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Full Length Research Paper

The effects of soil properties and vegetation cover on the sedimentation of forest roads

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This study was conducted to investigate the interaction of soil properties and vegetation cover on soil loss from forest road prism. Rainfall simulations were carried out on road surface, fillslope and cutslope. Runoff and sediment samples were collected every 4 min and then total soil loss was measured. Samples from top soil were randomly collected for analysis and grouping soil into A, B and C. Results showed that on cutslope, the highest soil loss was detected for soil group B, where sediment concentration in runoff was 21.83 g L^{-1} and vegetation cover was 0 to 30%. On fillslope, the highest soil loss was detected for soil group C, where sediment concentration in runoff was 18.07 g L^{-1} and vegetation cover was 10 to 40%. On road surface, the highest soil loss was detected for soil group A, where sediment in runoff was 8.99 g L^{-1} and vegetation cover was 2 to 5%.

Key words: Forest road, sediment, soil groups, rainfall simulation, principal component analysis (PCA).

INTRODUCTION

Globally, soil erosion is one of the most important environmental problems which threaten soil and water resources (Cerdà, 2007). An Iran, due to the arid climate and the human land use is affected by soil erosion and land degradation. Soil properties is one of the main parameters that affect runoff and soil loss processes. Water erosion of forest soil is naturally very low and can be neglected, but after clear cutting for road construction, the bare soil is exposed to rainfall and other erosive agents (Croke et al., 2001; Foltz et al., 2009). Road erosion is also found during the construction of the roads and the embankments and soil development only took place at a low rate. So, under this situation the inherent sensitivity of forest soil to erosion is appeared especially on steep slopes (Jordán and Martínez-Zavala, 2008). If a forest road is planned and constructed without considering region erodibility, the engineers would be faced to high cost to solve road sedimentation problem. Road is the main type of transportation system in Hyrcanian forests of Iran (Parsakhoo et al., 2009). Most of these roads traversed through hilly and mountainous areas. These mountainous roads experience numerous hazards such as water erosion and landslides which cause disruption, injuries and losses to life and economy

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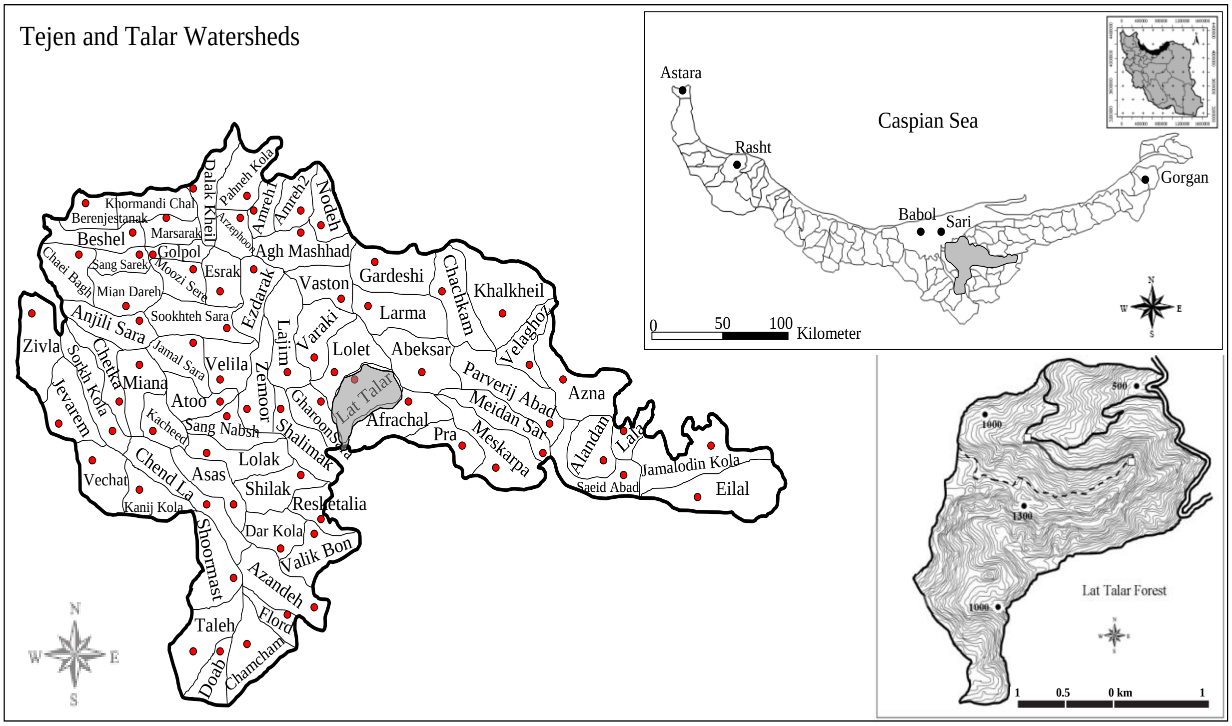

Figure 1. Geographical position of the study area.

(Mohammadkhan et al., 2011).

Kavian et al. (2010) reported that soil initial moisture, percentage of soil organic matter, bulk density and sand percent are most effective factors in runoff generation. Also, the results illustrated that percentage of soil organic matter, soil initial moisture and silt percent affect on soil erosion. Najafian et al. (2010) showed that both life form and vegetation cover significantly influenced the amount of runoff and sedimentation. Greatest runoff was found for forbs while grasses had lowest amount of runoff. Also bare ground and 100% cover showed the greatest and lowest amount of runoff, respectively. The concentration of sediment for shrubs was significantly greater than grasses and in 100% cover it was significantly lower than 50% and bare ground. Scientific understanding of factors influencing soil loss from forest road can effectively be used by managers in the design and sustainable management of road networks (Pappas et al., 2008; Olive and Marion 2009). Road prisms, including cutslopes, road surfaces, and fillslopes, can be important contributors of sediment to streams in forested watersheds (Bold et al., 2009; Morgan, 2005).

Interaction between soil properties and vegetation cover is one of the main factors responsible for soil loss (Fu et al., 2009). Monitoring of soil loss using rainfall simulator and runoff plots was cost-effective and provided valuable information about soil erosion caused by road construction. Thus, this study was conducted to (i) grouping soil properties for different parts of forest roads and (ii) investigate the effects of the interaction of some soil properties and vegetation cover on runoff and soil loss from road prism and forest lands located in Hyrcanian zone of Iran.

MATERIALS AND METHODS

Description of the study area

Lat Talar forest within the watershed number of 71 in Hyrcanian zone of Iran was selected as the study area. The research site has a total area of 3801 ha. The mean annual temperature of the study area is 15°C. Minimum altitude is about 300 m and the maximum 1650 m. The mean slope was 50%. The location of the research is in latitude 53° 9′ 40″ to 53° 13 ′55″ E and longitude 36° 12′ 55″ to 36° 15′ 45″ N. The region has very moist to mid moist and cold climate with a mean annual precipitation of 800 mm. The bedrock is typically marl, marl lime and limestone with a soil texture of loam and clay loam. Forest stands are dominated by *Fagus orientalis* Lipsky, *Carpinus betulus* and herbaceous species of *Carex silvatica*, *Buxus hyrcanus, Berachypodium silvaticum*, *Ruscus hyrcanu*s, *Phyllitis scolopendrium, Rubus hyrcanus* L. and *Polypodium auidinum*. Forest roads in the studied area are used by truck, motorcycle, Landrover and nissan. The traffic density is 5 vehicles per day. *Philonotis marchica* (Hedw.) Brid. and *Rubus hyrcanus* L. are dominant species on cutslopes and fillslopes of road (Figure 1).

Data collection

Totally, 38 rainfall simulations were randomly done all over the area

Figure 2. Rainfall simulator and runoff collection by the gauge.

for road surface (10 replications), fillslope (13 replications) and cutslope (15 replications). A portable single nozzle rainfall simulator simulated rain with drop size of 3 mm for duration of 20 min at intensity of 32.4 mm h^{-1} (Figure 2). Water with a mean temperature of 23°C was rained using a Schlick r86510 nozzle mounted 2 m above the ground onto a squared area of 0.48 m^2 that is bordered by a steel structure on cut slope and road surface. Runoff and sediment samples were collected every 4 min by gauge and then total soil loss was measured. The clear water was separated from deposited sediment. Sediment was air-dried for a week in temperature of 30°C. Besides, it was oven-dried at 105°C for at least 2 h and then weighted using digital balance. 25 samples of the top soil (0 to 20 cm deep) were randomly collected from cutslope, fillslope and road surface. Soil texture was determined by the Bouyoucos hydrometer method. Lime percentage (T.N.V or $CaCO_3$) was measured using the NaOH titration method. Soil organic carbon was determined using the Walkley–Black technique. Soil bulk density was measured using a relation of soil dry weight to volume of sampling cylinder (484 cm^3) (Koc et al., 2008). Runoff coefficient is calculated as Equation 1 (Figure 2).

$$RC = \frac{R_h}{P_h} \times 100 \qquad (1)$$

Where, RC is runoff coefficient in %, R_h is runoff height in mm and P_h is rainfall height in mm.

Statistical analysis

In grouping process of plots, each table of soil data sets was analyzed using principal component analysis (PCA) in PC-ORD software. Then, data were statistically analyzed using GLM procedure in SAS program. Student Newman Keuls (SNK) multiple comparison test at probability level of 5% was used to compare means among groups and diagram designed by Excel software.

RESULTS AND DISCUSSION

Effects of vegetation cover and soil groups on soil loss from cutslope

Figure 3 shows the PCA correlation circle for the soil variables on cutslope. Soil properties on cutslope were classified into three groups based on PCA. The purpose of this analysis is to define groups of items based on their similarities. The properties of each group have been recorded in Table 1.

The runoff and soil loss in soil groups B and C was significantly more than that of soil group A (Table 2). A soil with a high percentage of silt and clay particles has a greater erodibility than a sandy soil under the same

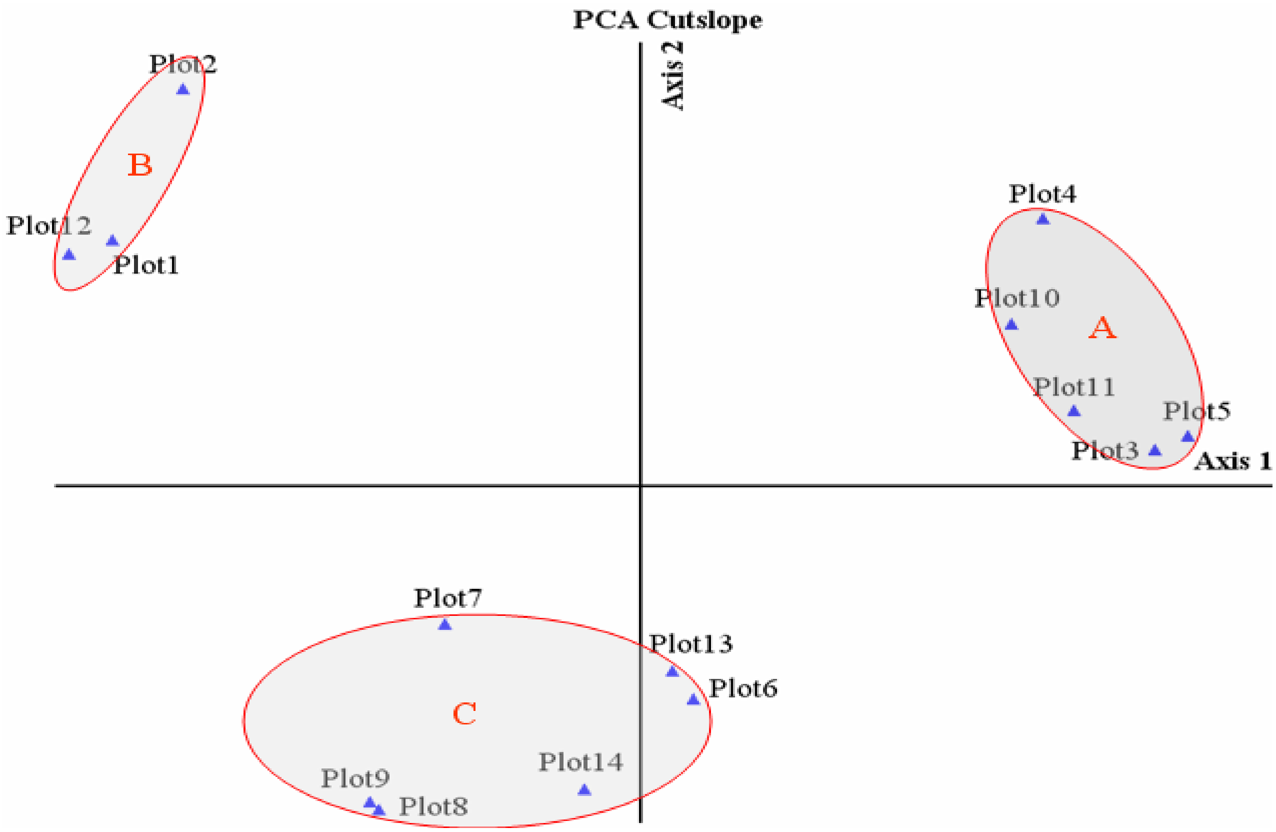

Figure 3. PCA analysis of soil on cutslope.

Table 1. Characteristics of the soil groups in cutslope.

Soil groups	Bulk density ($g\ cm^{-3}$)	Moisture (%)	Organic matter (%)	$CaCO_3$ (%)	Clay (%)	Silt (%)	Sand (%)
A	1.2±0.1	10.7±0.9	1.96±0.1	36.5±5.6	12.3±2.3	13.1±1.2	74.6±1.1
B	0.9±0.1	25.3±0.2	4.64±0.3	18.4±0.1	23.3±4.5	27.4±2.5	49.2±5.7
C	1.3±0.1	15.9±3.7	0.82±0.1	23.2±1.8	24.7±4.0	25.3±3.4	49.9±5.6

Table 2. Effect of soil groups on runoff and sedimentation from cutslope.

Soil groups / Variables	A	B	C	ANOVA, *p*
Runoff coefficient (%)	22.22^{B}	41.99^{A}	48.05^{A}	0.0122
Time to runoff (s)	240.67^{A}	169.80^{B}	182.67^{B}	0.0500
Sediment concentration ($g\ L^{-1}$)	11.27^{A}	19.32^{A}	10.39^{A}	0.5083
Total soil loss ($g\ m^{-2}\ h^{-1}$)	81.70^{A}	252.70^{A}	152.80^{A}	0.5690

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls test; Alpha=0.05.

conditions. Although all soils are potentially susceptible to water erosion, silts, silt loams and loams are most at risk because there is no adhesion forces among silt particles, (Ziegler et al., 2001).

The low-vegetated road cutslope increase their runoff coefficient. The soil loss was lower than 90 $g\ m^{-2}\ h^{-1}$ on

Table 3. Effect of vegetation cover on runoff and sedimentation from cutslope.

Vegetation cover / Variables	0-30%	30-45%	ANOVA, *p*
Runoff coefficient (%)	42.^{69A}	24.31^{B}	0.0420
Time to runoff (s)	180.13^{B}	233.33^{A}	0.0405
Sediment concentration (g L^{-1})	16.29^{A}	10.85^{A}	0.3858
Total soil loss (g m^{-2} h^{-1})	216.09^{A}	80.58^{B}	0.0325

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls test, Alpha=0.05.

Table 4. Interaction of soil and vegetation cover on runoff and sedimentation from cutslope.

Soil groups	A		B	C		ANOVA, *p*
Plant cover	0-30%	30-45%	0-30%	0-30%	30-45%	
Runoff coefficient (%)	20.8	22.5	48.0	44.1	33.4	0.348
Time to runoff (s)	162.0	256.4	182.7	182.7	118.0	0.004
Sediment concentration (g L^{-1})	11.8	11.2	21.8	10.4	9.3	0.433
Total soil loss (g m^{-2} h^{-1})	84.9	78.4	296.3	152.8	81.0	0.370

the high vegetated road cutslope and greater than 200 g m^{-2} h^{-1} on the low-vegetated ones in study area (Table 3). Vegetation provides a protective layer or buffer between the atmosphere and the soil by means of its canopy, roots, and litter components (Mohammad and Adam, 2010). Many studies have emphasized the importance of vegetation cover on soil loss. On cutslope, the highest soil loss was detected for soil group B, where sediment concentration in runoff was 21.83 g L^{-1} and vegetation cover was 0 to 30% (Table 4). There was no slope class of 30 to 45% in soil group B.

Effects of vegetation cover and soil groups on soil loss from fillslope

Figure 4 and Table 5 show the PCA correlation circle for the soil variables and the properties of each group on fillslope, respectively. Minimum runoff coefficient and sediment concentration as well as soil loss was observed in soil group B (P<0.05), this might be due to the high content of $CaCO_3$ and sand (Table 6). Soil texture determines the rate at which water drains through a saturated soil; water moves freely through sandy soils than it does through clayey soils (Clinton and Vose, 2003). In humid Mediterranean mountainous area it was detected that the sand content and clay content of the soil have significant correlations with runoff rates on the three parts of the roads, affecting in a negative or positive manner respectively. The organic matter content contributed to reduce the runoff rate on the road surface and on the fillslope. Soil loss was negatively correlated to the sand content and organic matter content, but positively correlated to clay content (Jordán-López et al., 2009).

Shixiong et al. (2006) indicated that vegetation cover could significantly reduce sediment yield from unpaved roads. The above-ground components of the vegetation, such as leaves and stems, partially absorb the energy of the erosive agents of water and wind, so that less is directed at the soil, whilst the below-ground components, comprising the rooting system, contribute to the mechanical strength of the soil (Morgan and Rickson, 1995). In current study runoff and soil loss from fillslope plots with higher percentage of vegetation cover was lower than that of plots with lower vegetation cover, but this difference was not significant which could be due to the effects of soil properties, different plant forms or different amount of plant residues (Table 7). On fillslope, the highest soil loss was detected for soil group C, where sediment concentration in runoff was 18.07 g L^{-1} and vegetation cover was 10 to 40% (Table 8).

Effects of vegetation cover and soil groups on soil loss from road surface

Figure 5 and Table 9 show the PCA correlation circle for the soil variables and the properties of each group on road surface, respectively. Minimum runoff coefficient and sediment concentration as well as soil loss was observed in soil group C (P<0.05), this might be due to high content of $CaCO_3$, organic matter and sand (Table 10). Calcium carbonate of soil is an effective factor on conjunction of clay particles (Feiznia et al., 2005). There was no significant difference between soil loss from plots with vegetation cover of 2-5 and 5-8% (Table 11).

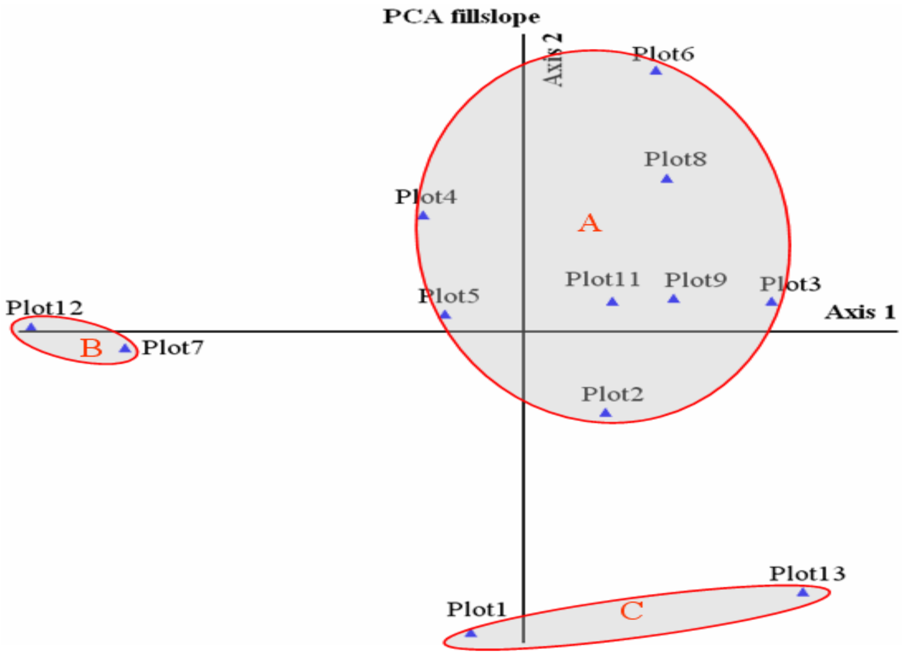

Figure 4. PCA analysis of soil on fillslope.

Table 5. Characteristics of the soil groups in fillslope.

Soil groups	Bulk density (g cm^{-3})	Moisture (%)	Organic matter (%)	$CaCO_3$ (%)	Clay (%)	Silt (%)	Sand (%)
A	1.4±0.1	19.1±1.3	1.6±0.5	33.8±4.5	30.4±2.8	23.5±4.5	46.2±3.7
B	1.4±0.1	18.9±3.3	1.4±0.1	36.3±0.0	16.7±0.0	16.2±0.0	67.0±0.0
C	1.3±0.1	17.7±0.8	1.7±0.0	30.0±4.3	26.7±4.2	23.9±5.6	42.4±5.8

Table 6. Effect of soil groups on runoff and sedimentation from fillslope.

Soil groups / Variables	A	C	B	ANOVA, *p*
Runoff coefficient (%)	9.62^{B}	16.08^{A}	9.81^{B}	0.0426
Time to runoff (s)	619.38^{A}	272.50^{B}	754.00^{A}	<0.0001
Sediment concentration (g L^{-1})	10.05^{A}	13.84^{A}	2.34^{B}	0.0388
Total soil loss (g m^{-2} h^{-1})	47.43^{B}	77.30^{A}	17.24^{C}	0.0024

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls test; Alpha=0.05.

Table 7. Effect of vegetation cover on runoff and sedimentation from fillslope.

Vegetation cover / Variables	10-40%	40-70%	ANOVA, *p*
Runoff coefficient (%)	11.00^{A}	10.18^{A}	0.3104
Time to runoff (s)	555.63^{B}	640.75^{A}	<0.0001
Sediment concentration (g l^{-1})	10.26^{A}	7.68^{A}	0.9650
Total soil loss (g m^{-2} h^{-1})	48.05^{A}	47.04^{A}	0.5516

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls Test, Alpha=0.05.

Table 8. Interaction of soil and vegetation cover on runoff and sedimentation from fillslope.

Soil groups / Plant cover (%)	A		C		B		ANOVA, *p*
	10-40	40-70	10-40	40-70	10-40	40-70	
Runoff coefficient (%)	9.2	10.7	18.3	13.9	18.6	0.96	0.0667
Time to runoff (s)	642.5	550.0	445.0	100.0	490.0	1018	<0.0001
Sediment concentration(g L^{-1})	11.5	5.6	18.1	9.6	3.3	1.37	0.4314
Total soil loss (g m^{-2} h^{-1})	51.5	35.2	119.6	35.0	32.3	2.14	0.0874

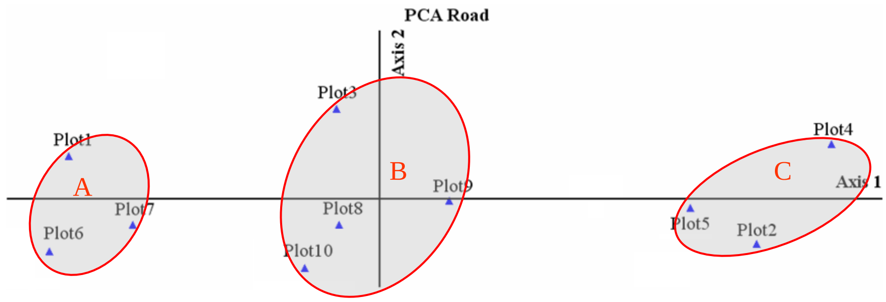

Figure 5. PCA analysis of soil on road surface.

Table 9. Characteristics of the soil groups in road surface.

Soil groups	Moisture (%)	Organic matter (%)	$CaCO_3$ (%)	Clay (%)	Silt (%)	Sand (%)
A	7.3±0.6	0.8±0.1	36.0±1.4	23.8±1.7	21.9±3.8	54.3±4.0
B	6.2±0.5	0.9±0.0	41.9±1.7	19.5±1.5	16.9±2.6	63.5±2.9
C	5.0±0.0	1.0±0.1	48.9±3.8	14.1±2.3	11.0±2.9	74.8±3.5

Table 10. Effect of soil groups on runoff and sedimentation from road surface.

Soil groups / Variables	A	B	C	ANOVA, *p*
Runoff coefficient (%)	75.04^{A}	74.41^{A}	36.68^{B}	<0.0001
Time to runoff (s)	53.67^{B}	58.50^{B}	104.00^{A}	<0.0001
Sediment concentration (g L^{-1})	7.34^{A}	7.26^{A}	6.98^{A}	0.7589
Total soil loss (g m^{-2} h^{-1})	168.55^{A}	171.46^{A}	85.70^{B}	0.0012

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls Test, Alpha=0.05.

On road surface, the highest soil loss was detected for soil group A, where sediment concentration in runoff was 8.99 g L^{-1} and vegetation cover was 2 to 5% (Table 12).

Conclusions

Soil properties and vegetation cover are two effective factors on sediment yield from different parts of forest road. In this study it was concluded that the runoff and soil loss was more in soils which had high content of silt and clay. The maximum sedimentation and soil loss from cutslope was observed in soil group B due to high moisture and low bulk density. In fillslope, minimum sedimentation and soil loss was detected in soil group B, because high content of sand and $CaCO_3$ in this group. This finding was also observed for road surface and forest ground in soil group C and A, respectively. It is possible to repair cut and fillslopes with revegetation methods. Moreover, soil properties can be improved

Table 11. Effect of vegetation cover on runoff and sedimentation of road surface.

Vegetation cover / Variables	2-5%	5-8%	ANOVA, *p*
Runoff coefficient (%)	69.15^{A}	59.36^{B}	0.0214
Time to runoff (s)	48.00^{B}	85.83^{A}	<0.0001
Sediment concentration (g L^{-1})	6.86^{A}	7.43^{A}	0.6514
Total soil loss (g m^{-2} h^{-1})	148.64^{A}	142.34^{A}	0.9371

In a row, means with the same letter are not significantly different based on Student-Newman-Keuls test, Alpha=0.05.

Table 12. Interaction of soil and vegetation cover on runoff and sedimentation from road.

Soil groups	A		B		C		ANOVA, *p*
Plant cover (%)	2-5	5-8	2-5	5-8	2-5	5-8	
Runoff coefficient (%)	70.9	77.1	78.9	72.9	43.6	33.2	0.8116
Time to runoff (s)	61.0	50.0	34.0	66.7	58.0	127.0	<0.0001
Sediment concentration (g l^{-1})	8.9	6.5	5.9	7.7	8.3	6.3	0.1607
Total soil loss (g m^{-2} h^{-1})	191.4	157.1	149.7	178.7	130.6	63.3	0.0344

through mulching, hydro-seeding and etc.

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Full Length Research Paper

The influences of forest fire on the vegetation and some soil properties of a savanna ecosystem in Nigeria

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The effect of forest fire on natural forest in Southern Guinea Savanna in Nigeria was investigated. The study was carried out in Oro forest reserve in Kwara State, Nigeria. The study site was located in the north-eastern and south-western portions of the reserve. In each location in the forest, one hectare (100 m × 100 m) was divided into 100 plots of 10 m × 10 m. Twenty plots were randomly selected for determining the frequency of burned trees, re-sprouted trees and the numbers of seedling/ha. Soil samples were also collected at three depths: 0 - 5, 6 - 10, 11 - 15 and 16 - 20 cm. Soil samples were taken before burning and one year after burning. The effect of fire on tree species recovery showed that regeneration of *Byrsicarpus coccineus*, *Grewia mollis* and *Butyrospermum Paradoxium* were very encouraging in the burned area. In contrast, *Adenodolichos peniculatus, Fadogia pobegunii* and *Terminalia aviceniodes* were very sensitive to fire as they failed to regenerate or poorly reproduced in the burned area. Fire had no effect on soil texture except 0 - 5 cm. Soil pH significantly increased available phosphorus increased significantly, whereas, soil organic matter, available acidity and total nitrogen significantly decreased in the burned area. Also, metallic cations (Ca, Mg, K) and cation exchange capacity increased in the burned area. These changes were related primarily to oxidation of the organic matter layer during fire and concurrent changes in the soil environment following fire (e.g. a reduction in organic matter content of the soil, and increased soil pH).

Key words: Guinea Savanna, soil properties, forest fire, Regeneration, *Byrsicarpus cocineus, Adenodolichos peniculatus.*

INTRODUCTION

Fire is an important natural disturbance in most forest ecosystems and can lead to rapid changes in soil and biogeochemical cycling, which, in turn can have important implications for long-term ecosystem dynamics (Schmoldt et al., 1999). Fire resulted in disturbance of many forest lands depending on its severity and forest composition also; severity and extent of forest fires had a significant effect on seeds regeneration (Lecomte et al., 2005). On the other hand, fire modifies the ecosystem for short, long term and some biota may be adapted to these changes in the ecosystem (Rydgren et al., 2004). In many instances, fire may used for forest management purposes e.g.

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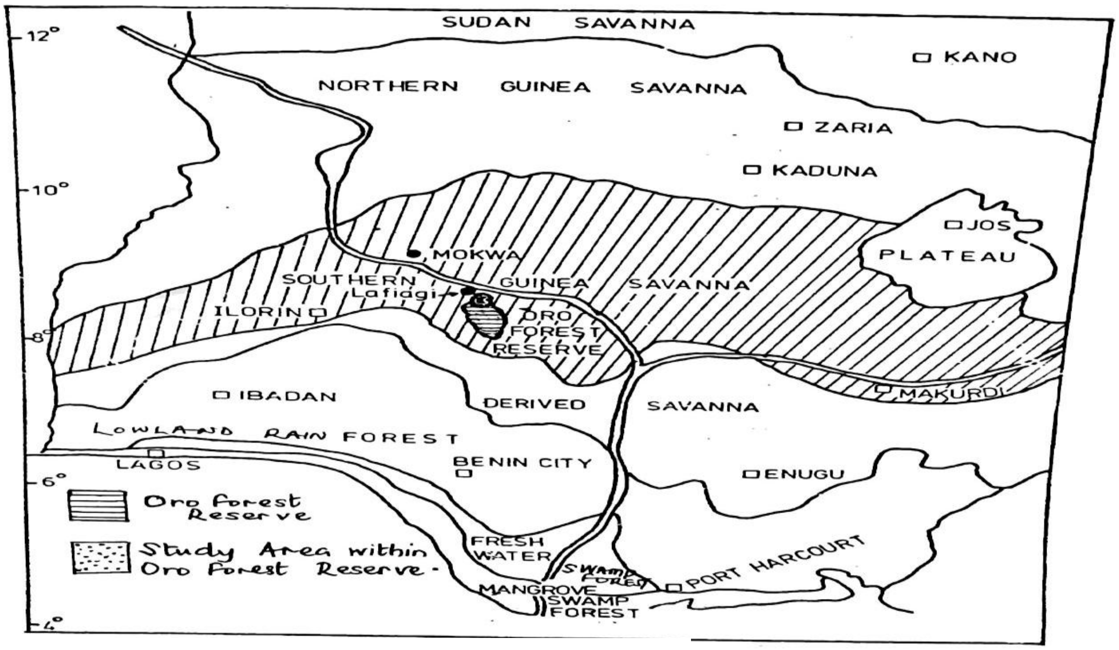

Figure 1. The location of Oro Forest Reserve within the Southern Guinea Savana of Nigeria.

prescribed burning (Bergeron et al., 2002). Basically, there are two types of forest fires, prescribed (controlled) fires and wildfires. Prescribed burning of naturally accumulated forest floor or slash following tree harvest is a standard practiced to reduce fuel levels with the intention of minimizing the extent and severity of wildfire or facilitating germination and growth of desired forest species. They are carried out when soil is moderatelymoist and thereby show a low level of severity (Wasterd et al., 1990).

It has been stated that logging after fire might have a considerable long term effect on vegetation and diversity in natural forest (Fraser et al., 2004). Spatial fire distribution has been widely used to categorize fire regime (Cui and Perera, 2008). Savanna ecosystems are characterized by the co-existence of carbon rich woody and carbon poor herbaceous plants dominated by grasses. Savannas occur in over 20 countries mostly in the seasonal tropics Nigerian inclusive with a limited distribution in temperate regions (Hutley and Setterfield, 2007).

Frequent and severe fires commonly result in degradation of soil (Anderson et al., 1981) forest fires threatened wild endangered species in Indonesia (Whitehouse and Mulyana, 2004). Fire is capable of exerting serious effects on soil properties (Giacomo, 2005). However, scarcity information is available on the influences of savanna burning on the vegetation and soil properties of southern Guinea savanna zone in Nigeria.

The objective of this study was to investigate the impact of forest fire on tree diversity and its effects on some soil physicochemical properties in the southern Guinea savanna vegetation of Oro forest reserve located in the southern Guinea savanna zone of Nigeria.

MATERIALS AND METHODS

The field studies were carried out in 2010 at Oro Forest Reserve in Kwara State Nigeria at longitude 08°53^{1}E and latitude 05°22^{1}N. The reserve is a wood land Savanna of about 5413 ha. The study site was located in the north-eastern and south-western portion of the reserve (Figure 1).

Plot description and samples collection

In each location in the forest, one hectare (100 m × 100 m) was divided into 100 plots of 10 m × 10 m. Twenty plots were chosen for determining the frequency of burned trees, re-sprouted trees and the numbers of seedling/ha. The frequency and numbers of trees before and after were determined in each sample plot using quadrant. Soil samples were also collected at three depths: 0-5, 6-10 and 11-15 and 16-20 cm. Soil samples were taking before burning and one year after burning by wild fire.

A Dutch auger was used to collect soil sample which were carefully kept in well labeled plastic bags and sent immediately to Laboratory for analysis.

Particle size analysis

This was done by hydrometer method (Gee and Bauder, 1986) using sodium haxametaphosphate (calgon) as dispensing agent.

Chemical analysis

The soil samples were dried for few days sieved to pass through 2 mm mesh and chemically analysed. The pH (in water) was

Table 1. Site plant community in the study area.

Species	Density/ha	Rank	Relative density (%)
Acadia nigrescan	17.25	13	1.5
Annona Senegalensis	5.75	19	0.5
Bridelia scleroneura	17.25	13	1.5
Bridelia stenocarpa	46.01	8	4.00
Butyrospermum paradoxum	143.77	3	12.50
Combretum collinumfresen	80.51	4	7.00
Daniellia oliveri	11.50	16	1.00
Detarium microcarpum	230.03	1	20.00
Ficus ingnens	5.75	19	0.50
Grewia mollis	184.03	2	16.00
Lannea kerstingii	5.75	19	0.5
Maytenus senegalensis	11.50	16	1.00
Prosopis africana	5.75	19	0.50

Table 2. Population dynamics of selected species of regenerating plants in permanent quadrant.

Species	Population sizes												
	J	F	M	A	M	J	J	A	S	O	N	D	J
Adenodolichos Paniculatus	25	26	35	30	30	28	26	26	22	20	16	10	0
B. paradoxum	89	97	109	105	75	75	75	24	72	72	70	68	4
Byrscarpus coccineus	115	123	122	101	166	154	142	35	25	15	12	7	0
D. microcapum	40	39	42	33	39	33	33	36	23	20	15	10	5
Fadogia pobeguinii	15	18	20	20	22	18	18	18	14	14	14	6	4
G. mollis	80	82	79	57	68	60	56	58	56	50	40	38	5
M. seregalansis	54	58	56	41	55	44	42	45	30	25	22	10	2
Terminalia aricenioides	48	51	57	44	60	54	52	51	52	42	40	28	2
Piliostigma thonningii	48	46	48	43	42	40	35	33	32	25	22	20	4
Total species	514	540	568	474	556	512	474	362	323	278	251	177	26

determined in a 1:2.5 solution (soil: distilled water) and was measured with a standard glass electrode. The organic carbon content of the soil was determined according to Walkley and Black (1965) dichromate oxidation method. The percentage organic matter content in the samples was calculated by multiplying the values of organic carbon by the conventional Van Bammeller factor of 1.724. Total soil nitrogen was determined by Macro kjeldahl methods (Bremner, 1965). Available phosphorus was extracted using Bray II method (Bray and Kurtz, 1965) and determined by spectrophotometer.

Exchangeable Na, K, Ca and Mg were extracted with $BaCl_2$ 0.1 M (Hendershot, et al., 1993) and analysed by atomic absorption. Exchangeable acidity was determined from 0.1 NaCl extracts and titrated with 1.0 N HCl.

Cation exchangeable capacity (CEC) was determined by summing up total exchangeable bases (TEBS) and total exchangeable acidity (TEA), which the base saturation = TEB/CEC × 100, where TEB = Total exchangeable bases, and CEC = Cations Exchangeable capacity.

Statistical analysis

The data were analyzed using two way analysis of variance (ANOVA) and means were separated by Duncan New Multiple Range Test and student t- test was used to test the level of significance of some properties in the pre and post burn periods at 5% level.

RESULTS

Burning and regeneration

In the study area, Detarium microcarpum had the highest density/ha of 230.03 and relative density of 20.00, while Annona selegalensis, Ficus ingnens, Lannea kerstingii and Prosopis africana had the least density/ha with relative density of 0.5 (Table 1).

It is apparent that *Adenodolrchios peniculatus* and *Byrsicarpus coccinetts* were most susceptible to forest fire. This is evident in the number of re-spouting of trees which were reduced to 0.0% (Table 2). However, fire also triggered–off regeneration more in *Brysicarpus coccineus*, followed by *Butyrospermum paradoxum* than any other species in the in the study area (Table 2).

The forest fire annually occurs between November and

Table 3. Effect of fire on soil texture.

Vegetation	Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)
Southern guinea savanna	0 -5	82.30^{a}	9.36^{a}	8.35^{a}
	6 - 10	84.90^{a}	7.30^{a}	7.80^{ab}
Before burning	11 -15	82.75^{a}	9.73^{b}	7.53^{ab}
	16 - 20	85.43^{a}	7.40^{a}	7.53^{ab}
After burning	0 - 5	83.31^{b}	10.37^{ab}	6.26^{b}c
	6 - 10	84.90^{a}	8.37^{ab}	6.73^{b}c
	11 - 15	82.75^{a}	9.73^{b}	7.53^{ab}
	16 - 20	85.43^{a}	7.80^{a}	7.53^{ab}

Means followed by the same letter in a column in a forest are not significantly different at P ≤ 0.05.

January. The most resistant tree species are *Detarium microcarpum and Fodogia probeguinic* which reduced from 10 to 5 and 6 to 4 respectively. It is also noted that fire did not affect them in term of regeneration.

Soil texture

Fire did not affect soil texture at the level below 5 cm. However, effect of fire was found in the top layer (0-5 cm). This was indicated by the fact that sand, silt and clay (%) were not different when compared together at the sampling level below 5-10, 10-15 and 15–20 cm in unburned and burned sites (Table 3)

Soil pH, soil organic matter and soil N

Soil pH increased significantly ($p \leq 0.05$) from 5.0 to 6.3 at 0 - 10 cm depth and 5.7 to 6.2 to 6.3 at 11 - 20 cm depth for both pre-burn and post – burned plots, soil pH was lower at 10 - 20 cm depth. The values were statistically different at both sampling depths (Table 5). The soil nitrogen was lower in the post-burned plots with the values decreased from 0.09 to 0.05% at 0 - 10 cm depths. While the values decreased from 0.07 to 0.04% at 10 - 20 cm sampling depths ($P \leq 0.05$). It was also noted that, the values of soil nitrogen was lower at 10 – 20 cm depth.

Available phosphorus

Available phosphorus was higher in post-burned plots at all sampling depths and increased from 12.01 to 22.50 mg/kg at 0 - 10 cm depth. At 10 - 20 cm depth, it increased from 11.4 to 21.5 mg/kg, (Tables 4 and 5).

Exchanged cations, aluminum and cation exchange capacity

Exchangeable calcium was significantly ($P<0.05$) higher in the post-burned plots at all sampling depths and increased from 3.90 cmol/ kg of soil to 4.20 cmol/kg of soil at 0 - 10 cm depth, the values increased from 1.41 cmol/kg of soil to 2.42 cmol/kg of soil at 10 - 20 cm depths and was statistically different (Tables 4 and 5). Exchangeable magnesium was also higher in the post burned plots in all sampling depths and not significantly different and increased from 1.20 cmol/kg of soil to 2.95 cmol/kg of soil at 0-10 cm depth. While at 10-20 cm depth, it increased from 1.0 cmol/kg of soil to 1.80 cmol/kg of soil. Exchangeable potassium values did not show any significant different in all the sampling depths and but higher in the post-burned plots. Exchangeable aluminum decreased from 2.5 cmol/kg of soil to 1.5 cmol/kg of soil at 0 - 10 cm depth and decreased from 0.30 cmol/kg of soil to 0.15 cmol/kg of soil at 10 - 20 cm depth and did not statistically different (Table 5).

The cation exchangeable capacity increased from 11.10 cmol/kg of soil to 12.65 cmol/kg of soil after fire at 0 - 10 cm depth as well as, increased from 3.16 cmol/kg of soil to 4.97 cmol/kg of soil after fire at 10 - 20 cm depth.

DISCUSSION

Very sketchy studies have investigated factors that affect tropical savanna forest (Sukumar et al., 2005). Climate change, animals and fire are some factors that affected vegetation dynamics in those ecosystems (Silori and Mishra, 2001). As forest fire could be useful or destructive to the forest, while tree species vary in their responses to forest fires. Prescribed fire may play an important role in sustainable management of forest subjected to wild fires (Matthias et al., 2009). *B. coccineus* benefited from fire, as was indicated by the substantial increase of regeneration and the fact that considerable number of B*. coccineus, Grawia mollis* as well as *B. paradoxium* responded after fire (Table 2). Hein et al. (2010) mentioned that in mixed forests, the probability is low for succession after fire. In hard seeded legume, heat from fire may break the hard seed coat and

Table 4. Comparison of the pre and post burning soil chemical properties at 0-10cm depth by student's t-test.

Properties	Pre-burning	Post-burning	t-test values
pH	5.9	6.3	2.94*
OC	0.8	0.58	2.34*
OM	1.38	0.8	2.36*
N	0.09	0.05	2.44*
C/N	0.6	0.69	2.31*
Ex. Ca	3.9	4.2	2.80*
Ex. Mg	1.20	2.95	1.02^{ns}
Ex. K	3.5	4.00	1.20^{ns}
Ex.A1	2.5	1.5	0.67^{ns}
CEC	11.10	12.65	0.91^{ns}
Av. P	12.01	22.5	2.12*

*Significant at ($p \leq 0.05$), ns = not significant at ($p \leq 0.05$), OC = organic carbon, OM = organic matter, Ex. Ca = exchange calcium, Ex. Mg = exchange magnesium, Ex. K = Exchange potassium and CEC = cation exchange capacity.

Table 5. Comparison of the pre and post burning soil chemical properties at 0-20 cm depth by student's t-test.

Properties	Pre-burning	Post-burning	t-test values
pH	5.2	6.2	2.55*
OC	0.7	0.4	2.4*
OM	1.21	0.69	2.28*
N	0.07	0.04	2.24*
C/N	6.2	5.5	2.15*
Ex. Ca	1.41	2.42	2.11*
Ex. Mg	1.0	1.8	1.15^{ns}
Ex. K	0.45	0.60	0.91^{ns}
Ex.A1	0.30	0.15	1.11^{ns}
CEC	3.16	4.97	1.04^{ns}
Av. p	11.4	21.5	2.24*

*Significant at ($p \leq 0.05$), ns = not significant at ($p \leq 0.05$), OC = organic carbon, OM = organic matter, Ex. Ca = exchange calcium, Ex. Mg = exchange magnesium, Ex. K = Exchange potassium and CEC = cation exchange capacity.

allow water absorption by the seeds and hence dormancy is broken (Mbalo and Witkowski, 1997). Removal of stem tips and young leaves by fires, for instance, may allow dormant buds to develop into new shoots. In appears that the presence of *B. coccineus, G. mollis, B. paradixium* and *Maytenus senegalensis* in fire prone ecosystem, as the case in the present study, facilitated its adaptation to fire in various ways including thickening of bark, ability to respond and dispersing of seeds. Hare (1965) mentioned that some trees have thick insulating bark, which protected them from the scorching heat of surface fires. In contrast, *Adenodolichos peniculatus*, *Fadogia pobeguinii* and *Terminalia avicenioides* in the present study, were very sensitive to forest fire since they failed to regenerate or poorly recovered in the burnt soils, *Detarium microcaupum* and *Piliostigma thonningii* were more or less negatively sensitive to fire in terms of regeneration and recovery after forest fire. Species diversity was considerably affected by forest fires, although this effect dependent on the severity of fire (Kodandapani et al., 2008).

Fire has no significant effect on soil texture in the studied locations. However sand content increased in the post-burned plots at the 0-5cm depth which might be due to destruction of soil organic matter. Soil pH increased significantly after fire in all locations studied. This finding is in line with the earlier studies (Creighton and Santelies, 2003; Ekinci, 2006). Giacomo (2005) reported that soil pH in non-calcareous soils increased after fire because of the release of the alkaline cations (Ca,Mg,K and Na) bound to the organic matter sites and a decreased in organic acids produced during the biological oxidation of organic matter (Wells, 1971).One pertinent implication of increased pH in the burned soils is the possibility of increasing nitrogen fixation under environmental conditions favouring both symbiotic and free-living nitrogen fixers.

The loss of soil organic matter represent one of the more obvious alteration to soil physical properties after a fire, significant reductions in soil organic matter were recorded in all locations studied during post-burned. The effect of fire on organic matter comprises volatilization, charring or oxidation (Giovannini et al., 1988). Fire causes burning and or total removal of organic matter (Simard et al., 2001). The decreased levels of soil organic matter observed in the burned plots in this study suggest important ramifications for other soil biological, chemical and physical properties. However, it is not likely that litter fall rates in post-burned forests will approximate those on pre-burned sites for sometimes and thus, soil organic matter content in post-burned plots will more than likely remain low for sometimes period. There was a significant reduction in total soil nitrogen after fire at all sampling depths in the study locations, which is in agreement with Neff et al. (2005). Forest floor layers are a major reservoir of soil N and their removal during forest fires can cause significant reductions in it (Driscoll et al., 1999). A likely explanation for decreased soil nitrogen in the post burning plots is through increased leaching of NO_2 during the rainy season that is characteristic of this area. Consumption of the litter layer during fire likely leads to increased infiltration rates for burned soils in rainy season, than in turn could lead to increased leaching of nitrogen in the form of NO_2.

Significant increase in phosphorus might be attributed to the fact that burning coverts some of the organic pool of soil P to orthophosphate (Cade-Menun et al., 2000). Also, at a large portion of the nutrient reserve in most forest ecosystems is contained in the organic material on the forest floor and that distributed throughout the profile (Wagner and Wolf, 1998). Nutrients contained in these organic materials are slowly released into the soil though biological oxidation is decomposition (Fuhrmann, 1998).

Exchangeable cation such as Ca, Mg and K were higher after fire, which is in agreement with Adams and Boyle (1980) who reported increase in alkaline cations after fire. Exchangeable aluminum was lower in the post-burned soil due to the conversion of aluminum into complex oxides, thereby reduces soil acidity after fire.

Conclusion

The present study revealed that fire encourages fire tolerant tree species and discouraged fire sensitive species as reported by Ivanauskas et al. (2003). *D.* microcarpum and *F. pobeguinic* have relatively thick and fissured barks and this might explain their resistance to fire relatively to *A. peniculatus* and *B. caccineus* which have relatively thin barks, probably the reason for their susceptible to fire. Effects of wild fire on soil properties in this highly fragmented ecosystem are not well conceived. Data from this study suggest soil properties vary in their response to fire; soil pH and available phosphorus were higher following fire. In the same vein, exchangeable cations such as Ca, Mg and K were more at post fire while the exchangeable acidity became low during post-fire period, changes in soil properties were more than likely a result of the oxidation of the litter layer during the fire and concurrent changes in the soil environment following the fire. Nitrogen content decrease was due to leaching of NO_3 while phosphorus increase might be due to changing of organic phosphorus to the available form. Organic matter content of the soils was lower in post-fire plots due to the destruction of organic layer in the forest. The savanna burning in Nigeria southern Guinea savanna is annual one, which is used as a cheaper means of land clearing for planting seasons. However, we found that fire can significantly affect some soil chemical and physical properties as well as plant species composition (Litton and Santelices, 2002), in these native forests. In light of these discoveries, we recommend that more emphasis should be placed on preventing and fighting human caused fires in native vegetation, aggressive public awareness on the effect of forest fire and fire breaks should be established around native forest to prevent further degradation of this ecosystem. In addition, further research is needed on long term effects of fire on Guinea savanna in Nigeria.

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