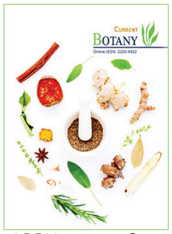
Current Botany 2022, 13: 64-69
doi: 10.25081/cb.2022.v13.7535
https://updatepublishing.com/journal/index.php/cb

Short-Communication



ISSN: 2220-4822

Natural Regeneration *of Parkia biglobosa* (Néré): Status and variation along the South-North climatic gradient in Mali

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ABSTRACT

Parkia biglobosa offers food, medicine and income to rural populations. A study, was undertaken in three agro-climatic zones in southern Mali, to characterise *P. biglobosa* populations. Plots of 0.25 ha each were established in fields and fallows and adult trees in the plots were monitored. Natural regeneration was monitored in five subplots of 12.5 m x 12.5 m = 156.25 m^2 each within each plot and data were collected from 2019 to 2021. Natural regeneration of *P. biglobosa* was found to be very weak in all sites. The mean density of seedlings varied from 11 to 24 seedlings ha^{-1} with a decreasing trend from 2019 to 2021. In Zanzoni, where the weakest regeneration was observed, the density varied from 0 to 8 seedlings ha^{-1}. The highest density of seedlings was observed in Somasso in 2019 (42 seedlings ha^{-1}) and 2020 (30 seedlings ha^{-1}). In 2021, the highest density was observed in Diou (25 seedlings ha^{-1}). The weakness of natural regeneration is very alarming for this tree species facing several other threats (ageing and decreasing adult tree populations, sanitary constraints, several pressures, etc.). It is therefore very important and imperative to investigate ways for regenerating the species for its sustainability and for maintaining the parklands biodiversity. Artificial regeneration (planting), could be the one and ultimate way to ensure the sustainability of *P. biglobosa*.

Received: February 16, 2022
Revised: October 03, 2022
Accepted: October 07, 2022
Published: October 17, 2022

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KEYWORDS: Agro-climatic-zone, Fallow, Parkland, *Parkia biglobosa*, Regeneration

INTRODUCTION

Parkia biglobosa is a forest tree species of the family of Leguminosae/Fabaceae (Sacandé *et al.*, 2016), common in agroforestry parklands in the Sudanian zone. In Mali, *P. biglobosa* is one of the most important parkland tree species, present in the North and the South Sudanian zones of the regions of Kayes, Koulikoro, Ségou, Sikasso and in the North Guinean zones of the regions of Kayes and Sikasso (Fagui, 2015). It is a useful multi-purpose forest tree species providing food for human beings (pulp and grains used to produce the spice called "soumbala" or "dawadawa"). This spice is rich in proteins and contains lipids, essential amino acids, essential fatty acids, vitamins and mineral compounds (Ouoba *et al.*, 2003). *P. biglobosa* provides food for animals also and generates income for rural populations contributing therefore fighting poverty. It also provides medicine and sometimes craft wood (mainly in the North and South Sudanian zones in Mali).

Populations of this species are highly threatened in large parts of its range due to over-exploitation and environmental degradation (Lompo *et al.*, 2017). In all study zones, sanitary constraints (Kelly & Kouyaté, 2020), low density of adult populations in farmed fields as well as in fallows due to several causes like natural mortality, density reduction by farmers in the fields to reduce competition with associated crops (mainly cash crops like cotton which was in expansion in the whole southern Mali) and decreasing fruits production were noticed. These constraints, in addition to climate change and other threats like fire and grazing, endangered the sustainability of this species.

In the objectives to contribute to the domestication of the species in Mali, and more specifically, to understand the status of the resource in different agro-climatic zones, including that of the natural regeneration, a study funded by the Malian Government within the frame of the Competitive Funds for Research and Technological Innovation (CFRTI) was conducted in southern

Mali along the south-north climatic gradient. The present communication highlights the status of the natural regeneration of *P. biglobosa* in the study area.

MATERIAL AND METHODS

Study Sites and Parcels

The study was conducted in three agro-climatic zones (the North Sudanian "NS" with 500 to 800 mm mean annual rainfall, the South Sudanian "SS" with 800 to 1100 mm and the North Guinean "NG" with mean annual rainfall over 1100 mm). In each zone, one site was selected based on the availability of *Parkia biglobosa* populations in fields and fallows. The selected sites were Somasso (51°31'N, 36°27'W) in the NS zone, Zanzoni (36°52'N, 32°05'W) in the SS zone and Diou (35°46'N, 58°33'W) in the NG zone. Figure 1 shows the localization of the three study zones within southern Mali and Figure 2 shows the localization of the sites within the respective districts.

In each site, fields and fallows stands were selected and square plots of 50 m x 50 m = 2500 m^2 (0.25 ha) were established with three replications of each stand within each site, giving six plots per agro-climatic zone and a total of 18 populations of *P. biglobosa*. For assessing natural regeneration, each plot in the fallow stands was subdivided into 16 subplots of 12.5 m x 12.5 m = 156.25 m^2 each. Five subplots were selected by plot (one at each corner and one at the centre of the plot) and the natural regeneration was monitored within selected subplots. Figure 3 illustrates the plots and subplots within each site.

Collected Data and Data Analysis

At the plot level, all adult *P. biglobosa* trees (DBH ≥ 10 cm) were marked and measured. The geographical position of each tree was recorded using a GARMIN eTrex 10 GPS (accuracy ± 3 m). The measured variables were the diameter at 1.30 m above the ground (DBH) measured with a forest compass, the total height (TH) measured with a 12 m ruler, and the crown diameter (CD) in the east-west and north-south directions measured with a tape.

At the subplot level, the regeneration (H ≤ 150 cm) was partitioned into three classes according to the height (H):

- class 1: H ≤ 50 cm (seedlings);
- class 2: 50 cm < H ≤ 100 cm (young saplings);
- class 3: 100 cm < H ≤ 150 cm (old saplings).

Data were collected according to class categories. For class 1 (seedlings), the number of seedlings was counted; for class 2 (young saplings), the height and the collar diameter were measured and for class 3(old saplings), the height, the collar diameter and the diameter at 1.30 m above the ground were measured. Data were collected each year from 2019 to 2021 and analysed using the software SYSTAT9 for windows. Descriptive statistics were computed and analysis of variance was run to compare sites.

RESULTS

Characteristics and Localization of Fallow Parcels' in the Respective Sites

Fallows were of different types of vegetation according to the agro-climatic zone. In the NS zone, the climate is characterized by two seasons (the long dry season from October to June and the short rainy season from July to September). The vegetation is shrubby savannah with some big trees such as *Parkia biglobosa*, *Vitellaria paradoxa*, and *Faidherbia albida* spared in the fields. In the SS zone, the climate is south Sudanian, with two seasons as

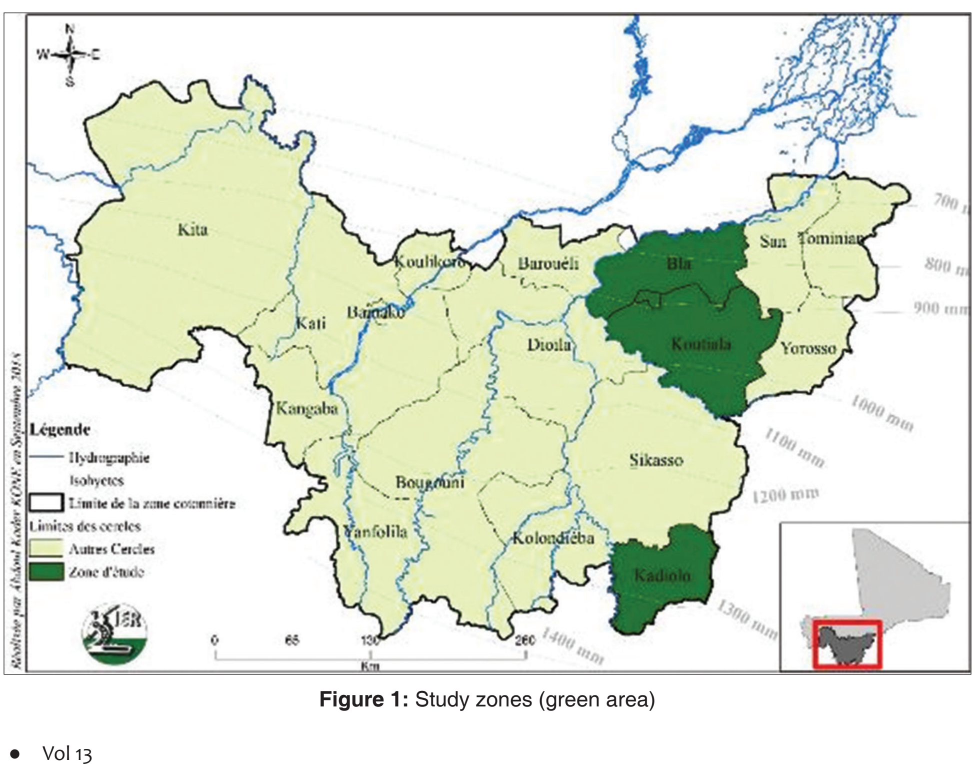

Figure 1: Study zones (green area)

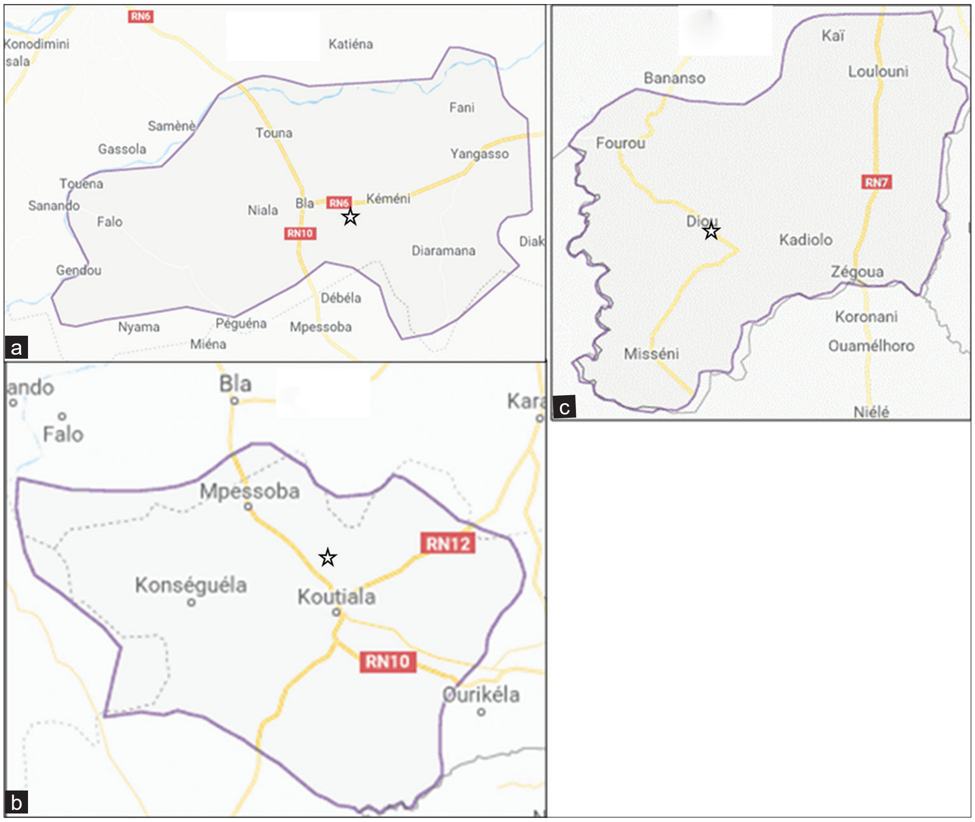

Figure 2: Sites localization in the respective districts is indicated by an asterisk: a) Somasso in the district of Bla, b) Zanzoni in the district of Koutiala and c) Diou in the district of Kadiolo

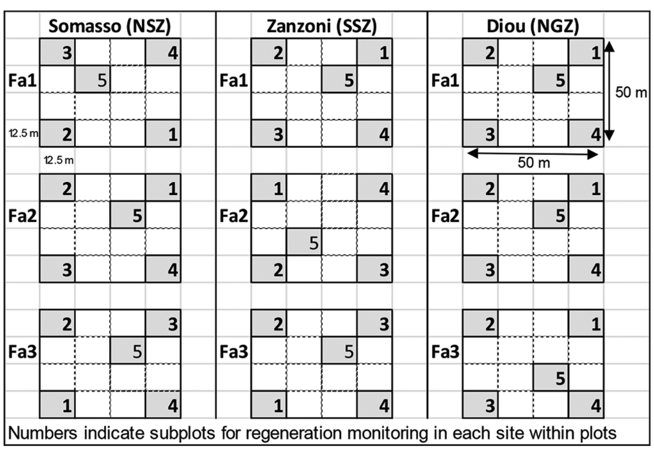

Figure 3: Subplots within plots in fallow stands at each site for regeneration monitoring Legend: Fa i = Fallow i (i = 1 to 3)

long as those of the NS zone. The vegetation in the SS zone is shrubby savannah in the northern part and a wooded savannah in the southern part. In the NG zone, the climate is north Guinean, with a shorter dry season (November to May) and a longer rainy season (June to October) compared to the NS and SS zones. The vegetation is a wooded savannah in the northern part and a clear forest in the southern part. The density of adult trees in the fallow parcels is shown in Table 1.

The density of *P. biglobosa* in fallow stands decreased from the south to the north (Table 1). The NG zone showed the highest

Table 1: Density of *P. biglobosa* adult trees in fallow parcels' by agro-climatic zone

Agro-climatic zones (ACZ)	Number of adult trees ha^{-1}
North Sudanian (NS)	9
South Sudanian (SS)	13
North Guinean (NG)	18
Mean over all CZ	13

density (18 trees/ha), while the NS zone showed the lowest density (9 trees/ha). The geographical position of fallow parcels in the respective sites is shown in Figure 4.

Growth and Production Profile of Adult Trees in Fallow Stands

Growth parameters

The analysis of variance showed that the difference between ACZ was not statistically significant for all growth variables. The means of the three growth variables were shown in Table 2.

Statistically, the difference between ACZ was not significant, but for the three variables, the NS zone showed the highest means (Table 2). This result rather highlights the importance of management practices on the growth parameters of *P. biglobosa*.

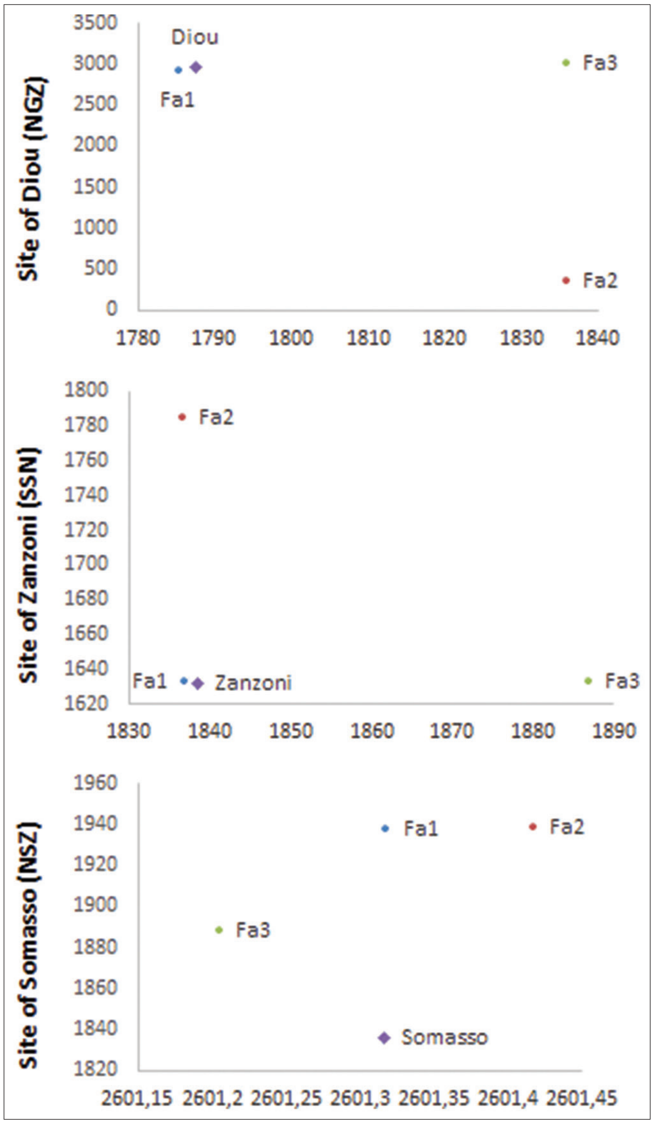

Figure 4: Geographical position of fallow parcels in the sites Legend: Fa (i) = fallow i (i = 1 to 3 for the 3 repetitions), the lozenge ( ) indicates the localization of the villages (Diou, Zanzoni and Somasso) where the study was carried out in the different zones

Pods, grains and pulp production in field and fallow stands

The production in pods, grains and pulp of adult trees of *P. biglobosa* were shown in Table 3.

Pod, grain and pulp yields increased in 2021 compared to 2019 and 2020 in all sites and field stands (Table 3). Increase rates of pod yield were 16 %, 260 % and 63 % for Somasso, Zanzoni and Diou; 80 % and 50 % for fields and fallows respectively. Increased rates of grain yield were 33 %, 400 % and 60 % for Somasso, Zanzoni and Diou respectively; 80 % and 67 % for fields and fallows respectively. Increased rates of pulp yield were 14 %, 300 % and 75 % for Somasso, Zanzoni and Diou respectively, 167 % and 33 % for fields and fallows respectively.

Table 2: Means of growth variables of *P. biglobosa* adult trees in fallow parcels by agro climatic zone

	Mean growth variables		
Agro-climatic zones (ACZ)	Mean TH (m)	DBH (cm)	Mean CD (m)
North Sudanian (NS)	12.65	61.40	13.64
South Sudanian (SS)	10.89	54.13	11.21
North Guinean (NG)	11.15	53.46	13.31

Legend: TH = total height, DBH = diameter at body height, CD = crown diameter

Table 3: Mean yields of pods, grains and pulp by site and by stand from to 2019 to 2021

	Mean yield (kg/tree)								
Sites	Pods			Grains			Pulp		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
Somasso	31	32[a]	37	7	6[a]	8	7	7[a]	8
Zanzoni	17	5[b]	18	5	1[b]	5	4	1[b]	4
Diou	27	19[ab]	31	7	5[ab]	8	6	4[ab]	7
Stands									
Fields	28	20	36[a]	7	5	9[a]	6	3	8[a]
Fallows	21	12	18[b]	6	3	5[b]	5	3	4[b]

Mean with the same character were not statistically significantly different

Status of the Natural Regeneration of *P. biglobosa*

Only three stems from the same stump were observed as young saplings in one sub-plot at Diou in the NG zone. There was an increase in the number of saplings during the monitoring time and the height of the tallest stem decreased from 70 cm in 2019 to 44 cm in 2021 (broken top).

Seedlings Count

The number of seedlings was less all the years at all sites. Often in some sites, the germinant appeared during the rainy season under the crown of adult trees from pods left on the ground. However, the seedlings are unable to withstand the dry season and they die. The number of seedlings by repetition within the site during the three years of monitoring is shown in Table 4.

Density of Seedlings

The density of seedlings of *P. biglobosa* according to site and year was shown in Table 5. The mean density over all sites varied from 11 to 24 seedlings ha^{-1} and showed a decreasing trend from 2019 to 2021. In 2019 and 2020, the highest density was observed at Somasso in the north Sudanian zone, whereas in 2021, the highest density was observed at Diou. Zanzoni in the south Sudanian zone had the lowest density in all years, varying from 0 to 8 seedlings ha^{-1} (Table 5).

DISCUSSION

Regarding adult trees of *P. biglobosa* in fallow stands, we observed a density varying according to agro-climatic zones from 9 to 18

Table 4: Count of seedlings of *P. biglobosa* by site from 2019 to 20121

		Number of seedlings by year		
Sites	Repetition	2019	2020	2021
Somasso	1	5	0	0
	2	5	7	2
	3	Reused for cultivation activities		
Total for Somasso		10	7	2
Zanzoni	1	2	0	0
	2	0	2	0
	3	0	0	0
Total for Zanzoni		2	2	0
Diou	1	0	0	0
	2	4	4	4
	3	1	0	2
Total for Diou		5	4	6
Total for all sites		17	13	8

NB: Regeneration was counted in an area of 12.5 m x 12.5 m x 5 subplots = 781.25 m^2 by repetition giving 2343.75 m2 by site (781.25 m^2 x 3 repetitions) and 7031.25 m^2 for all sites (781,25 m^2 x 3 sites)

Table 5: Density of seedlings by site and year

	Number of seedlings ha^{-1}		
Sites	2019	2020	2021
Somasso	42	30	8
Zanzoni	8	8	0
Diou	21	17	25
Mean density	24	18	11

trees ha^{-1}. This density was higher than the density observed by Froumsia *et al.* (2019) in Mount Mandara in Cameroon (7 trees ha^{-1}). From a global systematic review, Houndonougbo *et al.* (2020) cited Nchoutpouen *et al.* (2009), who reported again lower densities in Cameroon (2.04 trees ha^{-1}) on average with a disparity ranging from savannah (6.7 trees ha^{-1}) to other land-use systems (0.05 trees ha^{-1}).

For growth variables, Froumsia *et al.* (2019) reported an average diameter varying from 73.04 cm to 87.16 cm, an average height varying from 12.15 m to 14.76 m and an average tree archway size varying from 10.20 m to 14.13 m. These averages were closed to our results for the height (11 m to 13 m) and the crown diameter (11 m to 14 m), but for diameter, the averages observed by these authors were higher than ours (53 cm to 61 cm). Based on growth parameters, Froumsia *et al.* (2019) stated that *P. biglobosa* populations were composed of the majority of growing old individuals of big size. The ageing population of *P. biglobosa* was reported by several authors (Maes *et al*., 2009; Thiombiano *et al.*, 2010; Raebild *et al.*, 2012; Houndonougbo *et al.*, 2020; Diatta *et al.*, 2021).

Regarding the regeneration of *P. biglobosa*, very few saplings were monitored and the density of seedlings was weak in all sites. The mean density varied from 11 to 24 seedlings ha^{-1}. These densities were higher than those reported by Ky-Dembele *et al.* (2019) in the region of Koulikoro in Mali (4.3 ± 1.4 stems ha^{-1}). We also observed that germinants that appeared during the rainy season died in the dry season, suggesting that the seedlings of this species were sensitive to water stress occurring during the dry season. The same phenomenon was observed by Froumsia *et al.* (2019), who reported that “the survival of the seedlings between the rainy and dry seasons was difficult. Even if the seeds germinated in the rainy season, during the dry season, the seedlings in their majority perished”.

Froumsia *et al.* (2019) observed a regeneration rate of 13 %, which they considered as very weak compared to the socio-economic importance of this species and stated that, this regeneration was too low to ensure its sustainability. They conclude that it becomes imperative to develop effective strategies for its regeneration and conservation and stated that “the popularization of the products of the plant, a plan of afforestation, the production of nursery trees and the encouragement of farmers in the preservation of the potential availability were advisable”. In the same order, Brottem (2011) stated that “an extensive effort to plant seedlings is likely the only promising way to ensure the regeneration and maintenance of *P. biglobosa*”. Likewise, Padakale *et al.* (2015) stated that “the introduction of juvenile individuals into farmlands may be needed to ensure its conservation in agroforestry systems”.

Our results were corroborated by several other studies, highlighting the weak regeneration of *P. biglobsa*. A weak regeneration of *P. biglobosa* was observed in Burkina Faso (Ouédraogo 2009; Tiombiano *et al.*, 2010) and Senegal (Sambou, 2004). In Casamance (southern Senegal), Diatta *et al.* (2021) reported a weak regeneration of *P. biglobosa* in two study sites, the highest regeneration rate (16.13 %) being observed in the site of Kagnobon. In northern Ghana, Tomomatsu (2014) reported from the results of a survey that, *P. biglobosa* is no longer regenerating. In Togo, Padakale *et al.* (2015) observed a low density of *P. biglobosa* regeneration, which was higher in old fallows (24.60 stems ha^{-1}) compared to young fallows (14.20 stems ha^{-1}).

According to Padakale *et al.* (2015), the regeneration was almost null in old fields (0.80 stems ha^{-1}). They found two types of threats in *P. biglobosa* parklands: human threats and natural threats. These statements corroborate our observations in the three study sites, where wind and particularly sanitary constraints (Kelly & Kouyaté, 2020), were endangering *P. biglobosa* populations. Padakale *et al.* (2015) stated that the regeneration is not sufficient to ensure renewal of the ageing species population and conclude that “the weak regeneration of *P. biglobosa* will threaten its population in the future and consequently lower its productivity”.

In Cameroon, Nchoutpouen *et al.* (2009) reported an average regeneration density decreasing from 55 plants ha^{-1} in savannah to one plant per ha through other land use systems (farmland and fallow). In Tchad, Avana-Tientcheu *et al.* (2019) reported that the regeneration of *P. biglobosa* was quasi-absent due to perturbations in the dynamic of stems of the future. Other authors (Thiombiano *et al.*, 2010; Koura *et al.*, 2013) also reported weak regeneration of *P. biglobosa* and most of the authors explained this fact by the combination of several factors (fire, grazing, overexploitation of fruits reducing seed stock).

CONCLUSION

The results of this study showed a very weak natural regeneration of *P. biglobosa*. Saplings were almost absent and the density of seedlings was low. The very few germinants having emerged during the rainy season perished the following dry season. Our results were corroborated by those of several studies highlighting the weak regeneration of *P. biglobosa* and stressing the threat to the sustainability of the species. This weak regeneration and the sanitary constraint which causes the decline and/or the mortality of the adult trees as observed in all the sites, constitute a serious threat to *P. biglobosa*. To face this threat, it is very important and imperative to investigate ways to regenerate the species for its sustainability and for maintaining parklands biodiversity. Artificial regeneration (planting), could be the one and ultimate way to ensure the sustainability of *P. biglobosa*, as stated by several authors.

ACKNOWLEDGEMENTS

We are very grateful to the Malian government for funding the *Parkia* project through the Competitive Fund for Research and Technological Innovation (CFRTI). Many thanks to Somasso, Zanzoni and Diou villages' authorities and populations for allowing us to conduct this study on their field and fallow parcels and also for cooperating in field activities. We also thank field technicians (Isaïe Dembélé, Younoussa Diarra and Mamadou Diabaté), who achieved an important work in monitoring and data recording.

REFERENCES

Avana-Tientcheu, M. L. A., Keouna, S., Nguemo, D. D., & Masdewel, B. M. (2019). Structure des peuplements et potentiel de domestication de *Parkia biglobosa* dans la région de Tandjilé-Ouest (Tchad). *International Journal of Biological and Chemical Sciences, 13*(1), 219-236. https://doi.org/10.4314/ijbcs.v13i1.19

Brottem, L. (2011). Rediscovering "Terroir" in West African Agroforestry Parklands. *Society & Natural Resources, 24*(6), 553–568. https://doi.org/10.1080/08941920903377012

Diatta, E. A., Sambou, B., & Diatta, F. N. M. (2021). Caractérisation du parc agroforestier à *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don en Basse Casamance (Sénégal). VertigO-la revue électronique en sciences de l'environnement. https://doi.org/10.4000/vertigo.28668

Fagui. (2015). Répertoire des espèces forestières des régions de Kayes, Koulikoro, Sikasso et Ségou. Mali.

Froumsia, M., Takoua, Hamawa, Y., Souare, K., Todou, G., & Baye-Niwah, C. (2019). Structure and regeneration of *Parkia biglobosa* (Jacq.) R. Br Ex G Don in Mount Mandara, Cameroon. *International Journal of Biodiversity and Conservation, 11*(9), 241-251. https://doi.org/10.5897/IJBC2019.1274

Houndonougbo, J. S. H., Kassa, B. Mensah, S., Salako, V. K., Glèlè Kakaï, R., & Assogbadjo, A. E. (2020). A global systematic review on conservation and domestication of *Parkia biglobosa* (Jacq.) R. Br. ex G. Don, an indigenous fruit tree species in Sub-Sahara African traditional parklands: current knowledge and future directions. *Genetic Resources and Crops Evolution, 67*, 1051-1066. https://doi.org/10.1007/s10722-020-00892-w

Kelly, B. A., & Kouyaté A. M. (2020). *Parkia biglobosa* (Nere)-A threatened useful tree species: Directory of sanitary constraints according to north-south climatic gradient in Mali. *Current Botany, 11*, 132-137. https://doi.org/10.25081/cb.2020.v11.6068

Koura, K., Mbaide, Y., & Ganglo, J. C. (2013). Caractéristiques phénotypique et structurale de la population de *Parkia biglobosa* (Jacq.) R. Br. du Nord-Bénin. *International Journal of Biology and Chemistry Sciences, 7*(6), 2409-2425. https://doi.org/10.4314/ijbcs.v7i6.19

Ky-Dembele, C., Dayamba, S. D., Savadogo, P., Kalinganire, A., Bayala, J., Muchugi, A., & Ramni, A. (2019). Land use dictates diversity, density and regeneration of woody species in southwestern Mali, West Africa. *Tropical Ecology, 60*, 114–128. https://doi.org/10.1007/s42965-019-00015-2

Lompo, D., Vinceti, B., Gaisberger, H., Konrad, H., Duminil, J., Ouédraogo, M., Sina, S., & Geburek, T. (2017). Genetic conservation in *Parkia biglobosa* (Fabaceae: Mimosoideae)-what do we know? *Silvae Genetica, 66*(1), 1-8. https://doi.org/10.1515/sg-2017-0001

Maes, W. H., Achten, W. M. J., Reubens, B., Raes, D., Samson, R., & Muys, B. (2009). Plant-water relationships and growth strategies of *Jatropha curcas* L. seedlings under different levels of drought stress. *Journal of Arid Environments, 73*(10), 877–884. https://doi.org/10.1016/j.jaridenv.2009.04.013

Nchoutpouen, C., Mapongmetsem, P., Zapfack, L., & Mpeck, M. N. (2009). Effects of land use on the population structure of *Parkia biglobosa* (Jacq.) Benth. (Mimosaceae) in the periphery of Ngaoundere, Cameroon. *Forests, Trees and Livelihoods, 19*(1), 69–79.

Ouédraogo, O. (2009). Phytosociologie, dynamique et productivité de la végétation du parc national d'Arly (sud-est du Burkina Faso). Thèse de doctorat unique. Université Ouagadougou, Burkina Faso.

Ouoba, L. I. I., Rechinger, K. B., Barkholt, V., Diawara, B., Traoré, A. S., & Kakobsen, M. (2003). Degradation of proteins during the fermentation of African locust bean (*Parkia biglobosa*) by strains of Bacillus subtilis and Bacillus pumilus for production of Soumbala. *Journal of Applied Microbiology, 94*(3), 396-402. https://doi.org/10.1046/j.1365-2672.2003.01845.x

Padakale, E., Atakpama, W., Dourma, M., Dimobe, K., Wala, K., Guelly, K. A., & Akpagana, K. (2015). Woody Species Diversity and Structure of *Parkia biglobosa* Jacq. Dong Parklands in the Sudanian Zone of Togo (West Africa). *Annual Research & Review in Biology, 6*(2), 103-114. https://doi.org/10.9734/ARRB/2015/14105

Raebild, A., Hansen, U., & Kambou, S. (2012). Regeneration of *Vitellaria paradoxa* and *Parkia biglobosa* in a parkland in Southern Burkina Faso. Agroforestry Systems, 85, 443–453. https://doi.org/10.1007/s10457-011-9397-0

Sacandé, M., Sanogo, S., & Beentje, H. (2016). Guide d'Identification des Arbres du Mali. Royal Botanic Gardens, Kew: Kew Publishing.

Sambou, B. (2004). Evaluation de l'état, de la dynamique et des tendances évolutives de la flore et de la végétation ligneuse dans les domaines soudanien et sub-guinéen au Sénégal. Thèse de Doctorat d'Etat. Université Cheikh Anta Diop de Dakar, Sénégal.

Thiombiano, D. N. E., Lamien, N., Dibong, S. D., & Boussim, I. J. (2010). Etat des peuplements des espèces ligneuses de soudure des communes rurales de Pobé-Mengao et de Nobéré (Burkina Faso). *Journal of Animal & Plant Sciences, 9*(1), 1104- 1116.

Tomomatsu, Y. (2014). *Parkia biglobosa*-Dominated Cultural Landscape: An Ethnohistory of the Dagomba Political Institution in Farmed Parkland of Northern Ghana. *Journal of Ethnobiology, 34*(2), 153-174. https://doi.org/10.2993/0278-0771-34.2.153