EFFECT OF THE SEASONAL BURNING ON TREE SPECIES IN THE GUINEA SAVANNA WOODLAND, GHANA: IMPLICATIONS FOR CLIMATE CHANGE MITIGATION

AMOAKO, E. E.[1*] – MISANA, S.[2] – KRANJAC-BERISAVLJEVIC, G.[1] – ZIZINGA, A.[3] – BALLU DUWIEJA, A.[1]

[1]*Department of Ecotourism & Environmental Management University for Development Studies P.O. Box 1882 Tamale, Ghana*

[2]*Department of Geography, University of Dar es Salaam, Tanzania*

[3]*College of Agriculture and Environment Sciences, Makerere University, Uganda*

**Corresponding author*
e-mail: eamoako@uds.edu.gh

(Received 6th Oct 2016; accepted 7th Mar 2018)

Abstract. The indiscriminate burning of vegetation is a common practice in the Guinea savanna of Ghana. Burning begins at the onset of the dry season (November) and lasts until the end (April). This study investigated the effects of time of burning on tree diversity and density in the Mole National Park, Ghana. A total of 36 (10 m x 10 m) quadrats were randomly demarcated in three treatments of early and late dry season burning and non-burning study plots. Samples were taken in March, a few weeks after the late burning period. Twenty seven different species belonging to fourteen families were recorded in all the treatments. Most of the species identified belonged to the families *Combretaceae, Fabaceae* and *Leguminoceae*. *Vitellaria paradoxa, Terminalia avicennioides, Combretum adenogonium* and *Combretum molle* were the most common and abundant in all treatments. Late burning plots recorded the lowest diversity amongst the three treatments. Non-burning plots had higher tree density than burnt plots. Early burning treatment recorded more diverse individual species but had the lowest density. Higher tree densities would enhance carbon sequestration. However, ecosystem resilience is also dependent on the diversity of biotic communities among other factors. Sustainable land use practices including protections of trees on farms and prescribed early dry season burns could be an option to contribute to the mitigation of climate change in the region. Late dry season fires are a threat to tree species populations and should be discouraged.
Keywords: *burning frequency, species composition, Guinea savanna, Mole National Park*

Introduction

Savannas are known to support a large number of plant species with usually only one or a few kinds of grass and some common tree species (Scholes & Walker, 1993; Burgess, 1995). Anthropogenic disturbance including the use of fire is an important driver of vegetation types and diversity in the savanna (Sheuyange et al, 2005; Andersen et al, 2012). To a large extent, however, most savanna species have adapted different mechanisms to survive persistent fires, which include developing fire-resistant barks, roots that grow deeply into the ground and growing dormant buds. Thus, African savannas have been influenced by fire and have adapted to it over long periods of time. (Trollope, 1984; Beringer et al., 2007; Van Wilgen, 2009).

Fire is used by most rural dwellers in savannas to stimulate the growth of fresh forage for animals, for the tapping of honey and the hunting of animals. Fire is also used with the aim of minimising labour cost on land preparation and to increase agricultural production and productivity. It is used frequently and extensively by groups as well as

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

individuals for hunting, compared to the other methods of hunting. Vast areas are burnt through these activities, thus affecting the main sources of livelihood for local people (Eriksen, 2007; Adongo et al., 2012).The savanna ecological zones (Guinea, Sudan and Coastal Savanna) of Ghana, cover about two-thirds of the country (Bagamsah, 2005; Armah et al., 2011). They are characterised by scattered trees and shrubs usually interspersed with arable crops and referred to as 'agroforestry parklands' (Callo-Concha et al., 2013; Sinare and Gordon, 2015). A bulk of annual crops such as cereals, legumes, yam, as well as livestock are produced here, mainly for household consumption and for the local market and these are often the very drivers for the annual practice of bush burning in these ecoregions.

The Northern Region of Ghana contains about 50% of all the savanna areas in the country and has recorded higher occurrences of fires (40-80%) in the last 40 years, compared to all the other regions of Ghana (Korem 2005; Amanor, 2002; Kugbe et al., 2012). The frequent and uncontrolled fires may influence plant diversity and densities in the already sparsely populated tree ecosystems (Andersen and Williams, 2012). Consequently, this could exacerbate the impact of land degradation on ecosystems, which are already characterised by prolonged drought spells such as the Guinea and Sudan Savanna zones of Ghana. Some studies (Thonicke et al., 2000; Andersen et al., 2012) have shown that ecosystem degradation reduces carbon sequestration and thus may turn carbon sinks to sources thereby exacerbating the impacts of climate change in the region. Although fires rarely kill large trees, many other life forms are significantly affected. Saplings and some grass species may die as a result (Trollope, 1984).

However, fires are purported to break dormancy of some plant species source which results into enhancing the recruitment of many other species with different traits that might be adaptive in fire-prone environments (Auld and Bradstock, 1996). Fire is also reported to be effective in the elimination of competing plants and improving habitats (Denslow, 2002). However, fire has differential impacts on landscapes within savannas due to differences in factors such as ground water content, topography and plant type (Sheuyange and Weladji, 2005). Thus late season fires may be detrimental to some plant species and may cause the extinction of some plants. Slash and burn has been reported to affect the recovery and succession of species. Although fires are purported to be an indispensable tool for managing savanna ecosystems, including grassland and rangeland vegetation quality and monitoring, the influence of fire on plant species density and diversity still need to be studied further. This is because the regime of burning or non-burning has influence on tree populations and diversity, which is a major determinant of the health of terrestrial ecosystems (Brookman-Amissah et al., 1980; Kutiel, 1997).

The time of ignition of fire during the long period of drought in the savanna may have serious ecological implications on all life forms, particularly on plant species. The explicit role of the time and frequency of burning or non-burning in savanna ecosystem management is very significant in this regard. However, very few studies have been conducted on how the time of burning influences species composition in the savannas of Ghana. Some studies have shown that the frequency at which the vegetation is burnt determines the species that dominates a plant community but not the time of burning (Brookman-Amissah et al., 1980; Sackey and Hale, 2008). Sheunyang et al. (2005), argued that fires decreased shrub species richness, but positively influenced tree species richness. The study further showed that different plant species responded to fire differently. Thus, different fire regimes may favour the growth of different plant species

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

or gradually cause in the extinction of some plants (Myers et al., 2004; Penman, Binns and Kavanagh, 2007). The season of burning might affect different species differently.

This study, therefore, was conducted to investigate the effect of the time of burning on abundance and species diversity of trees. The assumption was that the time of burning in the dry season influences the composition of tree species in the Guinea savanna ecosystem of the Northern region of Ghana. We hypothesized that the time and frequency of burning does affect species composition. The paper also discusses the implication of tree species abundance and diversity for climate change mitigation.

Materials and methods

Study area

The study was conducted on study plots in the Mole National Park (Latitude 9°12' - 10°06' N; Longitude 1°25' - 2°17 'W with an elevation of 150m). The Park is 484.4 sq km and located in the West Gonja District of Northern Region of Ghana. It contains a wide variety of ungulates (Waterbucks, Hippos, Bushbuck Duikers, Warthogs, Elephants) birds and tree species. The park has a total of 32 fringe communities.

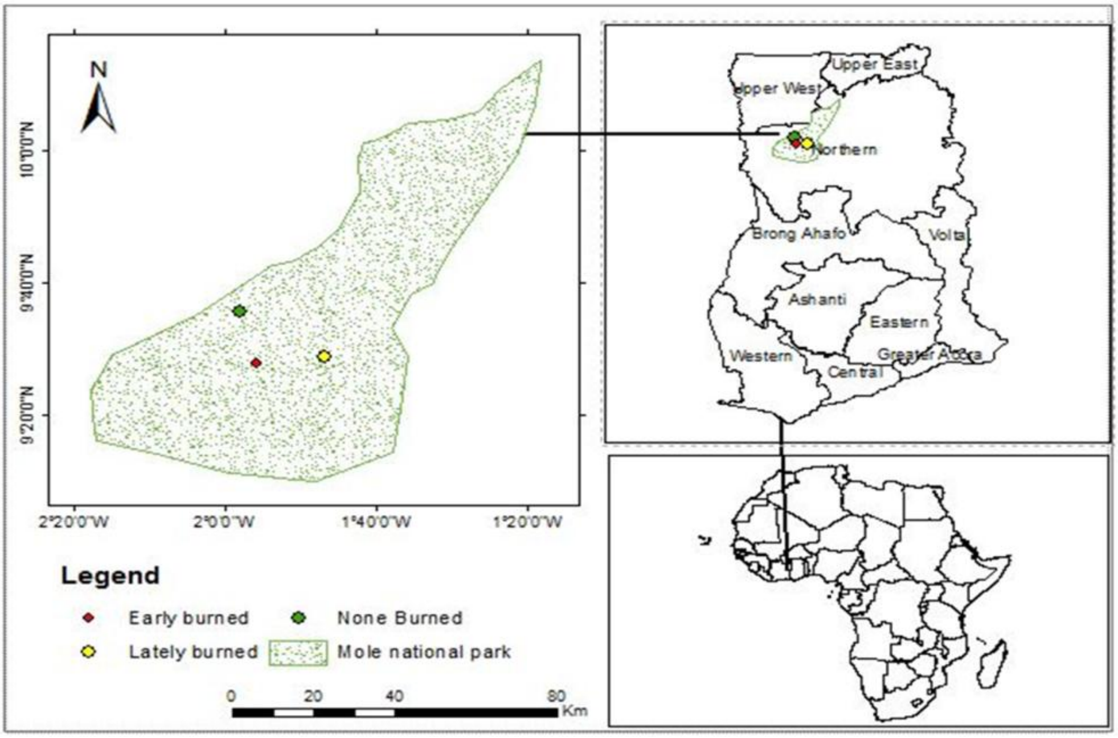

Figure 1. *Location of the study: Mole National Park, Northern region, Ghana (Created by Hadgu Hishe, 2015)*

The climate is semi-arid and sub-humid with a unimodal rainfall distribution. The rainy season begins in May and ends in October with a mean monthly rainfall ranging from 900 mm to 1000 mm during the peak between July and September (Boubacar et al., 2005).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

The vegetation is Guinea savanna characterized by drought resistant woody species such as *Vitellaria spp, Combretum spp, Burkea spp, and Isoberlinia spp.* The Guinea savanna occupies about 60 % total land area of the Northern Savanna zone.

The soils are laterite concrete formations of granite, votaian shale and sandstones. They are comparatively low in organic matter, with low moisture content as a result of their high drainage characteristics than soils in southern Ghana (Mikkelsen and Langohr, 1998; Owusu-Bennoah et al., 1991).

The region experiences long periods of drought from November to April with little or no rainfall. Maximum temperatures typically 40 °C occur towards the end of the dry season and minimum temperatures in December and January, with a mean annual temperature of 27 °C. The Harmattan winds, which occur during the months of December to early February, have a considerable effect on the temperatures in the region, which may vary between 14 °C at night and 40 °C during the day (Siaw, 2001). These dry conditions and the strong Harmattan winds facilitate vegetation burning.

Data collection and analysis

Information on vegetation burning as obtained from the Faculty of Renewable Natural Resources, University for Development Studies and the Management of the Mole National Park indicated that smaller portions in the Park are demarcated for early burning, late burning and non-burning for study purposes for the Natural Resource Management students at the University for Development Studies and the Kwame Nkrumah University of Science and Technology in Ghana.

Burning is prescribed in the Park for both late and early dry season burn, firstly, to prevent the vegetation from transitioning into thickets or closed woodland which may not be favorable for the variety of animals that inhabit the Park and also to stimulate more grass growth for the animals so that animals in the Park do not stray into the fringe communities.

Tree sampling was carried out in plots exposed to early burning (EB), late burning (LB) - and non-burning (NB). The plots were demarcated in 1994 in areas that were already subjected to prescribed early burning and late and non-burning. An area within the Mole Park was excluded from burning for study purposes. This was made possible because the area is bounded by roads, which serve as fire breaks. The early season burns are carried out between November and December, depending on the time the rains end, whereas the late dry season burning is carried out towards the end of February up to the ending of March. The map below indicates areas that are burnt early and late within the park. The non-burning area is not indicated on the map below, because it is a relatively small portion of land located behind the Park headquarters meant for study purpose, otherwise the whole park experiences some form of burning within the year.

Sampling of tree species was conducted to examine the impact of early season (November-January) late season (February-April) and non-burning regimes on tree diversity and densities. A total of 36 quadrats were laid in the three (200 m by 200 m) plots. Three (10 m x10 m) quadrats were located randomly within 4 (50 m by 50 m) subplots in each plot, about 50 m away from the plot boundaries to reduce edge effects. Trees of diameter at breast height >3 cm and height > 0.5 m tall were identified by their scientific names in each quadrat. This was done with the assistance of Warden, who has been working in the park for over 30 years. The numbers of species identified in quadrat was also recorded.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

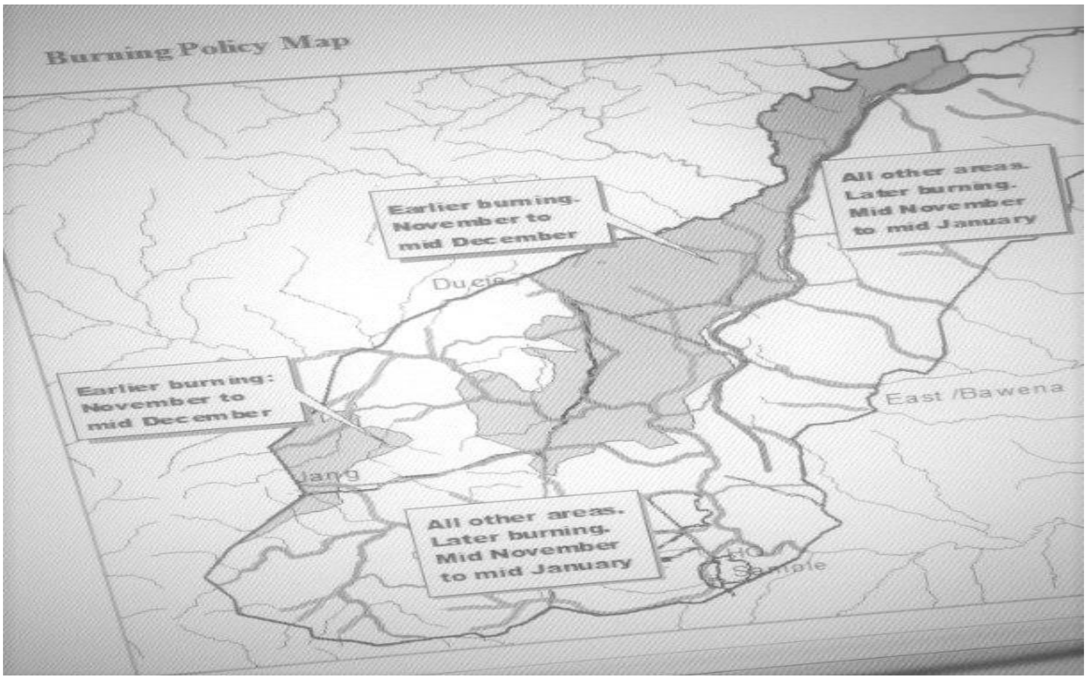

Figure 2. *Fire management plan, Mole National Park (Source: Mole National Park Management, 2017)*

A Geographical Positioning System was used to obtain the coordinates of location of treatment plots. EB (9°16'15.30"N, 1°51'02.90"W), LB (9°17'02.36"N, 1°49'08.11"W), NB (9°'15 40.20"N, 1°51'10.18"W). Sampling was done between 27th and 28th March 2015 and 29 and 1 April 2017, a few weeks after the late season burning.

The data collected on tree census in late burning, early burning, and non-burnt plots were extrapolated to a hectare as a measure of density per treatment. This was carried out to determine the influence of fire on tree population. Data was statistically analysed using GraphPad Instat 3 which tested for normality using Kolmogorov Smirnov and analysed the significance using Kruskal-Wallis. The means, standard deviation and frequencies of species were calculated in Microsoft Excel to compare the presence, abundance and composition of species in the treatments.

Results

The result of species frequency and tree density estimates are shown in *Table 1* below. The data did not pass a normality test. A non-parametric statistics test (Kruskal Wallis) was used to compare the mean between treatments. A *post hoc* was not performed, p=0.99.

Twenty seven different species, belonging to 14 families were identified in all the three treatments. Seven species were found common all the treatments (EB, LB and NB). Generally, species that recorded relatively higher (pooled) frequencies belong to *Combretaceae, Leguminoceae Sapotaceae Celastraceae, Meliaceae* and *Rubiaceae* whilest those occurring in low frequencies belonged to *Anacardiaceae, Olacaceae, Ebenaceae, Moraceae, Bixaceae, Phyllanthaceae*, and *Asparagaceae* (*Table 2*). *Combretaceae* had a higher occurrence of individual species (*Terminalia avicennioides*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

Guill. & Perr, *Combretum molle* R.Br. ex G.Don, *Combretum adenogonium* Steud. Ex A. Rich) and were more common to all treatments (*Fig. 3*) than species of the other families.

Seven species, including *Diospyros mespiliformis* Hochst. ex A. DC were found to be common in early season burning and non-burning treatments. *Anogeissus leiocarpa* (DC.) Guill. & Perr. was found in non-burning and late burning treatments. *Pterocarpus erinaceus* Poir., *Combretum nigrican* Lepr. ex Guill. & Perr, *Trichilia rubescens* Oliv. were found common in early burning and late burning treatments.

Some species were exclusive to the different burning treatments. These species were, however, relatively low in frequencies (*Table 2*). *Ditarium microcarpum Guill. & Perr Detarium microcarpa and Isoberlinia doka Craib* & Stapf. and *Pteleopsis suberosa* Engl. & Diels were present in early burning treatment only. *Chochlospermum angolense, Daniellia Oliveri and Ficus glumosas* Delile, *and Anacardium occidentale* were in late season burning treatment only. *Dracaena* species and *Pseudocedrela kotschyi* (Schweinf.) were identified in non-burning treatments only. *Vitellaria paradoxa* C. F. Gaertn was present in all treatments, with the highest frequency in non-burning treatment. All other species identified in non-burning treatment plots were also present in early burning and late burning plots (*Fig. 3*).

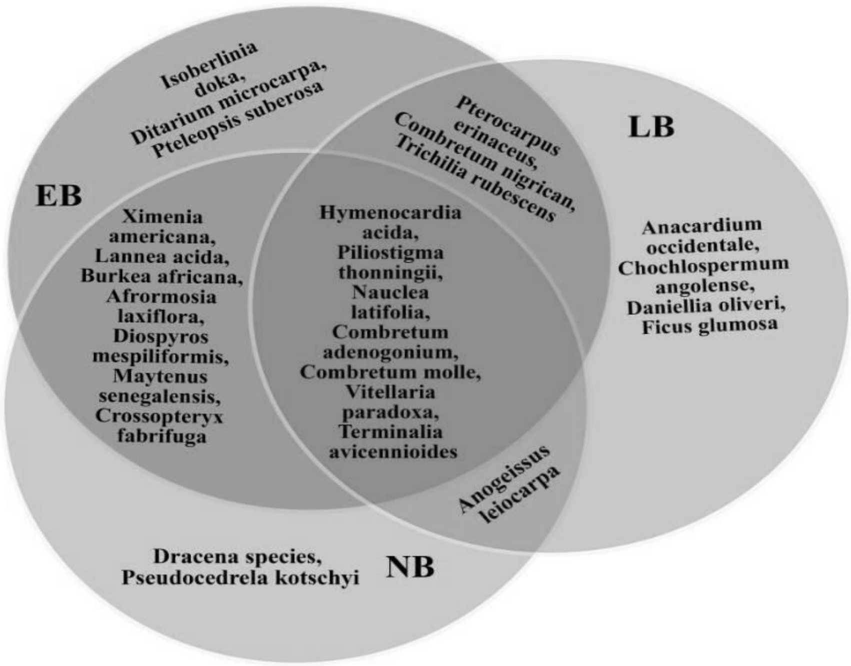

Figure 3 *Species identified in early burning, late burning and non-burning treatments (Field data, 2017)*

A total of 19 species were identified in early burning treatment. Two species, *Terminalia avicennioides and Combretum adenogonium* were found in relatively high frequencies (*Table 1*). The remaining 17 species including *Pteleopsis suberosa, Isoberlina doka, Combretum molle, Maytenus senegalensis, Burkea africana, Nauclea latifolia, Lannea acida, Detarium Microcarpa, Ximenia americana, Diospyros mespiliformis* were found in relatively low frequencies. The least occurring species were more even in frequency than the dominant species (*Table 1*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

Table 1. *Influence of fire on species population in treatments*

Species	EB		LB		NB		Pooled Freq	Family
	Freq	**Mean±SD**	**Freq**	**Mean±SD**	**Freq**	**Mean±SD**		
Afrormosia laxiflora	10	2.43±0.91	15	2.30±1.25	20	2.84±1.67	45	Leguminoseae
Anarcadium occidentale	0	0.000	1	0.29±0.08	0	0	1	Anacardiaceae
Anogeissus leicarpa	0	0.000	2	0.39±0.17	78	12.05±6.50	80	Combretaceae
Burkea africana	5	0.69± 0.46	0	0	1	0.29±0.083	6	Fabaceae
Cochlospermum angolense	0	0.000	6	0.68±0.5	0	0	6	Combretaceae
Combretum adenogonium	41	3.47±3.73	33	4.94±2.75	16	1.23±1.33	90	Combretaceae
Combretum molle	13	1.40±1.18	11	2.39±0.912	5	1.16+0.48	29	Combretaceae
Combretum nigricans	1	0.31±0.09	0	0	0	0	1	Combretaceae
Crossopteryx febrifuga	3	0.65±0.27	0	0	0	0	3	Rubiaceae
Daniellia oliveri	0	0.000	4	0.78±0.33	0	0	4	Fabaceae
Detarium Microcarpum	3	0.65±0.27	0	0	0	0	3	Leguminoseae
Diospyros mespiliformis	1	0.30±0.09	0	0	3	0.45±0.25	4	Ebenaceae
Dracena palm	0	0.000	0	0	1	0.28±0.08	1	Asparagaceae
Ficus glumosa	0	0.000	6	1.24±0.5	0	0	6	Moraceae
Hymenocardia acida	0	0.000	9	2.30±0.75	1	0.28±0.08	10	Phyllanthaceae
Isoberlinia doka	10	1.14±0.91	0	0	0	0	10	Leguminosae
Lannea acida	3	0.65±0.27	0	0	5	0.99±0.42	8	Anacardiaceae
Maytenus senegalensis	8	1.56±0.72	0	0	9	1.29±0.75	16	Celastraceae
Nauclea latifolia	4	0.51±0.36	15	2.63±1.25	1	0.29±0.08	20	Rubiaceae
Piliostigma thonningii	1	0.30±0.09	2	0.39±0.17	6	0.80±0.50	9	Fabaceae
Pseudocedrela kotschyi	0	0.000	3	0.45±0.25	13	3.18±1.08	16	Meliaceae
Pteleopsis suberosa	10	2.43±0.0.91	0	0	0	0	10	Combretaceae
Pterocarpus erinaceus	0	0.000	2	0.39±0.167	0	0	2	Fabaceae
Terminalia avicennioides	55	2.72±5.0	239	14.59±19.92	89	5.567±7.41 6	388	Combretaceae
Trichilia rubescens	1	0.30±0.09	10	0.84±0.83	0	0	11	Meliaceae
Vitellaria paradoxa	17	1.86±1.55	11	0.99±0.92	349	19.916±29.083	377	Sapotaceae
Ximenia americana	1	0.302±0.91	0	0	1	0.2887±0.083	2	Olacaceae
Total number of species	187	0	369	0	598	0		
Density (hectare)	1,558		3,075		4,983			
p-value	p=0.99							
Kruskal-Wallis Statistic		1.929						

(Field data, 2017)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

A total of 15 species were identified in the late burning treatment. Of the four common dominant species, (*Terminalia avicennioides, Combretum adenogonium, Afrormosia laxiflora and Nauclea latifolia), Terminalia avicennioides was found to be the most dominant.* The least occurring species were *Piliostigma thonningii and Pterocarpus erinaceus* (*Table 1*).

Non-burning treatment recorded a total of 17 different species, Out of which *Vitellaria paradoxa* was found to be the most dominant (*Table 1*). *Terminalia avicennioides, Combretum adenogonium and Isoberlinia doka* also recorded relatively high frequencies. *Lannea acida, Anogeissus leiocarpa and Burkea africana, Afrormosia laxiflora* were amongst the least occurring species.

Species with relatively low frequencies were more even in occurrence than the dominant species in all the treatments (*Table 1*). *Terminalia avicennioides* was present in all treatments. However, it had the highest frequency in the late season treatment whilst *Vitellaria paradoxa* recorded highest frequency in the non-burning treatment.

Discussion

Species richness and abundance

The characteristics of trees in this ecological zone are defined by the response to regeneration after fire, thus most are fire and drought resistant (Renes, 1991; Russell-Smith et al., 2012; Sinare and Gordon, 2015). However, some of the species identified may be absent or present in an uncontrolled fire disturbed savanna which may vary with the extent of disturbance and land use type (Denslow, 2002; Chimsah et al., 2013).

With the exception of *Anacardium occidentale* which was rare in occurrence in late burning treatment, all other species are native to the Guinea savanna (Sinare and Gordon, 2015; Cardoso et al., 2016). *Anacardium occidentale* was most probably brought in by animals or some other agents of dispersal from fringe villages that grow them on their farms.

The most dominant and widespread species identified in all three treatments belonged to the *Combretaceae, Leguminoceae and Fabaceae* which confirms other studies that most Sudano-Guinean savanna woodland species typically fall within these families (Aubréville, 1949). They thrive under harsh weather conditions and areas where fires are recurrent. Although the species *Parkia biglobosa,* was known to be a predominant species associated with the Leguminoceae in the Guinea savanna woodland as purported by Aubréville (1949), the species was not recorded in any of the treatments in this study and confirms the IUCN listing of the tree as a vulnerable species. *Isoberlinia doka*, *Anogeissus leiocarpa* and *Combretum nigrican* which were also predominant Combretaceae species that previously defined the Guinea savanna woodland recorded in a very low occurrence, thus may be threatened by the frequency and season of fire (Legris and Blanco, 1979). Most of the species identified in the early season and the late season burning treatments were present in the non-burning treatment (*Fig. 3*). This shows non-burning treatment as a replica of both the late and early season burning treatments. The species found solely in the non-burning treatment were *Dracaena and Pseudocedrela Kotschyi.*

Those species found exclusive to burning treatment are hardy and can withstand the frequency of burns, thus confirming findings from other studies that fire breaks seed dormancy of some savanna species ensuring natural regeneration after fire (Trollope, 1984; Higgins et al, 2000).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

Practicing non-burning may suppress the growth of some savanna species, which require fire to germinate. Also, the high leaf litter observed during sampling in the non-burnt treatment may not be a desirable condition for the growth of light tolerant species, thus the lowering prevalence of such species.

The higher species richness and evenness was observed in the early season burning treatment, which had the lowest tree density (*Table 1*). This could be attributed to the fact that there was not much dryness at the time of burning. Hence the fire did not destroy sensitive seeds and saplings, but rather enhanced the germination of the seeds by breaking their dormancy, increasing the diversity in early burnt areas of the park (Gijsbers et al., 1994). This also means that early burning favours the growth of different species in the savanna, compared to late burning, as observed in this study. Thus early season burning could be prescribed to promote diversity where particular species need moderate fire for regeneration.

Late burning had a relatively adverse effect on diversity, probably because late season fires are usually so hot that plant species may not be able to survive the intensity. Late season burns, as observed, do not not only kills grasses but tree species as well, depending on the intensity and duration of fire (Trollope, 1984; Cardoso et al., 2016).

The higher tree population in the non-burning treatment confirms that savannas are not climax vegetation; when disturbance is minimised, they can gradually transform into a woodland or forest (Bond and Midgley, 2001; Bassett et al 2003). This condition will allow seeds buried in the soil to germinate and grow, and if there is no disturbance, where initially grass was abundant, eventually tree species will dominate. The relatively low tree density identified in the burning treatment compared to the non-burning indicates that higher burning frequency in general, has a negative influence on tree density as it was also revealed in study conducted in the savanna of Ghana and Cote d'Ivoire (Brookman-Amissah et al., 1980 Basset et al., 2003).

The most common species identified regenerate from seed, but also through resprouting and this may not need a longer time lapse for regeneration after fire (Lovett and Haq, 2000; Sackey and Hale, 2008). Most *Combretaceae* species and *Leguminoceae* are tolerant to fires, drought and also to fire exclusion, with a higher probability of regeneration from resprouting after fire and other disturbances (Gijsbers et al., 1994; Higgins et al., 2000; Sackey and Hale, 2008). This explains their higher presence in all the treatments. Most of the species in this family are normally dehiscent or indehiscent and need fire to enhance germination which reflected in the very low presence in non-burning treatment, which presupposes that these species are also tolerant to late season fires. *Vitellaria paradoxa*, on the other hand, does regenerate easily by seed and also by resprouting as revealed by these others (Lovett and Haq, 2000), hence the higher number of species recorded in the non-burning treatment (*Table 1*).

Although fire plays a role in the structure and function of savanna ecosystems, a report on the Park management (Mole Park Management Report, 2005) indicated that some species are associated with types of soil in the park which, implies that the species identified in the various treatments may not solely be influenced by fire but also by the soil type (Van Wilgen, 2000; Dzwonko et al., 2015).

Implications of burning and tree populations and diversity for climate change mitigation

All vegetation absorbs carbon dioxide; however trees do absorb carbon on a larger scale than other forms (Scholes and Walker, 1993; Resh et al., 2002). Trees thus play an imperative role in climate change mitigation. A few studies purported that most savanna

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

trees are of the C3 photosynthetic pathway and therefore has a considerably greater atmospheric carbon exchanges than savanna grasses, which are mainly of the C4 photosynthetic pathway (Downton and Tregunna, 1968; Lloyd et al., 2008). Therefore, tree populations and species diversity may be used as a valuable proxy for healthy and resilient savannas, to mitigating the impacts of climate change through stocking and sinking carbon. The United Nations Framework Convention on Climate Change (UNFCCC) envisages mitigation through creating or enhancing carbon sinks and reducing anthropogenic emissions sources of CO_2. Thus, sustainable land use practices including traditional agroforestry practices such as the maintenance of agroforestry parkland in the Guinean-Sudano savanna would enhance mitigation (Bassett at al., 2003).

Frequent anthropogenic fires in the savannas, according to Murphy and Bowman (2012) are contributing to the loss of vegetative carbon to the atmosphere accounting for about 44% of the global emission (Van Der Werf et al., 2010). Thus, more fires in the savanna may exacerbate the impact of climate change by releasing carbon into the atmosphere and destroying carbon sinks (trees and grasses). Increasing wind, and rainfall, coupled with the high transpiration during the dry season according to Hulme, (2005) and Sheuyange, (2005) are a favourable condition for dry season burns, where the grass serve a fuel for burning. With this trend, it is apparent that large wildfires can be expected to increase in frequency, intensity and severity (Bassett et al., 2003; Hulme, 2005). Studies in tropical savannas in Australia have confirmed an apparent in change in fire conditions (hot temperatures and high fuel load), which will result in extensive fires (Cary, 2002; Catchpole, 2002).

The higher tree density as observed in the non-burning treatment could enhance carbon sequestration as most savanna trees with smaller leaf sizes are drought tolerant and have high carbon intake even in the dry season. Also, Langevelde et al. (2003) indicated that soil moisture availability is one of the main factors that regulate the growth of trees and grasses in the savanna. However, during the Harmattan (windy dry season in north of Ghana), as a result of the high evapotranspiration, coupled with high evaporative cooling, all the grass species wither, thus the process of carbon sequestration is halted (Simpson, 2013). More trees guarantee an all year round carbon intake when extrapolated to a larger scale (Lugo and Brown, 1992). Growing more tree through afforestation, reforestation and good forest management practices and also non-burning should be encouraged. Early season burns, on the other hand, could enhance diversity of some tree species and should also be encouraged (*Fig. 3*). Higher tree diversity contributes to building resilient terrestrial ecosystems, which is very important with the changing climates (Elmqvist et al., 2003). A characteristic of the resilient ecosystems is their ability to withstand and adapt to extreme weather conditions. The diversity of species implies a stable and sustainable ecological function: different tree species may have different levels of sequestering carbon and providing other ecosystem services better than others (Resh et al., 2002; Mandal et al., 2016). The study confirms previous studies (Myers et al., 2004; Fernandes et al., 2013) which found that prescribed early season burning plays a in savanna ecosystems by improving on vegetation diversity. However, annual late season burning that occur even under a good management system will consequently result in reduction of species density and diversity.

In the north of Ghana, the Hamattan conditions could enhance intensive and extensive fires, thereby the lost of more species during late season burns (Brookman-Amissah et al., 1980; Kasei et al, 2014). The heavy rains (900 mm to 1000 mm) but short rainy season (between June and October) are conditions conducive to the growth of grass

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

species, thus to the accumulation of more fuel load for burning during the dry season (Trollope and Trollope, 2002; Bassett et al., 2003; Kugbe et al., 2012). The continuous indiscrimate dry season burning and particularly, late dry season burning, will to a large extent affect the health and resilience of the Guinea savanna if not regulated. This could hamper mitigation efforts against rising global temperatures.

Conclusion

The study revealed that seasonal burning had a negative effect on tree density, relative to non-burning within treatments. Non-burning however promotes tree population density, rather than diversity. The annual burning had a negative effect on tree density, relative to non-burning within treatments. Species richness and evenness were higher in burning treatments than in non-burning. Burning promoted the growth of *Terminalia Avicennioide*s and other *Combretum sp*ecies whereas non-burning was a desirable condition for *Vitellaria paradoxa* (*Sapotaceae*). Thus, non-burning would increase the populations of species which are not fire-dependent for recruitment. The protection of *Vitellaria Paradoxa* from fire and other disturbances would easily increase populations which would have greater benefits for communities in the north of Ghana because of the role it plays in rural livelihoods.

A balance between tree density and diversity will be most desirable; therefore the frequency and time burning play a very important role in sustaining ecosystems for climate change mitigation. Non-burning should be encouraged in fire-degraded ecosystems to restore species and habitats and also enhance carbon sequestration.

This study could serve as a baseline for scaling-up of studies on burning, species diversity and density and also for further studies on unmanaged areas with unplanned fire regimes in the Savanna and Forest Transition zones of Ghana. There is the need to monitor the annual fires in the study site (Mole Park) to see what the Park is gaining or losing in terms of animal species diversity and populations through the fires. The findings calls for the strengthening of community sensitization and collaborative stakeholder engagement on the impact of burning and non-burning on species including economic species like *Vitellaria paradoxa.*

Traditional tree-based land use practices, such as agroforestry should be encouraged to minimise the conversion of savanna woodlands into grasslands. This is because grass species wither and die as a result of the Hammattan conditions, their efficacy of all year sequestration of carbon is reduced.

Prescribed early dry season burns should be the best option against indiscriminate burning as practiced in unprotected and community managed woodlands; this can be achieved through advocacy by district assemblies and other relevant stakeholders.

Acknowledgements. This research is supported by funding from the Department for International Development (DFID) under the Climate Impact Research Capacity and Leadership Enhancement (CIRCLE) programme.
We express our sincere gratitude to the Ghana Forestry Commission, for granting Permission for the field study to be carried out in Mole National Park. The lead author is also grateful to the Center for Climate Change Studies, University of Dar es Salaam which hosted me for the CIRCLE Programme. Dr Peter Burt of NRI - Department of Agriculture, Health and Environment University of Greenwich, UK, was an advisor during the fellowship, thanks for your inputs in improving the manuscript.

REFERENCES

[1] Adongo, R., Nkansah, D. O., Salifu, S. M. A. (2012): Social and psychological aspects of communal hunting (pieli) among residents of Tamale Metropolis in the Northern Region of Ghana African Journal of Hospitality. – Tourism and Leisure 2:1-15

[2] Agyemang, I., Mcdonald, A. Carver, S. (2007): Application of the DPSIR framework to environmental degradation assessment in northern Ghana. – Natural Resources Forum 31(3): 212-225.

[3] Amanor, K. S. (2002): Bushfire Management, Culture and Ecological Modernisation in Ghana. – IDS Bulletin 33(1): 65-74.

[4] Andersen, A., Cook, G. Williams, D. (2012): Savanna burning: The ecology and economy of fire in tropical savannas. – Austral Ecology 37: 633-633.

[5] Armah, F. A., Odoi, J. O., Yengoh, G. T., Obiri, S., Yawson, D. O., Afrifa, E. K. A. (2011): Food security and climate change in drought-sensitive savanna zones of Ghana. – Mitigation and Adaptation Strategies for Global Change 16: 291306.

[6] Aubréville, A. (1958): Sudano-Guinean Forest Flora. – Geographical Publishing Company, Paris.

[7] Auld, T. D., Bradstock, R. A. (1996): Soil temperatures after the passage of a fire: Do they influence the germination of buried seeds? – Austral Ecology 21: 106-109.

[8] Bagamsah, T. T. (2005): The Impact of Bushfire on Carbon and Nutrient Stocks as Well as Albedo in the savanna of northern Ghana. – In: Vlek, P. L. G., Denich, M., Martius, C., Rogers, C. (eds) Ecology and Development Series 25. Cuvillier Verlag, Gottingen.

[9] Bassett, T. J., Koli Bi, Z., Quattara, T. (2003): Fire in the savanna – In: Bassett, T., J., Crummey, D. (eds.) African Savannas. Global Narratives and Local Knowledge of Environmental Change Portsmouth, Heinemann Oxford, UK.

[10] Beringer, J., Hutley, L. B., Tapper, N. J. Cernusak, L. A. (2007): Savanna fires and their impact on net ecosystem productivity in North Australia. – Global Change Biology 13: 990-1004.

[11] Blench, R. (2001): Trees on the march: the dispersal of economic trees in the prehistory of West-Central Africa. – ODI, Safa Conference, 12-15 July, 2000. Cambridge, UK.

[12] Bond, W. J. Midgley, J. J. (2001): Ecology of sprouting in woody plants: the persistence niche. – Trends in Ecology & Evolution 16: 45-51.

[13] Bond, W. J., Woodward, F. I.,Midgley, G. F. (2004): The global distribution of ecosystems in a world without fire. – New Phytologist 165: 525-538

[14] Brookman-Amissah, J., Hall, J. B., Swaine, M. D., Attakorah, J. Y. (1980): A re-assessment of a fire protection experiment in North-Eastern Ghana savanna. – Journal of Applied Ecology 17: 85-99

[15] Brown, S. (1993): Tropical forests and the global carbon cycle: the need for sustainable land-use patterns. – Agriculture, Ecosystems & Environment 46: 31-44

[16] Burgess, T. L. (1985): Desert Grassland, Mixed Shrub Savanna, Shrub Steppe, or Semi Desert Scrub: The Dilemma Of Co-Existing Growth Forms. – In: McClaran, M. P., Van Devender, T. R. (eds.) The Desert Grassland. – University of Arizona Press, Tucson.

[17] Callo-Concha, D., Gaiser, T., Webber, H., Tischbein, B., Müller, M.,Ewert, F. (2013): Farming in the West African Sudan savanna: Insights in the context of climate change. – African Journal of Agricultural Research 8: 4693-4705.

[18] Cardoso AW, Medina-Vega JA, Malhi Y, Adu-Bredu S, Ametsitsi GKD, Djagbletey G, van Langevelde F, Veenendaal E, Oliveras I. 2016: Winners and losers: tropical forest tree seedling survival across a West- African forest–savanna transition. –Ecology & Evolution 6: 3417-3429.

[19] Cary, G. J. (2002): Importance of Changing Climate for Fire Regimes. – In: Bradstock, R. A., Williams, J. E., Gill, M. A. (eds.) Flammable Australia: The fire regimes and Biodiversity of a Continent. Cambridge University Press, Cambridge

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

[20] Catchpole, W. (2002): Fire properties and burn patterns in a heterogeneous landscape. – In: Bradstock, R. A., Williams, J. E., Gill, M. A. (eds.) Flammable Australia: The fire regimes and Biodiversity of a Continent. Cambridge University Press, Cambridge

[21] Chimsah, F. A., Nyarko, G., Yidana, J. A., Abubakari, A.-H., Mahunu, G. K., Abagale, F. K., Quainoo, A. (2013): Diversity of tree species in cultivated and fallow fields within Shea Parklands of Ghana. – Journal of Biodiversity and Environmental Sciences 3: 2220-6663.

[22] Denslow, J. S. (2002): Invasive alien woody species in Pacific island forests. – Unasylva 53: 62-63

[23] Dzwonko, Z., Loster, S., Gawroński, S. (2015): Impact of fire severity on soil properties and the development of tree and shrub species in a Scots pine moist forest site in southern Poland. – Forest Ecology and Management 342: 56-63

[24] Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker, B., Norberg, J. (2003): Response diversity, ecosystem change, and resilience. – Frontiers in Ecology and the Environment 1: 488-494.

[25] Eriksen, C. (2007): Why do they burn ? Fire, rural livelihoods, and conservation in Zambia. – The Geographical Journal 173: 242-256

[26] Fernandes, P. M., Davies, G. M., Ascoli, D., Fernández, C., Moreira, F., Rigolot, E., Stoof, C. R., Vega, J. A., Molina, D. (2013): Prescribed burning in southern Europe: Developing fire management in a dynamic landscape. – Frontiers in ecology and the Environment 11: 1-11

[27] Gignoux, J., Lahoreau, G., Julliard, R., Barot, S. (2009): Establishment and early persistence of tree seedlings in an annually burned savanna. – Journal of Ecology 97: 484-495.

[28] Gignoux, J., Clobert, J., Menaut, J.-C. (1997): Alternative fire resistance strategies in savanna trees. – Oecologia 110: 576-583.

[29] Gijsbers, H. J. M., Kessler, J. J., Knevel, M. K. (1994): Dynamics and natural regeneration of woody species in farmed parklands in the Sahel region (Province of Passore, Burkina Faso). – Forest Ecology and Management 64: 1-12.

[30] Higgins, S. I., Bond, W. J.,Trollope, W. S. W. (2000): Fire, resprouting and variability: a recipe for grass-tree coexistence in savanna. – Journal of Ecology 88: 213-229.

[31] Houghton, R. (2012): Carbon emissions and the drivers of deforestation and forest degradation in the tropics. – Environmental Sustainability 4: 597-603

[32] Hulme, P. E. (2005): Adapting to climate change: Is there scope for ecological management in the face of a global threat? – Journal of Applied Ecology 42: 784-794.

[33] Kasei, R. A., Ampadu, B.,Yalevu, S. (2014): Impacts of climate variability on food security in Northern Ghana. – Journal of Earth Sciences and Geotechnical Engineering 4: 47-59

[34] Korem, A., 1985: Bush fire and agricultural development in Ghana. – Ghana Publishing Corporation, Tema.

[35] Kugbe, J. X., Vlek, P. L. G., Fosu, M., Tamene, L., Desta, M. D. (2012): Annual vegetation burms accross the northern savanna region of Ghana. – Nutr. Cycle Agroecosyst. 93: 265-284.

[36] Langevelde, van F., Veenendaal, E., Oliveras, I. (2016): Winners and losers: tropical forest tree seedling survival across a West African forest-savanna transition. – Ecology and evolution 6: 3417-3429

[37] Legris, P., Blasco, F. (1979): Joint pilot project for tropical forest monitoring. – Unpublished report, FAO/UNESCO.

[38] Lovett, P. N., Haq, N. (2000): Diversity of the Sheanut tree (*Vitellaria paradoxa* C . F . Gaertn .) in Ghana. – Genetic Resources and Crop Evolution 47: 293-304.

[39] Lugo, A. E.,Brown, S. (1992): Tropical forests as sinks of atmospheric carbon. – Forest Ecology and Management 54: 239-255.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

[40] Mandal, R. A., Kumar. P, Chandra Dutta, I., Thapa, U., Karmacharya, S. B. (2016): Carbon Sequestration in Tropical and Subtropical Plant Species in Collaborative and Community Forests of Nepal – Advances in Ecology: 1529703
[41] Mikkelsen, J. H., Langohr, R. (2004): Indigenous knowledge about soils and a sustainable crop production a case study from the Guinea woodland savannah (Northern Region), Ghana. – Danish Journal of Geography 104: 13-26.
[42] Murphy, B. P., Bowman, D. M. J. S. (2012): What controls the distribution of tropical forest and savanna? – Ecology Letters 15: 748-758
[43] Myers, B., Allan, G., Bradstock, R., Dias, L., Duff, G., Jacklyn, P., Landsberg, J., Morrison, J., Russell- Smith, J.,Williams, R. (2004): Fire Management in the Rangelands tropical savanna's. – CRC, Darwin.
[44] Obuobie, E., Barry, B. (2005): The Volta river-basin. – In: Boubacar, B., Obuobie, E., Andreini, M., Andah, W., Pluquet, M (eds.) International Water Management Institute Report, 190.
[45] Owusu-Bennoah, E., Acquaye, D. K., Abekoe, M. (1991): Efficient fertilizer use for increased crop production: Use of phosphorus fertilizers in concretional soils of northern Ghana in alleviating soil fertility constraints to increased crop production in West Africa. – Dordrecht Springer, Netherlands.
[46] Penman, T. D., Binns, D. L., Kavanagh, R. P. (2007): Prescribed burning: how can it work to conserve the things we value? – Wildland Fire 20: 721-733
[47] Pistorius, T. (2012): From RED to REDD+: the evolution of a forest-based mitigation approach for developing countries. – Current Opinion in Environmental Sustainability 4: 638-645.
[48] Kutiel, P. (1997): Spatial and Temporal Heterogeneity of Species Diversity in a Mediterranean Ecosystem Following Fire. – Wildland Fire 7: 307-315.
[49] Renes, G. J. B. (1991): Regeneration capacity and productivity of natural forest in Burkina Faso. – Forest Ecology and Management 41: 291-308
[50] Resh, S. C., Binkley, D., Parrotta, J. A. (2002): Greater Soil Carbon Sequestration under Nitrogen-Fixing Trees Compared with Eucalyptus Species – Ecosystems 5: 217-231.
[51] Russell-Smith, J., Djoeroemana, S., Maan, J.,Pandanga, P. (2007): Rural Livelihoods and Burning Practices in Savanna Landscapes of Nusa Tenggara Timur, Eastern Indonesia. – Human Ecology 35: 345-359.
[52] Russell-Smith, J., Edwards, A. C., Price, O. F. (2012): Simplifying the savanna: the trajectory of fire-sensitive vegetation mosaics in northern Australia. – Biogeography 39: 1303-1317.
[53] Sackey, I., Hale, W. (2008): Effects of perennial fires on the woody vegetation of mole national park, Ghana. – Science and Technology 28: 36-47.
[54] Scholes, R., Walker, B. (1993): Tree–grass interactions. – In: Scholes, R., Walker, B (eds.) An African Savanna: Synthesis of the Nylsvley Study. Cambridge, Cambridge University Press., 215-229.
[55] Sheuyange, A., Oba, G.,Weladji, R. B. (2005): Effects of anthropogenic fire history on savanna vegetation in northeastern Namibia. – Environmental Management 75: 189-198.
[56] Siaw, D. E. K. A. (2001): State of forest genetic resources in Ghana. – Sub-regional workshop on the conservation, management, sustainable utilization and enhancement of forest genetic resources in Sahelian and North-Sudanian Africa (Ouagadougou, Burkina Faso, 22-24 September 1998). Forest Genetic Resources Working Group, FAO.
[57] Simpson S. E. (2013): The developing world: An introduction. – Longman Group Limited, Longman Scientific & Technical, Harlow.
[58] Sinare, H., Gordon, L. J. (2015): Ecosystem services from woody vegetation on agricultural lands in Sudano-Sahelian West Africa. Agriculture. – Ecosystems & Environment 200: 186-199

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949

[59] Thonicke, K., Venevsky, S., Sitch, S.,Cramer, W. (2001): The role of fire disturbance for global vegetation dynamics: Coupling fire into a dynamic global vegetation model. – Global Ecology and Biogeography 10: 661-677
[60] Trollope, W. S. W. (1984): Fire in Savanna. – Springer, Berlin.
[61] Trollope, W. S. W.,Trollope, L. A. (2002): Fire behaviour a key factor in the fire ecology of African grassland and savannas. – Millpress, Rotterdam
[62] Van Der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., Defries, R. S., Jin, Y.,Van Leeuwen, T. T. (2010): Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). – Atmospheric Chemistry and Physics 10: 11707-11735.
[63] Van Wilgen, B. W. (2009): The evolution of fire management practices in savanna protected areas in South Africa. – South African Journal of Science 105: 343-349.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1602_19351949