Project Title: Understanding Ecology, threats assessment and conservation of *Afzelia africana* Sm in Benin (West Africa)

FINAL TECHNICAL REPORT

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Januray, 2010

1. Background

My research project granted by the Rufford small grant for nature is related to the ecology, threat assessment and conservation of Afzelia africana Sm in Benin. The major activities of the project were:

- to do forest inventory of *Afzelia africana* populations in various natural stands of the three bioclimatic zones and estimate the tree-density of the species and some structural parameters related to the stands;

- to do ethnobotanical surveys among bordering people of the forest in order to assess the various threats the species is facing;

- to do educational actions targeted school people near the forests by increasing schoolchildren awareness on the importance of *A. africana* for human being, the main threats it is facing and the scarcity of its regeneration.

Characterization of *Afzelia africana* habitat in Benin forest reserves and assessment of the main threats

Abstract

A study was carried out in the Lama Forest reserve (Guineo-Congolese zone of Benin), Wari-Maro Forest reserve (Sudano-guinean zone) and Pendjari park (Sudanian zone of Benin) to characterize the habitat of *Afzelia Africana* Sm, an endangered multipurpose tree species (found in African humid, dry forests and woodlands), in order to define a sustainable management strategy for its conservation. An estimation of species density was done on 100 square plots of 1 ha each, while tree height and dbh of all the species were measured on subplots of 50 m x 30 m within the 1 ha plots. The regenerations of *A. africana* (dbh<10 cm) were counted in the diagonal quadrats of the principal plots. Presence-absence data of the species was subjected to multidimensional scaling and results showed four vegetation communities including: young fallow, old fallow, typical dense forest and degraded dense forest. Significant differences were noted between the four communities with respect to the density of the species. High density was noted for the species in typical dense forest (5.2 stems/ha) whereas the lowest values were obtained for the old preforest fallow. No *A. africana* tree was found in the young preforest fallow while more than 80 % of *A. africana* trees were found in the typical dense forest community.

Keywords: *Afzelia africana* Sm; habitat characteristics; population structure; Threats assessment; Guinean zone; Sudanian zone; Benin.

Introduction

The most important factor of degradation in species diversity in the world is the loss, fragmentation and modification of natural habitats. From 1990 to 1995, a total of 298,000 ha of Benin's forest cover have been lost (FAO, 1999). There is an average loss of 60,000 ha per year and the population develops a selective forest harvesting that leads to the scarcity of some species for instance *Milicia excelsa*, *Afzelia africana* and *Khaya senegalensis* (Glèlè Kakaï and Sinsin, 2009). *A. africana* is one of the most threatened multipurpose forest species in Africa used by local people for animal feeding (Sinsin, 1993), traditional medicine (Sinsin et al., 2002) and wood (Ahouangonou and Bris, 1997). The species is found in several types of natural forests ranging from the dense forest of the guineo-congolian zone to the woodland forest of the sudanian zone (White, 1983). The multiple uses of *A. africana* in West Africa led to a permanent pressure on its natural populations. It is frequent to observe adult trees of *A. africana* in savannah as well as in woodland and dense forests but its natural regeneration is rarely observed within the same habitats. The main question in this study is to understand how far the species is facing an extinction risk, since the observed results from some experimental plots established in some zones in West Africa showed a very low density of the species in its habitats (Ahouangonou and Bris, 1997). Based on the various types of pressure on the species, it becomes urgent to define a better conservation strategy for its sustainable management, not only by exploring the present status through a structural study of the populations but also by describing the species' habitat. Therefore, the present study aims at characterizing *Afzelia africana* habitat, identifying the main threats that the species is facing in its habitat and analysing the present structure of its populations in three forest reserves of Benin located in Guinean, Sudano-guinean and Sudanian zones of Benin (Lama forest reserve, Wari-Maro forest reserve, Pendjari Biosphere reserve).

Material and methods

Study area

- *Lama Forest reserve (Guineo-Congolese zone)*

The Lama Forest reserve, protected by law since 1946, is located in Southern Benin in the Dahomey Gap between 6°55' and 7°00' latitude North and 2°04' and 2°12' longitude East The total area of the forest is estimated at 16,250 hectares. The annual rainfall is 1200 mm. The mean temperature varies between 25 °C and 29 °C and the relative humidity between 69 % and 97 %. The original vegetation was dense semi-deciduous forest established on 4,777 ha composed of 292 ha of *Tectona grandis* and *Gmelina arborea* plantation, 1,900 ha of dense forest, the remaining area being constituted of fallows (Emrich et al., 1999).

The bordering population of the Wari-Maro forest reserve is constituted of two main ethnic groups spread out in the region. The first ethnic group is the "Fon" found in 20 bordering villages. The second is called "Holli" and come from Pobè (Sought Benin) and live inside the forest. The density of the bordering population is estimated at 120 habitants/km^2 at Zogbodomey in the northern part of the Forest and 60 habitants/km^2 at Toffo in the southern part of the forest.

- *Wari-Maro Forest reserve (Sudano-guinean)*

The Wari-Maro forest reserve is located at the centre of Benin Republic (112,622 km²), between 8°80-9°10N and 1°55-2°25E. This forest covers an area of about 120,686 ha. It is located in the Guineo-Sudanian transition zone defined by White (1983) as *"Sudanian woodland mainly composed of Isoberlinia"* and is characterized by a Sudano–Guinean climate with two seasons: a dry season from November to March and a rainy season from April to October. Annual rainfall ranging from 1964–1997 fluctuated between 1000 mm and 1100 mm with a mean of 1052 mm (Orthmann, 2005). In the Wari-Maro forests, stands under high anthropogenic pressure were "free stands" with no banning and were cjaracterized by a frequent harvest of *A. leiocarpa* leaves, branches, bark and wood for various purposes and also the use of these stands as pasture for cattle (Adoko, 2005).

- *Pendjari Biosphere reserve (Sudanian zone)*

Pendjari Biosphere Reserve is located in the extreme northwest of Benin (10°40'-11°28N and 0°57'-2°10'E). The total rainfall averages 1,000 mm with 60 % falling between July and September (Sinsin et al. 2002) with one rainy season (April–May to October) and one dry season (November to March). Temperature varies from 21°C during the night up to around 40°C during the day. Relative humidity varies between 17 % in dry season and 99 % in the rainy season (PAG2, 2005). Many small villages bound the Pendjari Biosphere Reserve. The density of the population in this area is low (13 inhabitants per km^2 compared with the whole country (60 habitants/km^2) (RGPH, 2002). Among the bordering people of the PBR, Berba (65 %), Gourmantche (23 %) and Waama (7 %) are the dominant socio cultural groups. The main activity of the local population is agriculture and herding. Women often exploit non timber forest product like fruits of shea trees, leaves of many species and also practice the trade of firewood.

Sampling design and data collection

Lama Forest reserve

Transects were designed using the map of the dense forest (*Noyau Central*) of the protected area. Through a random sampling scheme, hundred plots of 1 ha were selected on the map and their geographic coordinates were noted. The total sampled area in the forest is 100 ha representing 2.49 % of the total surface covered by the *Noyau Central*. Within each 1 ha square plot, rectangular sub-plots of 50 m x 30 m were designed to record ecological data

relating to all the species having at least 10 cm dbh. Moreover, adjacent diagonal 10 m x 10 m plots were established within each 1 ha plot for the natural regeneration study of *A. Africana*. Within each of the 1 ha plots, all individuals of *A. africana* were counted.

Wari-Maro Forest reserve

On the basis of the vegetation map of the forest reserve, a forest inventory was done in the natural stands mainly composed of *A. africana*. 27 rectangular plots of 50 m x 30 m were designed to record dbh and height of trees of dbh ≥ 10 cm. The regeneration density was estimated using adjacent diagonal plots of 10 m x 10 m as in the Noyau central of the Lama Forest reserve.

Pendjari Biosphere reserve

In the Pendjari Biosphere reserve, 33 rectangular plots of 50 m x 30 m were considered through a random sampling scheme as in the case of Lama forest reserve. Regeneraion was also estimated.

Threats assessment

In each climatic region, 100 people were selected in the bordering populations of the forest reserve according to socio-ethnic groups. A structured questionnaire was used to collect all the threats facing by the species and added to other threats noted in forest. People were asked to rank the listed threats according to their importance and discussions were made about conservation strategies of the species.

Data analyses

In the Lama Forest reserve, because of the complexity of the vegetation, we first of all identified the homogeneous communities through multidimensional scaling. The presence-absence data of all inventoried species within the 100 plots of 50 m x 30 m were grouped in a binary matrix and submitted to multidimensional scaling for mapping the plots according to their species composition. The ALSCAL procedure of SPSS software was used to build a bidimensional geometric structure based on the observed similarity or dissimilarity among plots. For Wari-Maro forest reserve, only woodland was considered whereas in Pendjari Biosphere reserve, inventory was done in the tree savannah stands. For These two forest reserves, a multidimensional scaling was then not applied.

For the three forest reserves, the following methods were applied.

Ecological and dendrometric parameters: the following dendrometric parameters were used: The tree-density of the stands (N), i.e. the average number of trees per plot expressed in trees/ha. *The index of Green (IG)* was to analyse the spatial distribution of *A. Africana*.

Characterizing natural regeneration of A. Africana: for the characterisation of the natural regeneration density of *A. africana*, the four identified vegetation groups were assimilated to strata. The regeneration density of the *A. africana* population was estimated.

Ethnobotanic data analysis

The interviewees were grouped according to socio cultural group, sex, and age so that in each socio cultural group, six subgroups were defined: young men (M1), adult men (M2), old men (M3), young women (F1), adult women (F2), and old women (F3). Thus we constituted 20 subgroups instead of 24 (4 socio cultural groups × 6 subgroups), because of the absence of some subgroups in the overall surveyed sample. Because the size of subgroups differed from one to another and an interviewee could know more than one uses, relative frequency of each use was determined for each of the 20 subgroups and for each species.

For each threat, we computed its value called 'the use value' and defined as the proportion of interviewees belonging to the subgroup who cited the threat. For each subgroup i and each species k, we calculated the importance index, $IP_{i,k}$ of the threat as follow:

$$IP_{i,k} = \frac{n_i}{N} \frac{\sum_{j=1}^{n_i} x_j}{N}$$

n_i is the number of informants in subgroup i (i=1,.., 20) who cited the threats and N is the total number of informants in subgroup i. x_j is the score of importance of the considered type of threat according to the informant j (j=1,…, n_i) in the subgroup i (3 for high importance of the use, 2 and 1 for medium and low importance of the threat, respectively).

We obtained a data matrix whose lines were the 20 subgroups and whose columns were related to the 8 different threats inventoried during the survey: pasture, rodents, defoliation, germination problems, bushfire, logging, climate changes. Principal Component Analyses (PCA) were applied to these matrices using SASv9 software in order to analyse the importance of the various threats in relation to the socio cultural groups (Höft et al, 1999).

Results

Lama forest reserve

The multidimensional scaling showed four vegetation groups: G1, G2, G3 and G4 (figure 1). G1 is characterised by the predominance of *Chromolena odorata* (75 % of cover). The mean density is estimated at 104.4 trees/ha with a mean tree diameter of 26 cm. The species richness is about 17 species in G1 (see Bonou et al., 2009). Group 2 (G2) is composed of 48 plots established in the typical non degraded dense forest during the forest inventory and can then be considered as a dense semi-deciduous forest. *A. africana* and *Ceiba pentandra* are the most represented species with the biggest diameter and height, followed by *Diospyros mespiliformis*, *Dialium guineense* and *Mimusops andongensis*. The less represented species are *Drypetes floribunda*, *Celtis brownii*, *Holarrhena floribunda*, *Malacantha alnifolia*, etc. The mean density was estimated at 178.5 trees/ha for the whole stand and at 5.2 trees/ha for *A. africana*. The presence of forest species such as *A. africana*, *D. mespiliformis*, *D. guineense* was also noticed because of the proximity and permanent mix of both types of vegetation, fallow and dense semi-deciduous forest.

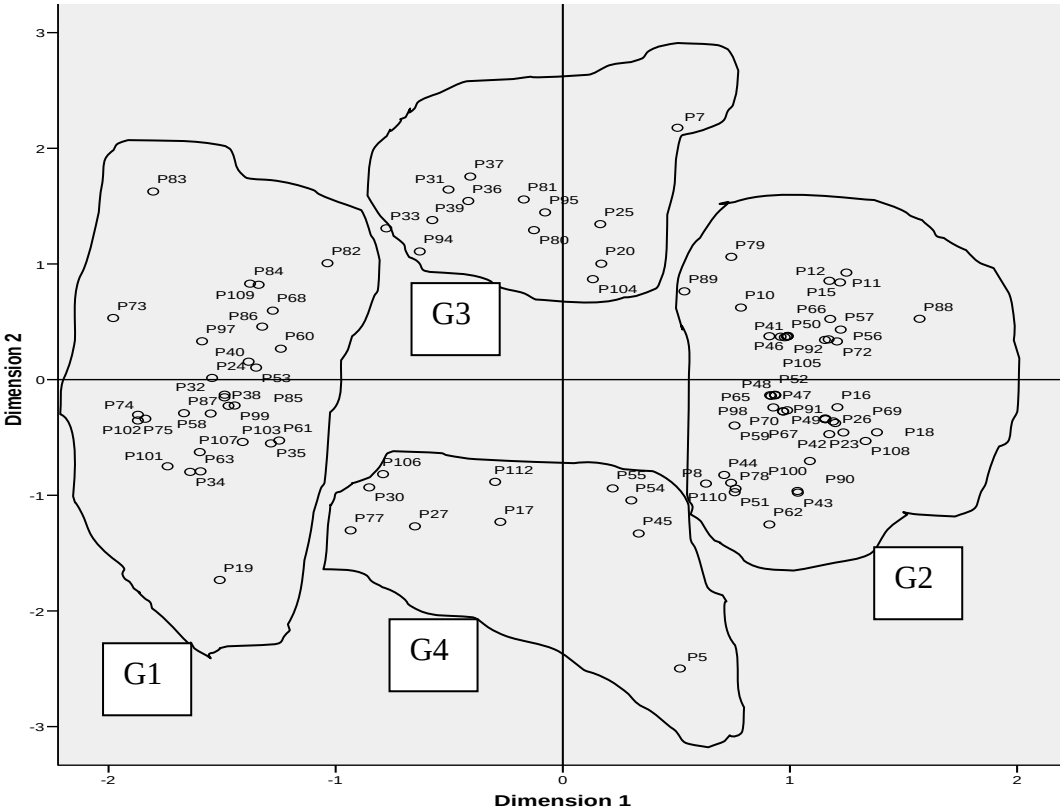

Figure 1. Projection of the 100 plots of 50 m x 30 m in the system axes 1 and 2
Pi=plot i ; G1= young preforest fallow; G2= Typical non degraded dense forest ;
G3= Old preforest fallow; G4= Dense degraded forest and humid semi deciduous forest of *C. megalophylla*.

The *C. odorata* cover is less than in G1 and estimated at about 30 % of the overall cover of the vegetation of G3. G3 could be considered as an old preforest fallow. The mean density was estimated at 116.9 trees/ha for the whole stand, whereas the species richness and Shannon's Diversity Index were 21 species and 3.4 bits, respectively. The mean density of *A. africana* and its regeneration were estimated respectively at 1.5 trees/ha and 11.5 trees/ha, while its mean diameter and height were 59.7 cm and 15.7 m, respectively. Group 4 is constituted of 10 plots mostly established in the degraded dense forest and humid semi deciduous forest of *Cynometra megalophylla*. G4 is different from the remaining groups because of the presence of *C. megalophylla*, which is characteristic of permanent humid zones. This vegetation group could then be considered as degraded dense forest. Some forest species such as *A. africana* and *D. guineense* become rare with the important regression of other dense forest species, such as *D. mespiliformis*, *M. andongensis*, *D. floribunda*, *C. brownii*, etc. In G4, the mean density of *A. africana* was estimated at 1.3 trees/ha with a mean diameter and height of 60.6 cm and 21.4 m, respectively. The overall density of the stand was estimated at 126 trees/ha whereas the mean density of the regenration of *A. africana* was 7 trees/ha.

Wari-Maro Forest reserve

Tree-density of *A. africana* in the Wari-Maro forest reserve was estimated at 142.4 trees/ha. Mean Diameter and basal area were respectively estimated at 26.8 cm and 7.9 m^2/ha. The

mean height of the species was 8.8 m. Stem diameter structure of *A. africana* trees is left dissymmetric indicating old stands of the species in the Wari-Maro forest reserve.
Density of regenerations was estimated at 924 plants per ha with standard deviation of 1038 plants/ha.

Pendjari Biosphere reserve

In the Pendjari Biosphere reserve tree-density of *A. africana* was estimated at 93 trees/ha whereas regeneration density was relatively high and estimated at 646.7 plants/ha. As noticed in the Wari-Maro forest reserve, the stem diameter structure of *A. africana* trees is left dissymmetric indicating old stands of the species.

Main threats on the species in relation to ethnic perceptions

Table 1 presents the mains threats on A. africana noted by the respondents. We noticed that Pasture in the natural stands and Bush fire constituted according to the people the most important threats on *A. africana*. However, some threats like climate changes and rodents were also most chosen by the respondents. According to them the scarcity of A. africana in natural stands is due to pasture in the stands by Peulh individuals to feed their animals but also by frequent bus fire caused by hunter especially in the northern part of the country. Rodents and monkey also used to eat the seeds of the species and then caused low regenerations. Climate changes were also indicated to explain the scarcity of the individuals of the species. According to people who cited this threat, the habitat of the species was modified nowadays by the impact of climate changes on the vegetation especially in the northern part of Benin (Figure 2 and 3).

Table 1. Frequency of threats noted by the respondents.

Threats	Number	Percent
Pasture	123	41.00
Rodents	111	37.00
Defoliation	61	20.33
Low regeneration	89	29.67
Bush fire	129	43.00
Logging	79	26.33
Climate changes	117	39.00

Moreover results of principal components analysis on the perception of ethnic group on the main threats revealed that (Figure 2 and 3) almost all the ethnic groups of the Northern part of the country considered climate changes as the main reason of the scarcity of *A. africana* in the natural stands. This perception could be explained by the fact that the northern part of Benin is the one most vulnerable in terms of climate changes where desertification coming from the Republic of Niger moves at high speed. In the south of Benin, Holli people considered Bush fire and Pasture as the main threats on *A. africana* whereas logging was considered as the main threat by Idatcha. Rodents and monkey are considered as the main threats by people of ethnic group called “Fon”, the most important ethnic group of Benin.

Discussions done with the bordering people about the possibility of drawing suitable conservation strategy for the species were summarized in the discussion.

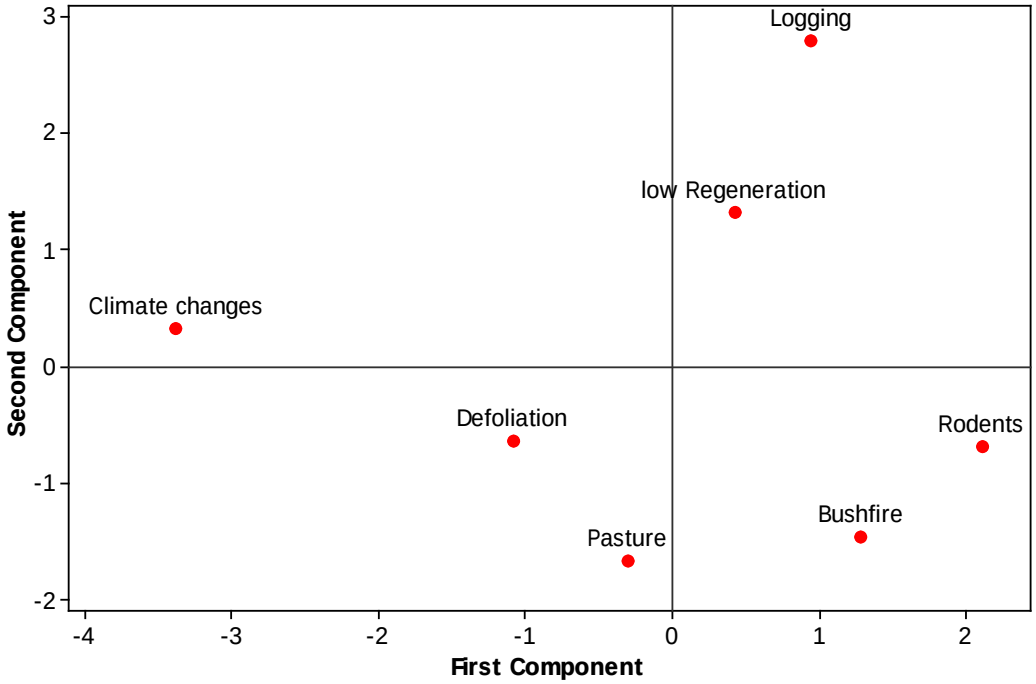

Figure 2. Projection of threats in the system axis defined by the principal components.

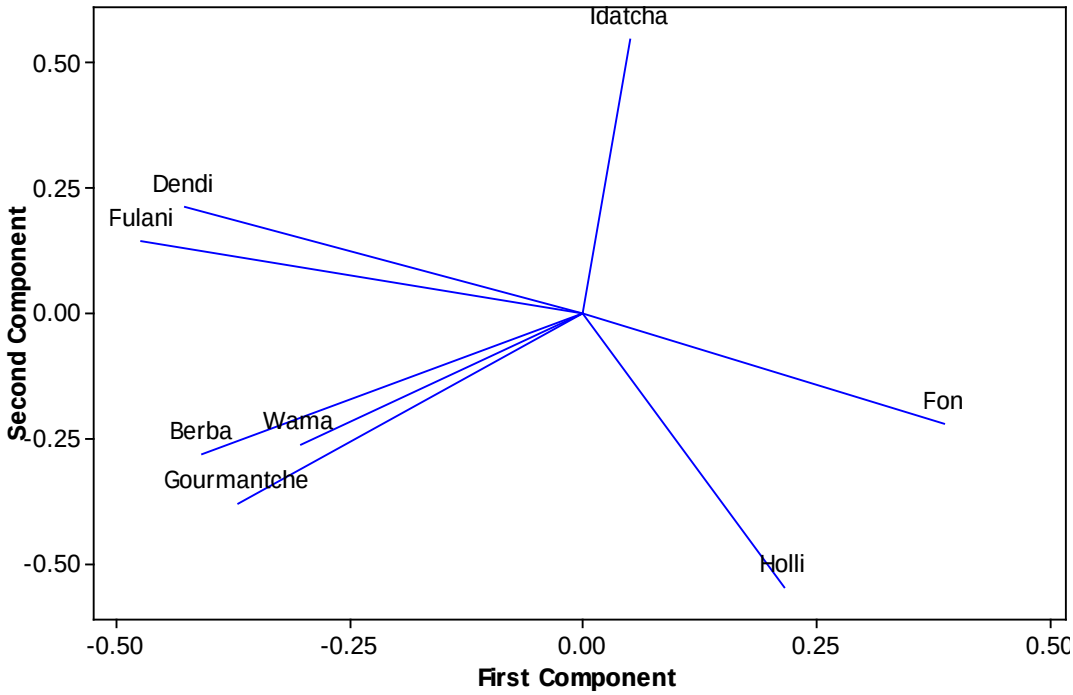

Figure 3. Projection of the ethnic groups in the system axis defined by the threats.

Educational actions targeted school people

During Forest inventory, 3 schools were selected in each zone according to their proximity to the forests. Group discussion with school people was done on the importance of *A. africana* for human being, the main threats it is facing and the scarcity of its regeneration. School people were made more aware of the necessity to conserve *A. africana* through sketches on the conservation strategies proposed for each forest reserve. Five saplings of *A. africana* were planted by the school children in the playground of the schools.

Discussion and conclusion

Characteristics of the identified groups of vegetation

The natural vegetation of the *Noyau Central* of the Lama forest reserve is a mosaic of dense semi-deciduous forest and fallow (Sinsin et al., 2004). Generally, the present study showed that both types of vegetation are equally represented (in the forest). The same observations were reported by Emrich et al. (1998), who observed in the same forest 51 % dense forest and 49 % fallow. However a floristic relevé in the forest revealed 4 groups of vegetation. The highest density of *A. africana* was observed in the non-degraded dense forest while the lowest one was observed in the preforest fallow. The relatively low density observed for this species in the degraded dense forest may result from the low rate of forest regeneration within stands without new disturbances. The lowest mean diameter observed in the young fallow revealed the first step of the establishment of forest where young individuals predominate while the highest value observed in a typical dense forest underlining the presence of big individuals, especially *A. africana*, *C. pentandra*, *D. guineense*, *D. mespiliformis* and *M. andongensis*. It is quite rare to encounter trees having a diameter more than 50 cm in the young preforest fallow because of the status of this type of vegetation.

Characteristics of A. africana populations in Benin

The timber potential, as indicated by the density of *A. africana* in the forest resezrves considered *Noyau Central* (2.8 stems/ha), represented about 2 % of the inventoried individuals and is remarkably lower than the one noted in the Wari-Maro forest reserve (142 stems/ha for *A. africana* and 35 % for the overall species, in Sudano-Guinean zone of Benin. Individuals of *A. africana* are scarcely encountered in the young preforest fallow in contrast to the typical non-degraded dense forest where the species is highly represented. In the old fallow, as well as in the degraded dense forest, the species density is less than 2 stems/ha. Within the first stand, a progressive regeneration of the species was noticed while in the second stand, the species was over-exploited by local people. The low value of the Index of Green for the overall stand (IG =0.1) explains a very low gathering of the species. However, some clumped individuals were observed on small areas generally lower than 0.25 ha. Such spatial configuration is similar to the one observed in the Wari-Maro forest reserve, where a random distribution patterns with a tendency of aggregation of the species individuals for the small radius (30 m) around a random point within the population was seen. Moreover, *A. africana* constituted 36.6 % of the global basal area of the forest despite its low contribution to the mean tree density of the forest, meaning that the majority of individuals are big in diameter compared to other species.

Protective measures and management strategy

The present study on the characterisation of the *A. africana* habitat, the assessment of the main threats on *A. africana* in the forest reserves of Benin and discussion with bordering populations helps to describe the present status of the species' populations within the country

and discussion on the possibility of designing suitable conservation strategy was also done. A large variation in the identified vegetation groups is observed, especially for the dendrometric parameters. Effective conservation strategies are needed for the species in the Lama forest reserve and should be designed based on the specificity of the identified vegetation groups. Therefore, conservation strategies for seeds to protect them against predators as well as for seedlings and saplings should be set up during the first years of their growth through assisted regeneration. Moreover, further studies should target the low level of regeneration observed for the species in its natural habitat. Also, conservation measures should be immediately designed for the species based on scientific research on its genetic diversity and propagation. In addition, permanent plots should be established in this ecosystem in order to follow the dynamics of the species' populations. For example, five plots of 0.5 ha each by vegetation group one by cardinal point can be reserved within the forest where an artificial enrichment will be carried out and followed until the maturity of the trees. To that purpose, various kinds of tests could be done to know the characteristics of the species in this ecosystem. The establishment of such kind of nursery will be used for enriching degraded natural stands. This action could be taken as part of a specific conservation plan of the species, with the agreement and the participation of the rural fringe communities. Together with the current study, additional studies will help to improve knowledge about the modification of the species' habitat according to climatic changes. That action requires dendrochronology and climate data record. It also requires the establishment of a programme of forest-threatened species conservation and should be integrated into a global biodiversity conservation programme of Benin.

Acknowledgement
This work was supported by the Rufford Small Grant for Nature.

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