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Factors affecting vegetation dynamics in the south of the Mokolo District in the Far North of Cameroon

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ABSTRACT: Plant dynamics is a natural process that occurs in the ecosystem. This dynamic becomes abnormal in the presence of human pressure. The vegetation of the district of Mokolo (Cameroon) faces many anthropic factors that disturb its steady evolution. This work aims to evaluate the different factors that influence the vegetation dynamics in the south of the Mokolo District. All traces of anthropization were identified on all woody species in a rectangular plot (20 m x 100 m). All individuals with a height $\leq$1.30 m and a Dhp less than 10 cm were considered regenerating individuals. Among the main plant factors, dynamics identified, regeneration, spread type, phytogeographic type have positive impacts while logging, debarking, pruning, grubbing, trampling and burning have negative impacts. Regeneration is the main positive natural factor with the highest frequency in wooded savannas (321±95%). Timber harvesting is the main negative anthropogenic factor with a higher frequency in the home garden (85.00%) and the shrub savannas (68.66%). To reduce the negative impacts and increase the positive impacts, the government must implement reforestation projects in this ecologically fragile area.

1. INTRODUCTION

Plant dynamics naturally occur in any plant space (Black, 1998). These dynamics can become abnormal when people settle in an area and develop natural resources. This results in a change in vegetation cover, which in most cases manifests itself as a regressive transformation of the vegetation (Bodel, 2011). This vegetation dynamic of savannahs is characterized by successions of vegetation formations observable at different scales in space and time (Huete et al., 2002). Vegetation dynamics become regressive in environments with intense human activities (Rabiou et al., 2019), which is reflected in high anthropogenic activity (Bai et al., 2008). A modification of the composition and disappearance of more minor and less active species in savannas with low vegetation cover (Sjöström et al., 2009).

Cameroon, particularly the Far North Region, loses significant savannah areas each year due to land clearing, abusive and anarchic logging, bush fires, overgrazing and climate change (Saleh et al., 2014). Agriculture is also responsible for over 80% of environmental degradation (Cerruti & Lescuyer, 2010). Besides its drivers of plant dynamics, wood fuel remains one of the most widely used forms of energy (Dkamela, 2011; Sonwa et al., 2011) and largely influences the dynamics of vegetation cover not only in rural but also in urban areas. Within a radius of about 25 km around Maroua, most of the wood comes only from the fields, representing only a tiny proportion (15%) of the city's consumption (Madi, 2003). Despite the various changes that these factors cause, the primarily poor populations depend on natural resources for their well-being (Kemeuze, 2017). This deterioration of the environment strongly accentuates the regressive changes of the vegetation cover (Black, 1998). These regressive changes are most visible in the Sudano-Sahelian zones of Cameroon. The scarcity of resources combined with the increase in demographic pressure on the natural environment leads to environmental degradation, the harms of which are felt every day (P-Eva, 2015). The main problems encountered in this area, both in terms of the environment and socio-economic development, are overgrazing, deforestation, poaching and bush fires (P-Eva, 2015). Ecosystem degradation is now a threat to biodiversity in that it contributes to the destruction of the natural environment, which inevitably leads to the disappearance of species (M. Tchobsala & M, 2013).

The southern part of the Mokolo District is located in the Sahelian zone, which is fragile to anthropogenic pressures (Samantha & Bolivard, 2017). Problems such as lack of wood energy, declining agricultural production, climate

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change, and conflicts between indigenous people arise in this locality to acquire wood and soil. The combination of the pressures of these populations on the vegetation leads to desertification. It is essential in this work to identify the main human factors that impact the vegetation dynamics in this area.

2. MATERIALS AND METHODS

2.1. Location of the study area

The arrondissement of Mokolo, department of Mayo-Tsanaga, Far North region (Cameroon). It is located at a latitude of 10° 44′ 25″ north and a longitude of 13° 48′ 10″ east. It has a population of around 242,274 people. Koza and Mozogo are to the north, Mogodé and Hina are to the south, Gazawa and Soulede-Roua are to the east, and Bourha and the Republic of Nigeria are to the west (Lebel & Pontié, 2011). Agriculture and livestock are the district's primary economic activities.

2.2. Physical Data

Mokolo District has a tropical climate at high altitudes. Temperatures are relatively low from November to January (20-25°C) and very high in March and April (40-45°C). Rainfall varies between 700 and 900mm in 50-60 days, and the rainy season lasts about five months, from May to September. The dominant wind is the harmattan that blows from north to south (Djarmaila, 2011).

Plains and hills dominate the relief of Mokolo, and the soils are varied. One can observe sandy-clay and sandy soils on the sides and feet of the hills littered with stones of various sizes; clay soils rich in humus on the edges of the mayos and very favourable to market gardening and food crops. Other types of soils range from the poorly developed soils of the mountains to the alluvial soils of the lowlands and the hardened or barren soils of the plains (Max, 2016; Seignobos, 1982).

In this locality, there is no longer any primary plant formation. It is predominantly shrubby and woody, mostly thorny. In general, it consists of species such as Acacia albida, Acacia seyal, Acacia nilotica, Ficus spp, Tamarindus indica, Azadirachta indica, Anogeiossus leiocarpus, Ziziphus mauritiana. These species are mainly used as shade trees in the fields, as a source of firewood and timber. This vegetation is undergoing severe deterioration due to population growth and excessive cutting of firewood and service wood (Seignobos, 1982).

2.3. Choice of plant formations

The shrub savannahs, forest galleries, fields, home gardens and tree savannahs were chosen based on the elaboration of maps by local populations (Dugué & Jouve, 2003). This approach aims to support a framework of consultation for developing natural resource management plans with the various actors (the oldest indigenous people) who have been in the villages for a long time. The approach, which is centred on cartographic self-design, is based on three steps based on the orientations of the traditional and administrative authorities. These are:

-External diagnosis of the situation;

-the reinforcement of endogenous skills

-the design of maps by the actors.

The first step consisted of an external diagnosis of the terroir south of Mokolo to determine the capacity and level of representation of territorial issues. This preliminary step, which was essential for the continuation of the process, made it possible to establish the stakeholders' lived space and territorial representations.

After this diagnosis, the second stage was planned to enhance the populations' cartographic analysis skills. The objective is to represent, through dialogue, the perceptions (knowledge, practices, and rules of use) of the stakeholders on cartographic medium in order to accompany them in the development of a plant resource management system. Cartographic exercises explain and illustrate the basic concepts for reading a map (title, orientation, legend and scale). Each cartographic exercise is punctuated by questions, explanations and exchanges between the participants.

The third step allowed the participants to make maps corresponding to their perceptions and needs. The diagrams and sketches resulting from these exchanges were transferred to cartographic support during the second visit to the respondents. The geographical data was supplied to all actors throughout the process to legitimise the cartographic synthesis collectively. The leaders' guides led us to the sites for our sampling work based on these stakeholder maps. Five vegetation formations were selected at the end of the work: forest gallery, fields, home gardens, and wooded savannahs.

2.4. Method of identification of plant dynamics factors

Within each plant formation, all woody species with height $H \geq 1,30$ m and Dhp ≥ 10 cm were inventoried and identified by their scientific names (Souare et al., 2019). All individuals with height ≤ 1.30 m and Dhp less than 10 cm were considered regenerating. In the same rectangular plot (20 m x 100 m), regenerating individuals were systematically counted (Figure 1).

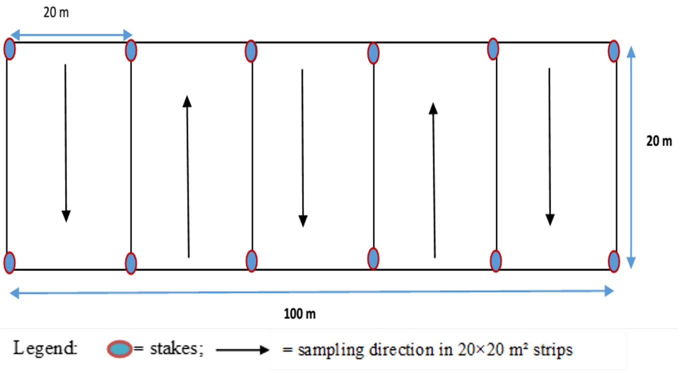

Figure 1. Woody data survey device.

For species branching before 1.30 m in height, the average stem circumference was used to determine the diameter at 10 cm from the ground (Jiagho et al., 2016). The following densitometric measurements were taken to determine the effect of the populations on the vegetation: 30 cm circumference at the base of the trunk; diameter of the crown projection on the ground in two directions (north-south and east-west); diameter at breast height (1.30 m from the ground); the species' height was also determined using the graduated stick (Haiwa, 2018; K.P. Tchobsala et al., 2018). In the same rectangular plot, indices of vegetation anthropization (pruning, bark, burn, cuts, diseases) were identified on each plant species (Ouédraogo & Nianogo, 2003; I.A. Tchobsala et al., 2016). These observations provided additional information that could improve the assessment of vegetation dynamics.

2.4.1 Traces of anthropization

A set of anthropogenic indices was collected by field observation. In each subplot, the presence of fires, woodcuts, grazing, tree abrasions, or other signs indicating the presence of human activities was noted. This information gave us an idea of the frequency of human action in the different reforested sites. The following formula was used to determine the frequency of these traces: Frequency of activity = (Number of an anthropogenic trace)/(Total number of traces) X100 (Baiyabe et al., 2018).

2.4.2 Biological types

Biological types were studied following the classification of Raunkiaer (1934) and adapted to tropical regions by Schnell (1971).

Perennial plants are plants that can live for several years.

Phanerophytes: are species whose aerial dormant buds are more than 50 cm from the soil surface. This group includes macrophanerophytes with woody stems exceeding 30 m in height; mesophanerophytes with woody stems between 10 and 30 m in height; microphanerophytes with woody stems between 2 and 10 m in height and nanophanerophytes with woody stems not exceeding 25 cm and 2 m in height.

2.4.3 Types of diaspores dissemination

The modes of dissemination were noted according to the classification proposed by Lebrun (1966), Schnell (1971) and Mandango (1982). The following categories were recognized:

A-Indigenous plants: These plants ensure themselves the dispersion of their seeds, a dispersion at a very short distance, generally under the foot of the tree. We distinguish:

- ballochores: Diaspores expelled by the plant itself following the movements due to the alternation of the pressure of drought and moisture;

- Barochores: Diaspores are not fleshy but heavy, falling at the foot of the mother plant under the effect of gravity. The regeneration is done on the spot.

B-Heterochorous plants: The dispersion of their seeds is ensured either by the wind (anemochory) or by animals (zoochory), or by water (hydrochory). Among them, we distinguish:

-the desmochores: diaspores with barbed appendages (zoochores) or diaspores clinging or adhesive;

the sclerochores: relatively light non-fleshy diaspores that can be transported over long distances (anemochores);

-pogonochores : Diaspores with feathery appendages or with aigrettes (anemochores) with a light tuft of hairs;

-the pterochores: diaspores with aliform or winged appendages (anemochores) disseminated over short distances;

-the sarcochores (Sar): Diaspores with soft and fleshy pulp, totally or partially chimneyed (anemochores, hydrochores and zoochores).

2.4.4 Phytogeographical distributions

The geographical distribution was made according to the classification of Raunkiaer (1934), adapted to tropical regions by Schnell (1971). It is composed of:

A. Species with an extensive world distribution, including:

- Cosmopolites, found in both warm and temperate regions;

- the Pantropicals, sensu stricto spread in Africa, America, tropical Asia and Australia;

- the Afroneotropics, species present in Africa and tropical America;

- the Paleotropics, present in Africa and tropical Asia.

B. African species with a wide distribution or African multi-regions among which:

- the continental Afro-tropics, in continental Africa;

- the Afro-Malagasy, distributed in Africa, Madagascar and neighboring islands;

- the species of Eastern and Southern Africa, occupying all of Eastern and Southern Africa.

2.4.5 Density and mode of regeneration

The number of seedlings in the circular subplots was determined by systematic counting. Seedlings less than 1.30 m in height and Dbh< 10 cm were considered regenerations. They were represented by suckers, stump sprouts and seedlings from seedlings. In each rectangular plot, careful and progressive excavation of the root system of the regeneration of each spotted and identified species was performed to determine its origin (Bellefontaine et al., 2018). Thus, natural seedlings exhibited a taproot system, while suckers maintained a morphological connection with the mother root (Bellefontaine et al., 2018; Bellefontaine & Monteuuis, 2002). This was done to avoid possible confusions between the sucker that is anatomically connected to the root of the mother plant and the seedlings from seedlings that have their root systems.

2.5. Statistical analysis

All data are summarized and analyzed statistically. Analyses of variance are used to compare plant formations. Principal component analyses (PCA) were calculated by Xl-stat pro to determine the dispersion of specific types of dissemination within each plant formation. Excel 2016 spreadsheet was used to estimate percentages.

3. RESULT AND DISCUSSION

3.1. Density of species regeneration

The regeneration of species in the sites is done by germination, stump rejection and suckering. The highest regeneration density was obtained in the plant formations (321±95.22 individuals/ha), while the lowest was obtained in the home gardens (39±14.43). The impact of the populations influences the dynamics of the regeneration of the species in the whole village (Table 1). In the home gardens, anthropogenic factors such as the establishment of fields and cutting wood considerably slow down seed germination. The low number of individuals that suckers can be explained by the fact that most species do not develop a superficial root system. Plants in this zone need water to develop a taproot system to go deep. On the other hand, in the tree savannas, the limitation of anthropic activities would allow easy and rapid germination of seeds. It is also possible to note the facilitation of the dissemination of seeds by animals. For this reason, Ngom (2008) asserts that the consumption of fruits facilitates natural seeding by animals, which reject the kernels in their droppings, thus facilitating germination.

In this village, there are protected areas with fewer human activities. In addition to cutting wood for energy and debarking, rainfall and fire are also factoring in the forest dynamics that are not negligible in the reconstitution of savannahs (Séghièri, 1990). These results also corroborate those of A. Tchobsala et al. (2010), where Daniellia oliveri and Hymenocardia acida regenerated very quickly and abundantly after logging, especially with the passage of fire the peri-urban savannas of Ngaoundéré. Another regeneration strategy is seed germination. A plant with easy germination conditions could have good regeneration statistics. If, in this work, the heavily cut environments (fields, home gardens and shrub savannah) are very rich in seedlings from germination, this proves that transport agents played a significant role in the dissemination of diaspores. Cut wood is rapidly replaced and recolonized by new species. However, despite the low density of plants, the increasing needs of local populations have led to various forms of exploitation that do not always guarantee the intrinsic capacities of the resources to regenerate (Froumsia et al., 2016; Hamawa, 2013; Todou et al., 2017). Variation is significant across plant formations (0.0000 < 0.0001).

3.2. Biological types of vegetation

The biological types of the different vegetation formations in the study villages varied significantly ($p < 0.001$). Nanophanerophytes ($0.25 < H < 2$ m) are more presented in the village. The highest frequency of these nanophanerophytes was obtained in shrub savannahs (72.88%), while their low frequency was obtained at the home garden level (6.29%) (Table 2). While microphanerophytes ($2 < H < 10$ m) and mesophanerophytes ($10 < H < 30$ m) have a relatively low average compared to nanophanerophytes. Nanophanerophytes are more important also in shrub savannas, with frequencies of 72.88%. The abundance of nanophanerophytes would be due to adapting these biological types in these environments. Raunkiaer (1934) emphasizes plants' nature and degree of adaptation during unfavourable periods. This implies that nanophanerophytes can withstand the adverse climatic conditions of tropical savannas. In the same sense, Sandjong et al. (2013) showed through their results that shrubs are more dominant in the Mozogo-Gokoro National Park in the Far North of Cameroon. The importance of nano and microphanerophytes would be explained by the fact that these biological types are easily adapted to Sahelian savannas. In addition, it would seem that these biological types indicate the anthropized savannah. On the other hand, Sonké (1998) and Guedjé (2002) have shown that nanophanerophytes are biological types that adapt quickly to forests.

Table 1
Regeneration of species in the study villages (individuals/ha).

Plant formation	Densité (individus/ha)
Shrubby savannah	207±89,33^{b}
Forest gallery	74±19,11^{d}
Field	125±34,14^{c}
Home gardens	39±14,43^{e}
Wooded savannahs	321±95,22^{a}

Numbers followed by the same letter in the same column are not significantly different (p> 0.05).

Table 2
Biological types in the study villages (%)

Plant formation	Mésophanérophytes	Microphanérophytes	Nanophanérophytes
Shrubby savannah	18.92^{b}	32.19^{a}	72.88^{a}
Forest gallery	14.32^{c}	23.17^{b}	60.43^{b}
Field	10.22^{d}	31.31^{a}	44.15^{c}
Home gardens	1.38^{e}	5.77^{c}	6.29^{e}
Wooded savannahs	21.16^{a}	28.23^{a}	33.14^{d}

Numbers followed by the same letter in the same column are not significantly different (p> 0.05).

3.3. Types of dissemination in the study area

The spread of diaspores varied by plant formation. Regardless of plant formation, zoochores are more represented in all plant formations. Anemochores are second (Table 3).

Zoochores show a frequency of 17.45 % in the home gardens and 48.78 % in the forest galleries. In the second position are the anemochores with a frequency that varies from 10.28 % in the home gardens to 40.31 % in the wooded savannahs. From the above, zoochores and anemochores are the most dominant for grain dispersal in plant formations. The high average rate of zoochores would be justified because zoochores include all animals, including humans. Dissemination through zoochory is higher in the wooded savannah. Animals of this type of dissemination would more frequent the wooded savannah.

Conversely, barochory is the least represented mechanism of diaspore dispersal. This low percentage can be explained by the fact that this mode of diaspore dispersal only concerns plants capable of expelling diaspores themselves. These types of plants are less represented in our study area. Statistical analysis reveals significant differences between the different modes of diaspore dissemination on the one hand and between plant formations and villages on the other hand ($p < 0.001$). It would seem that these types of plants are less in this area. The type of diaspora spread is one of the main factors in the dynamics of plant formations. This result is similar to Sandjong (2018) in the Far North region.

Table 3

Species spread according to plant formations (%)

Plant formation	Anemo-chory	Ballo-chory	Baro-chory	Sarco-chory	Sclero-chory	Zoo-chory
Shrubby savannah	40.31^{a}	2.34^{b}	1.14^{c}	1.12^{c}	1.23^{b}	33.10^{c}
Forest gallery	38.45^{a}	7.34^{a}	3.23^{a}	4.35^{b}	1.34^{b}	48.78^{a}
Field	15.51^{c}	1.90^{c}	2.33^{b}	1.21^{c}	2.34^{a}	31.44^{c}
Home gardens	10.28^{c}	1.23^{c}	3.34^{a}	5.44^{a}	1.48^{b}	17.45^{d}
Wooded savannahs	19.11^{b}	3.43^{b}	2.47^{b}	1.16^{c}	1.45^{b}	40.15^{b}

Numbers followed by the same letter in the same column are not significantly different (p> 0.05).

The principal component analysis allows us to study the mode of dissemination of species in the study sites. This distribution of species spread is based on the factorial design of axes 1 and 2. The PCA allows us to group the different types of spread according to their similar correlations. Anemochores and zoochores (positive correlation) are opposed to barochores and sclerochores (negative correlation) by axis two, which expresses 24.19% of variances. Ballochores and sarcochores indicate a strong relationship between them and move in the same direction (negative correlation). Principal component analysis of the variables shows that the anemochore is dominant in the forest galleria, the shrubby savanna. Ballochores and sarcochores are negatively correlated (Figure 2).

3.4. Phytogeographic distribution according to villages and plant formations

The study village is colonized by plants whose geographical distribution is more accentuated in tropical Africa. These species are very dominant in the wooded savannahs. Depending on the plant formation, their frequency varies between 47.75% in the fields and 72.51% in the wooded savannahs (Table 4). This result can be explained because the sites studied are located in a dry tropical zone conducive to the growth of certain species such as A. senegal, Guiera senegalensis, Combretum collinum, Prosopis africana, Azadirachta indica (Baiyabe et al., 2018). In the second position, we observe a high frequency of Paleotropics such as A. nilotica, Balanites aegyptiaca, Ziziphus mauritana, Commiphora africana, Grewia flavescens, ranked second with maximum values of 13.40%. These varied significantly between villages (0.04<0.05). Across all sites, southern African species are the least represented (Table 4). Miabangana and Ayingweu (2015), on the other hand, reveal the dominance of species from the Guinean-Congolese center of endemism (57%) in the vegetation of Loufézou Island in Brazzaville, Congo. These differences would be due to the geographical location of each study area.

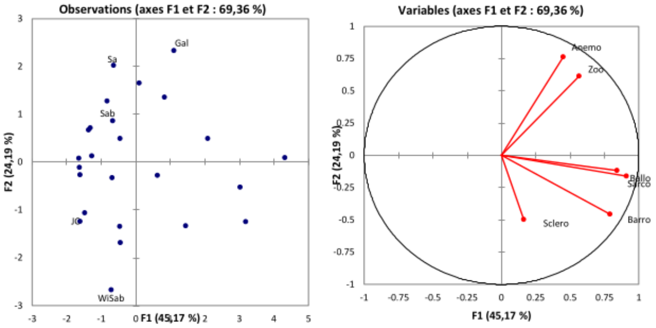

Figure 2. PCA of dissemination mode according to villagesand plant formations. SA: shrub savannah, Gal: forest gallery, Ch:field, JC: hut gardens, Sab: shrub savannah, Anemo: anemochory, Zoo: zoochory, Ballo: ballochory, Sarco: sarcochory, Baro: barochory.

Table 4

Phytogeography according to villages and plant formations (%)

Plant forma-tion	Tropical Africa	Western and Southern Africa	Eastern Africa	Paleotropical	Pantropical	Afro-Malagasy
Shrubby savannah	60.02^{b}	2.95^{bc}	0.00^{e}	13.40^{a}	0.90^{b}	0.95^{c}
Forest gallery	62.96^{b}	6.16^{a}	1.04^{c}	5.10^{c}	4.06^{a}	0.05^{d}
Field	47.75^{ab}	5.88^{a}	0.08^{d}	9.81^{b}	0.01^{c}	2.58^{b}
Home gardens	47.86^{ab}	4.36^{b}	1.73^{b}	4.88^{c}	0.00^{d}	0.00^{e}
Wooded savannahs	72.51^{a}	3.16^{c}	2.83^{a}	10.07^{b}	0.03^{c}	5.96^{a}

Numbers followed by the same letter in the same column are statistically identical (p> 0.05),

3.5. Indices of anthropization according to villages and plant formations

More than 98% of the people (natives) surveyed affirm that the massive arrival of displaced persons has had a very negative impact on the state of woody stands, particularly at their site and in the riparian villages, which, according to the populations, has led to a disappearance of species. In addition, all of the fields cultivated by the displaced are either borrowed or fallow land or pastoral rangelands. The signs of anthropization are more visible in the fields and home gardens and less frequent in the wooded savannahs.

All vegetation formations exhibit a greater degree of woodcutting. It occurs at a frequency of 85.00 percent in home gardens, 68.66 percent in shrub savannahs, 57.78 percent in fields, 49.13 percent in forest galleries, and 39.73 percent in shrub savannahs, in decreasing order. Wood provides essential services to the population, which leads to its high use in all villages. Debarking is the second indicator of site anthropization (Table 5). Woodcutting and debarking are the main income-generating activities in households. These two elements would be the most likely to impact the vegetation cover. Indeed, the settlement has deprived some (indigenous) people of their fields. Some indices such as trampling, burning, pruning, and grubbing have a significant frequency of occurrence in the different plant formations (Table 5). There is a significant difference (0.0000 < 0.0001) between plant formations.

Activities such as agriculture, animal husbandry and woodcutting are essential for the population's income. It must be noted that these forms of exploitation of natural resources are not always carried out under the conditions of equity and rationality required for sustainable management. The need to create a balance between the environment and development to improve the population's standard of living is essential. Ntoupka (1999) links the regressive dynamics of the formations to intense anthropic pressure characterized by anarchic cutting, fire practices, overgrazing, handicrafts and agriculture.

Table 5

Indices of anthropization in village plant formations (%)

Indices	Formations végétales Shrub Savannah	Forest Gallery	Field	Home Gardens	Wooded savannahs
Cutting	68.66^{a}	49.13^{a}	57.78^{b}	85.00^{a}	39.73^{a}
Debarking	30.61^{b}	42.14^{b}	49.93^{bc}	72.76^{b}	28.62^{a}
Pruning	33.03^{b}	29.00^{c}	8.90^{f}	5.04^{f}	8.62^{d}
Stumping	35.78^{b}	51.06^{a}	77.53^{a}	16.84^{e}	18.62^{c}
Burning	63.07^{a}	36.97^{ab}	62.81^{b}	66.53^{c}	25.57^{b}
Trampling	10.65^{c}	14.37^{e}	79.49^{a}	38.10^{d}	20.57^{b}

Numbers followed by the same letter in the same column are statistically identical ($p > 0.05$)

4. CONCLUSION

The objective of this work was to identify the main factors that impact the vegetation dynamics of the savannah in the south of the Mokolo district. This study shows that there are natural factors (regeneration, type of dissemination, type of phytogeography) and anthropogenic factors that influence the dynamics of the vegetation of the savannah of the Mokolo district. Natural factors have positive impacts, while anthropogenic factors negatively impact vegetation dynamics. Most of the activities carried out by the populations impact the vegetation. Wood, which is the primary source of energy for the population, is the primary factor in the regressive dynamics of the vegetation. All vegetation formations exhibit a greater degree of woodcutting. It occurs at a frequency of 85.00 percent in home gardens, 68.66 percent in shrub savannahs, 57.78 percent in fields, 49.13 percent in forest galleries, and 39.73 percent in shrub savannahs, in decreasing order. Environmental impact reduction activities require the funding of reforestation projects by the Cameroonian government, and it is essential to put in place strategies for the sustainable management of natural resources in this area.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest with regards to the manuscript.

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AUTHOR CONTRIBUTIONS

Paul Kodji wrote the original draft of the manuscript; Tchobsala, Adamou Ibrahima and Souare Konsala conceived and designed the experiments, contributed to the explanations and discussions on the results.

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