Influence of Anthropogenic Factors on Reforestation Activities in the Ecosystems of the Teaching and Research Forest (FER) of the National School of Water and Forests (ENEF) Mbalmayo in Cameroon

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Authors' contributions

Article Information

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ABSTRACT

Aims: This study, carried out in the Teaching and Research Forest (FER) of the national school of water and forests (ENEF) Mbalmayo, is part of the maintenance and protection of its biodiversity. The general objective is to identify the anthropogenic threats to the ENEF's FER. Specifically, to take stock of the reforestation, and to propose a restoration strategy corresponding to the ecological and social context of the RFM's reforestation.

Study Design: Forestry Department of the Mbalmayo National Forestry School. More precisely, in the school's teaching and research forest, commonly known as the "forest school". Between May 2021 and March 2022.

Methodology: To achieve this, four plots of 1 hectare each were set up according to the level of degradation caused by the type of human activity. The data collected included an inventory of degraded areas, identification of the threats caused by human activities to FER ecosystems through direct observations in the field, and botanical inventories in the degraded plots. Given that the information on past floristic potential (before the threat) is known, the current inventory data made it possible to assess the threats. Bush fires, the removal of bark by local residents and agricultural plantations are the main threats to the RMF.

Results: The Krustal Wallis test was used to compare the different plots, where a P-value of 0.00 for the Moabi and Bamboo plots means that there is no significant difference between these two sites at the 5% threshold with regard to the threats they face. On the other hand, this test shows that there is a significant difference between the plots in the inaugurated zone (ZI) and the burnt zone (ZB) at the 5% threshold with regard to their significant anthropogenic impacts, with respective P-values of 47% and 88%. These values show, following the determination of importance value indices (IVI), that threats are more severe on polyspecific sites such as inaugurated and burnt sites, as these are more coveted by local populations.

Conclusion: The anthropogenic activities detected in the course of this study were the debarking observed in the Moabi plots, the bush fires encountered in the ZB site and the field activities (agricultural plantations) encountered in the Bamboo site. However, 3,174 trees survived the anthropogenic threats, compared with 1,036 that barely survived. 181 trees miraculously regenerated naturally.

Keywords: Anthropogenic action; degradation; ecosystem; reforestation; teaching forest.

ABBREVIATIONS

RFM : Mbalmayo Forest Reserve
FER : Teaching and Research Forest
FAO : Food and Agriculture Organization

1. INTRODUCTION

In the Congo Basin (CB), forests represent important means of subsistence for millions of people and a vital habitat for many animal and plant species [1]. They are also the best preserved on the planet [2]. Moreover, for the past few decades, Congo Basin Forets (CBFs) have been an international issue on climate change and are home to some 30 million people [3]. They provide livelihoods for more than 75 million people from around 150 ethnic groups who rely on local natural resources for their food and nutrition, health and livelihood needs [2]. As such, these forests provide an important form of social security in countries where poverty and malnutrition are common [4]. Unfortunately, despite their multiple functions (social, economic and ecological), these forests are losing more and more of their area [5]. Between 2000 and 2010, they lost 5.2 million hectares, broken down into 13 million hectares of deforestation and 7.8 millions hectares of new forest; This is all due to galloping urbanization and exponential increase in population size [6].

However, the national school of water and forests (ENEF) in Mbalmayo Cameroon, is home

to a school forest classified as a Teaching and Research Forest (FER) [7]. It is subject to anthropogenic pressures and climatic disturbances that contribute to its degradation [8]. Over the years, these multiple stresses have led to a reduction in the area of forest cover and the rarity or disappearance of certain species [9,10]. In 2007, 58.59% of the FER landscape was made up of forests, but in 2017 this was replaced by degraded forests (63.37%) and built-up areas (8.12%) [11]. Faced with this finding, ENEF has been committed to restoring its forest cover through reforestation activities since 2003 [12]. The main aim of these initiatives is to significantly increase productivity and renew wood resources to compensate for removals resulting from various forms of degradation [13]. Unfortunately, the reforestation of the ENEF particularly that of the FER, is subject to numerous attacks caused by clandestine human activities. In order to assess these threats, the objectives of this study are (1) to identify the anthropogenic threat to the RMF, (2) to take stock of the reforestation, and finally (3) to propose a restoration strategy corresponding to the ecological and social context of the RMF reforestation.

2. MATERIALS AND METHODS

2.1 Study Site

This study was carried out in the FER, which is an application forest of the national school of water and forests (ENEF) Mbalmayo located in the Nyong et So'o Department, Central Cameroon Region. According to Doumenge (2001) [14], the FER covers an area of around 1095 hectares. Geographically, it is located at coordinates 3°49' north latitude and 11°50' east longitude.
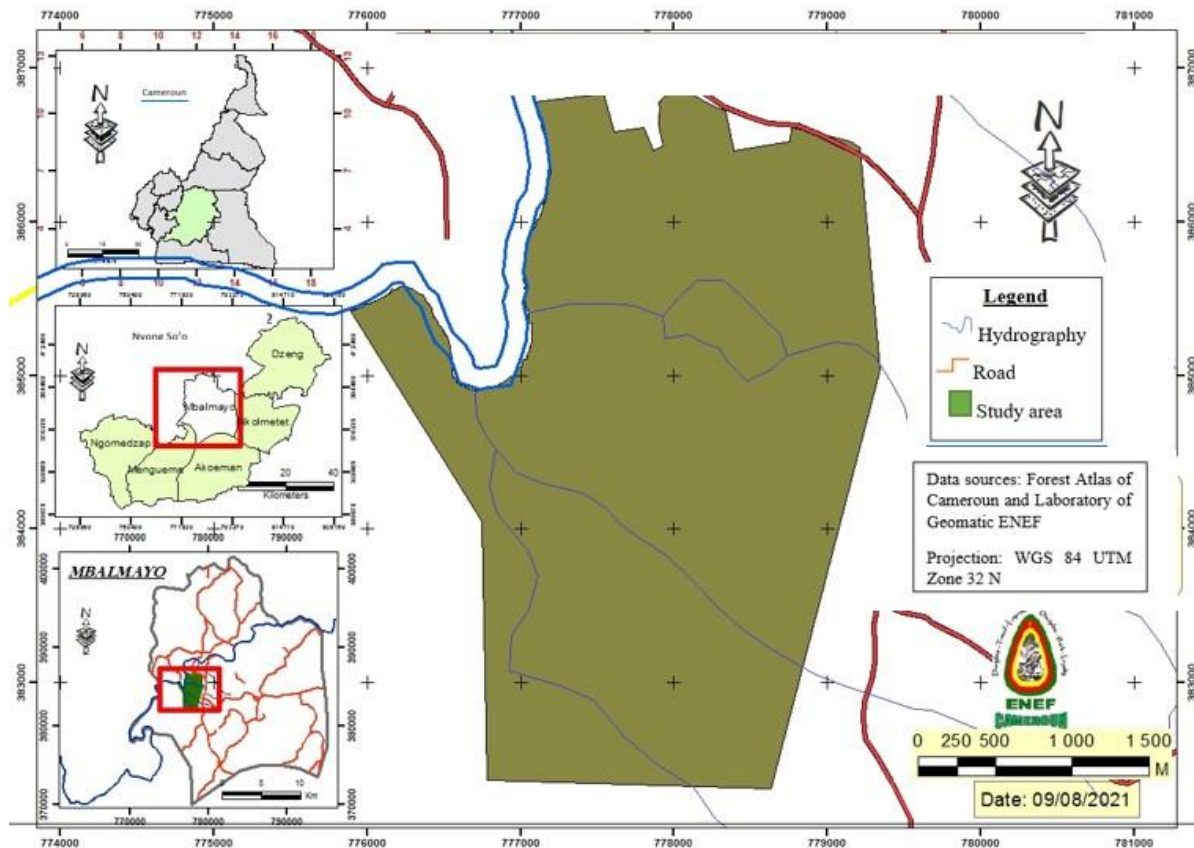

Fig. 1. Location map of the study area

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2.2 Sampling Design

The experimental set-up below was inspired by the Winrock International (2005) model cited by Bossiomo (2018) [15], in which the restoration of degraded forest areas is carried out by setting up permanent or temporary quadrats (Fig. 2).

2.3 Data Collection

2.3.1 Identifying anthropogenic threats to the RMF

In collaboration with the ENEF administration, four heavily degraded sites of one hectare each were chosen for this work, namely the site after the ponds (burnt area), the site inaugurated by the Minister (ZI), the bamboo site (SB) and the Moabi plot (P. Moabi); and the plants were classified into three (03) categories (dead, living and regenerated) according to their resilience.

Permanent Square plots (quadrats) measuring 25 m x 25 m (625 m²) were set up at each site. These land-use forms observed in the site are the result of previous studies by Bossiomo (2018) [8] who showed how to establish plots by land-use type, and by Temgoua (2018) [6], who were able to characterize these land-use types. Each one-hectare plot was divided into sixteen square sub-plots, marked by 11 lines. Each line consisted of 11 seedlings of plants, spaced 2.5 m apart, giving a total of 121 seedlings per sub-plot. All the sub-plots were marked out using a string carried by four stakes cut with a machete. The plots were installed in each of the four sites

crossed by the threat. For the purposes of this study, a total of 64 square sub-plots were installed, obtained by multiplying 1 ha by a 25 m x 25 m plot by the number of plots (10,000 m² / 625 m² x 4), giving a sampling rate of 0.37%. During data collection, if a seedling was not present on its row, it was considered dead. In addition, the circumference and height of each seedling were measured and recorded after each identification.

The identification of woody plants in the plots was carried out using the "Flore du Cameroun" keys [16].

2.3.2 Taking stock of reforestation in the FER

The Fig. 2 shows the various members of the data collection team in the field. They include two counters to records the number of plants observed, one botanist for the nomenclature of the plants, a pointer to record the geographical coordinates using a global positioning system (GPS), and the machete to open the layons.

Reforestation measures were assessed on the basis of simple field observations. A literature review was carried out at the ENEF library in order to confirm the soil type and vegetation type observed in the FER. In addition, a survey form was drawn up and administered to local residents and ENEF staff in order to identify the type and extent of human activity. In this way, sixty (60) individuals were surveyed, depending on the type of activity carried out in and around the RMF.
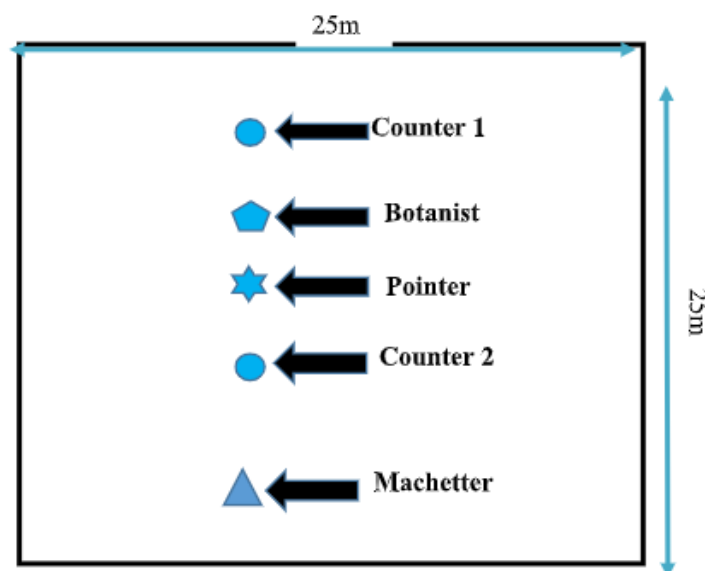

Fig. 2. Sampling design

2.3.3 Propose a reforestation strategy for the ENEF that corresponds to the ecosystem studied

In order to propose a reforestation plan for ENEF, data were collected through simple field observations and surveys of the population. In the case of field observations, several criteria were taken into account, including the nature of the soil and the type of plant. With regard to population surveys, the following parameters were taken into account: people living near the RMF and their main activities in and around the RMF. A literature review on the surfaces was carried out and a restoration strategy (restoration plan) compatible with the ecological and economic context of reforestation of the ENEF in the light of all the information gathered was defined.

2.4 Data Analysis

The data were analyzed using three software packages. The attached questionnaires were filled in manually, encoded and then analyzed qualitatively using the Statistical Package for Social Sciences (SPSS) 20.0 and EXCEL 2016. R" and "Past" software for statistical testing. The map showing the location of the RMF was produced using ARCGIS 10.5 and ENVI 5.3 mapping software. It also made it possible to highlight the restoration fronts and the various conflict zones linked to human activities. The dendrometric data collected was analyzed and processed using software such as 'R' for data processing and 'Past' for developing the various parametric and/or non-parametric tests.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Anthropogenic threats to the RMF

Three main types of anthropogenic threat to the RMF were identified depending on the areas selected (Table 1). These are: Bushfires (1); According to the zone after the ponds, or the burnt zone, there is a redundancy of bush fires and clandestine rural activities. These fires have caused a great deal of damage, destroying almost the entire lower stratum and some of the herbaceous plants in the area; Agriculture (2): The inaugurated zone is a coveted area for clandestine farming activities, which slow down the regeneration of tree species. Millettia laurentii (Wengé) and Milicia excelsa (Iroko) seedlings can be seen growing, but their growth has been

slowed by agriculture. Similarly, a strong presence of plantations and agricultural fields was observed in the bamboo sites, which consist mainly of Dandrokalamus sp, from the Poaceae family, and Bambusa vulgaris from the same family. This site has been reforested with these two species in particular, in order to limit the clandestine activities in the fields, which were steadily increasing and Bark harvesting (3) : Our observations in the field have enabled us to identify the threats listed in the table below per zone.

The Moabi plots in the FER are experiencing slower growth because of the upsurge in human activity, which here is focused exclusively on bark harvesting. This bark is used by local people for medicinal purposes.

Table 1. Type of anthropogenic threats per zone

Zones	threats
Burnt area	Bush fires/ agriculture
Inaugurated area	Agriculture
Bamboo site	Agriculture
Moabi plot	Bark removal

3.2 Comparison of Threats

3.2.1 Sorensen's similarity coefficient

Table 2 below shows the values resulting from the calculation of Sorensen's coefficient of similarity of degraded reforested areas in the ERF as a function of different human activities calculate using the following equation:

$S=(2c/(a+b)=)x100)$. It's used to compare the different stations with each other (where a=number of species present in the first station, b=number of species present in the second station and c= number of species common to both stations).

Table 2. Sorensen's similarity coefficient of degraded areas in the RMF as a function of human activity

Anthropogenic activities	Similarities (%)
Agriculture- Debarking	7,41
Agriculture-Bushfires	52,17
Debarking bushfires	0,0
Total	100

The table shows that there is no significant correlation between forest areas affected by

agricultural activities and those affected by bark harvesting activities (Si=7.41%). There is also no similarity between areas threatened by bush fires and those affected by bark harvesting (Si=0.0%). On the other hand, the similarity is accentuated and very significant in sites affected by agricultural fields and bush fires (Si=52.17%). These similarities clearly show the extent of the damage caused by bush fires and agriculture on reforested areas.

3.3 State of Reforestation in the FER

3.3.1 Floristic composition of reforested sites

3.3.1.1 Family composition

The floristic inventory of the study sites reveals the presence of 4391 individuals divided into 16 families and undetermined individuals. All of these families are represented by more than one individual, with the exception of the Papaveraceae (*Glaucium flavum*), represented by a single plant. The most dominant families are the Fabaceae with 977 individuals, mainly represented by trees; the Sterculiaceae family with 952 plants; the Ochnaceae family represented exclusively by 614 plants of *Lophira alata* (Azobé) and the Caesalpiniaceae family with 459 plants. The figure below shows the distribution of the number of individuals by family. This figure shows a low representation of individuals from the Combrétacées (14 plants), Euphorbiaceae (6 plants) and Apocynaceae (5 plants) families. The families of 109 samples could not be identified.

3.4 Species Composition

3.4.1 Species abundance

Fig. 4 below shows the distribution of species according to their abundance on the site. It shows that in the burnt area (ZB), there is an overabundance of *M. altissima* (Beté), with 820 individuals per hectare, and an abundance of *M. laurentii* (Wengé), *D. ebenum* (Ebony), *A. pachyloba* (Doussié blanc) and *S. rhinopetala* (Lotofa), respectively, of 316; 241; 206; and 103 units per hectare. The species least represented here are: one individual of *G. flavum* (yellow leaves), two individuals of *P. nitida* (Oberu), three *F. carica* (Fig tree) and 5 individuals of *A. bipindensis* (Red Doussié), making a total of 1,936 plant for 20 species inventoried. In the inaugurated zone, on the other hand, species such as *L. alata* (Azobé), *M. laurentii* (Wengé), *L. trichiloides* Dibetou, *E. ivorense* (Tali) and undetermined species are abundant, with 550, 449, 108 and 109 trees per hectare respectively. The least abundant species here are several varieties, including *P. nitida* (Oberu) (1 ft), *P. soyauxii* (Padouk d'Afrique) (1 ft), *I. eudulis* (Inga) (1 ft) and *R. heudolotii* (Njansan) (6 ft). A total of 1,932 plants for 24 species. However, as the Moabi plots and the Bamboo site are mono-specific, the abundance of individuals of *B. toxisperma* (Moabi), *Dandrokalamus* sp (Green Bamboo) and *B. vulgaris* (Yellow Bamboo) is 121, 100 and 300 respectively, i.e. a cumulative total of 521 plants inventoried for these three species.
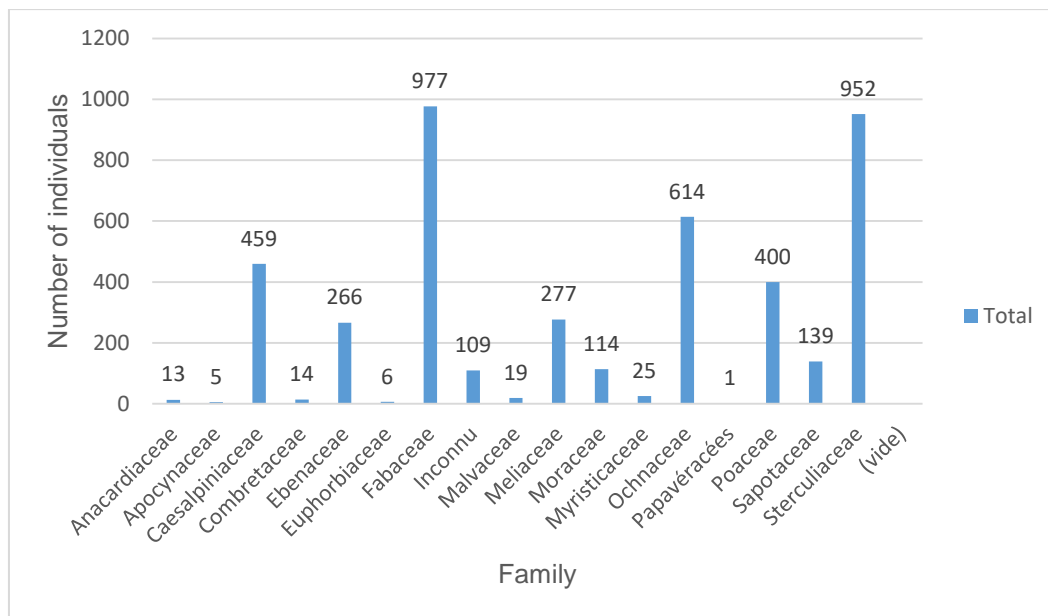

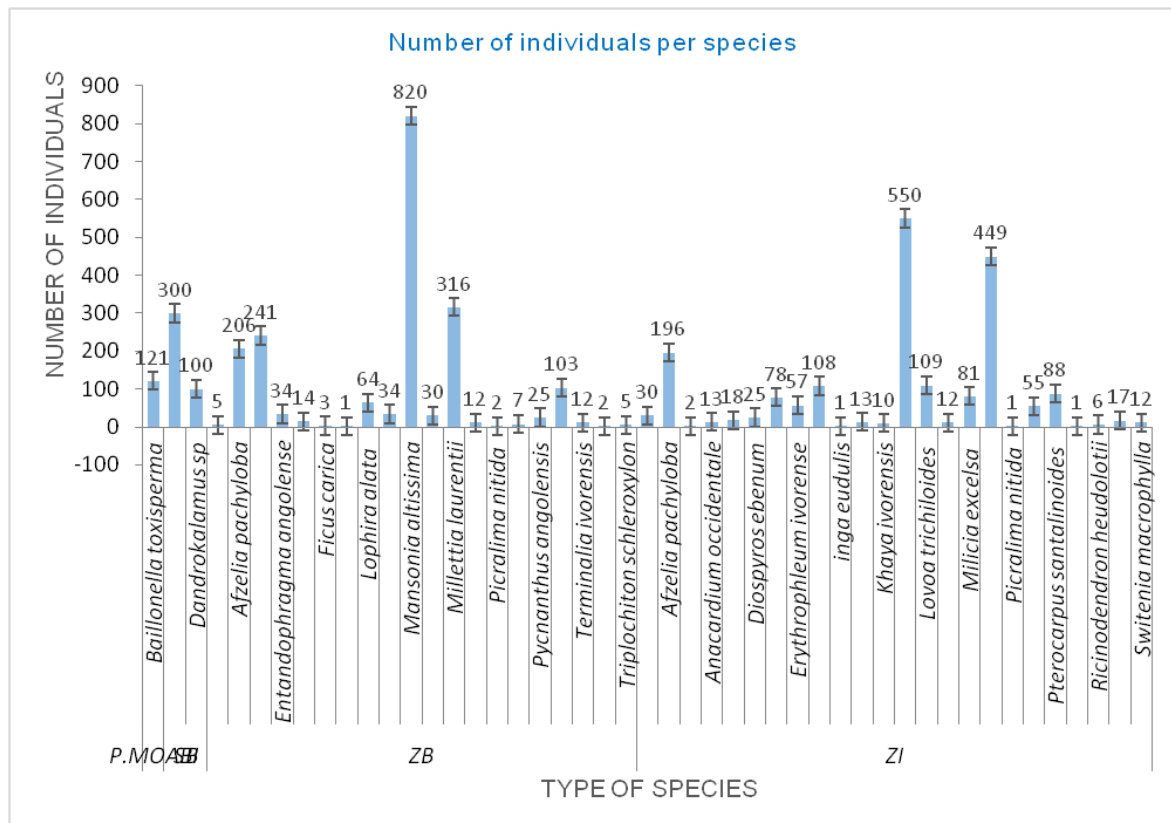**Fig. 3. Breakdown of the number of individuals per family**

Fig. 4. Distribution of individuals per species

Table 3. Some species and their use

Local name	Scientific name	Use
Moabi	*Baillonella toxisperma*	Pharmacopia
Iroko	*Millicia excelsa*	Timber
Yellow bamboo	*Bambusa vulgaris*	Fabrication des chaises
Green bamboo	*Dandrokalamus sp*	Decoration
Assie	*Entandrophragma cylindricum*	Timber
Djansang/essessang	*Ricinodendron heudelotii*	Alimentation
Ndo'o	*Irvingia gabonensis*	Alimentation and pharmacopia
Nfol	*Enantia chlorantha*	Pharmacopia
Essingang	*Guibourtia tessmanii*	Pharmacopia,timber
Eteng	*Pycnanthus angolensis*	Alimentation and pharmacopia
Atui	*Piptadeniastrum africanum*	Pharmacopia
Ekouk	*Alstonia congensis*	Timber and pharmacopia

3.4.2 Use of certain species

All these species are used daily by the local population, whose abusive and illegal exploitation is encroaching on the regeneration of reforested areas. The bark of some species, such as Moabi (Baillonella toxisperma), is used by local people for medicinal purposes. Table 3 shows some of the species used by the local population and their uses [17].

3.4.3 Importance of species

The importance value index indicates the most important species in each site. Table 3 shows the different importance indices for monospecific and polyspecific species depending on the site. In this table, the most important species in the burnt area are *M. altissima* (Bété), *M. laurentii* (Wengé), *D. ebenum* (Eben) and *A. pachyloba* (Doussié blanc), with indices of 41.08, 15.83, 12.07 and 10.32 respectively. On the other hand,

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species such as *P. nitida* (IVI=0.1), *G. flavum* (IVI=0.05), *T. schleroxylon* (IVI=0.25) and *A. bipindensis* (IVI=0.25) are of very little importance on this site, with importance indices ranging from very low to zero.

3.5 Reforestation Strategy Corresponding to the Ecological Context of the RMF

The restoration strategy proposed here is based on the natural regeneration of tree species in view of their resilience to human intervention.

The figure below shows all the species regenerated at each site.

The Fig. 5 shows us 4 main peaks of regeneration: two in the inaugurated zone with species such as M. laurentii, 69 feet, i.e. 5.48% and M. excelsa, 17 feet, i.e. 11.83%; and two in the burnt zone with once again species such as M. laurentii, 39 feet, i.e. 3.77% and M. altissima 19 feet, i.e. 1.84% (see Table 4). We can see here that regeneration is very low on the Moabi site (1.65%) and nil on the Bamboo site (0%).
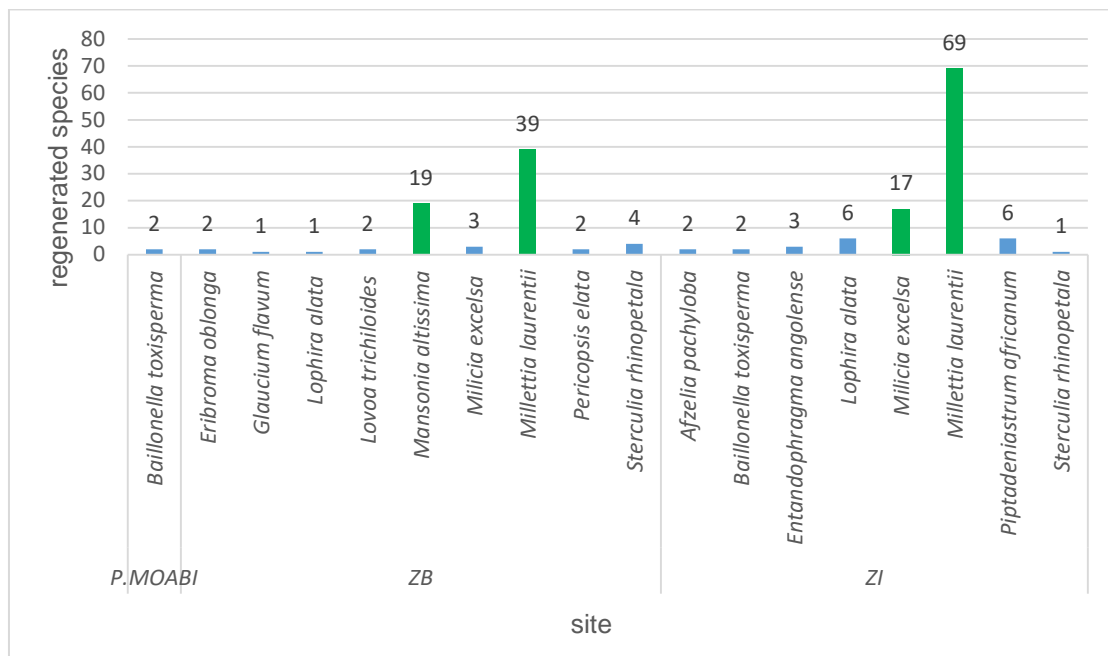

Fig. 5. Regenerated species per site

The Table 4 below shows the restoration strategies for each degraded site.

Table 4. Restoration strategies per site

Sites	Suggested species		Reasons	Strategies
	local name	scientific name		
Moabi plot	Moabi	*Baillonella toxisperma*	Can regenerate after being destroyed by excessive bark removal.	Securing plots to prevent seepage
Burnt zone (ZB)	Wengé	*Millettia laurentii*	Resistant to bush fires and plantations. It has a high regeneration rate (53.42%) after destruction.	Increase the spacing between plants for rapid growth
	Bété	*Mansonia altissima*	Resistant to bush fires and plantations: possibility of regeneration (26%) after destruction.	Secure the plots Raise awareness of the importance of reforestation among local communities
inaugurated zone (ZI)	Wenge	*Milletia laurentii*	Resistant to agriculture and regenerates rapidly after	-Implementation of agroforestry

Sites	Suggested species		Reasons	Strategies
	local name	scientific name		
			destruction, with a regeneration rate of around 66%.	techniques - Teaching agroforestry techniques to local communities -Use integrated approaches to resource assessment, planning and management.
	Iroko	*Milicia excelsa*	Resistant to agriculture, with a regeneration rate of 16%.	
	Azobe	*Lophira alata*	Resistant to agricultural activities and regenerates in certain cases (with a regeneration rate of 5.66%)	
Bamboo site (SB)	Green Bamboo	*Bambusa vulgaris*	Resistant to agriculture	

The observations drawn from this table show us that species such as Wenge, Bete, Azobe, Iroko and green Bamboo are the strategic species to adopt in these sites to ensure effective and sustainable reforestation in view of their restoration percentages.

3.6 Discussion

3.6.1 Various anthropogenic threats

Sorensen's coefficient of similarity (1969) showed a strong and very significant similarity in the sites affected by agricultural fields and bush fires (Si=52.17%). These similarities clearly show the extent of the damage caused by bush fires and agriculture on reforested areas. These results differ from those of Temgoua (2010), who found five (05) types of anthropogenic threat to the RMF, namely the sale of firewood, the collection of non-timber forest products, slash-and-burn agriculture, land clearance and illegal logging. According to Temgoua, at the current rate of clearing and illegal logging, the destruction of the application forest and the ENEF arboretum, which are the only two formations that still qualify as "teaching and research forest", is to be feared. In my opinion, this difference is due to the fact that the ENEF has worked throughout the Mbalmayo forest reserve of around 9700 ha, unlike our studies which were limited to the teaching and research forest of around 1095 ha, which is only one entity of the reserve [18].

3.6.2 Floristic composition threatened by human activity

The most abundant botanical families are Fabaceae, Sterculiaceae, Orchnaceae and Caesalpinaceae. The dominance of Fabaceae and Sterculiaceae is a fairly general phenomenon in most dense tropical rainforests. The studies carried out by Gueulou *et al.* 2018 on floristic diversity are in line with this, as they consider that the Fabaceae and Rubiaceae families are characteristic of tropical rainforests. Forests are marked by a few dominant families that can be used to characterise the forest type. If we refer to the dominant families, the RMF can be characterised as a Fabaceae and Sterculiaceae forest.

3.6.3 Reforestation strategy

The data collected showed that species such as *M. laurentiii*, *M. altissima*, *L. alata*, *M. excelsa* and *B. vulgaris* are resistant to bush fires and agriculture. What's more, they have a high regeneration capacity, so reforestation with these species would be ideal. The increase in human activity on restored sites would be considerably reduced if these sites were protected by fences or ecoguards.

In addition, surveys of local people have shown that the restoration of degraded areas of the RMF is more effective in multi-species plots than in single-species plots, which may be explained by the fact that single-species plots are less coveted by local people. These results differ from those of studies carried out by Anonyme, 2014, which proposes other restoration strategies, including the formulation and application of support policies and legal frameworks by public authorities; the transfer of responsibilities to local populations and equitable sharing; the use of integrated approaches to resource assessment, planning and management; and the mobilisation of ecological and silvicultural knowledge and efficient management practices.

4. CONCLUSION

This study enabled us to take stock of the reforested sites, to identify the various anthropogenic threats, to assess the current situation and finally to propose a reforestation strategy favourable to the RMF and the ecological context of ENEF. At the end of our analyses, an assessment of the floristic diversity of the sites studied revealed 4,391 individuals divided into 34 species and 16 families. The most dominant families were Fabaceae, represented mainly by species such as Wengé (765 plants), Padouk (88 plants), Dabéma (62 plants), Doussié blanc (35 plants), etc., giving a total of 977 plants in this family. The Sterculiaceae family, represented mainly by Bété (852 trees) and Lotofa (120 trees), and finally the Ochnaceae and Caesalpiniaceae families.

A number of species are used here by local people for a variety of purposes, including *B. toxisperma* (Moabi) for pharmacopoeia, *M. excelsa* (Iroko) for timber and *R. heudelotti* (Djansang) for food. The anthropogenic activities detected in the course of this study were the debarking observed in the Moabi plots, the bush fires encountered in the ZB site and the field activities (agricultural plantations) encountered in the Bamboo site. However, 3,174 trees survived hreats, compared with 1,036 that barely survived. Miraculously, 181 trees were regenerated naturally, mainly species such as Wengé (39 trees) and Bété (19 trees). In view of these findings, the reforestation strategy adopted was based on selecting species that are resilient to human activity and securing the reforested areas.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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