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Research Article

Influence of Wood Cutting and Fire on the Regeneration of the Vegetation Cover in the Sudano-Guinean Savannahs of Adamaoua, Cameroon

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Abstract

The various plant formations of the Guinean high savannah are subject to wood cutting and bush fires. This study aimed to assess the influence of logging and bush fires on the regeneration of the vegetation cover of the Sudano-Guinean savannahs. It was carried out on two types of plant formations (shrub and tree savannahs) with 18 plots, each 10 meters square, according to a randomized block experimental set-up and with different anthropogenic actions as treatments: wood cutting without fire, wood cutting with fire and control for a period of two years. Wood cutting by humans influences changes in the physiognomy of plant formations, and fire has an impact on the transformation of the savannah. In the shrub savannah, the number of trees varies from 76 to 160 (CSF), 60 to 109 (CAF) and 78 to 102 (T) in the first and second years respectively. On the other hand, in the tree savannah, 204 to 367 (CSF), 149 to 342 (CAF) and 189 to 257 (T). The regeneration rate of individuals increased from 6% to 24% in the shrub savannah and from 6% to 28%. The mortality rate was 9.46% CSF, 10.85% CAF and 15.89% T in the shrub savannah, while in the tree savannah it was 27.97% CSF, 15.51% CAF and 20.86% in the control site in the second year. The correlation between reiteration and mortality shows that, according to the analysis of variance, there is no statistically significant difference (0.8589>0.05) between plant formations and treatments. The phytogeographical distribution shows that Pantropical species (26.01%) are more important in both formations.

Keywords

Plant Formation, Savannahs, Regeneration, Mortality, Sudano-Guinean Savannahs, Cameroon

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1. Introduction

In Cameroon, and particularly in the Adamaoua region, savannah ecosystems are diverse and rich in species of socio-economic interest exploited by farmers [19]. This region is exposed to natural and especially anthropogenic pressure [28]. Plant formations in the Adamaoua region are under increasing anthropogenic pressure, as is the over-exploitation of land due to urbanisation. The degradation of ecosystems is now a threat to biodiversity, as the destruction of natural environments inevitably leads to the scarcity and even extinction of species [34]. Growing human pressure on natural resources is leading to dysfunctional terrestrial ecosystems and loss of biodiversity [30] because of the demographic explosion. This demographic explosion leads to the modification and fragmentation of natural ecosystem habitats. Interest in biodiversity has recently increased in response to the damage caused to ecosystems by human activities [23]. This anthropogenic pressure on plant cover is responsible for soil degradation and climate change [26]. Nature conservation is now one of the concerns of the entire international community. Savannas are fragile ecosystems based on the coexistence of a herbaceous layer and a woody layer. They are dynamic systems whose evolution depends on the intensity of environmental factors such as logging, drought, fire, livestock rearing and agriculture [7]. The pressure on natural resources is constantly increasing.

Studies carried out in the region have shown a decline in the various plant formations, such as the work of [40], which found that the area of savannah fell by 10.8% in 2001 compared with 1951. Satellite images of land use in Adamaoua from 2007 to 2017 show that vegetation is expanding from gallery forest to shrub savannah, and that vegetation is degrading rapidly because of wood cutting and bush fires [29]. Although ecological studies on biodiversity have been carried out for a number of years, for example by: [37] on Impact des coupes de bois sur la végétation naturelle de la zone périurbaine de Ngaoundéré; in Togo [5] on Impact des feux sur la biomasse dans les savanes guinéo-soudaniennes and [2] sur la biodiversité et gestion des feux de végétation dans la réserve de faune d'Abdoulaye. However, none of these studies addressed the influence of the logging and bushfire complex on the dynamics of regeneration in the high Guinean savannas of Adamaoua, whose savannic ecosystems are under heavy anthropogenic pressure.

2. Methodology

2.1. Presentation and Geographical Location of the Study Area

Located in Central Africa and in the center of Cameroon, Adamaoua is one of the most geologically diverse regions in Cameroon [3] and belongs to one of the most important cattle-breeding areas in Cameroon [39]. Adamaoua is also known as Cameroon's 'water tower', as many of the country's rivers have their source in this region. The region's rivers flow into three different basins: the River Niger, Lake Chad and the Atlantic Ocean. It is located between latitude 7° 26' 16'' North and longitude 13° 33' 34'' East. The population of Adamaoua, i.e. the regional capital and Ngaoundéré, is 1,015,622 (as of 1 January 2010), spread over an area of 63,701 km2, with a density of 15.9 inhabitants per km2 [18]. The population is divided into several ethnic groups, including the Mboum, Mbaya, Foulbés, Mbororo, Dii and Niam Niam. The Mboum and Mbaya are mainly farmers, while the Foulbés and Mbororo are livestock breeders [10]. It is in the northern part of Cameroon. Adamaoua borders the Central African Republic to the east and Nigeria to the west. This mountainous area marks the border between the forested Cameroon of the south and the savannahs of the north. The climate is of the Sudano-Guinean type, mild and cool, characterized by two seasons: a rainy season and a dry season with significant rainfall, fluctuating between 1,400 and 2,000 mm per year, low and not very variable temperatures (mean annual temperature of 23℃), and a strong contrast between the two seasons [9]. (Figure 1).

Table 1. Rainfall and temperature in Adamaoua (Ngaoundéré) from 2007 to 2017.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Precipitations (mm)	1455	1456	1458	1560	1580	1647	1669	1642	1646	1647	1645
Temperatures (℃)	28,09	29	28,25	28,67	29,08	28	30,25	31,08	31,08	31,16	29,83

Source: ASECNA, Ngaoundéré, data from 2007 to 2017

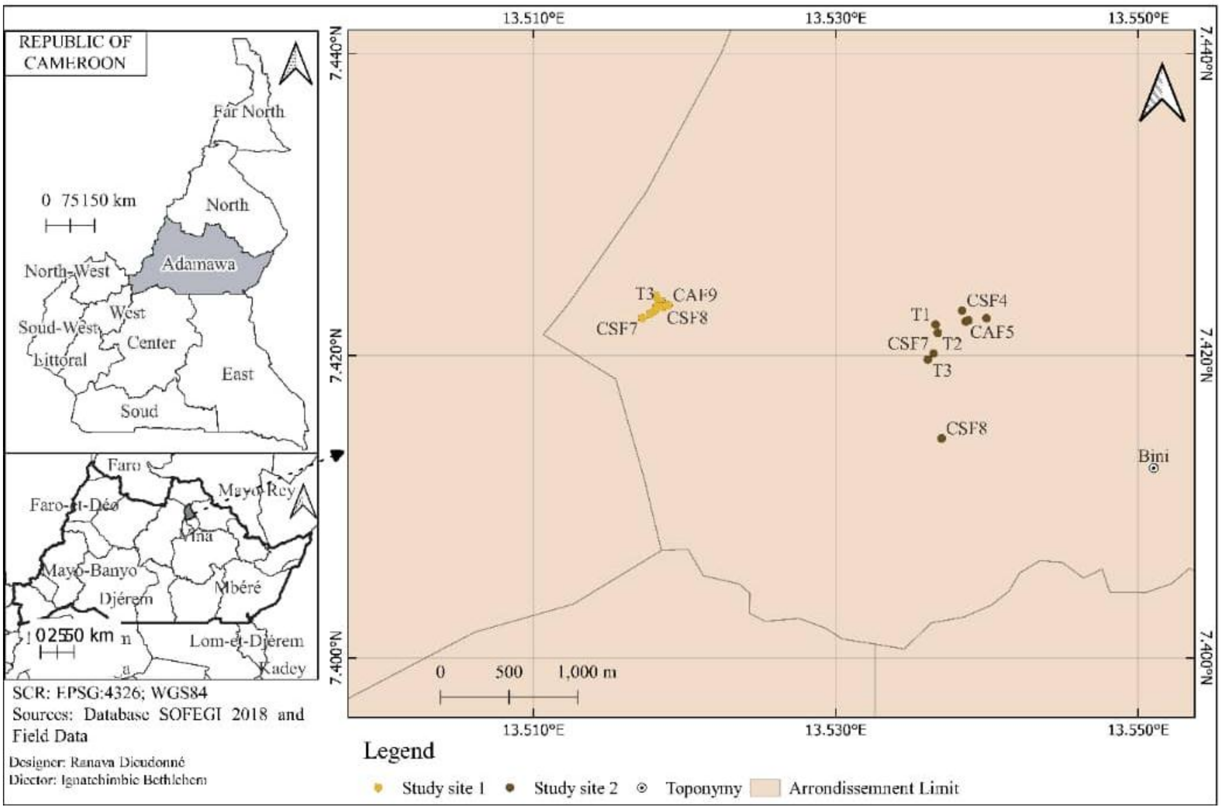


Figure 1. *Location of the study area.*

2.2. Choice of Study Sites

The choice of sites is justified firstly by the fact that the vegetation in Adamaoua is under anthropogenic pressure. The study focused on two types of plant formation: shrub savannah and tree savannah. The vegetation of the Adamaoua region is remarkably uniform in terms of flora and is divided administratively into five departments: Djerem, Faro and Deo, Mayo-Banyo, Mbere and Vina.

2.3. Experimental Set-up and Monitoring

The experimental design is a split-split plot with three factors. The type of savannah (shrub and tree savannah) is the primary treatment, the type of cut (no fire cut, fire cut and control) is the secondary treatment and the year is the tertiary treatment. A total of 18 10 m square plots were created, within which an inventory of the vegetation was carried out (using a pre-designed inventory form) and these plots were protected by firewalls.

In both the shrub and tree savannahs, we had three felling sites without fire, three felling sites with fire and three control sites (Table 2). After the wood had been cut and controlled fire had been set in the two types of plant formation, the first step was to make observations on the physiognomy of the vegetation at the various study sites over a period of 02 years (period of free and unprotected regeneration) and then to collect data on the dynamics of regeneration, the rate of reiteration and the mortality of each species at each site.

Table 2. *Experimental design.*

	Cutting without fir(CSF)			**Cutting with fire (CAF)**			**Control (T)**		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Shrubby savannah									
Woddy savanah									

2.4. Data Processing and Analysis

Once the data had been analyzed and grouped, they were entered into an Excel spreadsheet. A matrix was arranged according to the parameters and this matrix was subjected to multi-varied analysis techniques with the aim of highlighting the evolution and classification of species and plant formations. The various analyses were carried out using STATGRAPHICS plus 17.1.08 software and were used to check the differences between treatments in terms of number and surface area. In the presence of significant analyses of variance, comparisons of means were made using the Fisher test. In addition, the difference in the composition of the environments (types of plant formation) was tested using multivariate analysis of variance.

3. Results

3.1. Vegetation Physiognomy Before and After (Cutting and Fire)

In general, fire increases the mortality of adult individuals and eliminates natural regeneration by killing seedlings if the fire is late and uncontrolled. The study of composition and structure in the savannah showed that the resistant species have the typical characteristics of fire-tolerant species (large bark, regeneration by stump sprouts, etc.).

3.1.1. Shrub Savannah Physiognomy Before Cutting and Fire

(i). Physiognomy Before Logging and Fire

Logging by humans influences changes in the physiognomy of plant formations, and fire has an impact on the transformation of the savannah. Shrub savannah vegetation physiognomy before cutting and fire (Figure 2a and 2b).

a: site before cutting without fire (CSF)

b: site before cutting with fire (CAF)

Figure 2. *Shrub savannah physiognomy before cutting and fire.*

(ii). Physionomy After Cutting and Fire

Figure 3a shows the evolution of species (e.g. *Piliostigma thonningii*) in height in the first year and Figure 3b shows the number of the same species in the second year, while Figure 3c shows the rejuvenation of the vegetation after regeneration compared with Figure 3. The natural regeneration of species, i.e. the reiteration of plant stumps after logging and bushfire, is important in both formations.

a: Piliostigma thonningii 1st year

b: Piliostigma thonningii 2nd year

c: Rejuvenation of the vegetation two years later

Figure 3. *Shrub savannah physiognomy after cutting and fire.*

3.1.2. Tree Savannah Physiognomy Before and After (Logging and Fire)

When logging and bush fires are sufficiently intense, there is a transition from tree savannah to shrub savannah, as logging and fires cause the disappearance of tree biomass.

(i). Tree Savannah Before Cutting and Fire

Figure 4 shows the tree savannah and the physical state of the environment. Figure 4a shows the physiognomy of the vegetation at the cutting site without fire (CSF). While photo 3b shows the cutting site with fire (CAF).

a: Site cutting without fire

b: Site cutting with fire

Figure 4. *Physionomy of the wooded savannah before cutting and fire.*

(ii). Wooded Savannah After Cutting and Fire

The evolution of tree savannah vegetation and its transformation into wooded savannah depends on the frequency of transition from one state to the other, through the frequency of logging and bushfire events. This transformation requires a long period without fire or wood cutting. Figure 5a shows *Bridelia ferruginea* after logging in the site cut without fire (CSF).

a: Site cutting without fire (*Bridelia ferruginea*)

b: Site cutting with fire (*Cinera glomeratum*)

Figure 5. *Tree savannah physiognomy after felling and fire.*

3.2. Actors Involved in the Destruction of Young Plant

Figure 6 shows the extent of destruction by herdsmen, woodcutters and animals. In the shrub savannah, the activity of shepherds on the control site and the CAF is not particularly noteworthy. The woodcutters cut 3 trees at the control site. On the other hand, grazing by animals was high: 14 individuals in CSF, 18 individuals in CAF and 8 individuals in T. In the wooded savannah vegetation, shepherds were more active in pruning and thinning (9, 10 and 19 individuals) in CSF, CAF and T respectively, followed by animals with 10, 15 and 5 individuals destroyed in CSF, CAF and T respectively. On the other hand, logger activity was high at the control site and in the shrub savannah with 8 individuals. The ANOVA showed that there was no statistically significant difference in the number of species destroyed between the two types of savannah and between the treatments: cutting without fire, cutting with fire and controls (0.8118>0.05). We observed that the animals were very active in both formations, especially in the dry season, with young shoots being consumed because of the distance to fodder or its scarcity.

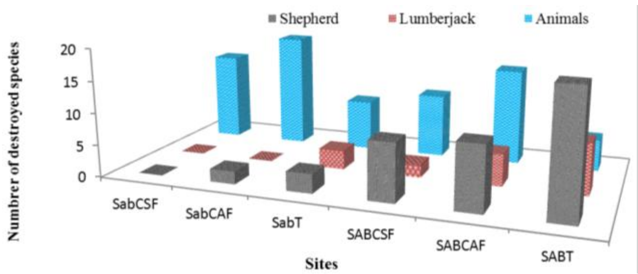


Figure 6. *Number of species destroyed by actors and site.*

3.3. Regeneration Dynamics

3.3.1. Evolution of the Number of Trees (stumps) Per Site

The number of woody plants varies between sites and plant formations (Figure 7). In the shrub savannah, the number of trees varies from 76, 60 and 78 in the first year to 160, 109 and 102 in the second year, in the CSF, CAF and T treatments respectively. For the tree savannah in the first year 204 (CSF), 149 (CAF) and 189 (T). In the second year, the number of stumps decreased as a function of the parameters 367 (CSF), 342 (CAF) and 257 (T). Statistical analysis shows that there is no significant difference (0.1659>0.05) between the number of plants and between the two savannas. The number of stumps is very low in the shrub savannah because of its easy access for the collection of energy wood by the population.

In the first year in the shrubby savannah (December to November), the number of individuals varies according to the treatments: 138 (CSF), 99 (CAF) and 101 individuals (T) while in the second year the number doubled or even tripled: 335 (CSF), 263 (CAF) and 256 individuals (T). In the wooded savannah, the number of individuals tripled or even qua-tripled. In the first year, there were 346 (CSF), 206 (CAF) and 260 (T); in the second year, there were 1239 (CSF), 850 (CAF) and 882 (T), with a remarkable increase in the sites treated with fire-free cutting (CSF).

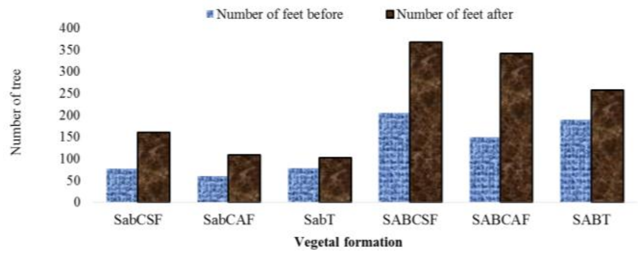


Figure 7. *Number of trees per site.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = shrub savannah control; SABCSF = shrub savannah cut without fire; SABCAF = shrub savannah cut with fire; SABT = shrub savannah control.

3.3.2. Number of Individuals Per Site

Figure 8 shows the evolution of individuals in the plant formations per year and per site by spreading out their floristic contribution in the savannas.

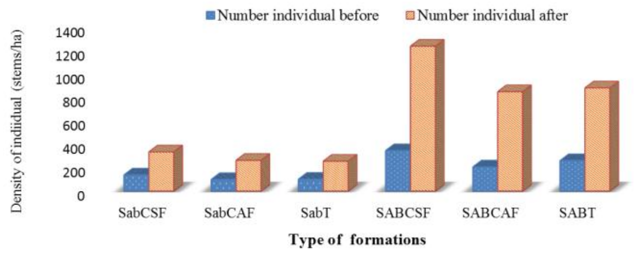


Figure 8. *Number of individuals per site.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = shrub savannah control; SABCSF = shrub savannah cut without fire; SABCAF = shrub savannah cut with fire; SABT = shrub savannah control.

3.3.3. Number of Individuals Cut as a Function of Time

Figure 9 shows that in the shrub savannah, the number of individuals destroyed decreased from 68 (CSF), 54 (CAF) and 27 (T) in the first year to 35 (CSF), 32 (CAF) and 16 (T) in the second year. Similarly, for the wooded savannah, the number of individuals decreased in CAF (161) and T (108) in the first year compared with 156 (CAF) and 45 (T) in the second year. There fore, in the clear-cut treatment (CSF) there was an increase in destruction in the second year (481) compared with 177 in the first year. The analysis of variance showed that there was no statistically significant difference in the number of traumatized species between the first and second years in the two plant formations (0.090>0.05).

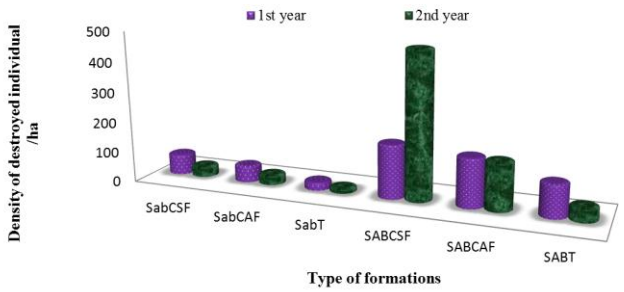


Figure 9. *Number of individuals destroyed per site.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = shrub savannah control; SABCSF = shrub savannah cut without fire; SABCAF = shrub savannah cut with fire; SABT = shrub savannah control.

3.3.4. Evolution of Woody Species by Formation

In the shrub and tree savannas, 338 ind/ha and 812 ind/ha were counted before the wood was cut and the savannas set on fire. After felling and burning, the density of individuals increased in both savannas (Figure 10). In the first year, the density of woody plants was 908 and 3586 ind/ha for the shrub and tree savannas respectively. In the second year, the density of woody plants decreased to 854 and 2971 ind/ha for the shrub and tree savannas respectively. Statistical analysis shows that there is no significant difference (0.5299>0.05) in the evolution of species in the two savannas between the second year, the first year and before logging.

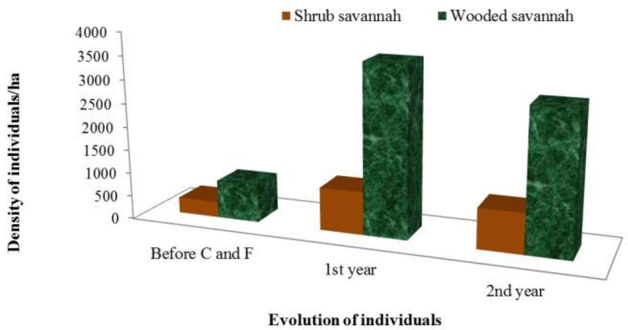


Figure 10. *Evolution of woody species by formation.*

3.3.5. Evolution of Woody Species by Site

Woody species increased over time in the plant formations and according to the wood-cutting and bushfire treatments (Figure 11): In the shrub savannah, the number of species increased from 12 (CSF), 11 (CAF) and 11 (T) in the first year to 18 (CSF), 12 (CAF) and 18 (T) in the second year. The number of species increased by 6 (CSF) and 7 (T), while only one new species (*Steganotaenia araliacea*) was recorded at the fire-free cutting site (CAF). This may be due to the fact that fire destroys vegetation.

In the tree savannah, we identified 23 (CSF), 21 (CAF) and 24 (T) species in the first year, and 30 (CSF), 27 (CAF) and 23 (T) species in the second year. There was an increase in 7 (CSF) and 6 (CAF), while in the control site one species (*Psorospermum febrifugum*) disappeared, possibly due to desiccation or felling. An analysis of variance revealed a statistically significant difference (0.0316<0.05) in the evolution of woody species per site.

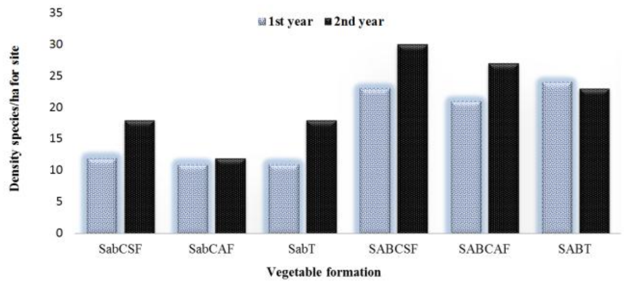
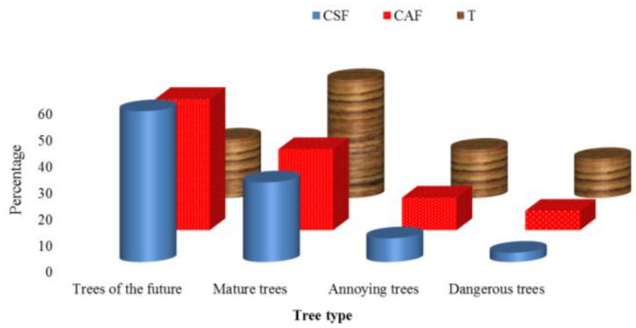


Figure 11. *Evolution of the number of woody plants.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah.

3.3.6. Classification of Trees in the Wooded Savannah



CSF = cutting without fire, CAF = cutting with fire, T = control

Figure 12. *Classification of trees in the wooded savannah.*

The classification of trees in the wooded savannah makes it possible to distinguish between future, mature, troublesome and dangerous trees given that this population is uneven-aged (Figure 12). After cutting, the trees of the future are dominant in CSF (57.22%) and CAF (49.7%) followed by mature trees 30.24% in CSF and 30.7% in CAF and then the troublesome trees 8.99% in CSF and 12.28% in CAF and finally the dangerous trees 3.54% in CSF and 7.3% in CAF. We observe that the CSF and the CAF have a decreasing percentage while noting that at the level of the CAF the troublesome and dangerous trees are slightly high compared to the CSF because of the bush fires. While in the control sites (T) where there was no logging and bush fire, mature trees dominate (44.74%) followed by trees of the future (22.17%), troublesome (18.28%) and dangerous (14.78%) this may be due to the fact that these parts have not suffered trauma. The analysis of variance shows that the trees by class in the sites and according to the treatments applied have no difference, and they are highly significant (1.0000>0.05).

3.4. Reiteration and Mortality Rates

3.4.1. Regeneration Rate of Species by Site

Figure 13 shows the percentage of reiteration of stumps and the appearance of new individuals after logging and bush fires. The regeneration rate varies according to the species and the treatment applied to the sites.

In the first year in the shrub savannah, the regeneration rate of individuals was 66.99% (CSF), 64.7% (CAF) and 78.9% (T). In the second year, there is an increase that varies from 6% to 24% and the rate is high in the cutting without fire treatment (CSF). For the wooded savannah in the first year: 66.15% (CSF), 56.13% (CAF) and 70.65% (T) the second year: 72.03% (CSF), 84.49% (CAF) and 79.14% (T). The variation in rate is from 6% to 28% remarkably high in CAF. The reiteration rate in the two plant formations, the first year was considerable in the control sites, but the second year the CSF site of the shrub savannah occupies the first place with an increase of 24% which is due to the speed of the regeneration of certain species such as *Annona senegalensis*, *Piliostigma thonningii*, *Hymenocardia acida*. In the wooded savannah in the second year, it is the CAF which comes in first position with 28%. This is due to the activities of cutting, fire, breeding and the distribution of species.

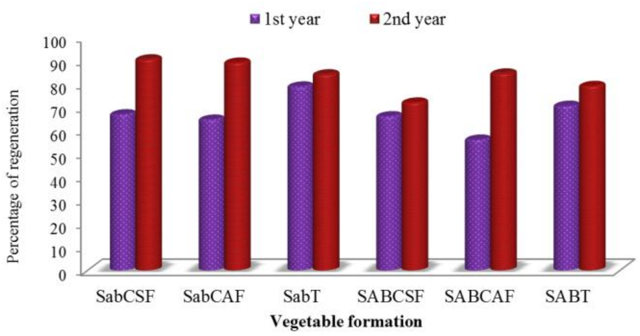


Figure 13. *Regeneration rate of individuals by site.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah.

3.4.2. Mortality Rate of Individuals

The mortality rate of individuals varies according to the species and by plant formation which is due to wood cutting, trampling and browsing of young shoots of species such as *Entada africana*, *Piliostigma thonningii*, *Cinera glomeratum*, *albizia zygia*, *Fagara senegalensis*, *Hymenocardia acida, and Syzygium guineense var*. *Macrocarpum* etc.

(i). Mortality Rate of Individuals in the First Year

In both formations for the first year the mortality rate of woody plants is high in the CAF site 35.3% and 43.87% followed by CSF 33.01% and 33.85% and finally the control site 21.1% and 29.35% respectively in the shrub savannah and wooded savannah (Figure 14). We note that the cutting treatment with fire in the two plant formations have a high mortality rate.

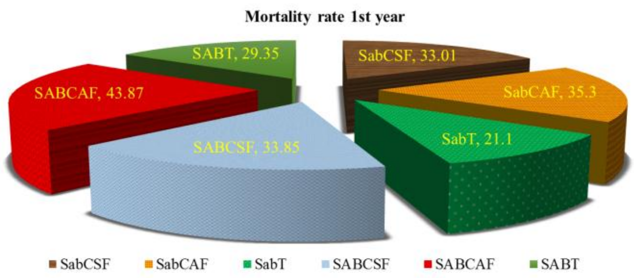


Figure 14. *Mortality rate of individuals in the first year.*

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, Sab = shrub savannah, SAB = wooded savannah.

(ii). Mortality Rate of Individuals in the Second Year

Figure 15 shows that the mortality rate decreased to more than three quarters (3/4) in all sites compared to the first year. This rate decreased in the second year because the shoots reached a level of development that allowed them to withstand certain conditions, except in the wooded savannah with the cut without fire treatment. In the shrub savannah there are 9.46% CSF, 10.85% CAF and 15.89% in T, while the wooded savannah presents 27.97% CSF, 15.51% CAF and 20.86% in control site.

The mortality of the species is due to the action of man by cutting, pruning and bush fire on the one hand and animals that consume the shoots during their juvenile stages on the other hand.

The mortality rate in both plant formations is high in the first year. This may be due to competition between individuals on the same stump (foot). The sites are in a livestock area illustrated by trampling and consumption of young plant shoots as fodder.

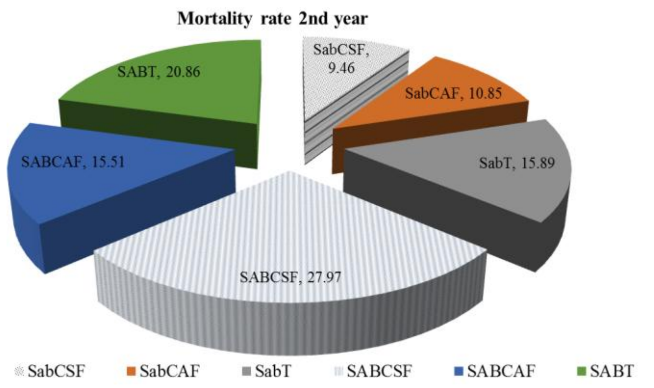


Figure 15. Mortality rate of individuals in the second year.

SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

3.5. Reiteration and Mortality of Individuals in Plant Formations According to Year

3.5.1. Reiteration of Individuals

Table 3 Homogeneity shows that there is no statistically significant difference between wooded and shrub savannah and between cuts. In the first year, the average of significant shoots is in CAF (25.91) shrub savannah and in CSF (65.35) wooded savannah. While in the second year only the sites with no-fire cutting (18.61) in the shrub savannah and for the wooded savannah (41.30). Concerning the species, regeneration is higher in *Syzygium guineense* var. *macrocarpum* (170.83), *Hymenocardia acida* (98.08) and *Harungana madagascariensis* (112.11). The high standard deviation for some species is explained by the fact that regeneration is generally done by shoots from the stumps or by seed germination. For species such as *Ziziphus mauritiana* (1.00 ±0), *Maytenus senegalensis* (2.00 ±0) and *Gardenia aqualla* (2.00 ±0) have a very low average, this is because they are new species or endangered in the area and others have a very slow regeneration.

Table 3. Reiteration of individuals.

Species	First year						Second year						
	SabC SF	SabC AF	SabT	SABC SF	SABC AF	SABT	SabC SF	SabC AF	SabT	SABC SF	SABC AF	SAB T	Moyenne
Piliostigma thonningii	92	74	82	50	96	49	79	67	80	47	76	50	70,17 ±17,36
Croton macrostachyus	46	6	11	27	22	8	22	3	9	27	17	8	17,17 ±12,32
Entada africana	6	7	3	167	53	40	11	7	1	101	62	46	42,00 ±50,05
Psorospermum senegalensis	11	4	7	0	0	2	13	4	8	0	0	3	6,50 ±3,96
Cinera glomeratum	24	21	8	50	28	22	18	14	9	17	28	23	21,83 ±11,00
Steganotaeniaaraliacea	4	0	7	49	23	21	4	2	7	19	23	21	16,36 ±13,75
Psorospermum febrifugum	8	18	13	4	21	0	3	16	13	0	16	0	12,44 ±6,23
Hymenocardia acida	40	21	22	135	323	121	24	26	22	50	274	119	98,08 ±103,46
Annona senegalensis	89	107	49	33	25	20	101	95	49	28	22	20	53,17 ±34,72
Lannea schimperi	34	8	18	16	12	43	30	12	19	14	9	40	21,25 ±12,27
Terminalia glaucescens	9	17	16	30	4	11	8	15	17	14	4	11	13,00 ±7,05
Terminalia macroptera	2	0	0	15	34	18	2	0	1	18	31	14	15,00 ±12,09

Species	**First year**						**Second year**						
	SabC SF	**SabC AF**	**SabT**	**SABC SF**	**SABC AF**	**SABT**	**SabC SF**	**SabC AF**	**SabT**	**SABC SF**	**SABC AF**	**SAB T**	**Moyenne**
Albizia zygia	3	0	0	56	29	40	3	0	2	45	24	37	26,56 ±20,07
Phyllanthus muellerianus	4	0	0	3	8	17	4	0	0	5	8	16	8,13 ±5,49
Heeria pulcherima	4	0	0	2	17	12	7	0	4	18	9	15	9,78 ±6,00
Gardenia aqualla	0	2	0	0	0	0	0	2	0	0	0	0	2,00 ±0
Vitex doniana	0	0	4	35	0	0	0	0	6	28	0	0	18,25 ±15,59
Harungana madagascariensis	0	0	5	278	100	180	4	0	6	174	95	167	112,11 ±96,07
Parkia buglobosa	0	0	2	0	0	13	0	0	1	0	2	16	6,80 ±7,12
Bridelia ferruginea	0	0	0	21	6	14	0	0	0	16	0	13	14,00 ±5,43
Fagara senegalensis	0	0	0	23	0	0	0	0	0	23	0	0	23,00 ±0
Allophylus africanus	0	0	0	162	40	62	0	0	0	60	38	62	70,67 ±46,07
Maesa lanceolata	0	0	0	35	0	0	0	0	0	45	0	6	28,67 ±20,26
Strychnos spinosa	0	0	0	23	0	4	0	0	0	21	0	0	16,00 ±10,44
Flacourtia indica	0	0	0	85	22	36	0	0	0	82	10	29	44,00 ±31,79
Cussonia barteri	0	0	0	10	12	7	0	0	0	13	12	5	9,83 ±3,19
Syzygium guineense var. *macrocarpum*	0	0	0	351	58	136	0	0	0	307	45	128	170,83 ± 128,54
Indéterminé	0	0	0	27	12	25	0	0	0	27	8	23	20,33 ±8,24
Paullinia pinnata	0	0	0	12	1	0	0	0	0	11	1	0	6,25 ±6,08
Ficus vogelii	0	0	0	0	4	0	0	0	0	8	4	0	5,33 ±2,31
Ficus glumosa	0	0	0	0	9	0	0	0	0	0	25	0	17,00 ±11,31
Ficus sur	0	0	0	0	0	10	0	0	0	0	0	10	10,00 ±0
Mangifera indica	0	0	0	0	0	0	1	0	2	3	1	0	1,750 ±0,96
Ziziphus mauritiana	0	0	0	0	0	0	1	0	0	0	0	0	1,00 ±0
Ximenia americana	0	0	0	0	0	0	0	0	0	3	0	0	3,00 ±0
Psidium guajava	0	0	0	0	0	0	0	0	0	2	0	0	2,00 ±0
Vernonia amygdalina	0	0	0	0	0	0	0	0	0	13	0	0	13,00 ±0
Maytenus senegalensis	0	0	0	0	0	0	0	0	0	0	2	0	2,00 ±0
Ochna schweinfurthiana	0	0	0	0	0	0	0	0	0	0	4	0	4,00 ±0
Mean	25,07	25,91	17,64	65,35	39,96	37,96	18,61	21,92	14,22	41,30	31,48	37,9	// //

Species	First year						Second year						
	SabC SF	SabC AF	SabT	SABC SF	SABC AF	SABT	SabC SF	SabC AF	SabT	SABC SF	SABC AF	SAB T	Moyenne
												1	
Standard-error	±30,20 ab	±33,47 ab	±22,06 d	±86,05 bc	±65,73 abc	±46,57	±30,20 ab	±27,06 ab	±20,07 a	±61,39 cd	±53,80 abc	±46, 59ab c	// //

The values assigned by the same letter are not significant at the 0.05% threshold.
SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

3.5.2. Mortality of Individuals

The mortality of species has a high average in the CAF sites, the first year: shrub savannah (6.75) and wooded savannah (8.05). Compared to the second year observed in CSF shrub savannah (5.00) and wooded savannah (26.72). For species, mortality is too high in *Harungana madagascariensis* (20.63), followed by *Hymenocardia acida* (18.75) and *Entada africana* (13.56) (Table 4). Climate change is a factor that reacts to the stabilization of species in their ecosystem and especially human activities by logging, livestock breeding, agriculture and fireusse.

Table 4. *Species mortality.*

Species	First year						Second year						
	SabC SF	SabCA F	SabT	SABC SF	SABC AF	SABT	SabCS F	SabC AF	SabT	SABC SF	SABC AF	SA BT	Mean
Piliostigma thonningii	13	15	6	14	16	5	5	7	7	3	20	1	9,33 ±5,99
Croton macrostachyus	5	2	0	5	5	0	18	1	2	0	5	0	5,38 ±5,37
Entada africana	7	3	0	19	11	5	1	1	0	66	9	0	13,56 ± 20,46
Psorospermum senegalensis	2	0	1	0	0	0	0	0	0	0	0	0	1,50 ±0,71
Cinera glomeratum	7	10	3	6	9	5	2	3	0	33	4	1	7,55 ±8,90
Steganotaenia araliacea	0	0	1	6	8	3	0	0	0	0	0	0	4,50 ±3,11
Psorospermum febrifugum	1	2	2	0	2	0	0	2	0	0	5	0	2,33 ±1,37
Hymenocardia acida	9	11	3	11	46	17	1	1	2	73	49	2	18,75 ± 23,85
Annona senegalensis	9	7	6	8	3	2	6	12	0	5	3	0	6,10 ±3,07
Lannea schimperi	3	0	0	0	0	6	0	2	0	2	3	0	3,20 ±1,64
Terminalia glaucescens	2	4	1	0	0	1	0	3	1	16	0	0	4,00 ±5,42

Species	First year						Second year						
	SabC SF	SabCA F	SabT	SABC SF	SABC AF	SABT	SabCS F	SabC AF	SabT	SABC SF	SABC AF	SA BT	Mean
Terminalia macroptera	1	0	0	0	6	2	0	0	0	0	3	4	3,20 ±1,92
Albizia zygia	2	0	0	13	10	7	0	0	0	11	5	3	7,29 ±4,19
Phyllanthus muellerianus	1	0	0	2	0	4	0	0	0	0	0	1	2,00 ±1,41
Heeria pulcherima	6	0	0	0	3	4	2	0	0	2	8	0	4,17 ±2,40
Gardenia aqualla	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Vitex doniana	0	0	2	5	0	0	0	0	1	7	0	0	3,75 ±2,75
Harungana madagascariensis	0	0	1	15	14	12	0	0	1	104	5	13	20,63 ±34,17
Parkia buglobosa	0	0	1	0	0	2	0	0	1	0	0	0	1,33 ±0,58
Bridelia ferruginea	0	0	0	3	2	3	0	0	0	5	6	1	3,3 ±1,86
Fagara senegalensis	0	0	0	2	0	0	0	0	0	0	0	0	2,00 ±0
Allophylus afrianus	0	0	0	8	4	5	0	0	0	36	2	0	11,00 ± 14,14
Maesa lanceolata	0	0	0	10	0	0	0	0	0	0	0	0	10,00 ±0
Strychnos spinosa	0	0	0	9	0	2	0	0	0	2	0	0	4,33 ±4,04
Flacourtia indica	0	0	0	4	3	0	0	0	0	3	12	7	5,80 ±3,83
Cussonia barteri	0	0	0	0	1	0	0	0	0	0	0	2	1,50 ±0,71
Syzygium guineense var. m	0	0	0	37	12	16	0	0	0	44	13	8	21,67 ± 14,98
Indéterminé	0	0	0	0	3	4	0	0	0	0	4	2	3,25 ±0
Paullinia pinnata	0	0	0	0	0	0	0	0	0	1	0	0	1,00 ±0
Ficus vogelii	0	0	0	0	1	0	0	0	0	0	0	0	1,00 ±0
Ficus glumosa	0	0	0	0	2	0	0	0	0	0	0	0	2,00 ±0
Ficus sur	0	0	0	0	0	3	0	0	0	0	0	0	3,00 ±0
Mangifera indica	0		0	0	0	0	0	0	1	0	0	0	1,00 ±0
Ziziphus mauritiana	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Ximenia americana	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Psidium guajava	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Vernonia amygdalina	0	0	0	0	0	0	0	0	0	2	0	0	2,00 ±0
Maytenus senegalensis	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Ochna schweinfurthiana	0	0	0	0	0	0	0	0	0	0	0	0	0 ±0
Mean	4,86	6,75	2,45	9,83	8,05	5,40	5,00	3,56	2,00	23,06	9,18	3,75	// //
Standard- error	±3,76a	±4,83a	±1,92	±8,28b	±10,02	±4,49a	±6,06a	±3,68a	±2,07a	±30,45	±11,25	±3,	// //

Species	First year						Second year						
	SabC SF	SabCA F	SabT	SABC SF	SABC AF	SABT	SabCS F	SabC AF	SabT	SABC SF	SABC AF	SA BT	Mean
	b	b	ab		ab	b		b	b	c	ab	74a b	

Value with the same letter are not significant at the 0.05% threshold.
SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

3.5.3. Study of the Relationship Between Reiteration and Mortality

(i). Study of the Relationship Between Reiteration and Mortality in the 1st Year

The correlation between reiteration and mortality shows that according to the analysis of variance there is no statistically significant difference (0.8589>0.05) between the plant formations and the treatments cutting with fire and cutting without fire (Table 5). In both savannahs, the high average is in regeneration with 22.87 and 47.76 ± compared to mortality (4.69 and 7.76) respectively in shrubby and wooded savannah. Similarly, the homogeneity shows that there is no statistically significant difference.

Table 5. *Relationship between reiteration and mortality in the 1st year.*

	SabCSF	SabCAF	SabT	Mean	SABCSF	SABCAF	SABT	Mean
Reiteration	25,07	25,91	17,64	22,87±4,55a	65,35	39,96	37,96	47,76±15,27a
Mortality	4,86	6,75	2,45	4,69±2,16a	9,83	8,05	5,40	7,76±2,23a

Values with the same letter are not significant at the 0.05% threshold. SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

(ii). Study of the Relationship Between Repetition and Mortality in the Second Year

Table 6 shows that the analysis of variance for the correlation between repetition and mortality in the second year. There is no statistically significant difference (F = 0.68 and P = 0.6559. The average in the shrub savannah is high for repetition (18.25), but in the wooded savannah it is high for mortality (12.00) while knowing that the homogeneity also presents the absence of significant difference in terms of repetition, mortality, plant formations and treatments (cutting without fire, cutting with fire and controls).

Table 6. *Relationship between repetition and mortality in the second year.*

	SabCSF	SabCAF	SabT	Moyenne	SABCSF	SABCAF	SABT	Moyenne
Reiteration	18,61	21,92	14,22	18,25±3,86a	41,30	31,48	37,91	36,90±4,99a
Mortality	5	3,56	2	3,52±1,50a	23,06	9,18	3,75	12,00±9,96a

Values with the same letter are not significant at the 0.05% threshold. SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

3.6. Adaptation and Dynamism Factor Facilitating the Regeneration of Species

3.6.1. Biological Type of Species in the 2nd Year

Table 7 presents the biological types of woody plants in the two plant formations according to the treatments applied to the sites (cutting and fire). In both plant formations, Nanophanerophytes (Nano) are the species that are mainly represented with 51.53% followed by Microphanerophytes (Micr) 35.77%, climbing Phanerophytes (Phg) with 6.02%. The least represented are Geophytes (Gor) 1.2% and Hemicryptophytes (Hc) with 2.56%, those that represent the second biological type group of Raunkiaer. Nanophanerophytes (Nano) and Microphanerophytes (Micr) are species that are mainly representative of the sites due to the adaptation of these species in the shrubby and wooded savannah. In both savannahs (shrub and wooded) the species with the high average are respectively the sites cut without fire (2.98) shrub savannah and wooded savannah (4.15) followed by the sites cut with fire (2.48) shrub savannah and wooded savannah (2.92). While, the control sites have a low average (1.97) in the shrub savannah and in the woody savannah (2.18).

Table 7. *Biological type of species second year.*

	Traitement	Micr	Nano	Phg	Th	Hc	Gor	Total	Moyenne
	CSF	3,28	7,54	2,01	1,85	0,25	1,85	16,78	2,80±6,27b
shrub savannah	CAF	1,57	4,31	1,45	0,69	3,28	0	11,3	1,88±4,14b
	T	0,69	3,32	2,28	0	0	0	6,29	1,05±2,54a
	CSF	13,12	9,54	2,01	2,28	0,89	1,45	29,29	4,88±11,11a
woody savannah	CAF	7,54	8,43	0,59	0	0	0	16,56	2,76±6,88a
	T	9,21	7,54	0	0,89	1,45	0,69	19,78	3,30±7,72a
Total		35,41b	40,68b	8,34a	5,71a	5,87a	3,99a	100	

Values with the same letter are not significant at the 0.05% threshold. Nanophanérophytes (Nano), Microphanérophytes (Micr), Phanérophytes grimpantes ou lianes (Phg), Hemicryptophytes (Hc) (Phan) Thérophyte (Th) et Géophyte (Gor), CSF = cut without fire, CAF = cut with fire, T = control.

3.6.2. Geographic Distribution

(i). Geographic Distribution in the 1st Year

Table 8. *Phytogeographic distribution of species in the first year.*

	SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT Total	Moyenne
Cos	5,89	2,38	3,32	5,89	2,12	3,32 22,92	3,82±1,68a
Pan	4,15	4,09	4,15	6,03	3,5	4,09 26,01	4,34±0,87a
Pal	4,09	2,12	2,12	3,11	2,09	0,07 13,6	2,27±1,34a
Pra	3,32	1,32	3,32	2,12	1,12	1,32 12,52	2,09±1,02a
Aft	1,32	2,45	1,31	2,12	1,23	3,45 11,88	1,98±0,88a
SZ	0,77	4,09	1,45	2,38	3,15	1,23 13,07	2,18±1,27a
Moyenne	3,26±1,92a	2,74±1,12a	2,61±1,15a	3,61±1,86a	2,20±0,97a	2,25±1,59a	// //

Values with the same letter are not significant at the 0.05% threshold. (Cos) Cosmopolites, (Pan) Pantropicales, (Pal) Paléotropicales, (Pra) Plurirégionales africaines, (Aft) Afrotropicales et (SZ) Soudano zambéziènnes. SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

Pantropical species (26.01%) are more important in savannahs (shrub and wooded). Cosmopolitan species occupy second place with 22.92% (Table 8). While paleotropical, African pluriregional, Afrotropical and Sudano-Zambézian species have less than 15%. This low representation of certain species allows us to say that they are not in their phytogeographic distribution areas.

(ii). Geographic Distribution in the 2nd Year

Table 9 shows the phytogeographic distribution of species according to plant formations (shrub and wooded savannah). The species with a high average are Pantropical species (34.60), followed by Cosmopolitan (17.76), Sudano Zambezian (11.66), Paleotropical (20.88) except the African Pluriregional which has a low Afrotropical average (9.93). For plant formations, it is observed that in the shrub savannah the average is high in the control site (18.94) while in the wooded savannah it is in the site cut with fire (18.33).

***Table 9**. Phytogeographic distribution of species in the second year..*

	SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT	Mean
COS	14,58	21,95	22,58	19,39	15,55	12,5	17,76 ±4,15a
PAN	34,5	29,26	32,43	32,6	37,78	41	34,60 ±4,20a
PAL	22,83	19,51	21,21	25,91	18,33	17,5	20,88 ±3,13a
PRA	11,33	7,31	10,4	10,86	11,11	10	10,17 ±1,48a
AFT	6,25	14,63	13,51	6,52	11,67	7	9,93 ±3,79a
SZ	10,5	7,71	13,51	8,69	15,55	14	11,66 ±3,16a
Mean	16,67	16,73	18,94	17,33	18,33	17,00	//
Standard-error	±10,35a	±8,20a	±8,15a	±10,43a	±9,90a	±12,28a	//

Values with the same letter are not significant at the 0.05% threshold.
(Cos) Cosmopolites, (Pan) Pantropicales, (Pal) Paléotropicales, (Pra) Plurirégionales africaines, (Aft) Afrotropicales et (SZ) Soudano zambéziènnes. SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

3.6.3. Species Distribution Mode

(i). Species Distribution Mode in the 1st Year

The modes of dissemination of diaspores vary according to the species (Table 10). It emerges from this table that anemochory (13.52%) is a mode of dissemination the highest in the two plant formations followed by nautochory (10.95%) and myrmecochory (10.76%), the rest has less than 8%. The treatments with the high average 1.41 (shrub savannah) and 1.40 (wooded savannah) is the treatment without fire cutting. The high rate of anemochory in the plant formations can be due to the scattered trees in places and the massive presence of species with diaspores easily transported by the wind.

***Table 10**. Species distribution mode first year.*

		SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT	Mean/standard-error
Hydrochorie	Naut	2,12	1,11	2,09	2,20	1,23	2,20	1,83±0,51a
	Ombr	0	1,23	0,79	1,11	1,23	0,90	0,88±0,46a
	Pléo	0,98	0,78	0	1,23	0,79	0,78	0,76±0,41a
	Sarc	1,11	0,78	1,11	0,90	0	0,98	0,81±0,42a

		SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT	Mean/standard-error
Zoochorie	Slér	0,78	0	0	0,79	1,11	0,90	0,60 ±0,48a
	Epiz	0,90	0,79	0	1,50	0,79	0,98	0,83 ±0,48a
	Endo	1,67	1,11	0,79	0,79	1,11	0,78	1,04 ±0,35a
	Myrm	3,47	0,90	1,11	2,20	2,12	1,11	1,82 ±0,68a
	Barr	1,11	1,50	2,38	0,79	0,90	1,23	1,3 ±0,58a
Anémochorie	Aném	3,47	2,38	2,12	2,20	2,12	1,23	2,25 ±0,72a
	Ptér	1,67	0,79	0	1,11	0,90	0,78	0,88 ±0,54a
	Pogo	0	0,78	1,11	1,23	1,11	0	0,71 ±0,57a
Autochorie	Ball	1,11	0,90	1,11	2,12	1,11	0,79	1,19 ±0,48a
Mean		1,41	1,00	0,97	1,40	1,12	0,97	
Standard-error		±5,54a	±0,54a	±0,84a	±0,58a	±0,55a	±0,48a	

Values with the same letter are not significant at the 0.05% threshold.
Nautochorie (Naut), Ombrahydrochorie (Ombr), Pléochores (Pléo), Sarcochores (Sarc), Sléochores (Slér), Epizochorie (Epiz), Endozochorie (Endo), Myrmécochorie (Myrm), Barrachores (Barr), Anémochores (Aném), Ptérochores (Ptér), Pogonochores (Pogo), Ballochores (Ball). SabCSF = shrub savannah cut without fire; SabCAT = shrub savannah cut with fire; SabT = control shrub savannah; SABCSF = cut without fire wooded savannah; SABCAF = cut with fire wooded savannah; SABT = control wooded savannah, CSF = cut without fire, CAF = cut with fire, T = control.

(ii). Distribution Mode of Species in the 2nd Year

The mode of dissemination of diaspores varies according to the species and according to the plant formations. Table 11 shows that the species with the high average are: Anemochoria (28.65 ± 3.93) whose diaspores are small appendages, Ballochoria (13.68 ± 3.90) the diaspores expelled by the plant itself followed by Myrmecochoria (12.29 ± 3.16) which have the presence of a substance attracting animals for transport. The low mode of dispersion of diaspores is observed in Barrochoria (3.68 ± 1.28) Slerochoria (1.50 ± 1.32) and Sarcochoria (2.46 ± 1.37). For both formations, we note that only the site with fire treatment has a lower average. The mode of dissemination by Anemochory with a high average (28.65) in the plant formations, this can be due to the trees scattered in places and the massive presence of species having diaspores easily transported by the wind followed by Ballochores (13.68) so the diaspores are expelled by the plant itself.

Table 11. *Mode of distribution of species in the second year.*

		SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT	Mean
Hydrochorie	Naut	7,54	7,14	6,25	11,29	10,34	10,2	8,79 ± 2,07
	Ombr	5,66	4,76	0	8,06	3,44	2,04	3,99 ± 2,83
	Pléo	1,88	2,38	0	4,83	3,44	4,08	2,77 ± 1,73
	Sarc	3,77	2,38	3,12	0	3,44	2,04	2,46 ± 1,37
Zoochorie	Slér	1,88	0	0	1,61	3,44	2,04	1,50 ± 1,32
	Epiz	7,54	11,9	9,37	9,67	3,44	10,2	8,69 ± 2,93
	Endo	3,77	2,38	6,25	4,83	3,44	2,04	3,79 ± 1,57
	Myrm	11,32	16,67	15,62	11,29	8,62	10,2	12,29 ± 3,16
	Barr	3,77	2,38	3,12	3,22	3,44	6,12	3,68 ± 1,28
Anémochorie	Aném	30,18	28,57	28,12	27,41	29,03	28,57	28,65 ± 3,93
	Ptér	1,88	0	3,12	4,83	3,44	2,04	2,55 ± 1,64

		SabCSF	SabCAF	SabT	SABCSF	SABCAF	SABT	Mean
	Pogo	5,66	4,67	6,25	4,83	8,62	8,16	6,37 ±1,68
Autochorie	Ball	15,09	16,66	18,75	8,06	11,29	12,24	13,68 ±3,90
Mean		7,69	7,68	7,69	7,69	7,34	7,69	//
SE		±7,80a	±8,48a	±8,42a	±6,88a	±7,19a	±7,36a	//

Values with the same letter are not significant at the 0.05% threshold. SE= standard -error
Nautochorie (Naut), Ombrahydrochorie (Ombr), Pléochores (Pléo), Sarcochores (Sarc), Sléochores (Slér), Epizochorie (Epiz), Endozochorie (Endo), Myrmécochorie (Myrm), Barrachores (Barr), Anémochores (Aném), Ptérochores (Ptér), Pogonochores (Pogo), Ballochores (Ball), SabCSF = savane arbustive coupe sans feu; SabCAT = savane arbustive coupe avec feu; SabT = savane arbustive témoin; SABCSF = coupe sans feu savane arborée; SABCAF = coupe avec feu savane arborée; SABT = savane arborée témoin.

3.7. Influence of Wood Cutting and Bush Fire on Stump Regeneration

3.7.1. Influence of Wood Cutting on Stump Regeneration

Wood cutting has an effect on the remaining stumps which dry out for some species on the one hand and are attacked by termites on the other hand (Figure 16a) there is also competition on the stumps between individuals. Figure 16b shows the ramification of the branches, they are not well arranged especially in *Hymenocardia acida* and *Piliostigma thonningii* which are consumed by animals (young shoots). This situation shows the different behavior according to the species after the fire.

a: Competition on the stumps

b: Branching of the branches

Figure 16. *Influence of cutting on regeneration.*

3.7.2. Influence of Bush Fire on the Regeneration of Stumps

Fire has an impact on certain species even after regeneration and the evolution in height they dry out and this is the case of *Cinera glomeratum* (Figure 17a). After the passage of fire on the stump of *Annona senegalensis* there was regeneration of three individuals on the same foot, during their growth the stump gave way because of the attack by termites (Figure 17b).

a: Species drying

b: Strain that dropped after regeneration

Figure 17. *Influence of fires on certain species.*

4. Discussion

4.1. Physionomy of the Vegetation Before and After (Cutting and Fire)

4.1.1. Shrub Savannah Physiognomy

Logging has an effect on changes in the physiognomy of plant formations, just as fire has an impact on the transformation of the savannah. These results corroborate those of [20], who studied the impact of post-fire salvage logging in boreal forests and found that regeneration determines the future characteristics of stands, as well as their composition and species abundance.

4.1.2. Tree Savannah Physiognomy

Intense bushfire and repeated felling transform the vegetation formation from tree savannah to shrub savannah. After cutting, the stumps regenerate and we can observe the evolution in height of the species. For example, *Cinera glomeratum* in the site cut by fire (CAF) has a strong growth in height, as do *Croton macrostachyus*, *Fagara senegalensis* and *Maesa lanceolata* (Figure 5).

4.2. Regeneration Dynamics

4.2.1. Evolution of the Number of Stumps Per Site

The evolution varies according to the plant formations, given that the density of a species corresponds to the number of plants belonging to the species per unit area [4]. These results are inferior to those of [24], who inventoried species ranging from 977 to 5047 in savannahs defended against fire in Ibi-village (Democratic Republic of Congo) under the effects of edge and litter.

4.2.2. Number of Individuals Per Site and Individuals Cut as a Function of Time

With regard to the number of individuals, the analysis of variance did not reveal any significant difference (0.5286>0.05) between individuals. These results are similar to those of [31] who obtained 2972 stems/ha in Mozogo Gokoro National Park (Extreme North Cameroon). However, [33] indicates that there is little difference (p=0.046) between densities in 2004 and 2006.

For traumatised individuals, our results are similar to those of [38] who showed that the number of dead shoots in the tree savannah varies from 14.03% (CSFSAB), 18.60% (CAFSAB) and 9.88% (TSAB). In the shrub savannah, on the other hand, they found 25.24% (CSF), 15.23% (CAF) and 18.62% (T).

4.2.3. Evolution of Woody Species by Plant Formation, Site and Tree Classification

For the evolution of species in the two savannas, statistical analysis shows that there is no significant difference (0.5299>0.05). Our values are lower than those of [17] who worked on the impact of deforestation on vegetation dynamics in the Sudano-Sahelian zone of Cameroon and recorded 6003 individuals for 74 species. However, for changes in woody species by site, the analysis of variance revealed a statistically significant difference (0.0316<0.05) in the tree savannah. In the CSF and CAF sites there is a decreasing percentage, although it should be noted that in the CAF the number of troublesome and dangerous trees is slightly higher than in the CSF because of bush fires.

4.3. Repetition and Mortality Rates

4.3.1. Species Regeneration Rates by Site

Given that the statistical analysis shows that there is no significant difference for the reiteration of species in the environments (P=0.915). These results for the first year in the shrub savannah corroborate those of [37] who had shown that Hymenocardia acida and Piliostigma thonningii are dominant species in the wet savannahs of Adamaoua because of their strong regenerative capacity after logging. Similarly, [33] shows that the regeneration rate of the stand in the Nazinou classified forest in central Burkina Faso is estimated at 72.43%, while [11] refers to rainfall distribution and soil water availability as the main factors regulating the rhythms of production and phenology of savannah trees.

4.3.2. Individual Mortality Rate

For the mortality rate in the first year, our results are similar to those of [2] who observed a high rate of dead trees, and the presence of pyrophyte species in these areas, when vegetation fire is very high in the shrub and wooded savannah. Similarly, [35] showed that bush fire is a factor that should not be overlooked for seedling mortality. As well as [27] also showed that the mortality rate is sometimes high when seedlings (young shoots) are grouped at the mother plant (stump).

In the second year, these results are different in the shrub savannah from those of [17] who found 36.91% and similar, in the wooded savannah with 27.25%. Our results are lower than those of [38] who found the high mortality rate in CSF (25.24%), followed by CAF (18.82%) and control (18.62%) for shrub savannah. While in wooded savannah the rate was 18.59%, in CAF, 14.03% in CSF followed by control site (9.78%). These results confirm those of [37] who showed that the plant mortality rate is very remarkable in shrub and wooded savannahs. As well as [25] in the savannah in Burkina Faso and they showed that the number of dead seedlings is worrying. 4.4 Reiteration and mortality of individuals in plant formations according to year.

For the reiteration, the analysis of variances of the numbers of species between sites and according to treatments shows a highly significant difference at the threshold of 0.05% with a probability of 0.0001. These results corroborate with those of

[38] who found the same species with high standard deviations. But these results are different from those of [13] on the diversity of flora and woody vegetation in Senegal. They showed that *Acacia seyal* (42%) and *Feretia apodanthera* (34%) have the highest regeneration rate and for [12] had obtained in some plots of the forest the five species: *Detarium microcarpum, Terminalia avicennioides, Vitellaria paradoxa, Strychnos spinosa* and *Pteleopsis suberosa*. Concerning the mortality of individuals, these results are similar to those of [35] indicating that bush fire is a factor not to be neglected for the mortality of seedlings.

4.4. Study of the Relationship Between Reiteration and Mortality

Concerning the correlation between reiteration and mortality of individuals, the statistical analysis shows that there is no significant difference between the two plant formations and the treatments applied the first (0.8589>0.05) and the second (0.6559>0.05) year. Our results differ from those of [8] who worked on Influence of logging on wood resources in the Lake Chad basin: case of the Ndjagare terroir (far north of Cameroon) noting that the species represent a high rate of mortality than regeneration; which means that species die more than they regenerate or reconstitute themselves.

4.5. Adaptation and Dynamism Factor Facilitating Species Regeneration

4.5.1. Biological Type of Species

Compared to the biological type in the first year, statistical analysis reveals a highly significant difference at P = 0.0001. These results are different from those of [36] who worked on the characterization and impact of timber exploitation on plant formations in the Adamaoua region and that of [16] in South Cameroon on the management of tree populations as tools for sustainable exploitation of non-timber forest products.

As in the second year for the biological type, the analysis of variance shows the existence of a statistically significant difference between the sites of two savannahs at P-value = 0.0001. These results corroborate those of the flora of the Michel Adanson botanical conservatory of Mbour in Senegal [14] which show that Nanophanerophytes (47.86%) are the most representative in the conservatory. Nanophanerophytes (Nano) and Microphanerophytes (Micr) are species that are mainly representative of the sites due to the adaptation of these species in the shrubby and wooded savannah. These results are also similar to those of [22] who worked on the floristic study and diversity of the Tanoé-Ehy marsh forest in Ivory Coast and they obtained the dominant Microphanerophytes with 99 species for 33%.

4.5.2. Geographic Distribution

For the geographic distribution in the first year, although the analysis of variance shows that there is no statistically significant difference (0.5233>0.05) between the values of the phytogeographic distribution of species in the different formations. These results corroborate those of [37] who showed that pantropical species (96.80%) are dominant in the Adamawa region. Similarly, [21] found species with wide distributions dominant in the Ruvubu National Park (Burundi). Similarly for the distribution in the second year, the analysis of variance shows that there is no significant difference between the sites and the distribution of species with P = 1.00. These results confirm those of [37] who showed that pantropical species (96.80%) are dominant in the Adamawa region and they are different from those of [15] who worked on the flora and vegetation of the Gueumbeul Special Wildlife Reserve (Senegal) and found that 30% of species are of Afro-Asian affinities, 28% African and 12% pantropical.

4.5.3. Species Distribution Mode

The analysis of variance shows that there is no significant difference between the wooded and shrub savannah (P = 0.36) concerning the mode of dissemination of diaspores in the first year. These results are in line with those obtained by [21] in the Ruvubu National Park (Burundi) on the comparative study of floristic parameters. The homogeneity shows that there is no statistically significant difference between the sites and the distribution modes of diaspores. For the second year our results are different from those of [1] who observed Endozochores with 65.70% of the total population, followed by Anemochores with 19.81% and Epizoochores 9.90% on the systematic and phytogeographic analysis of the classified forest of Bamo (Côte d'Ivoire).

4.6. Influence of Logging and Bushfire on Stump Regeneration

Taken in a particular way, the phenomenon of logging has an influence on stump regeneration. According to [32] and [6], the trauma caused by logging and bushfires improves the regeneration capacity of certain species. For the bush fire on the regeneration of the stumps, our results are close to the work of [33] in the classified forest of Nazinou (Burkina Faso) after the passage of the fire he observes the fall in the density of regeneration in others like Crossoptelyx febrifuga, Piliostigma thoningii, Terminalia avicennioides, Terminalia laxiflora. etc.5.

5. Conclusion and Perspectives

At the end of this study on the influence of wood cutting and bush fires on the regeneration of the vegetation cover of the Sudano-Guinean savannas, it emerges that wood cutting by man and uncontrolled bush fires influence the change in the physiognomy of plant formations through the transition from wooded savannah to shrub savannah. In the shrub savannah, the activities of the herders are slightly lower in the control site and the CAF, whereas in the tree savannah, the action of the herders is higher due to pruning and pruning for cattle feed (CSF 9, CAF 10 and T 19 individuals) and followed by the action of the animals. There was an increase in the number of species stumps per site and according to the parameters applied in the two formations, but in terms of individuals, the number doubled or even tripled in the shrub savannah and tripled or qua-tripled in the tree savannah with 346, 206 and 260 in the first year and 1239, 850 and 882 in the second year in CSF, CAF and T respectively. The number of individuals destroyed decreased from the first year to the second, except in the cut-and-fire treatment (CSF), which increased from 177 to 481 individuals. The classification of trees in the wooded savannah shows that future trees are dominant (57.22% and 49.7%) followed by mature trees (30.24% and 30.7% respectively in CSF and CAF), whereas in the control sites (T) it is mature trees (44.74%) followed by future trees (22.17%). The regeneration rate increased in the second year, varying from 6% to a remarkable 24% in the cut-and-fire treatment (CSF) in shrub savannah and from 6% to 28% in tree savannah in the cut-and-fire treatment (CAF). The mortality rate decreased to more than three quarters (3/4) in both formations in the second year. The correlation between reiteration and mortality in the first year was high in regeneration, with 22.87 ±4.55 in shrub savannah and 47.76 ± 15.27 in tree savannah. Logging has an effect on the remaining stumps, and fire has an impact on certain species even after regeneration and growth in height. It would therefore be judicious to extend this study to all the different plant formations and to carry out more in-depth studies on fire and wood cutting in order to determine the mechanisms of adaptation to bush fires and the exploitation of firewood and service wood.

Abbreviations

INS	National Institute of Statistics
SabCSF	Shrub Savannah Cut Without Fire
SabCAT	Shrub Savannah Cut With Fire
SabT	Control Shrub Savannah
SABCSF	Cut Without Fire Wooded Savannah
SABCAF	Cut with Fire Wooded Savannah
SABT	Control Wooded Savannah
CSF	Cut Without Fire
CAF	Cut with Fire
T	Control

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Conflicts of Interest

The authors declare no conflict of interest.

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