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Impacts of Wildfire and Prescribed Fire on Wildlife and Habitats: A Review

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Abstract
Forest fires controlled or uncontrolled have profound impacts on the physical environment including land cover, land use, biodiversity, climate change and forest ecosystem. Effects of fire on wildlife are either immediate impacts, which include direct injury or mortality of plants and animals and secondary impacts include an alteration of forage productivity, availability and quality, as well as creating, destroying, or degrading various habitat attributes. Fire may have direct short-term effects on density of animals and/or long-term indirect effects through habitat modification. The most important effects of fire on wildlife populations are due to changes in the vegetation. Burning can improve the habitat for some species through effects on the vegetation, resulting in a post-fire succession. Sustainable management of forest resources has become key agenda of biodiversity conservation. Forest fire is one of the important factors to be considered for better management of the forest resources including wildlife. Therefore, fire represents not only devastation, but also renewal of wildlife habitats.
Keywords: Forest fire, Habitat, Prescribed burning, Succession, Vegetation, Wildlife

INTRODUCTION

Fire has been a source of disturbance for thousands of years (Roy, 2003). After human, urban and agricultural activities, fire is the most existing terrestrial disturbance (Bond and van Wilgen, 1996). Burning is recognized as a ‘chronic disturbance’ (Singh, 1998) that can have substantial impacts on the entire forest ecosystem including impacts on vegetation, soil and water resources, fauna and micro-climate (Mehta *et al*., 2008). Forest and wild land fires have been taking place historically, shaping landscape structure, pattern and ultimately the species composition of ecosystems (Roy, 2003). Fire is an important tool for ecosystem management in many biomes throughout the world, particularly in tropical savanna (Gillon, 1983; Andersen and Muller, 2000). It is a natural disturbance process that can often shape ecosystems and influence habitat diversity and productivity (Bisson *et al*., 2003; Minshall, 2003). Fire is both a natural and human enhanced factor in ecological systems (Kormondy, 2001). The ecological role of fire is to influence several factors such as plant community development, soil nutrient availability and biological diversity (Roy, 2003). Fire feels warmth and cheer and also fear and destruction (Smith, 1992). It is both a destroyer and a regenerator of life. It is also one of the major influences on community development.

The ecological effects of fire are many and complex and it is highly unlikely that they will ever be well understood for all organisms and ecosystems (Burrows *et al*., 1995). Burning can affect the short-term population dynamics of vertebrates directly through mortality due to fire (Cook, 1959; Dieni and Anderson, 1999) or indirectly, due to changes in the structure of the vegetation initiated by fire (Zedler *et al*., 1983). Burning can also improve the habitat for some species through effects on the vegetation, resulting in a post-fire succession (Pianka, 1996; Layme *et al*., 2004). Fire not only affects burnt ecosystems themselves but also strongly modifies previous landscape patterns, causing the appearance of new landscape units, the elimination of others and the fragmentation of remnant patches (Trabaud and Galtie, 1996; Layme *et al*., 2004).

Fire is an important feature of many climax communities, favoring fire-resistant species and excluding others that otherwise would have dominated (Riggan *et al*., 1988, Ricklefs, 1990). In the tropics alone, it has been estimated that 2,700-6,800 million tones of plant carbon is burnt annually, mostly in savanna fires or shifting agriculture (Bond and van Wilgen, 1996). Fire annually destroys 80,000 or more km^2 of forest (Heywood and Watson, 1995). It is both accidental and intentional, exerts varied effects on species populations and has been responsible for the creation of a number of biotic climaxes in savanna types of vegetation in the tropics (Ewusie, 1980). Known impacts of fire in tropical forests include changes in species composition, abundance and diversity of plants (Woods, 1989) and animals (Barlow *et al*., 2002), loss of seed banks, increased tree mortality, reduced regeneration potential and changes in microclimate and soil conditions (Cochrane, 2003; Adeney *et al*., 2006). Fire effects on aquatic communities vary greatly by location and severity (Minshall, 2003), but are greatest in small headwater streams, with measurable effects decreasing as stream size increases (Minshall *et al*., 1989). Fire has a stronger influence on headwater streams than on large rivers because a greater proportion of the adjacent catchments are likely to be burned (Minshall *et al*., 1997; Mellon *et al*., 2008).

Fire causes natural fear in every living being on earth, only humans have found the way to control and use it in a way to improve the quality of life on earth (Ljiljana *et al*., 2005). Wildfires that burn out of control in areas with high fuel loads may remove many species of plants and may reduce or delay the extent to which wildlife repopulate the burn site (Main and Tanner, 1999). Even humans cannot control it in every situation and sometimes fire gets out of control and causes large damages (Ljiljana *et al*., 2005). Some forest and wildlife experts feel that too much emphasis has been placed on the harmful aspects of forest fire while its positive values has been ignored (Heywood and Watson, 1995). Primitive man presumably first used fire for heat, for cooking and in gathering honey (West, 1965). Man brings about deliberate firing of vegetation to aid his farming and hunting activities, and in grassland management (Ewusie, 1980). However, uncontrolled fire and misuse of fire can cause tremendous adverse impacts on the environment and the human society (Roy, 2003).

Fire is an important ecological factor in many habitats from forests to dry grasslands (Hassan, 2007). Deliberate use of fire by hominids started 2.5 million years ago and increased the fire frequency in grasslands (Brain and Sillen, 1988). Activities of humans, through use of fire as a wildlife and later livestock management tool in grassland habitats have influenced the structure and function of savanna ecosystems (Hassan, 2007). Without fire, considerable areas of grasslands could potentially develop into closed woodlands. Therefore, periodic fire maintains grassland by slowing down woody succession and stimulating grass thereby helping to maintain a dynamic balance between savanna and forest (Leach and Givnish, 1996).

In Ethiopia, the vegetation is deliberately burned in order to induce sprouting of fresh vegetation for cattle grazing. Sixty-five percent of the land area is subjected to this practice (IFFN, 2001). Use of fire as an aid to hunting, to control tsetse fly and manage tick populations are among the other major causes of forest fires in the lowland areas. In the highlands, where there is rapid population growth, fires are used as the major tool to clear forest land and convert it to agricultural use. Smoking out wild bees in order to gather honey is also another cause of forest fires. The traditional practice of using fire as a means to prepare land for agriculture and the enormous demographic growth exacerbate the impact of forest fires (IFFN, 2001; Goldammer and de Ronde, 2004). Forest fires hit Ethiopia in March 2000, the first big fires since 1984. The threatened, afro-montane forests and moist tropical forests were badly damaged with as much as 53,000 ha of Bale National Park destroyed (Goldammer, 2000; SCBD, 2001).

CONDITIONS AND CAUSES

It has long been recognized that fire in vegetation or forest can be caused by natural phenomena and happenings entirely unconnected with man's activities (West, 1965). Fires resulting from natural causes (volcanic eruption and lightning) probably played their part in moulding the earth's forest vegetation and animal life long before the advent of man (Harris, 1958).

Fires are described generally as natural/wild/uncontrolled and controlled (human-induced) (Woube, 1998). They can be set naturally by lightning and anthropogenically by accidental or deliberate human actions (Vidal and Devaux, 1995). Although some forest fires occur naturally, a combination of human activity, fuel availability, and climate accounts for majority of fires (SCBD, 2001). A major proportion of all forest fires are caused by man either intentional or due to carelessness (Shrivastava, 2002). Naturally caused fire is non-preventable, and includes lightning fires and those set by spontaneous combustion, while man-made fires are preventable. Natural fires are random and periodic while human-induced fires are deliberately set to clear ground for agriculture, to improve forage for grazing, to open up the way, and make travel easier (Smith, 1992). In East Africa, for example, forest or bush/grass fire has been practiced for a long time as part of the agricultural system (Backeaus, 1992). Most fires set by humans are in the non-growing season, when fires are more intense with severe damages (Smith, 1992). There is no research conducted on fire causes in Ethiopia, but it is expected that more than 80% caused by negligence and carelessness of the society (IFFN, 2001).

TYPES OF FIRE

The three major categories of fire are ground, surface and crown (Smith, 1992; Shrivastava, 2002).

GROUND FIRE

Ground fire is most destructive that consumes organic matter down to the mineral substrate (Smith, 1992). It occurs in the humus and peaty layers beneath the litter of undecomposed portion of forest floor with intense heat. It persists even without flame until all available fuel is consumed (Smith, 1992; Roy, 2003). It is most prevalent in areas of deep, dried-out peat and extremely dry and light organic matter (Smith, 1992). Such fire is relatively rare (Roy, 2003) (Figure 1).

SURFACE FIRE

It is the most common type. It burns off only the litter layer and debris on the ground (Smith, 1992; Roy, 2003). The depth of burn depends on the intensity and severity of the fire (Kormondy, 2001). It kills herbaceous plants and woody seedlings, and scorches the bases and occasionally the crowns of trees (Smith, 1992). Surface burning can keep the amount of litter to a minimum, thereby reducing the danger of a crown fire (Kormondy, 2001). If the fuel load is high and the winds are strong, surface fire may leap up into the canopy causing crown fire (Smith, 1992) (Figure 2).

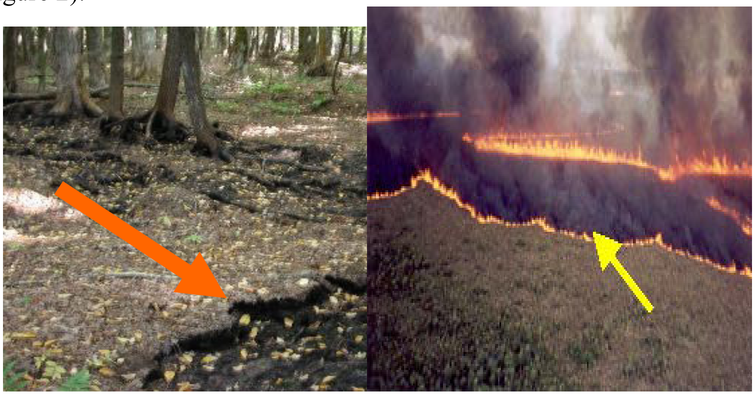

Figure 1: Ground fire (left) and Surface fire **(**right**)** (Source: Roy, 2003).

CROWN FIRE

Crown fire is typically very intense; consumes the entire plant community above the ground and is the most destructive among all fires (Kormondy, 2001). It can spread rapidly across the tree tops and destroys all above ground vegetation (Smith, 1992; Roy, 2003). Because of the severity of destruction, such areas present a barren landscape and typically take years to begin even modest recovery (Figure 3).

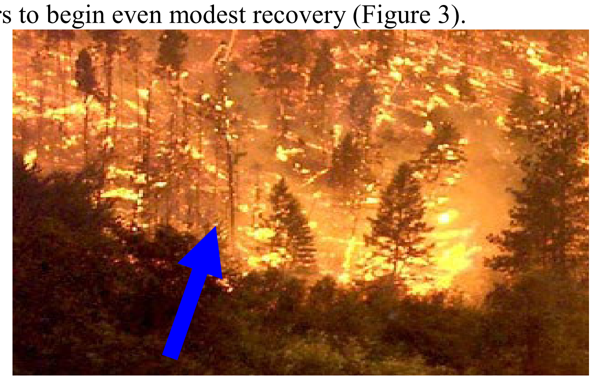

Figure 3: Crown fire (Source: Roy, 2003).

EFFECT OF FIRE

Forest fires controlled or uncontrolled have profound impacts on the physical environment including: land cover, land use, biodiversity, climate change and forest ecosystem (Roy, 2003). A major wildfire occurrence in Ethiopia affected the afro-montane forests in year 2000, mainly in Oromiya Regional State. The total forest area affected by fire was 95, 000 ha. The firefighting operations in March-April, 2000 involved more than 169, 589 people (villagers, army, students, and volunteers from Addis Ababa) and a group of foreign experts (IFFN, 2001; Goldammer and de Ronde, 2004). The Borana and Bale Administrative Zones reported the following losses of non-forest resources: 1,226 hectares of wild coffee, 112 houses of the farming community who live in the natural forest, 12 quintals of coffee, 12 storage facilities of farmers for grain; 8, 029 bee hives, 352 domestic animals (300 sheep, 33 hens, 9 cattle and 10 camels) and 335 wild animals (antelope, lion, colobus monkeys, etc) (IFFN, 2001).

IMMEDIATE AND SECONDARY EFFECTS

Effects of fire on wildlife are either immediate impacts, which include direct injury or mortality of plants and animals, animal fleeing (insects, small mammals, and birds) (Koprowski *et al*., 2006; MAFF, 2004) or seeking refuge. Secondary impacts include an alteration of forage productivity, availability and quality, as well as creating, destroying, or degrading various habitat attributes (MAFF, 2004; Layme *et al*., 2004). Fire may have direct short-term effects on density of animals and/or long-term indirect effects through habitat modification (Layme *et al*., 2004). The most important effects of fire on wildlife populations are due to changes in the vegetation (Ewusie, 1980). On a short-term basis, fire partially or fully destroys habitat and causes some injury and death, either directly or indirectly by predators who take advantage of prey suddenly driven from cover (Smith, 1992).

ADVERSE EFFECTS OF FIRE

Large-scale uncontrolled forest fires have increased worldwide over the past two decades (Goldammer, 1999; Nepstad *et al*., 1999). By far the worst forest fires, in terms of burnt area, in recent times occurred in 1997-98. Estimates suggested that fires adversely impacted as much as 20 million hectares of forest worldwide (SCBD, 2001). Forest fires cause potential effects on climate change (Roy, 2003). Biomass burning is recognized as a significant global source of emission contributing to almost 40% of gross Carbon dioxide and 30% of tropospheric ozone (Roy, 2003). In terms of the impact of large-scale uncontrolled fires, at a global scale, they can influence the chemical composition of the atmosphere and the reflectivity of the Earth's surface (SCBD, 2001) (Figure 4).

Figure 4: Adverse effects of fire (Source: Langevelde *et al*., 2003).

The major impact of a severe fire is disturbance of the ecological community, specifically the destruction of the organisms and their intertwined relationships (Kormondy, 2001). Severe fires alter the habitat and eliminate for a time those species dependent on it (Smith, 1992). At the regional and local scale, forest fires change biomass stocks, alter the hydrological cycle, impact plant and animal species functioning and detrimentally impact the health and livelihoods of the human population (Goh *et al*., 1999; Schwela *et al*., 1999). Smoke from fires can significantly reduce photosynthetic activity (Davies and Unam, 1999). Apart from the effect on forest vegetation, fire can have a significant impact on forest vertebrates and invertebrates (SCBD, 2001). The majority of impacts of uncontrolled, human-induced fires on forest ecosystems are generally negative (SCBD, 2001). Forest fires are a significant source of emitted carbon, which makes worst global warming as well as being an irreplaceable carbon sink (SCBD, 2001).

BENEFICIAL EFFECTS OF FIRE

The importance of fire in maintaining healthy ecosystems, wildlife populations and biodiversity has been widely recognized in recent decades (Heywood and Watson, 1995). From an ecological standpoint, any positive impacts would depend entirely on location, timing, intensity, and frequency of fires (SCBD, 2001). It has been suggested that fire may increase the spatial and temporal heterogeneity of supply and quality of food for large herbivores (Vermeire *et al.,* 2004), thus affecting large herbivore foraging behaviour at different scales (Augustine and McNaughton, 1998). Although fire exposes the top soil and damages microorganisms, it helps to grow fresh biomass for the grazers. It prevents bush encroachment, shapes the plant morphology, the age structure of plants and the tree species composition, and increases the nitrogen-rich green biomass (Parsons, 1976; Skarpe, 1991).

People use fire for the following purposes: (i) to facilitate hunting (Ewusie, 1980); (ii) to char footpaths and direction in the forest (Woube, 1998); (iii) to reduce the population of weeds; (iv) to grow crops (Ewusie, 1980; MAFF, 2004); (v) to enhance vigorous grass growth in the early rainy season (Ewusie, 1980); (vi) to drive away herbivorous animals that are dangerous to crop plants (Woube, 1998); (vii) to protect settlements from large fires; (viii) to get rid off dead plants, crop residues and pests (Smith, 1992); (ix) to evict bees before raiding hives for honey gathering; (x) for cooking and (xi) to make charcoal (Woube, 1998).

Fires may not reduce the availability of food resources for ground-foraging birds, but may increase food accessibility by removing leaf litter and dense vegetation, exposing both insects and seeds (Woinarski, 1990; Artman *et al*., 2001).

EFFECTS ON SOIL AND VEGETATION

Fire affects not only vegetation but also soil (Smith, 1992). All fires, regardless of whether they are natural or human-caused, alter the cycling of nutrients and the biotic, physical, moisture, and temperature characteristics of soil (MAFF, 2004). It can act as a mineralizing agent and can increase the short-term availability of nutrients for plant growth (Kauffman *et al*., 1994). Nutrient availability to plants is regulated by soil microorganisms, so their survival and recovery are essential to restore burned sites. Soil temperatures higher than 100^{o}C kill most microorganisms (Ditomaso *et al*., 2006). When compared to the impacts felt by other ecosystem components, fire effects on soil are typically minor, are often short-lived and can be either positive or negative. The degree of impact would increase with the level of severity of the fire (MAFF, 2004).

Fire can impact a variety of soil physical and chemical properties including the loss or reduction of structure and soil organic matter, reduced porosity, and increased pH (MAFF, 2004). Most of these changes to the soil are caused by an alteration in soil chemistry resulting from complex interactions among geomorphic processes, climate, vegetation, and landforms (Carrington and Kelley, 1999). Organic matter is also consumed or lost during a fire. This is dependant on the soil moisture content of the organic layer of the soil profile, fire severity and the subsequent precipitation (Smith, 1992). Any alteration in soil organic matter is significant, as it not only acts as a reservoir for site nutrients (particularly nitrogen), it also helps regulate the hydrologic cycle, and carbon/nitrogen ratio providing a site for nitrogen fixation, and maintains soil structure porosity and cation exchange capacity (Kauffman *et al*., 1994). Soil moisture is also affected by some of the changes that are induced by the burning of grasslands (Smith, 1992).

Forest fires may increase runoff and erosion (Morales *et al*., 2000) by alteration of the structure of the mineral soil and destruction of the organic matter (Vadilonga *et al*., 2008). Vegetation removal, combined with the changes in soil physical properties, will typically result in erosion following fire. Agricultural productivity in the highlands of Ethiopia is severely threatened by land degradation involving both soil erosion and declining soil fertility (IFFN, 2001). In most cases, fire increases the amount of nutrients available, and as a result nutrient cycling is increased (Kauffman *et al*., 1994). While various nutrients can become more available during and after fire, others may be volatilized and thus lost (MAFF, 2004). Following vegetation removal, an increase in soil temperature is often experienced. Numerous factors contribute to this increase including, the removal of vegetative cover, consumption of fuels, thinning or removal of the litter and/or bad layer, the enhanced "black body" thermal characteristics of the burnt material on the soil surface (NWCG, 2001). Following fire, the soil biota (living soil organisms) is commonly affected to varying degrees. In general, it appears that soil will often protect subsurface soil biota (including insect pupae) from fire. Hot fires typically have a more significant and longer-lasting impact on soil biota than low intensity fires, which tend to have little or no effect (MAFF, 2004).

Fire is among the global key ecological factors that determines structure, floristic composition and distribution of vegetation types across landscapes and ecosystems (Stander *et al*., 1993; Hassan *et al*., 2007). From Arctic Tundra and boreal forests to tropical grasslands and savanna, fire annually consumes enormous quantities of plant biomass (Bond and van Wilgen, 1996). Fire affects vegetation through both direct and indirect effects. Intense fire causes a direct decline in the cover of woody vegetation by killing trees or by reducing trees to smaller size classes (Langevelde *et al*., 2003). Fire is probably the most potent factor in shaping vegetation in tropical rangelands (Glover, 1968; Williams *et al*., 1994). Its severity is considered important in determining how a plant population responds to fire (Chappell and Agee, 1996; Ooi *et al*., 2006). Fire severity is the impact of fire on an ecosystem and is often assessed as the extent of canopy consumption (Pausas *et al*., 2003; Vivian *et al*., 2008). The vegetation in Ethiopia has now been reduced to 10 m^3 per hectare as a result of continuous cutting of trees for fuel wood, construction purposes and frequent forest fires (IFFN, 2001). Some of the plants have adaptive mechanisms that allow them either to survive fire or to regenerate after a fire.

EFFECT ON WILDLIFE

Fire is considered a major disturbance to forest communities and is under heavy anthropogenic influence (Koprowski *et al*., 2006). In forests, where fire is a natural part of the system, species are adapted to a natural fire regime and can benefit from the aftermath of fire. However, in forests where fire is not a natural disturbance or where man suppresses the natural fire regime, the impact on species can be negative (Kinnaird and O'Brien, 1998). Wildlife mortality due to fire is rarely documented apart from anecdotal observation (Koprowski *et al*., 2006). The direct effect of fire on forest fauna is death. Indirect effects of fires are far reaching and longer term, and include stress, loss of habitat, territories, shelter and food (Vernes, 2000). Fire can also cause the displacement of territorial birds and mammals, which may upset the local balance and ultimately result in the loss of wildlife, since displaced individuals have nowhere to go (Figure 5) (Bendell, 1974). Loss of food trees reduces the carrying capacity of the forest, causing overall decline in species that rely on fruits for food. This is especially true in tropical forests. The destruction of standing cavity trees as well as dead logs on the ground affects most small mammal species and cavity-nesting birds (Kinnaird and O'Brien, 1998). The loss of key organisms in forest ecosystems, such as invertebrates, pollinators and decomposers, can significantly slow the recovery rate of the forest (Burrows *et al*., 1995). Without exception, the impact of fire on forest mammals depends on habitat requirements, life history of the animal and on the intensity, scale and patchiness of the fire, or the extent of damage of habitat it made (Burrows *et al*., 1995).

Fire typically causes little direct mortality to large mobile animals but young animals are at greater risk of being killed by fires (Main and Tanner, 1999), especially among species with low mobility (Peres, 1999; Silveira *et al*., 1999). Direct, fire-induced mortality is reported for insects, fish, amphibians and reptiles (Koprowski *et al*., 2006). Most wildlife is directly impacted by fire and responds relatively predictably to its passage. The degree of impact is dependant on numerous factors including mobility as well as fire uniformity, severity, size and duration (Vernes, 2000). While most fires have the potential to injure and kill animals, it is generally the season, fire intensity and severity that determine the effects (Main and Tanner, 1999; Sutherland and Dickman, 1999). The season of burn can be an important variable in determining mortality. For example, fire that occurs when animals are nesting or have young with limited mobility (especially small mammals) may cause significant mortality (Sutherland and Dickman, 1999). This would be dependant on nesting characteristics, with those species who construct ground nests (ground nesting birds, harvest mice, wood rats) being more vulnerable to fire than deeper-nesting species (Sutherland and Dickman, 1999).

Figure 5: Effects of fire on wildlife (Source: Roy, 2003).

Among small mammals, burrowing mammals have the greatest likelihood of survival (Sutherland and Dickman, 1999). Larger mammals, due to their size, must escape fire by seeking refuge, either in an unburned patch within the fire or outside the extent of fire. They are more likely to be caught in fire when the fire is actively crowning, when its fronts are wide, and fast moving with thick ground smoke (Hassan, 2007). In fact, larger mammals are often described as moving calmly around the fire perimeter. For example, no large mammals were observed fleeing the Yellowstone fires, with most appearing even to crowning fires (MAFF, 2004). The most important effects of fire on fauna are often indirect, particularly through fire induced modification of habitat. Different animal species show a range of responses to any particular fire (Braithwaite 1987; Andersen *et al*., 1998).

Due to their ability to fly, birds can often avoid the direct effects of flames through moving into adjacent habitats not affected by the passage of fire (Lawrence, 1966). The severity and duration of impact of fire on bird populations is directly correlated with the size and intensity of fire. Small, patchy, low intensity fires have little long-term impact but birds take longer to recover following large, intense fires (Christensen *et al*., 1985). In general, fire effects on birds are typically secondary in nature. Direct effects are typically dependant on season, fire uniformity, and severity. Due to their mobility, mortality of adult birds is usually considered minor. If the fire occurs during nesting however, nestling and fledgling mortality will occur (Emlen, 1970). In addition to seasonality, severity also determines whether or not nests are damaged. While ground-nesters are vulnerable to most understory fires, canopy nesters can also be injured by moderately to severe surface and crown fires (Emlen, 1970; NWCG, 2001; MAFF, 2004). The ability of arboreal-dwelling mammals to survive forest fire is not well understood due to difficulty in documenting loss of animals (Koprowski *et al*., 2006).

Fire also impacts forage availability by directly consuming plant material. Thus, when considering the effect of fire on all forms of livestock and wildlife, it is important to consider the lag in forage availability (MAFF, 2004). Burning causes significant changes in the grassland structure (Hassan *et al.,* 2007) by removing old plant parts and debris and by stimulating re-sprout of the vegetation, thus changing the composition of forage available for herbivores. As herbivores selectively respond to spatial patterns of forage distribution (Bailey *et al.,* 1996), fire-induced changes in plant composition will have consequences for herbivore use. Several studies in African savannas and elsewhere show that wild large herbivores utilize burnt areas more than non-burnt areas (Figure 6) (Moe *et al*., 1990; Wilsey, 1996; Tomor and Owen-Smith, 2002). This may result that foraging ungulates concentrate in areas providing the optimal solution to the trade-off between forage quality and quantity (Wilmshurst *et al.*, 1995). The use of fire to increase wildlife production is based on recognition that forage growing after burning becomes more palatable and is preferred by wildlife (Hassan *et al.,* 2007). Anyone who has observed a recently burned forest or wetland may wonder how long before wildlife begins using what may look like a charred wasteland. This is an important question because the loss of habitat is recognized as the most serious threat to wildlife population worldwide (Main and Tanner, 1999).

Figure 6: Non-burned (left) and burned areas (right) (Source: Hassan, 2007).

Fire certainly can kill animals, but mortality among most species has been found to be minor and fire generally poses no significant threat to wildlife populations. There are a number of factors that influence the extent to which fires cause wildlife mortality including: wind speed, fuel loads, moisture content in vegetation, time of year, size of fire (Main and Tanner, 1999; Hassan *et al.,* 2007). There are many species of plants and animals that require periodic fire to maintain habitat conditions needed for their survival. In the absence of fire, habitat conditions change the diversity and abundance of wildlife leading to declines (Main and Tanner, 1999).

PRESCRIBED FIRE AND LAND MANAGEMENT

Fire plays a critical role for many biomes in controlling succession patterns, primary productivity and in carbon cycling (Isaev *et al*., 2002; Beringer *et al.,* 2003). Prescribed fire is an important tool for managing habitats and wildlife populations that depend upon them (Main and Tanner, 1999). In forest management, fire is used as a management tool (prescribed burning) to maintain ecosystems, allow regeneration and clear excessive debris (SCBD, 2001). Humans have used fire to manage vegetation since prehistoric times to improve opportunities for hunting and to encourage growth of useful plant species (Moore, 1996; Vale, 2002).

Fire is a common element in many savanna–grassland ecosystems around the world, but its use, safety, and success as a management tool vary with climate, soils, landscape context and conservation goals (Harrington and Katho, 2008). More recently, ‘‘prescribed fire’’ (controlled burn used to achieve a management objective) has been used to reduce fuel loads, restore historical disturbance regimes, improve forage and habitats, and promote biodiversity (Ditomaso *et al*., 2006). Fire also has been used to manage invasive plant species, either directly or as part of an integrated approach (Wright and Bailey, 1982; Pyne, 1997; Ditomaso, *et al*., 2006). Fire is used as a management tool to improve the forage quality for large herbivores (Hassan *et al*., 2007).

Prescribed fire is commonly advocated as a means of controlling fuel levels, thereby limiting the incidence, spread, intensity and final size of subsequent unplanned fires (Fernandes and Botelho, 2003). Increased levels of prescribed fire may therefore be beneficial to species that are perceived or known to be sensitive to the effects of high-intensity fires. Higher vertebrates that lack shelter and/or have limited dispersal ability may be disadvantaged by such fires (Bradstock *et al*., 2006).

Prescribed burning is frequently used as technique to control vegetation in shrub land and forested areas for a wide variety of purposes. These include wildlife habitat and plant diversity improvement, stimulation of selected plant species regeneration, and fire-regime restoration (Baeza *et al*., 2002; Vega *et al*., 2005). Negative effects of prescribed fire seem greatest for those species that depend on leaf litter or when the removal of surface cover temporarily increases predation (Bolen and William, 2003). Fire frequency can also be an important management consideration. Annual burns often have very different effects on native species abundance than less frequent burn regimes (Hoffman, 1999; Morgan, 1999; Emery and Gross, 2005). Prescribed fire is the subject of increasing legislative attention and regulation in many states (Haines and Cleaves, 1999).

TIME OF BURNING

Fire intensity and fire severity are influenced by weather and fuel composition mass of litter and moisture content at the time of burning (Pendergrass *et al*., 1998). Fire intensity becomes high when the weather grows hotter and drier and it decreases when cooler fog and rainfall occurs. Wind direction plays major roles in spreading fire (Woube, 1998). Setting prescribed fires under mild weather conditions early in the spring when fuel moisture content is variable across the landscape will usually result in low intensity and patchy fires (Burrows *et al*., 1995). Likewise, large hollow logs and old trees with hollows, both of which are important faunal refugia, are unlikely to ignite or burn away under these conditions (Burrows *et al*., 1995). Setting prescribed fires at the start of the dry season to meet several management objectives, ensure food supplies to sustain migratory herds in dry season refuge areas (Hassan *et al*., 2007). Attempts to protect nests have resulted in recommendations by some biologists to burn only during the winter months or after the nesting season. If their nests are destroyed, however, most birds will attempt to re-nest (Main and Tanner, 1999). Thus, the timing of the fire in relation with rainfall and seasonality is critical for the post-fire sward development, and for its implications for forage consumption for wildlife (Wilsey, 1996; Hassan *et al*., 2007). Mid to late spring burns provided maximum benefit to livestock and wildlife. Choice of season of burning may thus influence vegetation structure and composition and consequently habitat type (McLoughlin, 1998).

There are no forest fire statistics permitting an analysis of the causes, risks and extent of damage in Ethiopia. However, general information on the causes and season are available that could reveal information concern the timing of forest fires, which depends on the climate (IFFN, 2001). Every year, just before the short rainy season starts, very large areas of lowland woodland and grassland formations are affected by fires, particularly in the drier parts of the country.

FIRE CONTROL

Uncontrolled fire may move faster and burns at higher temperatures than prescribed fires, posing a much greater risk to wildlife and humans (Main and Tanner, 1999). During prescribed fires, however, a greater level of control is exerted over these factors by selecting environmental conditions that minimize risks. Prescribed fires are not approved during dry conditions or when wind speeds are too high (Main and Tanner, 1999). Because of their fear of not being able to control really fierce fires in hot, dry, windy weather, many ranchers and farmers compromise by burning too early in the season and at night, when fire can be easily controlled and far less effective against bush (West, 1965). Compartments are secured from unplanned fires by an extensive series of roads and graded fire-breaks (Andersen *et al*., 1998). Firebreaks are useful to reduce the extent of forest fire; however, when they are cleared down the slope, soil erosion is increased; erosion from firebreaks can become a serious problem. Erosion control measures are necessary when slopes exceed five percents (Pardini *et al*., 2007).

Firebreaks are constructed to act as a barrier to prevent the spread of fire to a particular area or property, to contain the spread from fire source or to break up large fuel areas where fire can spread rapidly or could be difficult to control (Figure 7) (Hanselka, 2006; NRCS, 2006). Natural barriers can be such as; rock outcrop, streams, water bodies, swamps, and cover with naturally low flammability, as well as artificial barriers such as roads and litter charred boundary lines (Hanselka, 2006; NRCS, 2006). A firebreak consists of a strip cleared (3-5 m width) of most trees, shrubs, and other large flammable material; and a narrower strip cleared (2-2.5 m) down to mineral soil (NRCS, 2006). Firebreaks are usually located with reference to probable sources of fire; may be along roads or fences or based on the usual direction spread (Hanselka, 2006; NRCS, 2006).

In Ethiopia, there are no people trained and equipped for firefighting and fire prevention mainly through education of farming communities about the usefulness of the forests and the damage resulting from forest fires (IFFN, 2001). Monitoring of forested areas and implementation of preventive measures has had limited effect due to weak institutional arrangements.

Figure 7. Firebreak (Source: Hanselka, 2006).

CONCLUSION

Increasing population pressure with immense demand for the domestic needs have affected the biosphere by modifying the forest ecosystems. Clearly, fire can have negative consequences when it occurs in the wrong place at the wrong time. From an ecological perspective, fire generally has positive effects on wildlife habitat and wildlife populations. When fire devastates a virgin forestland, it affects all animal and plant species. Although fire reduces many of the species locally, fire-adapted ecosystem processes would take place. Repeated fire occurrences gradually change the structure, physical appearance and regeneration of plants, composition of animal and plant species, as well as the hydrological cycle, soil structure and nutrients. Some animals (elephants, lions, buffaloes, etc.) migrate, while others take refugee, and still others (e.g. rats and snakes) hide in the physically cracking surfaces. When fire changes the ecosystem, animal and plant species find other survival strategies. In the process, green cover is lost at faster rate than expected. The rapid recovery of vegetation, the apparent ability for most species of wildlife to use recently burned areas, and the high-quality habitat provided during post-fire recovery suggests that fire enhances habitat for most plants and animals. The information available from research indicates that periodic less intensive fires benefit and are indeed vital to wildlife populations in fire-adapted habitats. In the absence of fire, habitat conditions change and as a result of which the diversity and abundance of wildlife eventually declines. Even when fire kills trees, positive wildlife benefits can occur. Many cavity nesting birds depend upon dead, decaying trees for excavating cavities. Other species, known as secondary cavity nesters, depend upon these nest sites after they have been abandoned. Decaying trees attract insects that are fed upon by many species of wildlife. The decay process also returns important organic material and nutrients to the soil. Sustainable management of forest resources has become key agenda of biodiversity conservation. When considering the effects of land management practices, we should ask whether our actions help to maintain healthy plant and wildlife populations and conserve the diversity and abundance. Forest fire is one of the important factors to be considered for better management of the forest resources including wildlife. Therefore, fire represents not only devastation, but also renewal of wildlife habitats.

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