shrubs in Pearl millet fields in semiarid Niger. Effect on millet production. Agroforestry Systems 48: 219–228.

[23] Sanogo D. épouse Diaité, 2000. La haie vive dans le Sud bassin arachidier du Sénégal : adoption et conséquences agro-écologiques. Thèse de doctorat de 3èrnc cycle de Biologie Végétale- Faculté des Sciences et Techniques – UCAD – Sénégal, pp.1-4.

[24] Gaze S.R., Brouwer J., Simmonds L.P., Bromley J., 1998. Dry season water use patterns under *Guiera senegalensis* L. shrubs in a tropical savanna. Journal of Arid Environments 40: 53–67.

[25] Diallo H., Bamba I., Barima S., Sadaiou Y., Visser M., Ballo A., Mama A., Vranken I., Maiga M., Bogaert J, 2011. Effets combinés du climat et des pressions anthropiques sur la dynamique évolutive de la végétation d'une zone protégée du Mali (Réserve de Fina, Boucle du Baoulé). Sécheresse vol. 22 n° 3, avril-juin, pp. 97-107.

[26] Briske, D.D., Fuhlendorf, S.D., Smeins, F.E., 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. Journal of Applied Ecology 40 : 601–614.

[27] Nasi R., 1994. La Végétation du centre régional d'endémisme soudanien au Mali. Etude de la foret de Monts Mandingue et essai de synthèse. Thèse de doctorat, université de Paris-Sud XI, 175p. + ann.

[28] Fournier A., Floret C., Gnahoua GM, 2001. Végétation des jachères et succession post-culturale en Afrique tropicale. In : Ch.Floret Ch, Pontanier R. Jachère en Afrique tropicale. Montrouge (France) : éditions John Libbey Eurotext, pp.123-160.

[29] Dossa E.L., Khouma M., Diedhiou I., Sene M., Kizito F., Badiane A.N., S.A.N. Samba S.A.N., Dick R.P., - 2009. Carbon, nitrogen and phosphorus mineralization potential of semiarid Sahelian soils amended with native shrub residues. Geoderma 148 : 251–260.

[30] Iyamuremye, F., Gewin, V., Dick, R.P., Diack, M., Sene, M., Badiane, A., Diatta, M., 2000. Carbon, nitrogen and phosphorus mineralization potential of native agroforestry plant residues in soils of Senegal. Arid Soil Res. Rehabil. 14: 359–371.

[31] Grouzis M., Akpo L.E., 1993. Tree and grass interactions in Sahelina zone (Ferlo, north of Senegal). International conference on desert development "sustainable development for our common future", Mexico city, Mexico, July 25-30: 20 p.

[32] Akpo L.E., Grouzis M., 1996b. Interaction arbre/herbe en zones arides et semi-arides d'Afrique : état des connaissances. Estratto dalla « Rivista di Agricoltura Subtropicale e Tropicale », Istituto Agronomico per l'Oltremare, FIRENZE,Volume 90 (1) : 96-105.

[33] Kizito F., Dragila M. Sene, M. Lufafa A., Dick R.P., Diedhiou I., Dossa, E. Khouma, M. Ndiaye S., Badiane A., 2006. Seasonal soil water variation and root patterns among two semi-arid shrubs coexisting with Pearl millet in Senegal, West Africa. J. Arid Environ. 67: 436–455.

[34] Bellefontaine R., Edelin C., Ichaou A., du Laurens D., Monsarrat A., Loquai C., 2000. Le drageonnage, alternative aux semis et aux plantations des ligneux dans les zones semi-arides : protocole de recherches. Sécheresse 11 : 221-2.

[35] Ouedraogo A., Thiombiano A., Hahn-Hadjali K., Guinko S., 2006. Diagnostic de l'état de dégradation des peuplements de quatre espèces ligneuses en zone soudanienne du Burkina Faso. Sécheresse ; 17 (4) : 485-91.

[36] Diouf, J.C., Akpo, L.E., Ickowicz, A., Lesueur, D., Chotte, J.L., 2005. Dynamique des peuplements ligneux et pratiques pastorales au Sahel (Ferlo, Séneégal). Atelier 2: Agriculture et biodiversité. Actes de la Confe´rence Internationale sur la Biodiversité, Sciences et Gouvernances, Paris, 24–28 janvier 2005. MNHN, Paris, 319 p. + CDRom.

[37] Diedhiou S., Dossa E.L., Badiane A.N., Diedhiou I., Sene M., Dick R.P., 2009. Decomposition and spatial microbial heterogeneity associated with native shrubs in soils of agroecosystems in semi-arid Senegal. Pedobiologia 52: 273-286.

[38] Diack M., Sene M., Badiane A.N., Diatta M., Dick R.P., 2000. Decomposition of a native shrub, *Piliostigma reticulatum*, litter in soils of semiarid Senegal. Arid Soil Res. Rehabil. 14: 205–218.

[39] Boffa J.M., 2000. Les parcs agroforestiers en Afrique de l'Ouest: clés de la conservation et d'une gestion durable. Unasylva 200, Vol. 51.

[40] Arbonnier M., 2002. Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest, deuxième édition, CIRAD, France.

[41] Wang X., Berndtsson R., Li X., Kang E., 2004. Water balance change for a re-vegetated xerophyte shrub area. Hydrol. Sci. 49 (2): 283–295.

[42] Hillel, D., 1998. Environmental Soil Physics. Academic Press Publishers.

[43] Bakhoum C., Ndour B., Akpo L.E., 2012. Diversité du peuplement ligneux des terroirs du bassin arachidier du Sénégal, sous presse, IJBCS. (*In press*)

[44] Sene A., 2000. Dynamique et gestion paysanne des parcs agroforestiers dans le bassin arachidier (Sénégal), édition IRD, pp.186-199.