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Influence of topography on the recovery of vegetation in a logging forest of Yingui, Cameroon

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Abstract

The recovery of vegetation after degradation is a major preoccupation for natural resources conservation. The regeneration could be hindered due to logging activities which include logs skidding trails into the forest. These activities thus compact the soils and remove their covering (i.e. vegetation), making them vulnerable to erosion. The present study aimed to evaluate the impact of ground slope on the renewal of vegetation due to erosion in tropical logging forest. The study was carried out on logging roads and parks in Yingui, situated between the Littoral and Center regions of Cameroon. Plots of 5 × 20 m² were established at various levels of slope from 0% to 20%whereplants species communities were identified and their diversity were calculated. A total of 186 species belonging to 166 genera included in 72 families were recorded. The high species richness was found at 0%, and this index was two time higher in logging roads than on parks. The average diversity was low at the parks (H'=2.60), and high (H'=4.44) at 5% of slope. It was in logging roads at middle slope (10% of slope) that we found the best plant recovery (80-90%), because of lowest soil loss and therefore less erosion. Woody plant was the most represented life form and the most dominant species on the study area were *Ipomoea involucrata* P. Beauv. The recovery of vegetation was also influence by the presence of seed trees along the logging roads and ploughing of compacted soils in the parks.

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Introduction

Forests constitute the biggest reservoir of biodiversity of the planet. The Congo basin forests cover 200 million hectares at the core of Africa, forming approximately 20% of the rain forests in the world. Tropical rain forest is at the center of sustainable developmental issues, both for its ecological (conservation of plant and animal biodiversity, regulation of water resources, carbon sequestration, etc.), social and economic aspects (Chazdon and Uriarte, 2016; Tchatchou *et al*., 2015; Wasseige *et al*., 2015; Leroy *et al*., 2013).

Several factors are responsible for the degradation of forests. Among which are population growth, agriculture, and forestry development (Mirazadi *et al*., 2017; Kassi *et al*., 2010; Wright, 2005). After the report on the dramatic situation of deforestation in tropical region, the necessity to take into account the various functions of the forest with regards to various activities of exploitation has increased, leading to the principle of sustainable management of the forests (Leroy *et al*., 2013).

Logging alters the forest environment by creating a heterogeneous canopy with a range of different microenvironments, such as loading bays, skid trails, logging gaps and logging roads, which differ primarily in light intensity and soil disturbance (Biwolé *et al*., 2015; Duah-Gyamfi *et al*., 2014; Obiang *et al*., 2014). The degree of intensive use of the forests raises the problem of the reconstruction of the ecosystem and its resources. It is certain that the climate, the soil quality, the cultural manners, the topography have an effect on this reconstruction, but it is still difficult to identify the hierarchy of their influence (Fournier *et al*., 2001).

Several studies on the natural regeneration of forests, emphasize on the vegetation reconstruction from a structural point of view and the specific composition; based on the factors of the environment (Gilman *et al*., 2016; Obame *et al*., 2016; Poorter *et al*., 2016; Fayolle *et al*., 2015; Goodale *et al*., 2014; Nnanga *et al*., 2014; Couwenberghe, 2011), the abandonment period (Zang and Ding, 2009) and the land use history (Ribeiro *et al*., 2010; Chinea and Helmer, 2003).

The objectives of many surveys are to explain the distribution of the species in relation with abiotic (climate, soils, etc.) or biotic factors (competition between individuals and species, presence of the seed banks), by highlighting the control factors of forest regeneration (Jankovska *et al*., 2015). Understanding the mechanisms that influence the regeneration has become an important area of research in tropical ecology (Ribeiro *et al*., 2010).

Bariteau (1992) shows that except for the presence of the big trees around the reconstruction site, the topography and the frequency of tree gaps also affect the distribution of the species. Ribeiro *et al*. (2010) suggest that the natural regeneration of the herbaceous species in the secondary tropical forest depends on the treatment that the soil has received.

Logging activities come along with the creation of roads and parks. Ground based logging operation can lead to soil compaction, soil displacement, increase runoff, cause deep ruts and erosion (Miller *et al*., 2010). Erosion and mass flow are natural processes occurring on all landscapes, but the rate and extent of erosion can be increased by forest management activities (Tavankar, 2013).

The soil surface constitutes both the living environment and the source of nutrition for plants. The presence of flora and structural complex of a plant community reduce erosion and contribute to the preservation of soils stability (Rey *et al*., 2003). Meanwhile, compaction and loss through erosion of the upper soil layer, which is rich in organic matter sand nutrients, bring down the efficiency of the forest regeneration (Croke *et al*., 2001).

The dimension of the impact created by skidding of the products directly on the ground varies depending on several factors such as the slope, site characteristics, production methods used, planning of skidding roads and production season (Demir *et al*., 2007).

The interest of this study is concerned with secondary roads and parks because during their implementation, they require a high level of clearing of the vegetation involving a big sensibility of soils to erosion.

This study assesses if slope of ground is a relevant factor determining the regeneration of vegetation on secondary roads and parks. This survey purpose is to evaluate the impact of ground slope on the replacement of vegetation due to erosion in tropical logging forest. Objectives are to determine the composition of plant on various abandoned roads and parks, to evaluate the plant covering in relation with ground slope and time and to characterize the reconstitution of vegetation (Species, biological forms) according to the degree of slope of ground.

Material and methods

Study Site

The study was carried out in the forest management unit (FMU) 00 004 located between the Littoral and Center regions of Cameroon (Fig. 1).

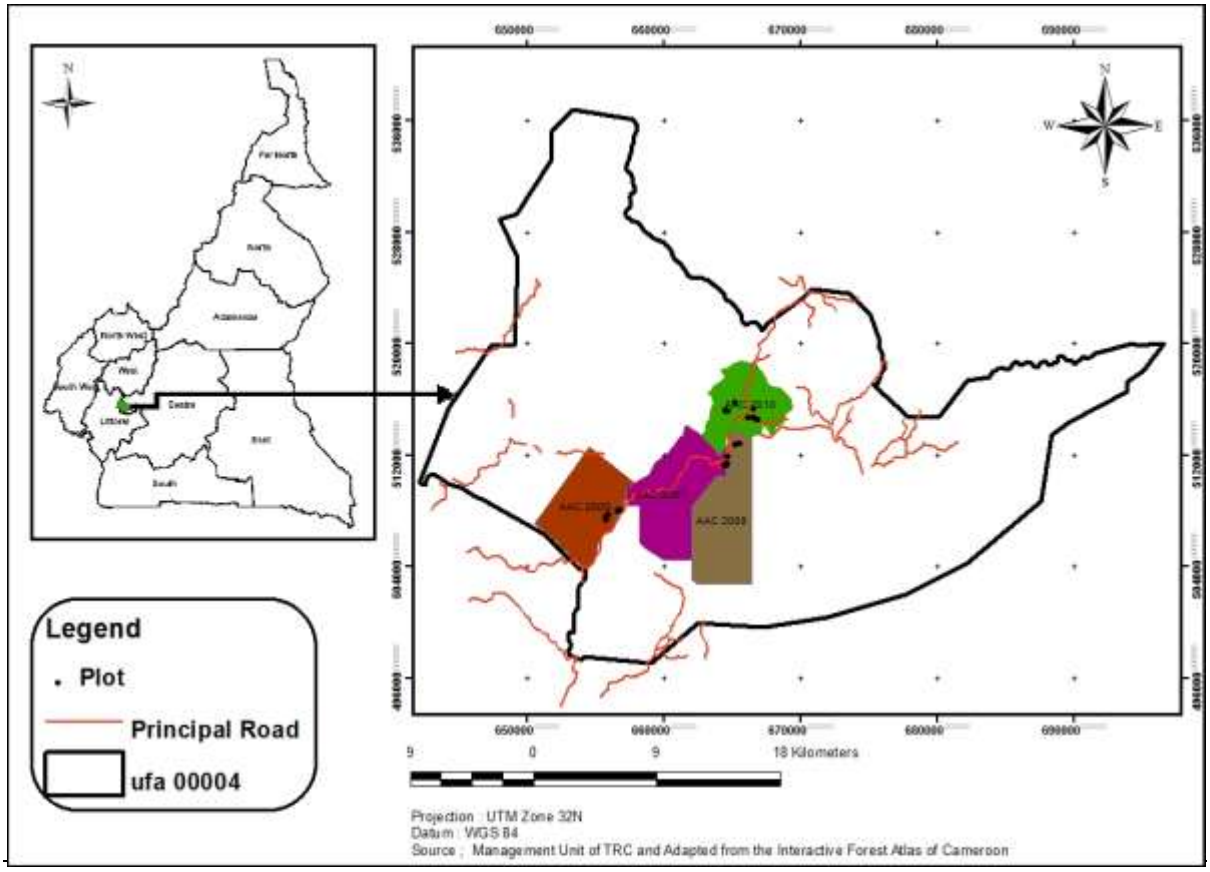

Fig. 1. Localization of the Forest Management Unit (FMU 00 004) and sampling plots.

This FMU has a surface area of 94917 ha and is divided into two topographic zones: a relatively hilly area (less than 500 m) on the West side of river Makombe and a hilly (up to 1300 m) in the East. The climate is characterized by a dry season ranging from December to February and a rainy season from March to November. Annual rainfall varies from 1500 to 2800 mm. The annual average temperature is 22.4°C witha thermal amplitude of 2.9°C (Choula *et al.*, 2013).

The soils of the study area as having a clay fraction few represented: 4 to 5%, silt: 20 to 30% and sand: 70%. The organic matter is abundant (10% in the first 20 cm and 3% to 50 cm) with high levels of nitrogen (4%, 1.5 to 50 cm). The absorbent complex has an exchange capacity of 50 meq/100 g at the surface, 19 meq long. The degree of saturation is therefore quite low. They are brown soils, sandy silty, very good structure, rich in organic matter and exchangeable bases but therefore the complex is partially de saturated.

The most abundant species are: *Musanga cecropioides* R.Br. & Tedlie, *Sterculia rhinopetala* K. Schum, *Pycnanthus angolensis* (Welw). Warburg, *Desbordesia glaucescens* (Engl) Van Tiegh., *Blighia. Welwitschii* K.D. Koenig, *Vitexciliata* (Pierre Pellegr.), *Funtumia elastica* (Preuss) Stapf., *Rauvolfia macrophylla* Stapf., *Plagiostyles africana* (Muell. Arg.) Prain, *Polyalthia suaveolens* Engl. and Diels, *Terminalia superba* Engl. and Diels, *Ceiba pentandra* (Linn) Gaertn, *Petersianthus macrocarpus* (P. Beauv.) Liben, *Pterocarpus soyauxii* Taub., *Lophira alata* Banks ex Gaertn., *Cylicodiscus gabonensis* Harms (Choula *et al*., 2013).

Sampling Design

Plots of 5 m × 20 m were established on three Annual Allowance Cuts (AAC) exploited between 2008 and 2010 (Fig. 1). On abandoned roads, slopes were determined using the clinometer. A sight was set to 25 m to the eye of the observer and measurement given by the clinometer indicates the percentage of slope. Selected percentages are: 0%, 5%, 10%, 15% and 20% corresponding respectively to P0, P5, P10, P15 and P20.

Two plots were established at every level of the slope and on parks (P). Every plot of 100 m² was divided into subplots of 1 m ×1 m. Within the subplots, species were identified and their percentage cover with regard to the surface area of the subplot was estimated by the coefficient oh abundance-dominance of Braun-blanquet (Priso *et al*., 2012). Individuals that were not readily identified in the field were collected for later identification at the National Herbarium of Cameroon.

Data analyses

The relationship between the index of cover-abundance of Braun-blanquet and the percentages of cover was established to facilitate the manipulation of the data (Priso *et al*., 2012).

Some parameters were computed for the understanding of the recovery:

- Importance Value Index (Klenk, 1985).

IVI (%) = (Relative Dominance + Relative Frequency) / 2

Where Relative Dominance = Cover per species/ Total cover of plot

Relative Frequency = (Number of quadrats in which species occur / total number of quadrats sampled) × 100

IVI is the synthetic expression and quantified of the species importance in a population.

- Shannon-Weaver diversity index (Kamdem *et al.,* 2013).

$$H' = -\sum_{i=1}^{S} \frac{CMi}{CM} \log 2 \frac{CMi}{CM}$$

Where H' is Shannon-Weaver diversity index, s is the total number of species, CMi is the average cover of the species I and CM the total cover of the plot.

- Evenness e=H'/log S

Where e is the evenness index, S is the number of species, and H' is the Shannon's species diversity index (Ngueguim *et al*., 2010).

Results

Flora inventory

Within the research plots, a total of 186 species belonging to 166 genera included in 72 families were recorded. The largest family was Euphorbiaceae (13 species and 11 genera), followed by *Fabaceae* and Caesalpinioideae both with 9 species and 8 genera. The family of Moraceae and Sterculiaceae were represented respectively by 8 species, 6 genera and 6 species, 4 genera.

The number of species on the 33 plots established varies from 29 on the park to 141 at P10. The mean value of the number of species on the secondary roads (46.53 ± 12.15 species) is two times higher than on parks (23.33 ± 11.94 species). The highest average number of species is 54.17 ± 15 at P10. The mean value of number of species is higher at the middle slopes P5 and P10 (respectively 52.50 ±14.76 and 54.17±15) (Table 1).

The extremes values of the diversity index in the AAC 2010, 2009 and 2008 is respectively 2.48 at park and 4.01 at P10; 2.31 at park and 4.79 at P20, 1.69 at P0 and 5.04 at P15. The mean value of H' at each level of slope is 2.60 at Park and 4.44 at P5. The mean of evenness is 0.51 in park and 0.71 at P5 (Table 2).

Table 1. Number of species at various slopes.

	Park	Po	P5	P10	P15	P20
AAC 2008	39	56	130	141	55	76
AAC 2009	72	44	110	100	94	102
AAC 2010	29	36	75	84	81	76
Mean	23.33±11.94	45.33±10.07	52.50±14.76	54.17±15	38.33±9.69	42.33±11.20

Table 2. Shannon-Weaver diversity index (H'), maximal diversity (Hmax) and evenness (*e*).

AAC	Parameter	Park	Po	P5	P10	P15	P20
	H'	2.48	3.67	3.92	4.01	3.83	3.63
AAC 2010	Hmax	4.75	5.17	5.86	6.00	5.95	5.93
	e	0.52	0.71	0.67	0.67	0.64	0.61
	H'	2.31	3.28	4.36	3.91	4.63	4.79
AAC 2009	Hmax	5.73	5.46	6.32	6.19	6.09	6.19
	e	0.40	0.60	0.69	0.63	0.76	0.77
	H'	3.03	1.69	5.04	4.87	3.55	3.38
AAC 2008	Hmax	4.81	5.81	6.55	6.58	5.36	5.73
	e	0.63	0.29	0.77	0.74	0.66	0.59
Mean	H'	2.60	2.88	4.44	4.26	4.00	3.93
	e	0.51	0.53	0.71	0.68	0.69	0.65

Plant covering in relation with the degree of slope

The variation of the plant covering in the 2008, 2009 and 2010 AAC is presented in Fig. 2. In the 2010 AAC, plant covering is lower than 20% on the parks, on secondary roads, the covering exceeds 30%, but it is steady with slope.

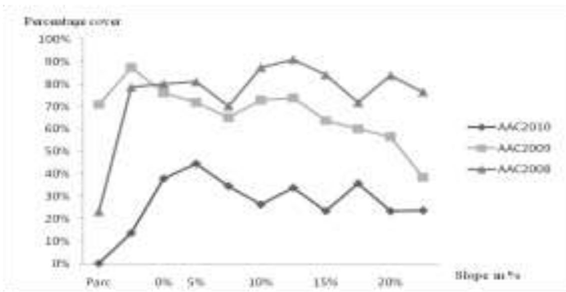

Fig. 2. Variation of plant covering according to the degree of the slope.

In 2009 AAC, the vegetation is between 70 and 90% on parks. On the secondary road, plant covering decreases when the slope is increase but remains more than 35%.

In the 2008 AAC, in spite of its age, one of the parks has a plant cover under 25%. On the secondary road, it is at P10 that is found the highest coverings. However at low (Po and P5) and high (P15 and P20) slopes, the covering is greater than 70%.

Floristic structure

Various plants life forms were found on the entire plots. The woody plants are the most represented with 104 species; the herbaceous plants are represented by 65 species and lianas by 17 species.

In the 2010 AAC, the herbaceous species are the most represented at almost all the levels of the slope, but it is at Po where tree species and herbaceous are most represented (Fig. 3a). On the other hand, in the 2009 AAC, the ligneous species dominate at all the levels of the slope especially in P20 and herbaceous is dominated at P5 (Fig. 3b). As for the 2008 AAC, it is at mid slopes that the ligneous species dominate (Fig. 3c). In this concession that was exploited three years before the inventory, the herbaceous species are still very present. Lianas species are weakly represented in all the pots, they are absent at park in the 2008 AAC.

The assessment of IVI of all the species show 12 species as the most important *Barteria fistulosa, Chromolaena odorata* (L.) King & Robinson, *Cyperus cylindrostachyus, Desmodium adscendens, Funtumia elastica, Ipomoea involucrate* P. Beauv. (*Convolvul aceae*), *Mukuna flagellipes, Panicum chionachne, Piper guineense, Setaria megaphyla, Sida rhombifolia, Terminalia superba*.

Ipomoea involucrata is the most presents species on plots with higher IVI on 13 plots. Followed by *Funtumia elastica*, a tall tree and *Chromolaena odorata* (Asteraceae), an herbacious species (Table 4).

Table 3. Assessment of IVI of some characteristic species.

Parcelles	Espèces	Dom	Fr	VIR
P5_2009	*Barteria fistulosa*	45,01	98	71,50
P15_2008	*Chromolaena odorata*	38,35	88	63,17
P5_2008	*Chromolaena odorata*	29,39	95	62,20
P0_2008	*Chromolaena odorata*	*28,94*	*94*	*61,47*
P15_2008	*Chromolaena odorata*	33,07	70	51,53
P5_2008	*Cyperus cylindros tachyus*	16,34	47	31,67
P20_2008	*Desmodium adscendens*	42,02	95	68,51
P10_2008	*Desmodium adscendens*	40,90	89	64,95
P0_2009	*Funtumiab elastica*	*40,94*	*97*	*68,97*
P10_2009	*Funtumiab elastica*	32,78	88	60,39
P20_2009	*Funtumia elastica*	25,49	77	51,25
P15_2009	*Funtumia elastica*	20,29	77	48,65
P20_2009	*Funtumia elastica*	21,07	66	43,53
P5_2009	*Funtumia elastica*	25,24	51	38,12
PARC_2009	*Ipomoea involucrata*	70,54	100	85,27
P20_2010	*Ipomoea involucrata*	64,44	98	81,22
P15_2010	*Ipomoea involucrata*	56,20	96	76,10
P10_2009	*Ipomoea involucrata*	54,79	97	75,90
PARC_2009	*Ipomoea involucrata*	42,99	92	67,50
PARC_2008	*Ipomoea involucrata*	39,52	90	64,76
P15_2009	*Ipomoea involucrata*	20,32	93	56,66
P20_2010	*Ipomoea involucrata*	23,58	81	52,29
P10_2010	*Ipomoea involucrata*	32,91	70	51,45
P10_2010	*Ipomoea involucrata*	22,64	80	51,32
P5_2010	*Ipomoea involucrata*	21,82	76	48,91
P5_2010	*Ipomoea involucrata*	14,30	73	43,65
P15_2010	*Ipomoea involucrata*	15,80	42	28,90
PARC_2010	*Mukuna flagellipes*	46,93	38	42,47
PARC_2008	*Panicum chionachne*	40,02	99	69,51
P10_2008	*Piper guineense*	18,20	87	52,60
P20_2008	*Setaria megaphyla*	40,92	85	62,96
P0_2010	*Sida rhombifolia*	*18,69*	*67*	*42,84*
PARC_2010	*Terminalia superba*	66,67	2	34,33

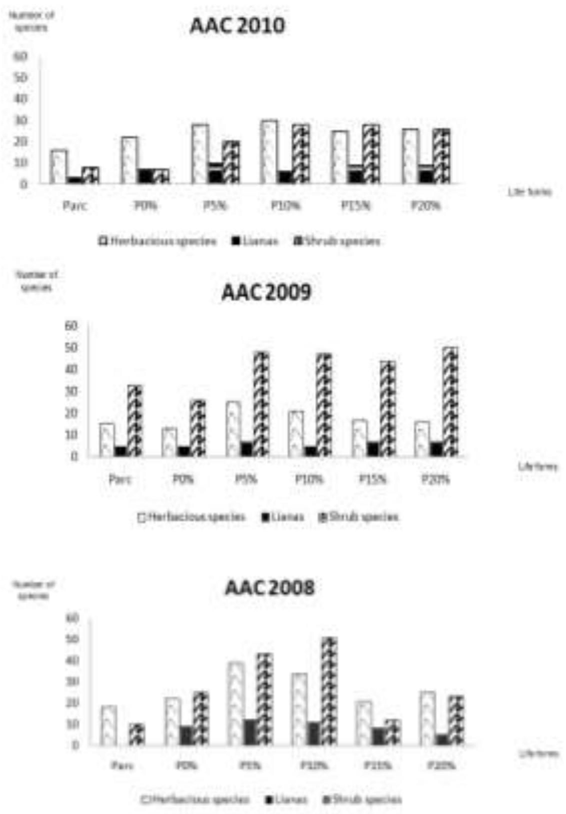

Fig. 3. Life forms at each level of slope in different AAC.

Fig. 4. Gap of vegetation created by wheels.
A, AAC 2010 at 20 % of slope; B, AAC 2009 at 15 % of slope (drain formed after 2 years); C, AAC 2009 at 15 % of slope (see the depth of the drain).

Discussion

At all levels of the slope and on parks, the Shannon-Weaver diversity index varies between 1.69 and 5.04 with a mean of 3.69 ± 0.91. This mean testifies a high diversity (Choula *et al.*, 2013; Priso *et al.*, 2012). These high values translate a good regeneration of the flora diversity mainly on roads due to favorable conditions of environment, proximity to forest remnants and to the seed bank as the forest soils constitute (Poorter *et al*,. 2016; Ramos *et al.*, 2016; Duah-Gyamfi *et al.*, 2014). The good species distribution along the roads is confirmed by the index of evenness that is more than 0.5, localised in slow slope. According to Liu *et al.* (2014) sites in valleys and on lower slopes, which are characterized by higher resource availability, have higher functional evenness and divergence than sites higher along topographical gradients. Functional evenness is an indicator of how functional space is occupied, with a higher value when species abundances are more even or regularly spaced in trait space (Villéger *et al.*, 2008). The numerous and close seedlings observed along the roads is due to the presence of nearby trees with an important regeneration capacity (Lu *et al*, 2016; Kassi *et al.*, 2010).

Normally, forests along road edges are selectively logged at relatively light intensity compared to the main logging areas to prevent soil erosion of the roads (Zang and Ding, 2009). The recovery on the parks are more difficult than on the secondary road (P5, P10, P15, and P20). This is due to the effect of compaction exercised on the ground by machines and timber that has accumulated all year round during logging activities (Ampoorter *et al.*, 2010; Afrifa, 2012).

Harvest activities that compact soils limit the effective rooting depth of plants by restricting access to water and nutrients and reducing gaseous exchange (Tavankar, 2013). Compared to up-slope edges of roads, the down-slope edge area tends to be infiltrated by topsoil, which kills some existing seedlings and inhibits seedling emergence from soil seed banks (Zang and Ding, 2009).

The present results suggest that plant recovery depends on the treatment undertaken by the soil before it is set lying as a fallow (Ribeiro *et al.*, 2010). Indeed the parks that have been influenced by a high compaction degree indicate a slower recovery rate than the secondary roads (Wright, 2005)

The high percentage of plant covering in park 2 years after logging is due to ploughing. The ploughing of parks after logging activities in an annual allowance cut is therefore very important because it allows the infiltration of water in soil and can return topsoil.

One year after logging the plant cover is very low, but the vegetation is abundant from the second year (Duah-Gyamfi *et al.*, 2014). Loading bays and roads are completely cleared of vegetation, and the soil often becomes much degraded through compaction, and they show poor regeneration (Hawthorne *et al.*, 2011). Sidle *et al.* (2004) showed that during the first year after logging, soil losses were 13.3 t ha^{-1} on logging roads, but decline to 3.1 t ha^{-1} in the second year.Regarding rate of recovery, a period of about 4 years is needed for sediment concentration to return to original levels after logging has ceased (Hooi *et al.*, 2003).

It is in the middle slopes (P10) that the best percentage of plant cover (80-90%) was found. According to Hooi *et al.* (2003), in logged forest, on sandy loam soil, with vegetation cover of 85% is on slopes between 5-15% that the lowest soil loss is find and therefore less erosion and an increase in trapped sediments.

The presence of various life forms of plants, enhances the protection of the soil against erosion (Dupuy *et al.*, 1997; Menashe, 1993). The first year after logging, herbaceous is most represented.

Logging roads represented big gaps on forest canopy. This has a negative impact on tree regeneration and promotes an alternative successional pathway, where the large gaps become dominated by herbs, shrubs and herbaceous or semi-woody climbers (Babaasa *et al.*, 2004).

The implementation of herbaceous species in degraded environment leads to the rehabilitation of this environment (Rey *et al.*, 2003). The floristic composition is very different depending on the site; sometimes represented by herbaceous species or by tree seedlings. Liu *et al.* (2014) showing that floristic composition changed with elevation, convexity and slope.

The specie with the greatest Importance Value Index (IVI) is *Ipomoea involucrata*, which is a creeper found in various habitat like forest. It is distributed throughout tropical Africa and northern South Africa (Uche *et al.*, 2011). It is represented on every plot. It is the most dominant species in this sites; with the highest IVI of 36.25 % (Table 4), Followed by *Funtumia elastica*, a tall tree and *Chromolaena odorata*, an herbacious species; in P0 with IVI of 23% and 20.49% respectively. According to Burkill (1985), the plant by virtue of its active growth has been found suitable as a natural forestry cover in south Nigeria and in west Cameroon.

Followed by *Funtumia elastica* and *Chromolaena odorata* which is considered as major threats to natural regeneration and succession in the natural forests of Ghana (Duah-Gyamfi *et al.*, 2014). Choula *et al.* (2013) studying diversity of tree in the same area showed that the five most represented species were *Desbordesia glaucescens*, *Funtumia elastica*, *Plagiostyles africana*, *Pycnanthus angolensis* and *Sterculia rhinopetala*. *Chromoleana odorata* require a disturbance before colonize a site. Once established, it is competes aggressively with herbs, shrubs, and tree seedling in open areas (Joshi, 2006).

Conclusion

The objective of this study was to evaluate the impact of erosion through topography on the replacement of the vegetation in a tropical logging forest. In general, the recovery is good on the roads due to the seed bank that the forest soils contain by the presence of nearby trees close to this roads. Meanwhile it is at middle slope that we have the best plant recovering due to lowest loss soil, therefore less erosion.

The compaction due to ground based logging operation reduces plant recovering. *Ipomoea involucrata* (Convolvulaceae) is the most abundant species in the study area, followed by *Funtumia elastica* (Apocynaceae) and *Chromolaena odorata* (Asteraceae).

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