Lessons and Implications for REDD+

Implementation Experiences from Tanzania

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The 5 year CCIAM programme which ended in December 2015, focused on promoting natural forest conservation, afforestation, reforestation and better agricultural practices for improved livelihoods related to the "Reduced Emissions from Deforestations and Forest Degradation (REDD)" initiative.

Chapter 1

Developing Fire Reduction Strategy for Miombo Woodlands as a Potential tool for Carbon Storage and Sequestration

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Abstract

World-wide, wildfires cause problems and when uncontrolled or misused they wreak havoc on society and the environment. In Tanzania, fire occurs in most parts of the Miombo woodlands, and some of them cause significant eco-logical and socio-economic impacts. Several efforts have been made in Tanzania to reduce the occurrence of fire in Miombo but their success has been constrained by underfunding and/or lack of proper strategies. Moreover, in many districts of Tanzania there are no apparent solutions to the fire problem, despite years of regulation and attempts to control fire, and in many places fire incidences are actually increasing. Therefore, this study intended to develop a fire management strategy for the Miombo woodland as a tool for climate change mitigation. This study also strived to identify causes, effects and factors contributing to fire prevalence. Spatial and temporal distribution of fires and burnt extents of wooded areas were determined from the Moderate Resolution Imanging Spectroradiometer (MODIS) active fires product and Landsat satellite images for the past 40 years (1972–2012). Vegetation and household surveys were used to capture empirical data on carbon stock and how different burning regimes and forest management scenarios influence carbon sequestration potentials.

Furthermore, the role of formal and informal framework for the prevention, control and management of wild fires in the Miombo was determined. The main output of this study is a proposed fire reduction strategy in Miombo. The study findings show that, to a wider extent, 1.8 and 2.9 years mean fire return interval persist in western and eastern dry Miombo areas, respectively, burning up to 50.6% of the woodland. These wildfires were largely human-driven and commonly occur in all the villages surveyed whereas the existing local governance structures and institutions suffered from poor coordination, severe underfunding and poor support from the villagers. Torching of forests was largely perpetuated by weak enforcement of laws and regulations, poverty and existing local beliefs. On average, there is an indication that the central government forests have higher stock of carbon than the local government forests and village government forest reserves. However, there was no significant difference in carbon stock between forests experiencing no burning, early burning and late burning. The proposed fire management strategy for Miombo woodlands focused on the promotion of sustainable alternative land preparation methods, improved household income sources and awareness, sustainable land use management and promotion of sustainable charcoal production. The strategy indicates a number of activities to be implemented and actors responsible for each activity.

1.0 Introduction

1.1 Background information

The global greenhouse effect caused by the rising levels of atmospheric CO_2 and the disturbance of the ozone layer as a result of burning fossil fuels and forest destruction is regarded a major threat to life (Sarre and Goldammer, 1996, Danthu *et al.*, 2003). The Inter-governmental Panel on Climate Change (IPCC) estimates that 20-25% of the current annual carbon emissions result from the loss of tropical forests (*IPCC, 2007*). Forests that store 20-100 times more carbon per unit area than cropland play a critical role in the terrestrial carbon cycle. One major way of mitigating carbon emission is emission avoidance or conserving the existing carbon pools on land by slowing down deforestation or by adopting improved forest harvesting practices. In fact, tropical forests have a greatest potential for mitigating atmospheric CO_2 emissions through conservation and management and their biomass and carbon content are high, thus influencing their role in the global carbon cycle (Munishi *et al.*, 2000).

Wildfires constitute a worldwide problem with uncontrolled or careless fire wreaking havoc on society and the environment, destroying property and natural capital, including killing people (Sarre and Goldammer, 1996). The main effects of fires on forests are losses in stocks of biomass, change in the hydrological cycle and nutrients (Salati and Vosep, 1984) and impoverishment of native plants and animal communities, which may be followed by biological invasions (*Mueller-Dombois, 2001*). Moreover, wildfire contributes to the changing the landscape structure and species composition in addition to altering site quality by influencing the vegetation, soil property and processes of grasslands, savannahs, closed forests and woodlands (Christensen, 1985; Goldammer, 1990; Tyler, 1995).

Globally more than 350 million ha of forest were burned in 2000 of which 95% were caused by human activities (FAO, 2003). Global records show that about 3.9 Gt of carbon (*Gt C*) are released annually into the atmosphere through biomass burning (Andreae, 1991). This amounts to more than 70% of the annual anthropogenic fossil fuel emissions. With its inherent sensitivity to climatic conditions, and with the prospect of rapid future climate change, wildfire has been a focus of intensive investigation in recent years (Hesseln, 2001). The World Summit for Sustainable Development (WSSD) in Johannesburg, South Africa, 2002, provided groundwork for an action programme to reduce the negative effects of wild land fire on the environment and humanity. The follow-up International Wild land Fire summit held in Sydney, Australia in October 2003 was geared towards developing synergistic solutions to strengthen international cooperation in order to reduce the negative impacts of forest fires on humanity and the global environment.

Africa leads the world in the number of wildfires and area burned almost every year in total or by areas (*FAO, 2003*). For example, in 2000 an estimated 175 million hectares of forest, savannah woodlands and grasslands were burned south of the equator in Africa. Many of these wildfires were intentionally set to clear land for agriculture, and many others spiralled out of control to burn much larger areas than those originally intended. It is not possible to state conclusively that there is a long-term upward trend of wildfires at the global level, since historical data are available for only a small number of countries. However, the problems experienced by individual countries and regions are such that an increasing number of national and local governments are placing wildfire as a priority issue requiring increased policy attention and increased allocation of resources (*FAO, 2005*). In Tanzania, between 2000 and 2009, forest fires affected about 65,000 ha of forests and woodlands annually of which more than 75% occurred in Miombo woodlands (FAO, 2011; Kideghesho *et al.*, 2013). On the average, 11 million ha burn annually (*ranging between 8.5 and 12.9 million ha*) in Tanzania and this corresponds to between nine and 14 % of Tanzania´s land area (Rücker and Tiemann, 2012). This widespread burning has alarmed the Tanzania government, forest managers, researchers and communities. In response, different efforts have been made to address the challenge. These efforts include the Community Based Fire Management Plan (CBFMP) and bye-laws in Bukombe district and East Usambara (Nssoko 2002, WWF 2006). Despite several efforts having been made in Tanzania to reduce fire outbreaks in Miombo woodlands, the success has been constrained due to lack of appropriate strategies.

1.2 Rationale for the study

Fire occurs in many parts of the Miombo woodlands. In fact, local farmers adjacent to the forests practice subsistence traditional farming and use fire as a management tool. Moreover, fire is used for hunting, taboo reinforcement, encouraging growth of grasses on grazing land by pastoralists, and pyromaniacs. Sometimes such fires are started out of recklessness or arson motives. Some of these fires cause significant ecological and socio-economic impacts. The negative environmental consequences of the loss of the Miombo woodland through fire include the reduction in water supply and biodiversity, pollution of water sources, carbon sequestration and reduction in agriculture production.

Human agents can promote carbon sequestration in woodlands by increasing the fire return interval and/or by decreasing the pressure of grazing animals exert on the grass layer. In addition to this management driven carbon sequestration, potential elevated atmospheric CO_2 is expected to favour carbon sequestration in woodlands and facilitate tree growth. Although savannas and woodlands have the potential of flipping between carbon-poor and carbon-rich states, the current and future carbon storage potential of the African savannah woodland has hitherto not been well articulated or quantified. In fact, there have been very little or no concerted efforts made to bring about on-the- ground interventions in relation to fire management in the area. Remote sensing followed by ground truth could be a compromise in determining burnt areas and estimate the amount of carbon pumped into the atmosphere through fire and/or sequestration.

In many districts of Tanzania, there are no apparent solutions to the fire problem, despite years of regulation and attempts to control, and in many areas, fire incidence is actually increasing. National forest laws preventing fires also exist, but they tend to be ignored in the rural areas where local bye-laws are more important. In fact, there are some areas where fire incidences are rare and these local successes in fire control can be scaled up to address the fire problems in the Miombo. In the Miombo woodland, the major handicap to forest fire management is lack of forest fire records, which should highlight the location of the incident, time and day of occurrence, causes of the fire, and financial losses incurred. There is also lack of detailed local fire knowledge and practices. These data would provide a foundation for the design and prioritisation of future wildfire management activities in the country. Several efforts have been made in Tanzania to reduce fire frequency in Miombo woodlands but the success has been constrained by underfunding and/or lack of proper strategies. In recent years, fire has compromised efforts towards forest sustainability and biodiversity conservation, raising great concerns among government authorities and local and international researchers and conservation agents.

The institution of policies and establishment of procedures for fire occurrence documentation at village, ward and district, regional and national levels can help villagers in the planning process, as well as in sourcing funding, infrastructure and training human resources capable of contributing to combating fire. Moreover, little is known on the place of fire in the society in terms of what triggers the fire and whether there are traditional institutions governing the use of fire. Also, what do villagers know about the impact of fire on the environment in terms of water supply, species diversity of flora and fauna? What are the best mechanisms of fire control from their point of view? Therefore, the understanding of the fire regimes and the effects on the vegetation under different management scenarios as well as the overall socio-economic situations can help to develop fire management strategies that can serve as a tool for carbon storage and sequestration in the Miombo ecosystem. On the whole, the fire management strategy is critical for local, national and global interests.

The envisaged strategy can enhance the establishment of an effective and functional National Forest Policy in Tanzania. For smooth running of the project, local communities and forest practitioners were involved during project design and implementation stages.

1.3 Objectives of the study

The main objective of this study was to address climate change mitigation and adaptation strategies through the development of a fire management strategy for the Miombo woodlands as a potential tool for carbon storage and sequestration. Specifically the project focused on the following objectives:

1. To determine the intensity and impact of fire on forest degradation in the entire Miombo ecosystem
2. To determine carbon stocks in woodlands under different burning regimes scenarios
3. To identify causes, impacts and factors contributing to fire prevalence
4. To determine the role of formal and informal governance structures for the prevention, control and management of wild fires in the Miombo woodlands

2.0 Methodology

2.1 Location

The study was conducted in three districts, namely Handeni, Kilosa and Kilwa (Figure 1.1:). However, for the determination of the intensity and impact of fire on forest degradation data were collected from the entire Miombo ecosystem in Tanzania. These districts were chosen based on the availability of Miombo, annual fire incidences and different forest management regimes therein. In these districts, some Non-governmental organisations (NGOs) are also involved in forest conservation. Three forests one each either under Central government management (CGFR), Local government (LAFR) and Village Forest (VLFR) was selected. The chosen forests were Handeni: Kiva hill (LAFR), Handeni Hill (CGFR) and Gumba (VLFR); Kilosa: Palaulanga (CGFR) Magubike South (LAFR) and Ihombwe (VLFR); and Kilwa: Mitalule (CGFR), Kiwawa (LAFR) and Kikole (VLFR). In each forest, three blocks of three plots each were established. Within each block, the plots are as follows: main plots (28x28 m); sub-plots plots (7x7 m); sub-sub plots (3.5x3.5 m). A 30m strip was marked to separate the main plots and fire breaks of 4 m width surrounded each main plot. Three treatments were considered for this study; no burning, early burning and late burning. Experimental early burning was conducted in July and late burning in September for all the sites for three consecutive years from 2011 to 2013.

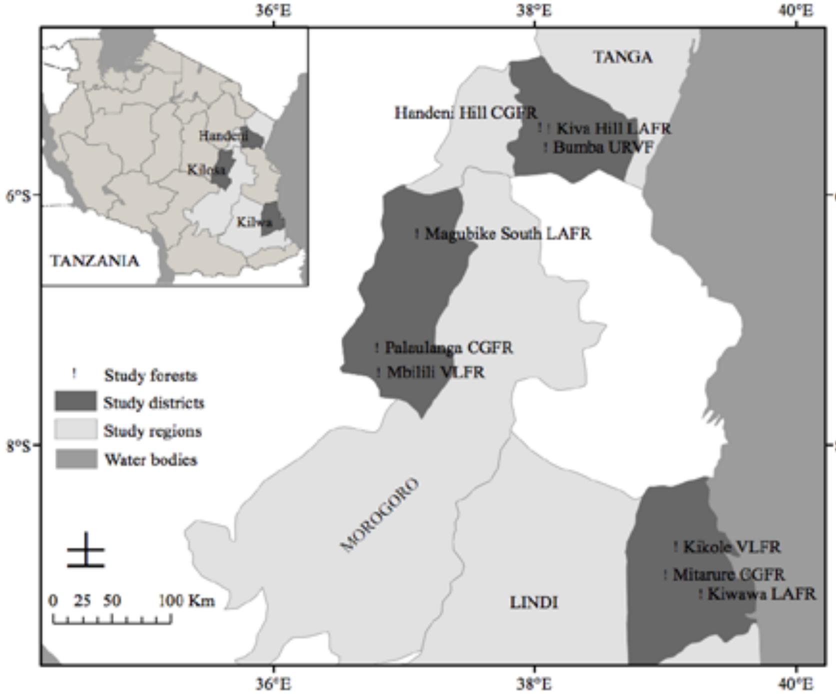

Figure 1.1: A map showing study ditricts and miombo woodlands

2.2 Approaches to data collection and analysis

Different methods were used to capture empirical data in this study. Spatial and temporal distribution of fires and burned wooded savannah areas in Tanzania were determined from the MODIS active fires product and Landsat satellite images for the past 40 years (1972 – 2012). The images were analysed following standard procedures in GRASS GIS V.7 and ArcGIS 10.0. Data on carbon stock was collected in December of the current year after short rains. Data were collected for three consecutive years; 2011, 2012 and 2013. In each site and each main plot (28 x 28 m) all the trees with dbh >10 cm were identified and measured for diameter at 1.3 cm and height. To determine forest biomass, we used the allometric equation developed by Chamshama *et al.* (2004). This equation includes trees from 1 cm diameter at breast height (dbh) and it has the advantage of requiring only dbh as a variable. It also had R^2 of 97%, hence making it reliable for the estimation of biomass. The equation is:

$$\textbf{\textit{Biomass}} = 0.0625\textbf{\textit{D}}^{2.553}$$

Where: ***Biomass*** = total tree biomass (kg/ha) and

D = tree dbh (cm)

(R^2 = 0.97)

The biomass was then converted into carbon using a biomass-carbon ratio of 0.49 (49 (MacDicken, 1997; Brown, 1997; Brown, 2003).).

The analysis of Variance (ANOVA) was performed to compare the study variable between different management regime and burning regimes. Significant differences in carbon stock in trees were tested using Tukey's Test in SAS-JMP software.

The availability and contribution of formal and informal governance structures in fire prevention, control and management was captured through Participatory Rural Appraisal (PRA) and Structured Interviews. Similarly, the causes, impacts and factors contributing to fire prevalence were captured using the same methods. PRA methods include Participatory Resource mapping, Transect Walks and Matrix Scoring. Ten village participants from different backgrounds were used for the PRA exercise and nine PRA meetings were conducted during data collection. Direct observations helped the researchers to cross check the validity of the information obtained using other methods and to gain more understanding of the real situation on socio-economic activities, fire incidences, forest conditions, and understanding the organisation of existing governance structures on how they played their roles. A total of 270 structured questionnaires were administered with the heads of randomly selected households from one village adjacent to the study forests (30 households in each village). Also, semi-structured interviews were conducted with key informants such as village leaders, traditional leaders and heads of NGOs and district natural resources officers including District Forest Officers to capture issues related to wildfires. Content analysis was used for the qualitative data collected through PRA, direct observation and key informant interviews. This method involved breaking down the components of recorded discussion with the respondents into smallest meaningful units of information or themes. The quantitative data from structured questionnaires were coded and entered into the Statistical Product and Service Solutions (SPSS) version 22 for analysis. Descriptive statistical analysis was used in exploring the data for distribution of responses. The Chi square (χ^2) tests at 99% ($\alpha = 0.01$) and 95% ($\alpha = 0.05$) Confidence Intervals (CI) were used to test the hypotheses (H_0: The causes of wildfires do not differ across the different management regimes; H_1: The causes of wildfires differ based on differences in forest management regimes). Furthermore, Analysis of Variance (ANOVA) was used on responses across management regimes based on the matrix scores developed during PRA exercises.

3.0 Results and key lessons from the study

3.1 Fire intensity and impact on forest degradation

3.1.1 Fire return interval

The mean fire return interval for an area of ~314ha was 2.7 years (range: 1 - 13 years) based on MODIS detected fires between 2001 and 2013. When the analysis was performed for every 2500ha during 1972 – 2011 based on burned areas detected from Landsat images, the interval was shortened to 2.1 years (Tarimo *et al.*, 2015). Moreover, 74% of the woodland area had a return interval of <2 years for every 2500ha between 1972 and 2011. Field observations in a dry Miombo site have shown a mean fire return interval of 1.6 years in Zambia (Chidumayo, 1997), whereas a return interval of 3 years on a regional scale was observed based on satellite data (Frost, 1996). The fire return interval and burning seasonality have selective effects on different components of the woodland, as they influence the intensity of fires and extent of the burning. Results from a study that combined field observations and modelling from Miombo sites in Zimbabwe and Mozambique show that, at least two years are required between successive low intensity burns to allow for tree establishment and development (Ryan *et al.,* 2011).

The mean fire return interval was 2.5 years and 3.8 years for western and eastern dry Miombo, respectively, for the period 2001 – 2013. On a wider scale, 1.8 and 2.9 years mean return intervals were observed in western and eastern dry Miombo areas respectively for the period 1972 – 2011(Tarimo *et al.,* 2015). Similar findings were established in southern African savannas where return intervals were shorter in higher rainfall areas than in low rainfall areas (Van Wilgen *et al.,* 2000). Management strategies can, therefore, benefit from this information on recurrence and seasonality of fires, which when combined with stand level ecological characteristics may highlight spatially specific management needs of wet and dry Miombo.

3.1.2 Impacts of burning

Analysis of Landsat satellite images revealed that annually, up to 12.6% and 13.7% of the total area with available imagery was detected as burned in dry and wet Miombo, respectively (Tarimo *et al.*, 2015). Between nine and 14% of Tanzania's area was detected as burned on an annual basis between 2000 and 2011 from a lower (500 m) resolution burned area product (FAO, 2013). Much of the burned areas in the country are evidently not detected at this resolution. Lower detection rate is possibly higher in the mixed burned-unburned patches. However, rigorous validation was not performed for partially burned areas. They provide crucial information for understanding vegetation dynamics, which require seasonality and severity of fires at specific areas but may be less useful in emission estimates which require accurate sizes of areas burned. For the later extensive validation of partially burned areas may be required.

3.2 Impacts of burning and management regimes on carbon stock

Both burning regimes and management scenarios did not show any significant impacts on above ground carbon stock (Table 1.1). However, there was a noticeable lower carbon stock in late burning than in other burning regimes. Similarly, there was lower carbon stock in forests under village management than other management regimes.

Treatment	Carbon stock for trees dbh>10 cm (t/ha)		
	2011	**2012**	**2013**
Burning regime			
No burning	26.07 (4.6)[a]	28.84(4.4)[a]	26.12(4.9)[a]
Early burning	28.32 (4.6)[a]	28.94(4.4)[a]	28.24(4.9)[a]
Late burning	23.12 (4.6)[a]	23.22(4.4)[a]	19.81(4.9)[a]
Management regime			
Village Forest Reserve	21.74 (4.4)[a]	23.84(4.4)[a]	22.22(4.9)[a]
Local Authority Forest Reserve	25.22 (4.4)[a]	27.23(4.4)[a]	23.52(4.9)[a]
Central Government Forest Reserve	30.55(4.4)[a]	29.92(4.4)[a]	28.43(4.9)[a]

Table 1:1: Above ground Carbon stock for trees dbh>10cm across different burning regimes and management scenarios.

The number in parenthesis is Standards Error and the numbers in columns with similar letter are not significantly different (p>0.5).

The range of carbon stored in trees (21.74 – 30.55t/ha) in the study forest reserves is slightly higher than the one reported for Miombo woodlands in the southern highland Miombo forests (17.9 – 20.4 t/ha) (Munishi *et al.*, 2010). These differences could be attributed to the fact that the present study included only reserved forests, which are a bit protected from illegal extractions, hence limiting human activities. Another study by Munishi *et al.* (2010) included trees outside forest reserves.

3.3 Causes, effects, factors contributing to fire prevalence and potential strategies to reduce wildfire incidences

3.3.1 The proximate causes of wildfires

Five proximate causes of wildfires were identified by local communities in the study villages in order of prevalence in terms of farm preparation, hunters, arsonists, livestock keepers and charcoal makers. The study hypothesised that causes of wildfires depended on differences in forest management regimes. Farm preparation was identified as the most significant causes in CGFR as compared to the VLFR and the LAFR. The practice was most (94.4%) common in Kilwa district followed by Kilosa (45.6%) and least practiced in Handeni district (34.4%). Kilwa leads in such practice due to the abundance of unreserved land and low population density estimated to be 13 people/km^2 compared to 31 and 77 people/km^2 for Kilosa and Handeni, respectively (URT, 2013). Wildfires caused by livestock keepers were mostly (15.6%) reported in LAFR compared to VLFR (67%) and CGFR (4.6%). It was further established that illegal hunting was mostly reported in CGFR whereas arson was mostly reported in LAFR. Charcoal-burning is a potential cause of forest fire in CGFRs and LAFRs. This could be attributable to factors such as weakness in law enforcement, increasing demand for charcoal in big cities, and construction of tarmac roads connecting these districts to charcoal markets. Forest clearing and charcoal-burning have been responsible for the rapid loss of forest cover and the deterioration of local biodiversity along Tanzania's main roads (Ahrends *et al.*, 2010; Kideghesho *et al.*, 2013). Chi-square test revealed no significant difference ($\chi^2 = 16.391$ and $p = 0.089$) on the most important cause of forest fire across forest management regimes, implying that there are similarities when it comes to the causes of wildfires.

Wildfires were either deliberate (arson) or accidental in occurrence. The former was a result of fire due to anthropogenic activities such as taboos (measuring life-span e.g. in Tanzania some ethnic groups believe that if one starts a fire and it lasts longer and spreads to a large extent such a person is considered to live a long life); clearing up of landscapes to allow safe and free movement in the forest during hunting or collection of forest products, forage production, controlling parasites such as ticks and tsetse flies and vermin and eliminating cover to discourage dangerous animals. The use of fire during hunting of small mammals such as Giant rats (Ndezi) was practiced in all the forests under study. Such traditional hunting involves burning of bush on one side and waiting for escaping animals on the opposite side of the bush. The causes of wildfires in this study have also been acknowledged in other studies, with farm preparation being the main cause (Fitzgerald, 1971; URT, 1998; FAO, 2007; FAO, 2011).

The months of June, July, August, September, October, November and December were reported by 5.6%, 17.3%, 51%, 63.5%, 66.3%, 33.3% and 12.4% of respondents respectively as a season of wildfires. The months of August, September and October were reported by 20.5%, 25.5% and 26.6%, respectively, as the peak fire season. Similar peak fire season was reported in Masito Ugalla Ecosystem (Kashula and Gobbo, 2011). The months of June, July, November and December had low wildfire incidences as reported by 2.3%, 6.9%, 13.5% and 5% of respondents, respectively. It was observed that June and July were onset months of the dry season with little fuel load and fresh grasses. November and December had low fire incidences because of the short rains that minimise combustibility of fuel biomass. In addition, during that period, most of the villagers are usually engaged in farm activities with little engagement in risky activities such as illegal hunting and honey collection that could cause fire eruption.

Further analysis shows that the peak fire season is not determined by forest management regimes but rather by geographical locations of research sites. Minor variations were observed among the sites. For instance, Handeni hill CGFR and Kiva hill LAFR (in Handeni District) experienced peak fire season in September and October whereas Bumba proposed VLFR (in Handeni District) experienced it in September. Variation in peak fire season was also found in Kilosa District where Mbilili VLFR experienced a peak fire season in August whereas Palaulanga CGFR and Magubike South LAFR experienced fire season in October. In Kilwa, Kikole VLFR and Mitalule CGFR experienced the peak fire season in September and October whereas in Kiwawa LAFR the fire season peaked in October. Across all the forests very few fire incidences were reported before and after the peak fire season. Such findings suggest that any campaign attempting to reduce forest fires incidences should start at the end of the rainy season mainly in May and June. Frost (1996) and Kall (2006) argue that fire burning in the early dry season (May-June), when the ground layer is still moist tends to be very low in intensity and limited in extent and, hence, affects grasses and mammals negatively whereas woody plants are less affected.

1.1.2 Point of ignition of forest fires

The point of wildfires in the forests under review was identified to be around residential areas, inside the forest reserve and around farms. The chi-square test indicated a significant difference in origin of forest fires across forest management regimes ($\chi^2 = 13.341$ and $p = 0.031$). About 59%, 46% and 69% of respondents adjacent to VLFRs, CGFRs and LAFRs respectively revealed that most of the forest fires start from inside the forest. The high proportion of wildfires starting from inside the forest suggests the existence of illegal anthropogenic activities. Such illegal activities include hunting, honey harvesting, livestock keeping, charcoal-burning and lumbering, which usually happen inside the forest. About 16%, 28% and 16% of respondents adjacent to VLFRs, CGFRs and LAFRs respectively reported that wildfires start from around residential areas. Wildfires that start around farms were common in VLFR as reported by 10% compared to NFR and LAFR reported by 7.8% of the respondents.

3.3.3 Effects of forest fires in the study villages and forests

Discussion with people living in villages adjacent to the forests covered by this study revealed both positive and negative effects of forest fires. Positive effects of forest fires as perceived by local communities in order of importance include simplifying farm preparation, chasing away pests/parasites, stimulating growth of grass for fodder, a tool during illegal hunting, improving soil fertility especially in millet fields, and as a tool for clearing routes during the harvesting of forest products such as timber. The F test indicated that there was no significant difference on the positive effect of forest fires across forest management regimes (F=0.111, p=0.895). Nevertheless, the results suggest existence of social ties between forest fires and the daily life of local communities. Economically, forest fire was perceived to increase household income when it was used to stimulate growth of fodder, hunting, collection of forest products, and killing of pests/ parasites, which could transmit disease to livestock. Culturally, forest fire is used as a yardstick of the lifespan of individuals involved in torching forests.

Negative effects of forest fires in order of severity include loss of biodiversity, causing climate change, loss of the property, causing soil erosion, drying of water sources and loss of soil fertility. Comparing people's perception on negative effects of forest fires across forest management regime using F test indicated no significant difference (F = 0.852 and p = 0.446). Citing an example of the negative effect of forest fire on biodiversity, elders in Kwedibangala Village, in Handeni District, reported that the forest fire of 1977 led to the disappearance of Mnwahungo forest. In such incidence, animals and birds that escaped were also affected by changes in their habitat. Moreover, a loss of soil fertility in burnt areas negatively affects crop production, especially paddy. Similarly, Zolho (2005) reported that in the long-term frequent fires may result into changes in productivity and population structure of the plant and animal species due to reduced plant biomass and litter, thereby altering the energy, nutrient and water fluxes between the soil, plants and atmosphere.

3.3.4 Factors underlying forest fire incidences

Factors underlying forest fire incidences include poverty, weak law enforcement, climate and ignorance of the local people (Figure 1.2). Of the four factors, poverty was reported by 34% of the respondents living adjacent to LAFR as compared to 22% in VLFR and 28% in CGFR. Poor economic situations were reported to drive local communities to engage in unsustainable and often destructive means of accruing income or food from the forests such as illegal hunting, honey collection, extraction of forest products and shifting cultivation.

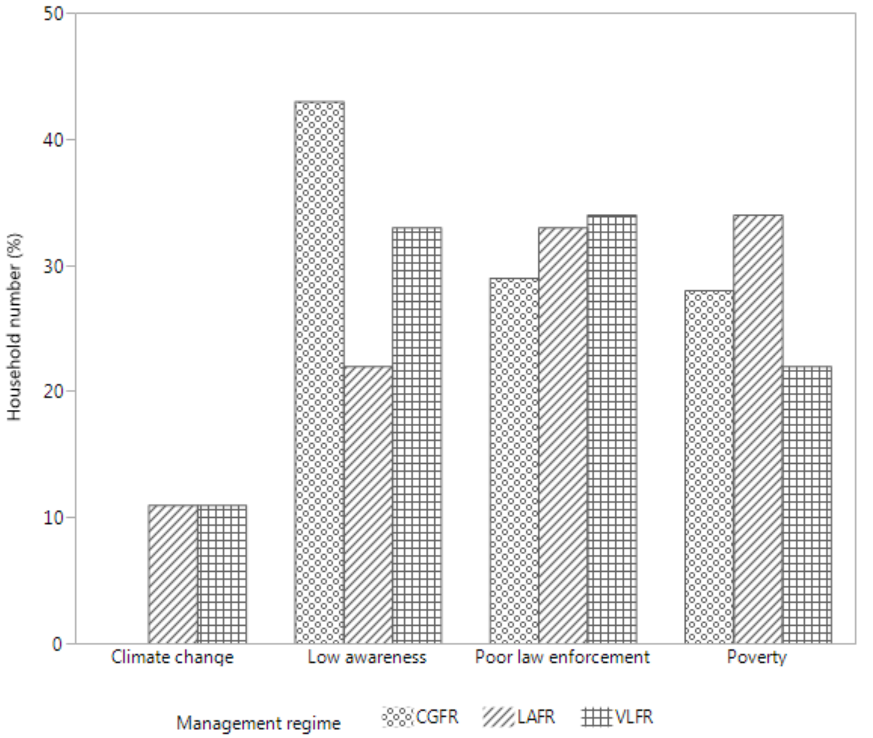

Figure 1.2: Factors underlying occurrence of forest fires in VLFR, LAFR and CGFR.

Ignorance on negative effects of forest fires was more evident among local communities adjacent to CGFR (43%) as contributing to fire incidences as compared to VLFR and LAFR. Ignorance could be partly explained by the majority of forest adjacent communities failing to link biotic and abiotic components of the environment. Therefore, it was not surprisingly for someone to start a forest fire when hunting small mammals to earn cash income. Moreover, weak enforcement of the existing laws and bye-laws was acknowledged by most in VLFR (34%) and in LAFR (33%) as an underlying factor behind forest fires as compared to CGFR. Lack of funds, vehicles and staff to patrol forest were singled out as overriding factors hindering law enforcement. Climatic factor mainly drought and wind were also reported by local communities adjacent to VLFRs and LAFRs as underlying factor of forest fires.

3.3.5 Potential focus areas to reduce forest fire incidences in the study area

Figure 1.3 presents five (5) potential focus areas to reduce forest fire as identified by communities living adjacent to forest reserves. These include awareness creation, formulation and enforcement of bye-laws, making firebreaks, provision of alternative income generating activities (IGAs) and improving agriculture through the provision of subsidies. Awareness creation, which was the most prioritised by communities adjacent to VLFRs and CGFRs entail the provision of conservation education. This probably due to limited extension and publicity services provided in villages adjacent to the study forests. For instance, only 38.9%, 37.8%, 36.3% and 32.2% of the respondents living adjacent to LAFR, VLFR and CGFR, respectively, acknowledged having seen forest fire campaigns being conducted in their respective villages. Kashula and Gobbo (2011) reports that awareness creation for forest adjacent communities is important in minimising forest fires in the area as it has been confirmed to work efficiently in the conservation of forests in Western Tanzania, where forest fire incidences have been reduced by 80%.

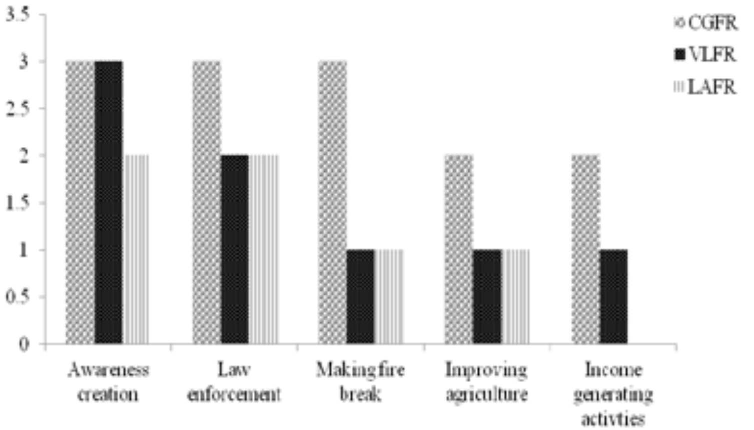

Figure 1.3: Focus areas to reduce fire incidences identified by local people during household survey

Enacting and enforcing existing laws and bye-laws as a focus area of reducing forest fires ranked first in CGFR and second in VLFR and LAFR. Both laws and bye-laws have provisions on restricting burning of vegetation. For instance, the Forest Act no. 14 of 2002, sections 70–76, restrict burning of vegetation (URT, 2002). With regard to bye-laws, they vary across villages. Of the nine (9) villages surveyed, only Kikole and Ihombwe had approved forest bye-laws. On the other hand, making firebreaks was identified and prioritised by communities living adjacent to the forest reserves. Firebreaks help to protect forest reserve from forest fires started outside the reserve. Essentially, out of the nine forests surveyed, only Kikole VLFR had firebreaks. Nevertheless, neither CGFRs nor LAFRs had firebreaks. With regard to IGAs, local communities identified fish farming, beekeeping and commercial tree-planting that could increase income of the rural poor, hence reduce pressure on the forest reserves. In addition, the adoption of such environmental-friendly activities could instil a sense of ownership in the forest resources, and potentially ultimately protect the forests and biodiversity (Songorwa, 1999). Furthermore, increasing agricultural production through the provision of subsidies on agricultural inputs could relieve of forests of some of the human pressure, therefore, reducing the eruption of forest fires. Such intervention could reduce dependency on forest resources.

3.3.6 Role of formal and informal governance structures for the prevention, control and management of wild fires in the Miombo woodlands

In this study, 57.8%, 64.4% and 50% of the respondents sampled in villages adjacent to VLFR, CGFR and LAFR, respectively, acknowledged the presence of informal and formal governance structures which deal with environmental issues including the management of wildfires. Nonetheless, the chi-square test indicated that the difference in responses of villagers regarding the presence of governance structures was not statistically significant (χ^2= 3.847, p = 0.146) between forest management regimes. This suggests that there is no variation across forest management regimes, possibly because the structures are formed based on the provision of the law. Informal governance structures identified include elders, traditional/clan leaders and herbalists. Their role include 1) disseminating information to youngsters on the importance of not starting wildfires in sacred forests/plants or mountain; 2) transferring knowledge to youngsters on traditional rituals, norms, taboos and initiations; and 3) punishing any person found guilty of starting fires in the restricted area by using customary rules. It was also revealed that these informal governance structures had been proven to be powerful in the past contrary to the current situation, presumably due to changing attitudes and beliefs among many youths. Similarly, increased ethnic intermarriages, in-migration, modernisation and technological intervention are threatening and transforming or eroding the cultural rules, beliefs and taboos governing the management of forests (Katani, 2010).

Furthermore, the formal governance structures identified in the villages include Village Government (VG), Village Council (VC), Village Natural Resource Committee (VNRC) or Village Environmental Committee (VEC), Ward Development Committee (WDC) and the Primary court. These structures have been established in accordance with formal laws such as the Local Government Act No. 167 of 1982, Forest Act No. 14 of 2002 and Environmental Management Act No. 20 of 2004. Matrix ranking based on activeness of the structure on forest protection including the prevention, control and management of wildfires revealed that VEC/VNRC was leading followed by VC whereas WDC ranked third and the Primary Court was the least effective. Table 1.2: presents the roles of these formal governance structures. The roles of VG/VC and VEC/VNRC originated from forest management plans, PFM guidelines and bye-laws, Forest Act No. 4 of 2002, Local Government Act No. 167 of 1982 and Environmental Management Act of 2004. The roles of WDC with regard to forest protection have been extracted from section 32 of the Local Government Act No 167 of 1982.

Governance structure	*Roles*
Village government (village assembly)	-Discuss and approve draft of management plan and by-laws including those prohibit wildfires; and -Participate in forest management activities including making fire breaks.
Village council	-Discuss and provide suggestions of forest management by-laws; -Dislodge VEC/VNRC if proved failure in performing its duties including failure to reduce incidences of wildfires; -Awareness creation on forest protection including matters related to wildfires; and -Enforce bye-laws.
VEC/VNRC	-Plan and supervise everyday forest activities including doing forest patrols; -Propose draft of by-laws that govern management of the forest reserve; and -Enforce bye-laws including fining any person caught committing illegal activities and take criminals to the court including those caught starting wildfires.
WDC	-formulation, and submission to the village councils or to the district council proposals for formulating bye-laws in relation to the affairs of the ward.

Table 1.2: Roles of existing formal governance structures in the surveyed villages

3.3.7 Performance of governance structures in the management of wildfires

Governance indicators including accountability, transparency equity, rule of law, responsiveness, participation and effectiveness were used to measure the performance of different governance structures at the village level based on 5-points scale (very good = 5, good =4, satisfactory =3, poor =2 and very poor =1). Overall, the performance of governance structures in forest protection against wildfires was rated as poor in all the villages under review. This finding suggests that local structures have not been adhering to the principles of good governance. The reported increasing wildfire incidences testify to the weakness of the existing local governance structures. For instance, VC and VEC/VNRC were rated as poor and as satisfactory, respectively, upon looking at the issue of accountability. This performance was, perhaps, due to limited village assemblies convened to discuss forest related issues. And even in such assemblies, the agenda of forest protection against wildfire never feature in the discussions. Such a situation denies the villagers of their right to access information regarding forest protection, and potentially increases conservation threats to the forest. Similarly, very few forest patrols were made and lawbreakers were not punished accordingly. Our results also show that 68.7% of the respondents claimed not to participate in forest protection owing to their discontent over how the existing governance structures handled forest management activities.

Furthermore, interviewees in villages adjacent to the forests under review reported a low level of transparency amongst members of VC and VEC/VNRC. Members of the respective structures withheld information on income and expenditure and often took no action against offenders reported to them by villagers. Similar scenarios were reported by Rafael and Swai (2009) and Nuru *et al.* (2009), which found poor transparency in the handling of forest destructive actions. There are several reasons contributing to poor performance of the local governance structures. These include poor co-ordination among structures at the village level, severe underfunding and poor support from the villagers. For instance, VEC/VNRC were frequently found to be engaged in a tussle with the VC on who is responsible for collecting and managing forest revenue. With regard to funding, the only source was fines from arrests of people implicated in illegal activities within the forests, an unreliable source of funding that cannot be integrated in the forest protection plans. On the other hand, funds generated by the village government from other sources such crop levies were not allocated to forest protection. As a result, members of the VEC/VNRC lacked incentives and protection gears to execute forest protection duties such as forest patrols.

4.0 Implications of the lessons learnt relevant to the REDD+ process and climate change mitigation and adaptation in general

i) *Socio-economic welfare*: Reduced fire incidences and frequencies will improve or increase ecosystem services and goods in the areas consequently the livelihood of the people

ii) *Environment aspects*: Fire is usually an environmental nuisance and, therefore, its reduction could lead to an improved environment for both humans and other living organisms

iii) *Policy reforms*: Fire problems are not well-articulated in our natural resources (forestry, wildlife, land, agriculture and beekeeping) based policies and laws despite the fire being caused by different activities related to different sectors. Findings from this study could be used to review and improve these policies and laws

iv) *Capacity building*: During the project development and implementation, villagers through VEC, District officers, NGOs and Project researchers have increased their understanding on forest fires and REDD initiatives at large.

v) *Cross-cutting issues* i.e. *Collaboration, gender and HIV/AIDS:* Through this project participating researchers have increased their scientific/social network at village, district, Institutional, national and International level. Similarly, constraints hindering the smooth implementation of the project such as lack of or limited women's empowerment and participation, diseases, education and poverty were discussed.

5.0 Recommendations:

Results from this study lead to the proposed fire management strategy in Miombo woodlands of Tanzania (Table 1.3):

Main causes of Fire	***Focus area***	***Activities***	***Actors***
Farm preparation	Promote sustainable alternative land preparation methods	Provision of agricultural extension services Construction of fire break between farms and the forests	Community members, Village Council, District Council, , NGOs Forest owners and farmers
Hunting	Improvement of household income	Promote alternative livelihood strategies Awareness creation through meetings, seminars, posters, leaflets,	Community members, Village Council, District Council, , NGOs
Arsonism	To reduce ignorance among local communities related to fire and environment	Awareness creation through meetings, seminars, posters, leaflets, Law enforcement	Community members, Village Council, District Council, Central government, NGOs
Livestock keepers	Sustainable land use management	Land use planning Law enforcement Awareness creation Provision of livestock extension services	Community members, Village Land Use Planning Committee (VLUPC), Village Council, District Council, Central government, NGOs, Judiciary
Charcoal makers	Promote sustainable charcoal production	Use of alternative and sustainable source of energy Law enforcement Awareness creation	Village Land Use Planning Committee (VLUPC)Village Council, District Council, Central government, NGOs

Table 1.3: Fire reduction strategy in Miombo woodlands of Tanzania

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