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Assessment of causes that contribute to the occurrence of plantations forests fires in Niassa Province, North of Mozambique

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Although, Niassa province has natural potential for exotic plantations introduction, forest fires have proved to be a very compromising factor in attracting investments for commercial forestation. Only in two years, fires have devastated approximately 2887.8 ha of *Pinus* sp. and *Eucalyptus* sp. of the Chikweti Forests Company. This research was conducted in order to assess the main causes that contribute to the fire occurrence in three Niassa's districts, where the company Chikweti Forest of Niassa operates. Two year (2010 and 2011) of weather data (temperature, precipitations and relative humidity), have shown favorable conditions for fire occurrence. Data on fire occurrences collected by Chikweti Fire Monitory Center has shown that, arson fires were most predominant, followed by clearing-fields fires. The chi-square test ($P < 0.01$) showed that the causes that contributed to the occurrences of fires, in each of the evaluated district were not the same in 2010, but for 2011 it showed the opposite. It also showed that the causes of fire were not associated with daily periods (morning, afternoon and night). Most of the forest fires in the studied period occurred in September and October, independently of causes. Arson fires normally occurred in the night, while the remaining causes tend to occur in the morning and afternoon.

Key words: Arson fire, weather condition, householders, forests companies.

INTRODUCTION

Most of sub-Saharan Africa has distinctive wet and dry season, which favor regular vegetation fires. While the wet season stimulates growth, the dry season provides ideal conditions for burning (FAO, 2006b). Data on climate observations in Mozambique over a period of 45 years (1960 – 2005), suggest significant trends in climate conditions over most of the country, particularly in northern Mozambique where was observed a later start of the rainfall season, which has been delayed by up to 45 days and temperatures have increased approximately

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1.1°C (INGC, 2009).

About 70% of Mozambique (65.3 million hectares) is covered by forest and others woody vegetations. Natural productive forests for wood production cover 26.9 million hectares (67% of all forest area). The average wood volume for all forest are 36.6 m^3/ha (Marzoli, 2007) and this stocks tends to decrease when going to Miombo ecosystem, which is probably first related with fire frequency, (clearing lands, especially for shifting cultivation, slash-and-burn practices, maintenance of grassland for livestock management, hunting, honey collection and negligence), and second with extraction of wood and non-wood forest products (timber, charcoal, firewood, medicinal plants and fruits) (Clarke et al., 1996; FAO, 2006a,b; Helkkilä et al., 2007).

Miombo woodland is most extensive seasonal woodland and dry forest in Mozambique. It covers about 63% of the all native forest and all most in the center and northern part of the country (Marzoli, 2007). Productivity in Miombo woodland is low, due to the soils textures, that are often loamy sand, sandy loam and sandy clay loam (which is predominate in both the top and subsoil), shallow, low nitrogen and low deep (Frost, 1996), frequent and intense disturbance from herbivores and fire (Chidumayo and Frost, 1996) and anthropogenic woodland use such like, light fuel wood coppicing, selective harvest of charcoal production and land clearing (Schwartz and Caro, 2003).

Mozambique has an area of 799 390 km^2, with a population of 17.24 million inhabitants (Ribeiro, 2001; Hegde and Bull, 2007), however, of these, 71.4% live in rural areas, whilst 92.7% of these rural dwellers depend directly on natural resources for food shelter and income. In addition, 41.0% of the labor force from the urban areas is also engaged in agriculture, forestry and fishery production (Ribeiro, 2001). Given to low natural forest productivity, population growth and land use pressure, associated with wide unproductive land abandoned by farmers, particularly in study area (Snyman and PrSciNat, 2004), the Mozambique government decided to promote exotic forest plantation for companies that plant large-scale monoculture. Since 2005, Niassa province was the focus of many forests companies. Currently more than seven forests companies are operating in Niassa. Frequency's of fires in Niassa commercial plantation is an enormous risk for companies. In just two years (2010 and 2011), fire had destroyed 2887.8 ha, of *Pinus* sp and *Eucalyptus* sp in a company Chikweti forests of Niassa. Several of these fires affected forests investments in Niassa and it's probably associated with land clearing, hunting and land use conflicts between forests companies and rural local communities.

This research was conducted in order to understand the main causes of the fire. These causes of fires, were assessed in three districts of Niassa (Lichinga, Lago and Sanga) where Chikweti Company operates, based on fires occurrence records database of the company and local weather data, that is available in Lichinga Agricultural Research Station (Weather station).

MATERIALS AND METHODS

Site location and characterization

The three districts (Lago, Lichinga and Sanga) where the study was cured out are a part of extensive corridor of new plantations of *Pinus SP* and *Eucalyptus SP*, introduced since 2005. All districts are located in the Niassa Province, northern of Mozambique (Figure 1). The attraction of wide number of plantations forestry for this specific part of Mozambique is more related with easy adaptability of fast growth species (specially Pinus and Eucalyptus), due to edaphic climatic conditions. Most of planted area has been established in areas severely and negatively impacted by shifting cultivation. These plantations concessions was delineated in open common lands and lands formerly used for agriculture and others sources of forests ecosystems goods and services which was later abandoned (Landry and Chirwa, 2011).

According to the last census of 2007, Lichinga is the most populated District of Niassa, with 62,802 total inhabitants and a population density of 15.9 inhabitants/km^2, followed by Lago with 55.892 inhabitants and a population density of 11.5 inhabitants/km^2. Sanga is the least populated with 44, 225 inhabitants and a population density of 4.5 inhabitants/km^2. Agriculture is the dominant economic practice. Most of the householders from these rural villages are farmers, growing mainly maize, beans and potatoes for subsistence purposes, except the people in the Lago district, where fishing and tourism are the major economic activities because of Niassa lake potential (MAE, 2008). Charcoal production and hunting are also other practices which bring income to the households. In all districts the company Chikweti Forest of Niassa, had planted total of 13, 392.46 ha by November 2011, in different rural abandoned lands.

Provided that the forest companies began to operate in Niassa in 2005, more than 2000 people were employed in Chikweti until 2011, being almost 75% of those in rural areas. More details of site location and districts characterizations are represented in Figure 1 and Table 1.

Data collection

Fire occurrences data collected during the fire season of 2010 and 2011 were provided by Chikweti Fire Monitory Center (FMC). The fire season generally beginning in June and lasts until mid-November. All fire data occurrences were recorded every 24 h in FMC, which also recorded all fire "history" from the initial moment, through intervention until the extinction, via radio. Burned area was measured using GPS one day after fire. This study does not analyze the extension of fires (burned area) because some data were missed and others were not accurate. The classification of fire occurrence causes was made without taking in consideration the Mozambican National Law of Forest and Wildlife, because it consider as criminal burning any kind of fire which was placed voluntarily to destroy harvest, forest and wildlife (Serra and Chicue, 2005).

It was considered more realistic to use Heikkilä et al. (2007)' definitions of causes of fire. They consider that unintentional fires are usually caused by one of the following activities: grassfires for grazing purposes; slash fires for cultivation; prescribed burning for fire prevention in fire hazardous areas; prescribed burning for silviculture (slash, litter, and debris burning for clearing, road maintenance, etc) and all outdoor burning for farming, hunting, campin, etc.

This work considering the following fire causes category: Arson

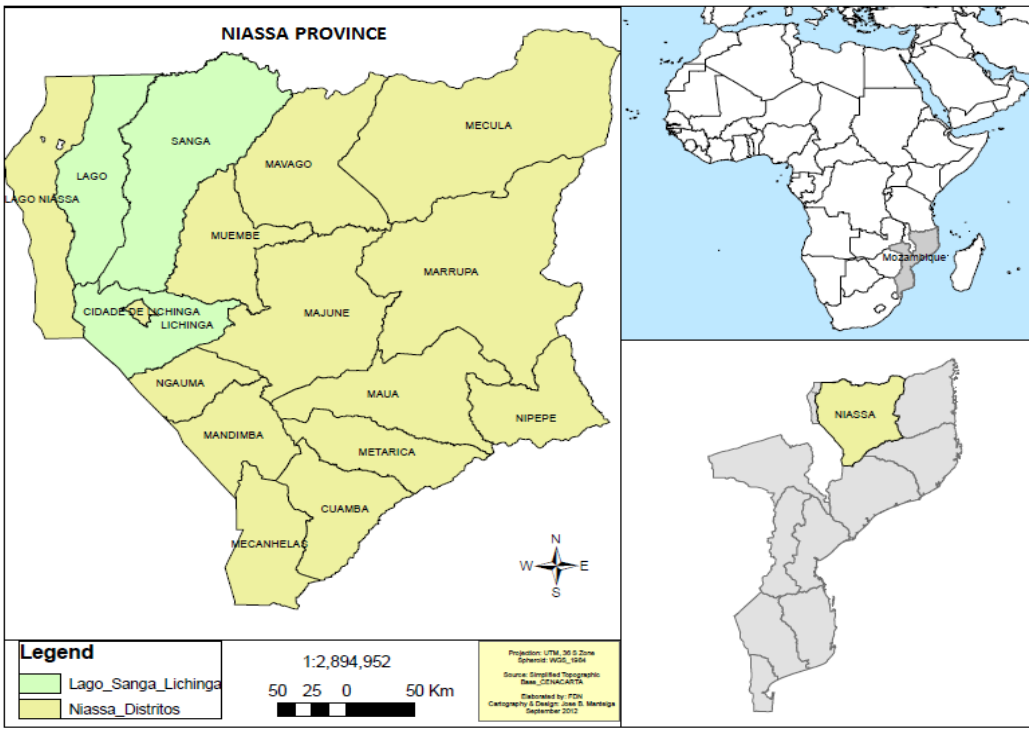

Figure 1. Map of the study site location

Table 1. Site location and characterizations of the three districts of Niassa Province where the study was conducted.

Features	Districts		
	Lichinga	**Lago**	**Sanga**
Location	It is located in the eastern part of the Niassa province and extends in a surface of 5,342 km^2. Confined in the north by districts of Sanga, Lake, and Muembe and in the south by Nguama district	Located in the northern part of the Niassa Province. Extends in surface of 6,438 km^2, bordered on the north by the Republic of Tanzania, south Lichinga district, east district of Sanga and west by Niassa Lake	It is located in the north of the province of Niassa, with an area of 13,469 km^2. It is bordered on the north by the republic of Tanzania, Southern by District of Lichinga and east Districts Muembe and Mavago
Coordinates	LAT 13°23' 48°S and LONG 35° 13' 43" E , The altitude ranges from 1000 to 1300m above sea.	LAT 12° 41' 55° S and LONG 34° 54' 16° E, The altitude range from 550 to 1200 above sea level.	LAT 13° 01' 05° S and LONG 35°18'37°E, The altitude range from 900 to 1200 m above sea
Climate	The climate of the region is tropical humid with two distinct seasons: hot and rainy summers and dry and could winters. Average annual temperature is around 21°C and mean annual precipitation is 1200 mm	The climate of the Lago District is tropical humid with two distinct seasons: rainy and humid summers and dry winters. The average annual temperature is 23 °C and the average rainfall of 1200 mm	The hot and rainy season lasts from December to March, which dry and cool going from May to October. Mean annual rainfall is 1350 mm and the mean values of temperature range from 20 to 23°C

Source: MAE (2008).

Fires (ArS), all the fire that started in the plantations without the consent of the property owner. Fires that started out of Chikweti plantations and then entered to the plantations were not considered as ArS. Other categories were considered: Hunting Fire (HuF), fire normally used for hunting animals; Cleaning-Field's Fire (CFF), are normally fires associated with slash-and-burn method which is widely used in African agricultural to clear agricultural sites or remove agricultural residues; Grazing Fire (GrF), consists on management of grazing land for both livestock and wildlife (burning the bush to open it up and stimulate a new grass); Careless Fire (CaF), are fires originate from the forest plantations activities such as prescribed burning to prepare sites for planting or firebreaks around and within the plantations compartments or even smoking cooking and warming fire. Most of those plantations fires originate

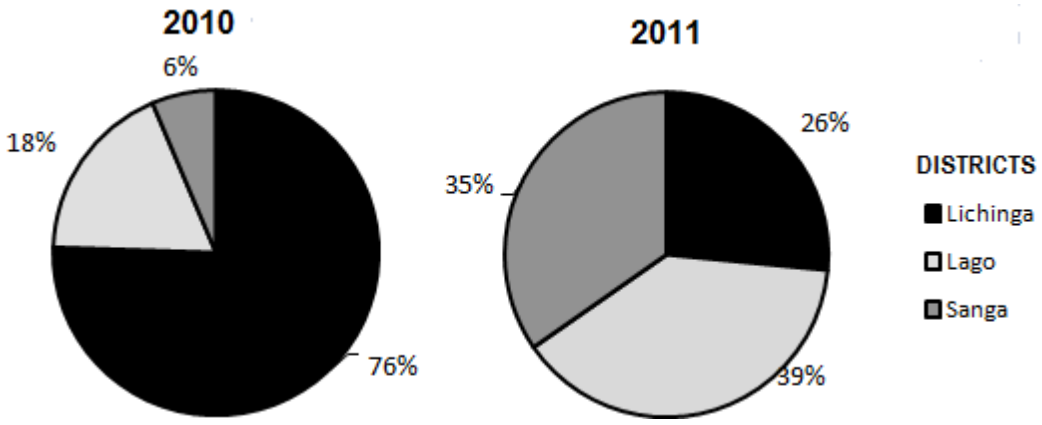

Figure 2. Distributions of the fire occurrence per districts in the years 2010 and 2011.

due to lack of training of personnel and Fire Unknown (FuK) fire that wasn't possible to identify the cause.

Daily weather data, that is, temperature (mean, maximum and minimum), precipitation and relative humidity, were provided by the meteorological station of Lichinga Agricultural Research Station for the period of January 1998 to May 2011.

Data analyses

Simple descriptive statistic was carried out to analyze the fire data collected. The causes of fires in different districts where Chikweti operates were analyzed separately in the two years (2010 and 2011). To understand whether there were differences between the different causes of fires that ravaged the three districts, a Chi-square test (X^2) at $P < 0.01$ was performed, based on contingency tables and starting from the null hypothesis that the causes of fire did not differ between districts. A chi-square test was also performed to test the null hypothesis that causes of fire did not differ between daily periods (morning, afternoon and night).

Monthly trends of the weather variables (mean temperature, precipitation and relative humidity) were crossed with fire occurrence data to verify if the peak of fire occurrence were favored by climatic conditions.

RESULTS

Fire distributions and causes

Figure 2 shows the percent of distribution of fire occurrence per district in 2010 and 2011. In it, it is easy to observe that, in 2010, Lichinga was the most affected district, with 76% occurrences, followed by Lago (18%) and Sanga (6%). In the following year, Lichinga was the less affected district, with a reduction in occurrences from 76% to 26%, followed by Sanga (35%) and lastly, Lagos (39%).

100 of fires registered in Chikweti plantations in 2011 were attributes to human-induced causes and (97.87%) in 2010, were attributed the same cause, the others (2.13%) were not identified (unknown causes) (Table 2). Those human-induced caused, in both years totaled, (55.24%) arson fire, (25.9%) land clearing, (7.96%) careless, (6.99%) hunting and (2.80%) grazing. In the year, 2010 was recorded 94 fires, ArS was the major cause of fire (43.62%), followed by CFF (30. 85%), HuF (9.6%) and CaF (9. 57%), the other causes were residual. Notwithstanding, the total number of occurrences recorded in 2010 decreases from 94 to 49 in the following year (2011), which corresponds to reductions of approximately half percent. Arson fires increased in approximately (33, 93%). Sanga was the most affected district (82.35%), followed by Lago district, (78.95%) and Lichinga (69.23%). The second major cause was CFF, with percents of (23.8%), (15,79%) and (11,76%) for Lichinga, Lago and Sanga respectively. The rest of the causes, were residual (Table 2).

The chi-square test showed that the causes contributed to occurrences of fires in each district were the same in 2010 ($\alpha = 0.1067^{ns}$) and 2010 and 2011 ($\alpha = 0.4696^{ns}$). In 2011, the same test shows difference between the causes that affect the three different districts, ($\alpha = 0.0092^{**}$). Arson fires were the most dominant in all districts of Niassa where Chikweti operate, (69.23%) in Lichinga, (78.95%) Lago and (82.35%) Sanga.

Fires occurrences periods

Climatic variables (temperature, precipitation and relative humidity) were overlapped with fires occurrences from May to December; consider that the fire occurrence period was not only defined by climatic variables, but also by the human behavior (the first fire occurrence was observed in June), to observe the fire patterns and the influence of climatic variables on the occurrence of forest fires (Figure 3). It was observed that, in general the major number of fire occurred in September (33.57%) and October (36.36%). Although, the first fire occurrence was registered lately in 2010, oppositely to 2011, where the first occurrences was observed in June, one month earlier than the previous year, in 2010 were recorded more occurrences (94) than in 2011 (49).

Table 2. Frequency and causes of fire occurrences in Chikweti operational areas of Lichinga, Lago and Sanga districts in years 2010 and 2011.

Years	Causes	Distrito							
		Lichinga		Lago		Sanga		Total	
		FR	FR (%)	FR	FR (%)	FR	FR (%)	FR	FR (%)
2010	CaF	7	9.86	2	11.76	0	0.00	9	9.57
	CFF	20	28.17	7	41.18	2	33.33	29	30.85
	ArS	34	47.89	5	29.41	2	33.33	41	43.62
	FrK	2	2.82	0	0.00	0	0.00	2	2.13
	HuF	6	8.45	3	17.65	0	0.00	9	9.57
	GrF	2	2.82	0	0.00	2	33.33	4	4.26
	Total	71	100	17	100	6	100	94	100
2011	CaF	1	7.69	1	5.26	0	0.00	2	4.08
	CFF	3	23.08	3	15.79	2	11.76	8	16.33
	ArS	9	69.23	15	78.95	14	82.35	38	77.55
	FrK	0	0.00	0	0.00	0	0.00	0	0.00
	HuF	0	0.00	0	0.00	1	5.88	1	2.04
	GrF	0	0.00	0	0.00	0	0.00	0	0.00
	Total	13	100	19	100	17	100	49	100
2010 and 2011	CaF	8	9.52	3	8.33	0	0.00	11	7.69
	CFF	23	27.38	10	27.78	4	17.39	37	25.87
	CrF	43	51.19	20	55.56	16	69.57	79	55.24
	FrK	2	2.38	0	0.00	0	0.00	2	1.40
	HuF	6	7.14	3	8.33	1	4.35	10	6.99
	GrF	2	2.38	0	0.00	2	8.70	4	2.80
	Total	84	100	36	100	23	100	143	100

FR= count (relative frequencies) and FR(%), percentage of occurrences. FR, was also used to perform CHI-SQUARE TEST (X^2). Where it was observed: $\alpha = 0.1067^{ns}$, $\alpha = 0.0092^{**}$ and $\alpha = 0.4696^{ns}$ for 2010, 2011 and 2010 and 2011, respectively (ns= not significant, **= significant at $P < 0.01$).

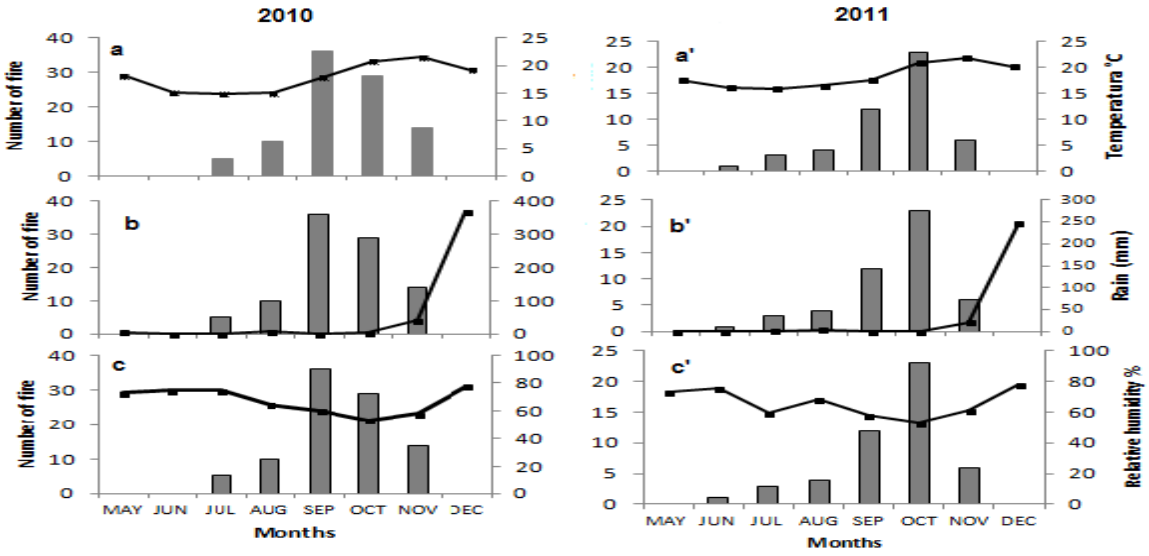

Figure 3. Numbers of fire per month (May to December), as a function of weather conditions. In both years temperature and precipitation followed the same patter. Relative humidity shows a different pattern in 2011, with sharp decreases in July, in approximately 15% (Figure 3).

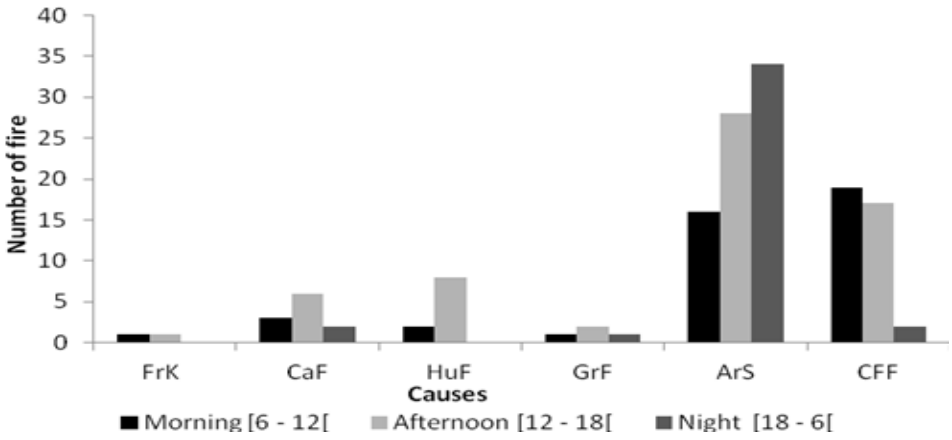

Figure 4. Causes of plantation fires occurrences in the daily periods.

Regarding the daily fire occurrences (Figure 4), ArS fire were recorded more predominant in the afternoon (28) and night (34), whereas CFF, were more predominant in the morning (19). ArS fire tends to increase from morning to night (16, 28 and 34), whereas CFF fire, tends to decrease (19, 17, 2). In general, all cases of fire trend to be sharper in the afternoon, FrK, (1); CaF, (6); HuF, (8); GrF, (2); except Ars fires and CFF which were more predominate in the night (34) and morning (19) respectively. Frk and HuF, were not recorded on the night.

A chi-square test was performed to test whether causes of fire did not differ between daily periods. The null hypothesis was refuted ($\alpha = 0{,}002^{ns}$), suggesting that, the distributions of fire ignition are not following the same behavior during daytime.

DISCUSSION

Fire distributions and causes

Almost all fires in the studied area were assigned as human-induced causes, not only in 2010, but also in 2011, according to MICOA (2008), in Mozambique, general (90%) of fire occurrences are resulting for human activities and the rest 10% are caused by natural and unknown causes. It is noteworthy that, Niassa is the province most affected by fire in the north of Mozambique. data provided by MICOA (2008) revealed that in the period (2001 to 2003), Niassa province was the most affected by forest fires, approximately 8984 occurrences were being recorded and almost related with anthropogenic causes. FAO (2006b), comment that even where causes were given “unknown” it’s believed that most fires are caused by people. The list of human-induced causes includes land clearing (especially for shifting cultivation and other agricultural activities), maintenance of grasslands for livestock management, extraction of non-wood forest products (NWFPs), industrial development resettlement, hunting, negligence (such as the careless disposal of cigarettes) and arson. In this study, the most predominate human-induced factors related with fires, were ArS (55.24%) and land clearing for agriculture (25.87%), both having totalized (81.12%). The wide occurrence of ArS, may probably be associated with displeasure of non-employed (non-wage earning) households. Landry and Chirwa (2011) sampled 331 households in various communities throughout the proposed afforestation area in Sanga district.

According to findings, that there were minimal wealth gaps between rural households; but that the introduction of the forest industry and the subsequent employment created thereof may result in larger wealth gaps between wage earning and non-wage earning households. Nube et al. (2013) sampled 486 households in various communities around the planted areas by Chikweti and two others forests companies (Florestas do Niassa and Green Resources), they found that, among non-wage earning households, (15%) were belong to med socio-economic class and the rest 85% were poor.

In relation to wage earning householders, they reported that (44,8%) were med socio-economic class and the rest (55,2%) were poor, the author commented that, there were a good improvement on social-economic conditions to the wage earning householders, despite the fact that most of forest companies pay fees below to the minimum wage. Thus, we may infer that, Social-economic gaps between wage earning and non-wages earning may also been one of the causes that motivate the wide occurrences of ArS.

The low level of education may be another cause of all kind of fires occurrences. In all studied districts, most householders (approximately 80%) is either non-educated or have only a primary degree (MAE, 2008; Landry and Chirwa, 2011; Nube et al., 2013). According

to Heikkilä et al. (2007) the best way to reduce causes of fire in areas where the education level of the local communities are very low, is by education. First of all, the public should be taught how to burn safely. Then, they should learn how to minimize all hazards safely and at last the public should learn how to minimize all outdoor burning during the fire hazard periods. A key aspect of effective fire management concerns participatory and particularly community-based, approaches as an adaptive and sustainable mechanism, this may call for the inclusion of local communities in proper application of fire (participation and community-based approaches to fire management), (FAO, 2009).

Regarding to the fact that CFF have been the second most dominant cause of fire occurrences in both years, (30.85%) in 2010 and (16.33%) in 2011, in all districts, may be related to the fact that, in the areas where Miombo woodland is the most predominant, culturally fires has been used as the most inexpensive and efficient way to open the land for cultivation. Complete fire exclusion in Miombo areas is not practical, because in certain circumstances, fire play a key important role in the cultural life of community (Chidumayo et al., 1996). According to Zolho (2011), in many Mozambicans regions, fire incidences are on increases at an alarming rate in areas outside the conservation and the trend is to increase as more people occupy these areas. The traditional slash-and-burn cultivation, charcoal burning and population increases are some of the causes. Heikkilä et al. (2007) also comment that, in most countries, agricultural burning, such as shifting cultivation, grazing, and fires to control vermin and insects, together with the many variations of rubbish and debris burning are major causes of wildfires.

Fires occurrences periods

Although fires have started one month later in 2010, there were a greater number of occurrences recorded in 2010, thus, differences on pattern of fire start and number of occurrences in both year may be probably associated with human-induced fires (especially ArS fires), indeed, all fare recorded in June 2011 were caused by arsonists, in additionally, most of fires occurred in 2010 (43.62%) and 2011 (77.55%) were ArS fire. Zucula (2003), in his research entitled quantification of wildfires in Mozambique using satellite images, observed that fires season in Mozambique, normally begins in the first week of June and it ends in the last week of October, in this period, the peak of fires occur from August to October. This last statement is in accordance with our findings, as the peaks of fires in both years occurred in September and October. Chidumayo (1995), also comment that, the most damaging fires in the Miombo zones occur during the late dry season because of the high quantities of extremely dry litter biomass.

Daily fire tendency suggest that the distributions of the different causes of fire is not following the same behavior, this assertions was supported by the chi- square test ($\alpha = 0{,}002^{ns}$), indeed, all causes of fire except ArS, tend to reach his peak in the afternoon, whereas, ArS occur more frequently in the night. Most of the causes of fire occurred in the hour of the day where temperature is higher and relative humidity were lower, therefore, these fires respond to weather conditions. ArS fires do not follow this trend and they do not respond to the weather conditions during the day, but are regulated by other factors, namely people's behavior. On the other hand, the other causes of fire appear to be regulated both by people behavior, which start then, but also by weather conditions, which explains the peak in the afternoon (midday to 3 PM). Thus, it can be inferred that, rural communities have a better knowledge about the time that they may spread fire without risk of being caught. FAO (2006a), commented that fires may be deliberately set as a form of protest or vengeance against one another or against the government, for spite entertainment or employment in firefighting. In some cases, it is a cause of half of total fires in some countries. However, it isn't easy to detain arsonists.

The occurrence of many CFF in the fire hazard hours (during the morning and afternoon), means that there is lack of communication between rural communities, government and forestry companies in terms of fire management, and communities also have a poor knowledge in terms of fire use and management.

Future trends predictions of forests fires occurrences in Chikweti plantations

As the above results showed, most of fires are first related with arsonists and second with land clearing, especially for shifting cultivations. To mitigate these fires and avoid similar situation in the future, companies need to work with government, local authority and non-governmental organizations in improving education and participation of rural communities. Clearing for shifting cultivations, needs to be monitored by companies and also local communities in daily appropriate hours where the fire hazards are very low.

The need of future research to underlying the patterns of fire occurrence found in this research is another key issues, these research must be done as soon as possible, before the decisions makers decides on how to deal with this issues or else, most of the effort will fall down.

Preventive silviculture is needed in Niassa to prevent constant fires occurrences. According to Soares (2002), preventive silviculture consist of forests fuel management such as firebreak constructions, chemical and mechanical weeding, controlled burn, etc. In short, preventative is also a set of general rules of silviculture with the purpose of obtaining forests stands with higher resistance to fire propagation (Vélez, 2000).

The establishment of efficient legislation and the application of severe penalties for offenders is another important point in the prevention of fires. The guidelines for fire management in rural areas can be an important tool to regulate the use of fire and guide the specific legislation on the subject (Soares, 2002; FAO, 2009).

Conclusions

Despite the fact that most of the forest fires in the study area were caused by human-induced causes ArS (55.24%) and CFF (25.24%), weather elements on the study (temperature, relative humidity and precipitation), showed a good correlation with peak of fire occurrence. Arson fires were not only related with discontentment of non-wage earning householders due to poor socio-economic conditions, but may also be related with poor salaries that the local empowered householders earning from the companies and low level of householders education. Land clearances and others causes of fire maybe associated which lack of communications between companies and local communities. ArS fire tend to occur in the night, whereas other causes of fire occurs during the day.

Even though the association test has shown that there was difference between the causes of fires that affected districts in 2011, ArS and CFF tend to be the most dominant causes in all districts.

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