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The *Erica* Fire Impact on Small Mammal Species Composition and Relative Abundance in the Chilalo-Galama Mountains Range: Implications for Conservation

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Abstract

The sub-Afroalpine and Afroalpine ecosystems in Ethiopia are fire-prone, but limited studies have been conducted on the effects of *Erica* burn on small mammals. In particular, little is known about the impacts of *Erica* burn on small mammals in the Chilalo-Galama Mountains Range. This study aimed to fill this gap by investigating the impact of *Erica* burn on small mammal species composition and relative abundance in the area. The study was carried out from September 2013 to December 2016, and trapping was conducted using collapsible Aluminium Sherman Live Traps. The impacts of burning were quantified in terms of faunal species composition, relative and absolute abundance, and species richness. The highest capture rate per trap night was recorded for categories of time since *Erica* fire above six years, and the lowest was for *Erica* fire since less than six months. Species richness was least for categories time since *Erica* fire of one year and six months. The capture rate and relative abundance for each species showed high variation among the rodents and shrews captured, of which Lophuromys brevicaudus and Stenocephelomys griseicauda had the highest rates. The study highlights the urgent need for conservation action in the face of *Erica* fire, particularly given the high endemicity (more than 83%) of the small mammals in the area. To control the expansion of *Erica* fire, well designed fire break should be constructed. This study provides important information for the management of small mammal habitats in such fire-prone ecosystems, and underscores the need for further research in this area.

Key words/Phrases: Arsi Mountains National Park; Afroalpine; Chilalo-Galama; conservation; *Erica;* fire; small mammal

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1. Introduction

Among the vertebrates, small mammals have a number of attributes that provide valuable results in ecological and paleontological studies (Manthi, 2007). Their study is needed due to their high abundance, comparatively easy to study, well known general principles of their ecology, good ecological indicators, exhibition of habitat or dietary specificity and specimens that are easily prepared and transported (Barnett and Dutton, 1995). For instance, unlike the highly mobile macro-fauna, most small mammals usually have very specific habitat requirements (Manthi, 2007). Their fast metabolism and short life span and high reproductive rates enable them to respond quickly to environmental changes (Barnett and Dutton, 1995; Nowak, 1999; Bagne and Finch, 2010). Their demographic plasticity, high turnover rate and adaptability make them interesting in the study of demography and population dynamics (Barrett and Peles, 1999). These characteristics make small mammal populations as good subjects for assessing ecosystem health and effects of landscape alterations (Bagne and Finch, 2010). They exhibit different adaptations to the environment and play a great role in determining the patterns of biodiversity and ecosystem functioning. Hence, they use as good indicators for the health of ecosystems like the impact of *Erica* burn (Barragan *et al.*, 2010).

Fire is a major disturbance force in many biomes across the world including forests, grasslands, savannas, Mediterranean systems sub-Afroalpine and Afroalpine habitats (Parr and Chown, 2003; Langlands *et al.*, 2012). It is a key component of natural process which influences the ecological and evolutionary processes in fire-prone area (Bagne and Finch, 2010). It is the most important ecological regulator of plant and animal populations in tropical savannas and grasslands worldwide (Radford, 2012). Like other groups, small mammals can be strongly influenced by fire-induced vegetation changes (Radford, 2012). In particular, fire causes the abundance of small mammal to decline by limiting resources (food and shelter) and exposing them to predation and disease (Letnic *et al.*, 2013). It is also widely used to manage habitats to achieve conservation goals (Kelly *et al.*, 2012). However, Haslem *et al.* (2011) argued that fire management might not be compatible with conservation objectives. The variations in fire management can also cause changes in vegetation community structure, leading to multiple cascading effects in animal communities (Sutherland *et al.*, 2009).

The effects of fire on biodiversity is poorly known and there is an ongoing debate about its effects on fauna (Parr and Chown, 2003). For instance, Letnic *et al.* (2013) indicated fire had relatively little effect on the small mammal assemblage in desert habitat. However, Andersen *et al.* (2012), showed with strong evidence that increased fire frequency, incidence and intensity contributed to the broad-scale decline and extinction of savannah small mammals fauna.

Fire severity depends on the magnitude effect on environment and on all components of ecosystems (Roberts *et al.*, 2008). It can also threaten human life and assets in fire-prone regions (Haslem *et al.*, 2011). Ignition methods may play a role in affecting fauna because line-ignited fires are likely to cover a wider area and be more intense than point-ignited fires, and thus it could be expected that they would have a great impact on fauna (Parr and Chown, 2003). The most important effects on fauna are typically indirect, through changes in habitat, resource availability and predation risk, rather than through direct mortality (Andersen *et al.*, 2012). Small mammals are strongly influenced by fire-induced vegetation changes (Weltzin *et al.*, 1997). Fire-related vegetation structural changes can cause change in predator–prey interactions, habitat use and food preference (Radford, 2012). Recent analyses suggest that fire-induced declines may relate to increased impacts by predators due to frequent fire removal of ground-layer vegetation (Radford, 2012). Inadequate understanding of biotic responses to fire and strong public pressure to minimize fire hazards (Haslem *et al.*, 2011) increases the potential for prescribed fire to negatively affect biodiversity. Woody debris created during thinning may provide greater protective cover for small mammals, but eventual removal of these materials may result in reduction of small mammal populations (Bagne and Finch, 2010). The availability of food resources and predation pressure are the more important factors influencing the abundance and assemblage composition of small mammals than vegetation structure or time since last fire (Letnic *et al.*, 2013). Fires may also directly affect the abundance of seeds, stems and leaves of grasses and forbs and shelter sites (hollow logs, tree hollows and dense tussocks of grass) and other critical resources for small mammals (Andersen *et al.*, 2012).

Fire history is significantly correlated with the abundance, diversity and composition of mammal assemblages, typically with fewer mammals at sites with a recent history of more frequent or intense fires (Andersen *et al.*, 2012). A primary mechanism for this is linked with the properties of fire mosaics that determine the amount of suitable habitat in a landscape (Kelly *et al.*, 2012). Changes in the spatial extent of different fire histories will modify the total amount of these resources available in the landscape and thereby influence the abundance and distribution of species (Kelly *et al.*, 2012). Intense fires with short recurrence times severely limit the opportunities for recovery by fire-sensitive fauna (Andersen *et al.*, 2012). Severely burnt areas act as small mammals population sinks, requiring repopulation from unburnt source areas (Andersen *et al.*, 2012). Unburnt patches in the landscape can provide refugia for animals. Following fire, the patches can provide a source for recolonization into disturbed areas (Kelly *et al.*, 2012). The shape, size and patchiness of fire are also important in determining the abundance and distribution of small mammals. It affects animal movements during, after fire, and for the potential survival on unburnt area as re-colonization possibilities (Parr and Chown, 2003).

Small mammals can influence vegetation structure through feedback mechanisms leading to altered fire regimes (Weltzin *et al.*, 1997). However, it is also important to focus on the longer-term effects of fire particularly on responses to fire regimes rather than to individual fire events. The observation that some fires or fire regimes lead to highly negative impacts on mammals while others lead to more subtle or no impacts, suggests that fire effects on mammals are not uniform. Rather, they may depend on fire-specific properties (e.g. season, intensity, area burnt) and site-specific environmental context (e.g. rocky vs. non-rocky habitat) (Andersen *et al.*, 2012). In the absence of a clear understanding of fire-related impacts on small mammals, it is difficult to prescribe management programmes (Radford, 2012). In particular there are the limited studies on the impact of fire on Subafroalpine nd Afroalpine areas which is dominated by *Erica*. The effects of *Erica* burn on small mammals and other biodiversity are poorly studied. However, several studies indicate fire intensity, interval, land and use pattern significantly affect the abundance, distribution and diversity of small mammals. In addition the previous studies conducted by Zerhiun

Girma *et al.*(2012) and Gutema Jira *et al.* (2013) in nearby Mount Kaka and Honkolo and conceptual frameworks for the dynamics of small mammal assemblages, it is hypothesised that small mammal species composition and relative abundance is affected by of *Erica* burn. The current study on the impact of *Erica* burn on small mammal species composition and relative abundance is aimed for the conservation of small mammal and their habitat management.

2. Materials and Methods

2.1. Description of the study area

The investigation was carried out on Chilalo-Galama Mountains Range, as one of the largest block of AMNP occurring between 7°30′ to 8°05′ N latitude and 39°10′ to 39°35′E longitude (Mohammed Kasso et al., 2010) (Figure 1).

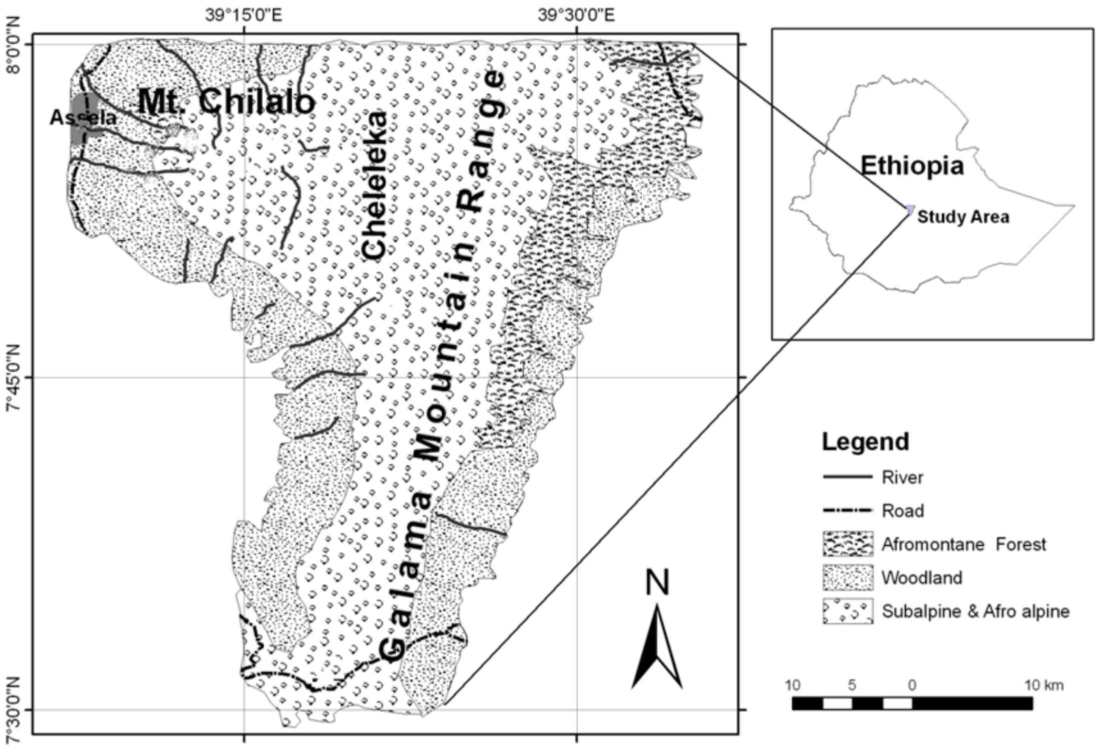

Figure 1. Map of the study area (Source: Mohammed Kasso et al., 2010)

Chilalo-Galama Mountains Range has a great diversity of landscape which forms triangular shaped highland massifs that creates three different water drainage systems. It also possesses several peaks of more than 4,200 m asl. The area possesses different types of soils and vegetation zones at different altitudes (Alemayehu Mengistu, 1975). It encompasses dry evergreen montane or Afromontane forest and Afroalpine and sub-Afroalpine vegetation types based on its attitudinal zonation which is the second highest Afroalpine habitat in Ethiopia (Mohammed Kasso et al., 2010).

More than 90% of the area of Chilalo-Galama Mountains range is covered by Ericaceous and Afroalpine vegetation zones (Malcolm and Sillero-Zubiri, 1997). In addition to the natural vegetation, there are also some patches of plantations of non-native tree species like *Cupressus lusitanica*, E*ucalyptus globulus*, *Eucalyptus amygdalina*, *Pinus patula*, *Pinus radiata* and *Pinus carribean* (Evangelista *et al.*, 2007; Mohammed Kasso and Afework Bekele, 2011). The ericaceous forest zones (3,100 – 3,900 m asl) is characterized and dominated by *Erica arborea* and *Erica trimera* and also other dwarf Erica species named Erica tenuipilosa. In this zone, the low temperature inhibits tree growth, except low bushes, tuft grasses and lichens. The Afroalpine vegetation (3,300 – 4,200 m asl) largely comprises *Alchemilla helichrysum*, *Artimesia trimera,* and *Lobelia rhynchopetalum* and different grass species (Mohammed Kasso and Afework Bekele, 2011).

Chilalo-Galama Mountains Range is endowed with varieties of Afromontane and sub-Afroalpine and Afroalpine animals with high proportion of endemic species. However, due to uncontrolled hunting and destruction of their natural habitat, there is rapid decrease of wild life in size, species and distribution (Yazachew Etefa and Kasahun Dibaba, 2011).

Chilalo-Galama Mountains range of AMNP has two rainy seasons, namely the small rainy season and the heavy rainy season. The small rain falls between March and June with its peak in April. The heavy rainy season is between July and October, with the highest peak in August. In the lower altitudes the amount of annual rainfall reaches 600 to 1000 mm while the higher altitudes get rainfall of 1000 up to 1400 mm annually (Miehe and Miehe, 1994). The mean annual temperature and rainfall vary depending on the altitude. Areas above 3,300 m asl have annual mean temperature less than 10oC and areas <3,300 m asl have annual mean temperature of 10-15oC (Mohammed Kasso et al., 2010). However, there is a slight variation of temperature based on months and seasons (Yazachew Etefa and Kasahun Dibaba, 2011). During the dry season, diurnal temperature is high and nocturnal temperature is low (Mohammed Kasso et al., 2010).

The area is considered as one of the Afrotropical hotspots for biodiversity. It is also one of the areas that are affected by habitat fragmentation due to climate change and anthropogenic factors like deforestation. In addition to the burning of *Erica*, there is deforestation of remnant forests for settlement, agriculture and construction (Mohammed Kasso and Afework Bekele, 2011).

2.2. Methodology

The study was carried out from September 2013 to December 2016. During the preliminary survey, all the available and relevant information such as vegetation types, topography, altitudinal zonations, extent of the area, level of human encroachment and habitat fragmentation, duration of fire burn of Erica, nature of vegetation and habitat types were gathered. Based on the different vegetation and habitat types, the topography and altitudinal zonation and duration of *Erica* burn, different representative habitats types from each representative transects and grid were identified.

The number of sampling grids selected from each transect was based on the size of the area, altitudinal zonation, nature and type of habitats and vegetation, duration fire of *Erica* and ease of accessibility and representativeness of habitats. Trapping was carried out for three consecutive days. Trapping of small mammals (rodents and shrews) was carried out by using collapsible Aluminium Sherman Live Trap of 7.5 x 9 x 22 cm. Hence, for mole rate O-sized gopher foot trap was used. For porcupine, indirect observation methods like burrow scat and quill, remains of food were in the selected grid and its close vicinity.

In each trapping grid, five parallel transect lines with a length of 75 m that form square gird of 5,625 m2 (75 m x 75 m) were established at different habitats and altitudinal ranges. Each live trapping grid has 25 trapping stations spaced at 15 m interval. Each trap station was marked by colored plastic tags on tall branches of the tree or on deliberately erected poles prepared from any branch or stem of suitable tree to easily locate the traps during checking and collection. For each line, the first and last trapping stations were marked uniquely to identify the position of the traps during checking and collection. Strings were put down along each line in dense and tall *Erica* thicket to mark and locate the trap stations easily. Traps were covered by available material like hay, leaves, branches, ferns and lichen and grasses in order to avoid the trapped animals from harsh environmental condition and to minimize its observation to foreign intruders. Traps were mostly baited with peanut butter and during favorable climatic condition; it was also baited with peanut butter mixed with roasted barley flour. The bait was replenished each day or at any time if it was eaten by trapped animal or other animals (insects), got wet, grew mold, or dried up. Traps were checked twice a day early in the morning (6:30 to 8:30 a.m.) and in the late afternoon from (4:30 to 6:30 p.m.).

Information on weight, sex, approximate age (young, sub-adult, adult) and reproductive conditions from all trapped small mammals were gathered.

2.3. Data analysis

The collected data were tabulated and organized and both qualitatively and quantitatively analysed. The impacts of burning are quantified in terms of both faunal species composition, relative and absolute abundance and species richness (Parr and Chown, 2003). Hence the relative abundance and richness were used to quantify the impacts of *Erica* burn on small mammals. Thus, the impact of fire severity and related spatial and temporal parameters on species of small mammals were assessed following the procedures of Roberts et al. (2008) and Gutema Jira *et al.* (2013).

Data were examined and Chi-square ($\chi 2$) used to test for differences among since *Erica* burn and environmental attributes. Nested repeated measure analysis of variance was used to test for differences in small mammal species abundance between trap sites and post-fire interval by using the slight modification of Radford (2012) procedures.

Since there was variation in the number of trap night in the categories of time since *Erica* fire capture per 100 trap-nights was used for the comparative capture of rodents and shrews in the categories:

$$CTN = \frac{C}{TN} x100$$

$CTN = C/TN \times 100$

Where:

CTN = capture per 100 trap night

C = total new captures in the specific category

TN = total trap night in particular category

In similar way, mean capture per 100 trap night and its mean relative abundance was used for each species in each categories of time since *Erica* fire. All the decimal numbers above zero was roundedup as there was at least one individual of that particular species existed.

3. Results

A total of 1372 small mammals out of which 1174 were new captures and 198 were recaptures in 3150 trap nights were captured from the nine conventional categories of time since *Erica* fire (Table 1). See Plate 5 for the different stages of *Erica* regeneration during post *Erica* fire.

The highest capture per trap night (50) was recorded for categories of time since *Erica* fire above six years, then 48 and 47 for time following *Erica* fire of five and six years, respectively whereas the lowest is Eric fire since less than six months. Nothing was captured from *Erica* burn for less than a month. The capture per trap night in each categories was statistically not significant (χ^2 = 21.19, df = 7, $p<0.05$). There was no capture from habitats since the time *Erica* fire of less than a month (Table 1).

Plate **1**. Different stage of Regeneration of *Erica* post fire

Table **1**. Abundance of small mammals, trap night and capture per 100 trap-night since *Erica* fire

Time Since *Erica* fire	**Grid**	**Trap night per Grid**	**Capture per Grid**	**Total trap-night**	**Total New Capture**	**Capture per 100 trap night**
Above six years	CH-13	300	98(14)	600	297	50
	CH-23	300	199(35)			
Five years	CH-16	300	143(27)	300	143	48
Six years	CH-03	300	158(26)	600	283	47
	CH-09	300	125(25)			
Four years	CH-08	300	104(12)	300	104	35
Three years	CH-17	300	110(17)	300	110	37
Two years	CH-12	300	95(13)	300	95	32
One year	CH-20	300	73(18)	300	73	24
Six month	CH-07	300	69(11)	300	69	23
Less than month	CH-04	75	0	150	0	0
	CH-11	75	0			
Total	12	3150	1174(198)	3150	1174	296

Number in bracket shows recapture

The total mean capture per 100 trap night in all conventional categories of time since *Erica* fire was 318 (Table 2). The maximum (17.3%) capture per trap night for rodents and shrews were recorded for *Erica* fire above 6 years and followed by six years time since *Erica* fire.

There was no capture for *Erica* habitat time since *Erica* fire less than a month and capture rate was least for *Erica* habitat time since *Erica* fire of six month (Table 19). *Erica* above six years old time since *Erica* fire had more (12) species followed by six year time since *Erica* fire. The numbers of species were least (4) for categories time since *Erica* fire of one year and six month. Even for time since *Erica* fire of less than a month, species of rodents and shrews were not recorded (Table 1).
Although capture rate seems lower for two years since *Erica* fire than three years, however, in species richness, it was higher (Table 1).

The capture rate and relative abundance were high for *L. brevicaudus* and *S. griseicauda*. Except in habitat time since *Erica* fire less than a month, *L. brevicaudus* and *S. griseicauda* were recorded from all categories of *Erica* fire. *Otomys helleri* was also recorded from six different categories with the exception of habitats since time *Erica* fire of five years, three years and less than a month (Table 2).
Lophuromys brevicaudus, *M. mahomet*, *O. helleri* and *S. griseicauda* were the only captured small mammals from *Erica* fire less than 18 months' time since *Erica* fire (Table 2).

Table 1. Mean capture per 100 trap night and relative abundance of each species in different years of time since *Erica* fire

Species	Above six years (600)	Six years (600)	Five years (300)	Four years (300)	Three years (300)	Two years (300)	One year (300)	Six months (300)	Less than a month (150)	Total	R. abundance (%)	Species occurrence
A. abyssinicus	1(2)	0	0	0	0	1(2)	0	0	0	2(4)	0.63	2
A. blicki	5(29)	0	1(1)	0	0	0	0	0	0	6(30)	1.89	2
C. fumosa	0	1(5)	0	0	1(1)	1(1)	0	0	0	3(7)	0.94	3
C. glassi	2(10)	1(2)	0	2(4)	0	0	0	0	0	5(16)	1.57	3
C. lucina	0	1(2)	0	0	0	0	0	0	0	1(2)	0.31	1
C. olivieri	0	0	0	1(3)	0	0	0	0	0	1(3)	0.31	1
C. thalia	2(10)	6(35)	0	2(5)	3(8)	0	0	0	0	13(58)	4.09	4
***Dendromus* sp.1**	0	1(2)	0	0	1(1)	0	0	0	0	2(3)	0.63	2
D. lovati	1(1)	0	0	0	1(1)	0	0	0	0	2(2)	0.63	2
L. brevicaudus	23(134)	15(89)	2(6)	19(56)	20(59)	11(31)	2(6)	1(3)	0	93(384)	29.25	8
L. melanonyx	4(19	0	9(27)	0	0	0	0	0	0	13(46)	4.09	2
M. natalensis	3(13)	0	4(10)	0	0	4(12)	0	0	0	11(35)	3.46	3
D. nikolausi	0	0	1(1)	0	0	0	0	0	0	1(1)	0.31	1
M. mahomet	0	0	0	0	0	0	14(41)	15(45)	0	29(86)	9.12	2
O. helleri	1(5)	1(6)	0	3(7)	0	1(1)	6(18)	6(17)	0	18(54)	5.66	6
S. albipes	3(15)	6(31)	3(9)	0	0	6(17)	0	0	0	18(72)	5.66	4
S. albocaudata	1(6)	5(28)	11(32)	1(1)	0	0	0	0	0	18(67)	5.66	4
S. griseicauda	9(53)	14(83)	19(57)	10(2	14(40)	11(31)	3(8)	2(4)	0	82(304)	25.79	8
Total	55(297)	51(283)	50(143)	38(104)	40(110)	35(95)	25(73)	69(24)	0	318(1174)	100.00	
%	17.3	16.04	15.72	11.95	12.58	11.01	7.86	7.55	0			
No. species	12	10	8	7	6	7	4	4	0	17		

**Number in bracket () shows new capture*

5. Discussions

The human society used fire for hunting, to drive game, heating, cooking lighting and to improve pasture (Kelly *et al.*, 2012). At present, also fire is used as a traditional land management practice in different part of the word including Ethiopia. Large amount of African vegetation is managed by fire mainly during the dry season from November to April in East Africa from Senegal to Ethiopia (Kamiya *et al.*, 2013). Whether it is natural or human induced fire is widespread and the occurrence depends on vegetation type and state, climatic and meteorological conditions and land use (Kamiya *et al.*, 2013). Human induced fires are mostly related to land use and management issues. It causes significant impact when combined with other ecosystem disturbance factors like grazing.

Fire is a natural process that shapes the structure and function of ecosystems across the globe (Bagne and Finch, 2010). It is a major driver of ecosystem structure and function worldwide. It is also widely used as a management tool to achieve conservation goals. It could be beneficial or disadvantageous at local and landscape levels depending upon its magnitude and extent. The magnitude of fire is determined by the type of fire, season of firing, timing and duration of fire, and meteorology and weather conditions and fuel load and soil moisture (Kelly *et al.*, 2012). The study made by Andersen *et al.* (2012) in the Australian savannah indicated a decline of the diversity of many small mammal species that are sensitive to frequent fire. As a result, many species show a dramatic population decline over recent decades although the causes are poorly understood. The most important impact of fire on small mammals is indirect through changes in habitat, resource availability and predation risk, rather than through direct mortality (Andersen *et al.*, 2012). The direct impact of fire on vegetation are through plant and seed death or indirectly through subsequent increase in soil temperature and decrease in soil moisture content. In Ethiopia, fire incidence and occurrence has increasingly become rampant (Tadesse Habtamu and Afework Bekele, 2008). Its scientific investigation on fire ecology in the country has not been extensive and as a result, its influence on fauna and flora poorly understood. The reasons behind mainly technical problems and ecological knowledge gaps in characterizing fire regimes, lack of institutional and infrastructural facilities to regulate and control and due to lack of fire policy at national and local levels. The most reliable information on the ecological effects of fire is obtained from controlled field experiments.

The Arsi Mountains particularly Chilalo-Galama Mountains Range hosts several endemic species of flora and fauna some of which threatened with extinction.

The regeneration and recovery of *Erica* and other vegetation post *Erica* fire showed significant variation from place to place. This variation is influenced by soil fertility, moisture, temperature and fire intensity and severity. In places with good soil fertility, moisture, relatively high temperature and with weak intense fire, the *Erica* and other vegetations regenerate faster. Grass and other herbaceous vegetation grow much earlier than *Erica* shooting. In the present study, in most places where *Erica* fire occurred on old and matured are intensity and the severity of the fire was high. It affects the *Erica* regeneration resulting with open space or gap due to death of some *Erica* bundle. Except with some herbs and sparsely sprouting grasses, there was no

Erica regeneration in habitats of less than a month burn since time of *Erica* fire and even up to one year in areas with thin soil and moisture and temperature stress and dominated by bare land. Contrary to this, Gutema Jira *et al.* (2013) stated that six months time since *Erica* fire habitat did not show any *Erica* recovery because of the effect of fire. However, the *Erica* sprouting and growth of grasses and herbs during one and above year since the time *Erica* fire in line with the present study. In two year the since time of *Erica* fire showed good levels of recovery with shrubs, herbs and grasses and reached a height more than a meter within three to four years since the time of *Erica* fire under good soil, moisture and temperature condition. In five years time, *Erica* habitat showed a significant recovery in canopy cover compared to unburned *Erica* habitat. Six years time *Erica* habitat had better recovered vegetation comparable to the old and matured habitat that was not brunt for long time. The *Erica* recovery condition in Chilalo-Galama Mountains Range was almost similar to the recovery condition with nearby Bale Mountains (Gutema Jira *et al.*, 2013). Mohammed Kasso and Afework Bekele (2011) revealed *Erica* fire has tremendous effect on small mammals lasting for long time. In addition, the decline of individuals trapped might be due to the drying of herbaceous vegetation that serves as food and cover (Mohammed Kasso and Afework Bekele, 2011; Gutema Jira *et al.*, 2013) and also due to direct death by fire. Fire affects shelter sites, such as hollow logs, tree hollows and dense tussocks of grass. Extensive fire, excessive grazing effects and absence of surface water during the dry season are the most important threats for the survival of small mammals (Tadesse Habtamu and Afework Bekele, 2008).

The record of some species in relatively recently burnt *Erica* shows their overall resilience their fire suggests that they are secure under all but the most extreme fire regimes. However, it is clear that more fire-sensitive groups such as small mammals need special fire management attention. This needs to involve less frequent and finer-scale burning, along with the protection of some large, infrequently burnt source areas. Many previous studies also showed the abundance and habitat preference of rodents are positively correlated with vegetation cover and heterogeneity, availability of food and water resources, and reproductive conditions of the species (Demeke Datiko *et al.*, 2007). The vegetation structure and cover affect the microclimate and hide small mammals against predators (Demeke Datiko and Afework Bekele, 2014).

Information on the effects of fire on small mammals is immense. Its effects have been shown in lowering the species diversity, in the destruction of vast areas of their habitat and food, changing their behaviour and leading to population fluctuation (Clausnitzer, 2003). The data on capture per trap night of the present study revealed variation among the habitat categories since time of *Erica* fire. The highest capture per trap night was recorded for categories of time since *Erica* fire above six years. From the observation, a matured *Erica* has a closed canopy with many mosses, ferns and lichens and the open understory mostly covered with different shrubs, herbs and grasses. Such habitats become the home for many species of small mammals to their level of climax succession. Previously Mohammed Kasso and Afework Bekele (2011) also concluded the number and abundance of small mammals to increase with the age of post *Erica* fire. However, Gutema Jira *et al.* (2013) from Bale Mountains National Park hypothesised the intermediate community succession by stating high species diversity and abundance recorded from the intermediate succession stages of post *Erica* fire. In the present study, there was no capture from *Erica* habitat in *Erica* fire less than a month and capture rate was least for *Erica* habitat time since *Erica* fire of six month.

Similar to the present result, Mohammed Kasso and Afework Bekele (2011) reported the absence of record from recently burnt *Erica* from Mount Chilalo. There was also no record from habitats up to one-year time since *Erica* fire from Bale Mountains National Park (Gutema Jira *et al.*, 2013). This demonstrates the earlier impacts of *Erica* fire on small mammals are tremendous. This mainly resulted from direct mortality by fire, change in vegetation composition and structure affecting shelter and food as well as availability of water in the habitat (Clausnitzer, 2003).

The capture per trap night variation among habitats and grids with different categories since time of *Erica* fire clearly indicated the extent of impact of *Erica* fire on small mammals and extent of their resilience to it. In most grids, there was few number of small mammals capture from grids less than six months of post *Erica* fire. Fire results in mortality, and emigration of rodents to nearby habitats. Post-fire emigration of small mammals attributed to lack of vegetation for food and shelter (Clausnitzer and Kitty, 2000). Nevertheless, some grids of the recently burnt *Erica* harbour small mammals particularly in places where there is patchy unburnt of *Erica* close to it. This remnant unburnt *Erica* patch serves as stock for small mammals to recollonize the regenerated *Erica* and other vegetation after the post fire. This shows that habitat quality is important to sustain rodent populations in their natural habitat. Similarly, Clausnitzer (2003) also reported increase growth of annual and perennial forbs in burned habitats to attract high diversity of small mammals. In the present study, grasses of scrub vegetation such as *Helichrysum* and *Alchemilla* regenerated in good condition after *Erica* fire provided shelter and food for small mammals. The maintenance of 'fire mosaics' comprising spatially heterogeneous patches of differing fire history enhances the conservation of fauna (Kelly *et al.*, 2012) even though there is unclear properties of fire mosaics that enhance conservation efforts efficiently.

The species richness is relatively highest for *Erica* above six years old time since *Erica* fire. Contrary to this Gutema Jira *et al.* (2013) recorded least abundance and density of small mammals from unburned *Erica* vegetation. There was no record of any species of small mammals for time since *Erica* fire of less than a month. The absence of record from the recently burnt *Erica* habitat is might be related to the direct effect on food resources seeds, stems and leaves of grasses and forbs, a critical resource for many rodent species. Changed fire regimes may also force longer-term changes in grass species composition, and therefore the availability of preferred seeds (Andersen *et al.*, 2012).

A total of 18 species of small mammals was recorded from all categories of time since *Erica* fire in the present study area. Out of the 18 species recorded, 15 were endemics to the country of which some are local endemics to the Eastern plateau of Ethiopia (Yalden *et al.*, 1992; Mohammed Kasso *et al.*, 2011; Afework Bekele and Yalden, 2013). This high endemicity of the small mammals shows the existing challenge *Erica* fire requires urgent intervention and conservation action. The number of the recorded species was higher than the number of small mammals previously recorded from the same habitat from Arsi Mountains by Mohammed Kasso *et al.* (2010), Mohammed Kasso and Afework Bekele (2011), Zerihun Girma *et al.* (2012) and by Gutema Jira *et al.* (2013) from Bale Mountains National Park. Overall, the distribution and occurrences of the small mammals listed in the present study area agree with the previous finding in similar habitats.

6. Conclusion and Recommendations

5.1. Conclusion

Sub-Afroaline and Afroalpine Ecosystem is one of fire pron ecosystem in Ethiopia where a very limited studies were conducted on the effects of *Erica* burn on small mammals. In particular, there is high gap on the impacts of *Erica* burn on the small mammals of Chilalo-Galama Mountains Range. In the absence of a clear understanding of fire-related impacts on small mammals, it is difficult to prescribe management programmes. Hence, the current study on the impact of *Erica* burn on small mammal species composition and relative abundance clearly indicated the urgent importance conservation of small mammal and their habitat management. The highest capture per trap night was recorded for categories of time since *Erica* fire above six years and the lowest and the least was from the recent *Erica* burn. Even the lack of capture from *Erica* burn for less than a month clearly indicated the severity of *Erica* fire impact on the rodents and shrews. Beside the abundance, the species richness of the *Erica* above six years since *Erica* fire had more than the recent categories time since *Erica* fire of one year and six months. Although capture rate seems lower for two years since *Erica* fire than three years, however, in species richness, it was higher. The capture rate and relative abundance for each species showed high variation among the rodents and shrews captured of which high for *L. brevicaudus* and *S. griseicauda*. Except in habitat time since *Erica* fire less than a month, *L. brevicaudus* and *S. griseicauda* were recorded from all categories of *Erica* fire. Otomys helleri was also recorded from six different categories with the exception of habitats since time *Erica* fire of five years, three years and less than a month. *Lophuromys brevicaudus*, *M. mahomet*, *O. helleri* and *S. griseicauda* were the only captured small mammals from *Erica* fire less than 18 months' time since *Erica* fire. In general, the result of this study clearly indicated the *Erica* fire impact on the small mammals. From the recorded species of rodents and shrews more than 83% are endemics to the country of which some are local endemics to the Eastern plateau of Ethiopia hence this high endemicity of the small mammals shows the existing conservation challenge with *Erica* fire.

5.2.Recommendations

Based on the findings of the study, several conservation actions could be taken to address the impact of *Erica* fire on small mammals in the Chilalo-Galama Mountains Range of Ethiopia.

- One possible action is to implement controlled burning regimes that take into account the specific needs of small mammal species. This would involve burning at appropriate intervals, and in a manner that minimizes the impact on small mammal populations which would create a fire break. To control the expansion of *Erica* fire, well designed fire break should be constructed.
- Another action is to establish buffer zones around small mammal habitats to reduce the risk of fire spreading into these areas. These buffer zones could be created by removing dry vegetation and fuel, or by creating firebreaks.
- In addition, it is important to raise awareness among local communities and stakeholders about the importance of small mammal conservation. Education and outreach programs could be developed to increase awareness about the role of small mammals in the ecosystem, and the potential impacts of *Erica* fire on their

populations. This could also include training programs for local conservationists and park rangers to better monitor small mammal populations and respond to threats.

- Finally, further research is needed to better understand the impact of *Erica* fire on small mammals and to develop more effective conservation strategies. This could include research on the long-term effects of fire on small mammal populations, as well as studies on the effectiveness of different management techniques for mitigating the impact of *Erica* fire on small mammals.

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7. Conflict of Interest

There is no any conflict of interest.

8. References

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