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Population size and behavioral ecology of Bale monkey (*Chlorocebus djamdjamensis*) in human-dominated landscapes of Sidama Highlands, Southern Ethiopia

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This is to certify that the dissertation prepared by Gezahegn Nega Chekol, entitled: “Population size and behavioral ecology of Bale monkey (*Chlorocebus djamdjamensis*) in human-dominated landscapes of Sidama Highlands” and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology) complies with the regulation of the University and meets the accepted standard with respect to the originality and quality.

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ABSTRACT

Population size and behavioral ecology of Bale monkey (*Chlorocebus djamdjamensis*) in human-dominated landscapes of Sidama Highlands, Southern Ethiopia

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Bale monkeys (Chlorocebus djamdjamensis) are endemic, bamboo specialists, restricted to a narrow geographic range in the Ethiopian highlands currently recognized as vulenerable speceis by IUCN. The study was conducted to investigate the impacts of habitat loss and fragmentation on behavioral ecology and population size by comparing two groups of Bale monkeys in relatively continuous Garamba Forest and fragmented Afursa Forest in human-dominated Sidama highlands. Phenological pattern was assessed within each group's home range to investigate the overall vegetation composition and temporal changes in food availability. Phenological data was analyzed from eight plant species: five trees, two shrubs and one bamboo. Total count method was used to estimate the population size of Bale monkeys. Data on activity budget, feeding ecology, and ranging ecology of the two groups of Bale monkeys were quantified using scan sampling method. Ranging ecology data were analyzed using a combination of ArcGIS and Home Range Tools. Plant species with DBH ≥ 10 cm in the range of Garamba Forest group (G) had higher stem density (768 stems/ha) than Afursa Forest (A) (624 stems/ha). Plant species diversity and evenness were lower and dominance was higher in Garamba Forest than in Afursa Forest. There were statistical differences in food availability indices of young leaves (P<0.05) and matured leaves (P <0.05) between the two Bale monkey groups across months. The total population size of Bale monkeys was 225 individuals. The average group size was 20.5 at Worbadula, 25.5 at Afursa and 33.25 at Garamba. Group-A spent significantly less time feeding (54.1% vs 57.3%, moving (19% vs 22.1%) and significantly more time on resting (17.2% vs 13.2%), socializing (8.69% vs 5.1%) than Group-G. More plant species (32) were identified as food source for Group-A than species in Group-G (14). Food item consumption markedly varied between groups (P<0.05), Group-G spent more time feeding on bamboo young leaves (51.02% vs 0%), bamboo young shoots (12.15% vs 0%) and significantly less time feeding on non-bamboo young leaves (3.43% vs 36.69%), fruits (12.9% vs 22.53%), stems (4.25% vs 19.63%) and insects (3.8% vs 12.35%). The time spent feeding on different growth forms of plant species by two groups of Bale monkeys also varied, Group- G spent more time feeding on bamboo (63.49% vs. 0%) while Group-A spend more time feeding on trees (27.98% vs 24.67%), graminoids (19.6% vs 1.94%), shrubs (19.28% vs 4.87%) and forbs (17.34% vs 1.23%). Bale monkeys in Garamba Forest had higher movement rate (m/hr) than in Afursa Forest group. Bale monkeys are highly threatened due to habitat loss and fragmentation and adapted anthropogenic alteration by adjusting ecological flexibility with respect to habitat type. Conservation managers should do more to ensure the long-term survival of this unique, little known, endemic and endangered species.

Keywords: Bale monkey, feeding flexibility, fragmentation, population status, Sidama

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TABLE OF CONTENTS

LISTS OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS

BA	Basal Area
EWCA	Ethiopian Wildlife Conservation Authority
IUCN	International Union for Conservation of Nature and Natural Resources
KDE	Kernel Density Estimation
MCP	Minimum Convex Polygon
NMA	National Meteorological Agency
SNNPR	Southern Nations, Nationalities and People’s Region

1. INTRODUCTION

The combined impacts of climate change and habitat loss cause unprecedented rates of environmental change and biodiversity loss (Thomas *et al*., 2004). The world is currently losing species at a rate of 100-1000 times faster than the natural extinction rate (Pimm *et al*., 1995). The worldwide mammal status analysis on global scale shows that primates are the most threatened mammals (Schipper *et al*., 2008). Recent evaluations have suggested that out of the world's primate species, more than half of them are threatened with extinction. Most of these occur in tropical regions (IUCN, 2014). The most important threats for primate species are mainly associated to habitat loss and fragmentation due to human activities (Lee and Priston, 2005; Isabirrye-Basuta and Lwanga, 2008; Dickman, 2010). Rapid human population growth and associated land use changes such as agriculture and urbanization are transforming primate habitats (Estrada *et al*., 2012; McKinney, 2015). Agricultural land expansion causes habitat loss and fragmentation (Gibbs *et al*., 2010), which alter vegetation structure and composition, shrink natural habitat and decrease food quality and availability for species (Laurance *et al*., 2014; Addisu Mekonnen *et al*., 2018). At present, habitat loss is the gravest threat facing primates inhabiting tropical forests (IUCN, 2012; Addisu Mekonnen *et al*., 2018).

Due to habitat loss and fragmentation, approximately 40% of the global land surface has been converted for agricultural use and more than 50% of the terrestrial biosphere has undergone anthropogenic changes (Foley *et al*., 2005; Ellis *et al*., 2010). Due to this land conversion, vast area of native plants have been destroyed and transformed into other vegetation types. Tropical forest is the biome that is lost most rapidly in this process (Myers, 1994; Leperrs *et al*., 2005; Wright, 2005; Hansen *et al*., 2008). Although tropical forests only cover a small proportion of the world's land surface (6-7%), they contain at least 50% of all animal species worldwide (Wilson, 1988; Groombridge and Jenkins, 2002). Due to this concentration of biodiversity in tropical forests, processes like habitat loss, habitat destruction, and fragmentation pose major threats to the survival of many species (Turner, 1996; Wilcove *et al*., 1998; Sih *et al*., 2000; Fahring, 2003; Ewers and Didham, 2006).

Habitat fragmentation is often defined as a process where large expanse of habitat is transformed into a number of smaller patches. Such process can affect the survival of the vulnerable species through a number of different mechanisms including reduction of habitat types and subsequent reduction in quantity and quality of food resources. It also resulted loss of sleeping site trees, genetic deterioration by minimizing gen flow and edge effects (Anderson *et al*., 2007; Baumgarten and Williamson, 2007; Dunn *et al*., 2009, 2010; Chaves *et al*., 2012).

Some non-human primates historically shifted their diet and survived with a new adaptation in a modified habitat. Series of environmental changes have transformed tropical forests into savanna woodlands. Frugivore primates face reduced food abundance and were forced to use alternative sources such as meat, nuts, or underground storage organs of plants (Bunn and Ezzo, 1993; Reed and Rector, 2007). Habitat specialists like

Theropithecus oswaldi, *Theropithecus brumpti* and *Theropithecus darti* and Koala lemur (*Megaladapis edwardsi)* became extinct due to failing to adapt to habitat modifications (Hughes *et al*., 2008). In recent habitat fragmentations, some researchers argue fragmented habitats are able to sustain species capable of exploiting resources in anthropogenic habitats (Daily *et al*., 2003). Dietary flexibility and ranging patterns as well as the ability to use matrix environments appear to be crucial to the survival of primates in fragments (Anderson *et al*., 2007; Onderdonk and Chapman, 2000). However, this is controversial and could be critical for habitat specialist species which do not have the adaptation for wide range of food types.

A long-term ecological study across populations that live in different habitats is necessary to understand their behavioral response to habitat disturbances (Chapman and Press, 2001; Struhsaker, 2008) to enact appropriate primate conservation programs (Southwick and Blood, 1979). In addition, conservation plans that center on the exclusion of human activities from primate habitats will be difficult to maintain in the presence of human population growth, urban development, mining and poverty. Thus, understanding the level of behavioral and ecological modifications and strategies of primate survival in anthropogenic habitats as well as the need of local people is necessary for devising better conservation actions and strategies.

The other outcome of habitat loss and fragmentation following expansion of human settlement and cultivated land in wildlife habitat is crop raiding. Crop raiding may cause extensive damage to agricultural crops that compromise local food security (Hill, 2000).

Crop raiding may result increasing time spent for cultivated field protection (Loudon *et al*., 2006). Such conflict usually reduces to wildlife from neighboring human communities (Sekhar, 1998).

Ethiopia has diverse wildlife resources (Afework Bekele and Yalden, 2013). This is reflected by altitudinal ranges and diversity of climate, vegetation and landscape. Altitudinal variations along with other physical factors have contributed for a diverse set of ecosystems ranging from humid forest and extensive wetland to the desert of Afar depression. The variety of ecosystems and diverse topography of Ethiopia provides a wide spectrum of habitat types and ecological niches of different fauna and flora. The fauna and flora of Ethiopia contain distinctive endemic species (Hillman, 1986; Yalden and Largen, 1992). The country contains over 310 species of mammals belonging to 43 families, of which 55 species are endemic (Cole *et al*., 1994; Jacobs and Schloeder, 2001; Afework Bekele and Yalden, 2013; Laverenchenko and Afework Bekele, 2017). Among the mammals of Ethiopia, non-human primates comprise 10.5% species and sub-species (Kingdom, 1997; Grubb *et al*., 2003; Groves, 2005). There are 13 species of non-human primates in Ethiopia (Afework Bekele and Yalden, 2013). Out of these, gelada (*Theropithecus gelada*), blue monkey (*Cercopithecus mitis boutourlinii*) a sub-species of *Cercopithecus mitis* and Bale monkey (*Chlorocebus djamdjamensis*) are endemic to the country (Gippoliti, 2010; Laverenchenko, and Afework Bekele, 2017).

In Ethiopia, natural resources are depleted rapidly due to unsustainable forest use, agricultural expansion and livestock grazing practices. The forest resources of the country have been significantly declining over time both in size and quality (Alemnew Alelign *et al*., 2007). Statistical figures of Ethiopian forest cover diminished from 40% in the early 1950s, to 16% in 1950, 3.1% in 1982, 2.7 % in 1989 and less than 2.3% in 1990, (EFAP, 1994; McCann, 1997). The estimated human population size of Ethiopia is 99,465,819 and increasing at 3.2% (CIA World Face book, 2015) that implies more challenges to biodiversity conservation. Remote, inaccessible and naturally unsuitable areas for human use are now invaded by humans including steep hillsides which were once exclusively used by wildlife species. Like many other tropical primates (Marsh, 2003), much of the Bale monkey's historical geographical range has been converted into agricultural land, grazing land and human settlements, leaving many populations in small and isolated forest fragments (Addisu Mekonnen *et al*., 2012).

Despite high level of habitat destruction and degradation due to high population growth, most of Ethiopian unique primates remain little-studied. Among Ethiopia's endemic primates, Bale monkey (*Chlorocebus djamdjamensis*) is endemic to Ethiopian highlands east of the Rift Valley. While new Bale monkey populations are reported in the eastern escarpments of the Bale Mountains and Sidama highlands recently (Addisu Mekonnen *et al*., 2012), the entire range of the species has never been adequately surveyed. The population size has declined from its historical range primarily due to effects of habitat fragmentation. They are listed as Vulnerable by IUCN (Butynski *et al*., 2008). The species is estimated to have less than 20,000 km^2 range. They also consume up to 80% of bamboo leaves and shoots in intact forests. Habitat loss may greatly threaten the survival of the species (Butynski *et al*., 2008; Addisu Mekonnen *et al*., 2010a, b).

The Bale monkey's high degree of specialization is unique among its sister species, including the vervet (*Chlorocebus pygerythrus*) and grivet (*Chlorocebus aethiops*) monkeys, which are able to exploit many different habitat types (Isbell *et al*., 1998; Enstam and Isbell, 2007). The two latter species are abundant in many African countries across wide ecological zones with wide spectrum of plant species and they spend a large portion of their moving time on the ground (Dunbar and Barrett, 2000). The recent discovery of Bale monkey populations in several heavily-disturbed forest fragments lacking bamboo suggests that the species may be capable of greater habitat flexibility (Addisu Mekonnen *et al*., 2012) than previously thought (Carpaneto and Gippoliti, 1994; Butynski *et al*., 2008; Addisu Mekonnen *et al*., 2010a).

1.1. Statement of the Problem

Recent evaluations about the world's non-human primate species have suggested that, more than half of them are threatened with the risk of extinction. Most of these are located in tropical regions (IUCN, 2014). The most important threat of primate species is mainly associated with human impacts through habitat loss and fragmentation that has high potential impacts not only on primates but also on the local biodiversity as a whole. Particularly, primates living in poor developing nations may be affected by human population growth, with increasing extraction of resources from the forest and by destruction of primates' natural habitat. External factors affect primate conservation like hunting of pest species (grivet, macaques, baboons, Bale monkeys) as a result of conflict over crop raiding (Dickman, 2010; Addisu Mekonnen *et al*., 2012).

Ecological generalist primates are known to inhibit wide geographical ranges and consume diverse food resources and are able to cope with changes in response to habitat disturbance and degradation by exhibiting substantial ecological and behavioral flexibility (Eppley *et al*., 2016). Ecological specialists like Bale monkeys are adapted to narrow geographic and dietary niches and be less tolerant to habitat disturbances (Kamilar and Tecot, 2016; Addisu Mekonnen *et al*., 2010a, b). Thus, specialist species are highly vulnerable to adverse ecological consequences of habitat degradation (Harcourt *et al*., 2002; Colles *et al*., 2009) and seasonal changes (Hill, 1997; Dunbar, 1998). Therefore, species-specific studies on details of the conservation threats of primates are a crucial step towards effective conservation management plan. Data on population size and behavioral ecology is vital to their conservation (Addisu Mekonnen *et al*., 2010a).

Bale monkeys are vulnerable to future decline throughout their ranges due to their proximity of habitats to human settlement area, loss of their original habitat (bamboo) by anthropogenic factors, competition with livestock on grazing pasture and conflict with the local farmers as the result of crop raiding habit. Therefore, there is a need to study the ecological and behavioral flexibilities for survival of the Bale monkeys by comparing such degraded bamboo forest with total loss of their natural food (bamboo) habitat as well as with already published works at intact bamboo forest habitats. Expanding such scientific knowledge on the behavioral ecology and population status is important in order to take appropriate conservation management action.

Chlorocebus species of Ethiopian generalist primate species have been the subject of studies for decades, but only few studies have focused on the little known conservation status and behavioral ecology of the endemic and specialist Bale monkeys. More precisely, nothing is known on the population size of Bale monkeys in Sidama highlands of southern Ethiopia. Accordingly, the research can contribute to the future conservation of endemic and specialist Bale monkeys.

1.2. Objectives

1.2.1. General Objective

To determine the population size and behavioral ecology of Bale monkey (*Chlorocebus djamdjamensis*) in human-dominated landscapes of Sidama Highlands, Southern Ethiopia

1.2.2. Specific Objectives

- To estimate population size of Bale monkeys in human dominated areas of Sidama highlands
- To determine the impact of anthropogenic habitat alteration on the diet and feeding ecology of Bale monkeys
- To determine the influence of habitat alteration on activity budget of Bale monkeys
- To identify the feeding behavior of Bale monkeys at Garamba and Afursa Forests
- To assess the effect of seasonality on food availability and behavior of Bale monkey

- To determine the effects of habitat fragmentation on the daily travel distance and ranging ecology of Bale monkey

1.3. Research Hypothesis

- Bale monkey is an arboreal primate specialized on bamboo forest. When the habitat is fragmented, it should adapt to the terrestrial habitat and new food items.
- Bale monkeys in Sidama highlands are distributed in a limited and fragmented patch with small population sizes.
- Habitat fragmentation will greatly reduce the principal food items of Bale monkeys in its natural habitat.
- Habitat fragmentation will decrease daily travel distance and movement rate of Bale monkeys.

1.4. Research Questions

This research focuses on the following main research questions:

- What is the effect of habitat loss and fragmentation on habitat use, feeding ecology, and activity budget of Bale monkeys?
- How is the population size of Bale monkeys in human dominated Sidama highlands?
- In which habitat types do Bale monkeys use small home range and travel short distances per day?
- How is the activity budget of Bale monkeys in human-dominated Sidama highlands?

2. LITERATURE REVIEW

2.1. Distribution and Biology of *Chlorocebus* Species

The Bale monkey (Chlorocebus djamdjamensis) is medium-size, an arboreal and enigmatic primate species that lives exclusively in a region of approximately 12,000 km^2 in the southern Ethiopian Highlands east of Rift Valley. The dorsal fur of Bale monkey is dark brown and the lower portion and the hair ring around the face is a whitish yellow. The face hands and feet are hairless and black, although their abdominal skin is bluish. Males have a blue scrotum and red penis. Bale monkeys are sexually dimorphic, adult males ranged 42 to 60 cm and females are 30 to 50 cm and they live in multiple males/multiple female groups. Female Bale monkeys signal her vulva to males when it needs for showing its sexual interest. Since groups are made of several more females than males, each male mates with several females. Male do not take parts in raising the infants, but others females of the group share the burden. The gestation period is about 163-165 days and births are typically of a single infant (Addisu Mekonnen *et al*., 2012).

The births usually happen at the beginning of the rainy season, when sufficient food is available. Infants are weaned at about six months of age and are fully matured in three to four years. Age-sex of categories of Bale monkeys are identified by: Infants have nipple contact with mother and carried by mother (infants of more than 6 months usually only carried when in danger), Juvenile are independent from mother and primarily socializes with playmates, Sub-adult male body size is larger than an adult female, Sub-adult females are sexually active (give and receives sex socialization), Adult male have descendant testes and Actively participate in male dominance hierarchy, Adult females have elongated Nipple.

The distribution and diversity of species are shaped by a combination of historical and contemporary factors. Currently, many species are affected by accelerated habitat destruction caused by both climate change and anthropogenic activity; resulting in fragmentation, population decline and loss of genetic diversity (Dixo *et al*., 2009; Pauls *et al*., 2013; Estrada *et al*., 2017; Miranda *et al*., 2017). Habitat characteristics and human actions are the leading forces of primate distribution in the world. The diversity and density of primates in natural forests, both in the Neotropics and elsewhere depend much on primary forest productivity, precipitation and climatic seasonality (Peres, 1999). Different primate species occupy different forest microhabitats, preferring different forest strata or forest types of different structure (Wallace *et al*., 1998; Bobadilla and Ferrari, 2000). Vegetation is thus an important factor for wildlife survival, providing food, cover and protection for wild animal species (Afolayan and Agbelusi, 1997).

The distributions of primates in their natural habitats have been affected by habitat fragmentation and loss from the growing human population. Habitat fragmentation through deforestation is the main cause of wildlife habitat shrinkage and change, and it is one of the major threats that most of the world protected areas are facing today (Blake, 2002). These forest degraders are also known to facilitate the invasion of natural forest by exotic species speeding up natural change processes (Ojima and Galvin, 1994). Tropical forest loss and fragmentation have been advocated at the main causes of flora and fauna population decline in the tropics (Laurance *et al*., 2002). The most vital steps in designing effective conservation management strategies are the assessment of population parameters such as size, density, and distribution of a species across the landscape population size. These are important for long-term monitoring, and the distribution of individuals and their use of space are important in targeting key areas of protection (Moore and Vigilant, 2014).

Savanna monkeys (Genus *Chlorocebus*) are among the most widespread of the African primates and inhabit large parts of sub-Saharan Africa (Kingdon, 1997). They are found across the continent from northwest Senegal to Eritrea, Djibouti and Somalia, as well as southward over much of southern Africa. *Chlorocebus* species live in a wide variety of habitats but show preference to savanna and savanna woodland mosaics and are not found in the moist forests of Central and West Africa, or in the deserts of Southwest Africa (Hill, 1966). Their taxonomic status and phylogenetic relationships remain unclear and the taxonomy of the entire genus is in urgent need of revision (Groves, 2001). Groves (2005) accepts the division of the genus into six species. The six *Chlorocebus* monkey species are: the grivet (*Chlorocebus aethiops*) of Ethiopia and northeastern Africa, the vervet monkey (*Chlorocebus pygerythrus*) of eastern and southern Africa, the malbrouck monkey (*Chlorocebus cynosures*) of Angola and the southern Congo, the green monkey (*Chlorocebus sabaeus*) of West Africa, the tantalus monkey (*Chlorocebus tantalus*) of Central Africa and the Bale monkey (*Chlorocebus djamdjamensis*) of Ethiopia (Groves, 2005). The Ethiopian endemic primate, Bale monkey (*Chlorocebus* *djamdjamensis*), was first reported by Neumann in 1902 as a species and named *Cercopithecus djamdjamensis*. This species was named after the Djam-Djam Mountain where it lives, a region found approximately 30 km west of Harenna Forest and east of Lake Abaya (Carpaneto and Gippoliti, 1994).

In addition to the Bale monkey, Ethiopia harbors two other native, but not endemic *Chlorocebus* species, the vervet (*Chlorocebus pygerythrus*) and grivet (*Chlorocebus aethiops*) (Onderdonk and Chapman, 2000; Shipley *et al*., 2009; Claves *et al*., 2011; Panthi *et al*., 2017). These two species are habitat generalists that inhibit a variety of savanna woodland, forest and grassland habitats, feeding on a wide array of food sources (Kingdon, 1997; Zinner *et al*., 2002; Enstam and Isbell, 2007). However, Bale monkeys primarily inhabit bamboo forest and are described as bamboo forest habitat specialists with a high dietary specialization on young bamboo leaves and shoots. This accounts from 73 - 80 % of their diet in their natural bamboo habitat (Addisu Mekonnen *et al*., 2010a, b, 2018). Despite differences in habitat and dietary requirements, interspecific gene flow with grivets and vervets has been suggested to occur in the contact zones of fragmented parts of the Bale monkey range (Tan, 1999; de Silva and Ribeiro, 2015).

Bale monkey is an arboreal endemic primate species restricted to the southern Ethiopian highlands (Addisu Mekonnen *et al*., 2010a, b). It is the least known and most region-restricted among other *Chlorocebus* species (Groves, 2005). The effects of habitat alteration are particularly determinant to species with small geographical ranges and specialized niche requirements (Colles *et al*., 2009; Dixo *et al*., 2009; Paulls *et al*., 2013;

Fietz *et al*., 2014). One of the species that is severely affected by habitat fragmentation is the Bale monkey (*C. djamdjamensis*) (Addisu Mekonnen *et al*., 2012). This arboreal primate is endemic and estimated to have less than 20,000 km^2 range in the southern Ethiopian highlands including the Bale Mountain National Park, Sidama Highlands, Harenna Forest, Kacha and Rirra areas (Butynski *et al*., 2008; Addisu Mekonnen *et al*., 2010b, 2012; Kingdon, 2015).

2.2. Population size of Bale monkeys

The living species of primates are influenced by diet, feeding behavior, nutritional quality of the food as well as distribution and availability of preferred food items (Barton *et al*., 1992; Hunter, 2001). The decline of population size of primates is strongly correlated with habitat loss, reduction of abundance and nutritional quality (Hobbs and Hanley, 1990). Bale monkeys are distributed over small geographical range compared to the other sister taxa species. The population density of wild animals often depends on habitat quality and disturbance (Dunbar, 1978). The relatively higher density of Bale monkeys in Odobullu Forest may be related to the high abundance and productivity of their main food source, bamboo (Addisu Mekonnen *et al*., 2012). Bale monkeys exclusively inhabit bamboo forests irrespective of season and avoid tree-dominant forest and bushland (Addisu Mekonnen *et al*., 2012). The occurrence of Bale monkeys has been documented in the Bale Mountain National Park, Harenna Forest, Kacha and Rirra areas (Carpaneto and Gippoliti, 1994; Kingdon, 1997; Butynski *et al*., 2008), and in Odobullu Forest (Addisu Mekonnen *et al*., 2008). In addition, Bale monkeys have been recorded in bamboo forest 23 km northwest of Dodolla and in the Djam-Djam Mountains near Abera, east of Lake Abaya at 3,000 m asl (Butynski *et al*., 2008).

Bale monkey populations occur at elevations ranging from 2,355 - 3,204 m asl. In addition to Bale Mountains National Park, 26 new Bale monkeys' sites with 37 Bale monkey groups containing 722 individuals were recorded with groups ranging in size from 9 to 29 individuals (Addisu Mekonnen *et al*., 2012). All 26 new Bale monkey sites consist of fragmented forest in human dominated landscapes outside officially protected areas. At most sites where Bale monkeys occurred, the bamboo forest had either been degraded or, in several cases, eliminated and converted into human use areas for settlement, agriculture or livestock grazing. Most sites containing Bale monkeys occur on public lands (including my both study sites, Afursa and Garamba Mountains). Several of the sites with the best protected remaining bamboo and Bale monkeys occurred on privately owned land (Guticha and Womma Shella) (Addisu Mekonnen *et al*., 2012). The distribution pattern and population size of Bale monkeys is not well known in the present study area.

An understanding of population dynamics is critical to the development of effective conservation management plans and realistic models of population and behavioral ecology (Lwanga *et al*., 2011). Data on population size of primates are essential to determine whether numbers of a particular species are being maintained, in decline or in recovery and to design conservation and management plans and wildlife management policies (Beehner *et al*., 2007). The density of primates can be estimated by several methods, such as complete count of individuals, home range monitoring, playback and estimates using line transect surveys (Fashing and Cords, 2000; Strier *et at*., 2006; Ferrari *et al*., 2010). Other savanna monkeys are at lower risk while the Bale monkey status was not determined (Kingdon, 1997; IUCN, 2008). However, Kingdon (1997) argued that Bale monkeys are endangered species which inhabit areas where other unique species are similarly endangered. Currently, this species are living in a very narrow with severe fragmentation due to ongoing habitat loss and degradation.

2.3. Behavioral ecology of Bale monkeys

Bale monkey (*C. djamdjamensis*) is a dietary specialist and endemic to montane forests of southern Ethiopian highlands. These are intact forest habitats of bamboo specialist herbivores that rely on a single species of highland bamboo (*Arundinaria alpina*) accounting for 77- 81% of their annual diet (Addisu Mekonnen *et al*., 2018). Bale monkeys are diurnal and spend most of their time on feeding. The seasonal availability of food means that this species varies its diet during the year; mainly feeding on bamboo young leaves and shoots during the wet season and on fruits during the dry season (Addisu Mekonnen *et al*., 2010a). The living space of primates is influenced by the diet, feeding behavior, nutritional quality of food and availability of preferred food items (Barton *et al*., 1992; Hunter, 2001). The current worldwide decline in primate population is due to anthropogenic activities (Wich and Marshal, 2016).

Different challenges including decline of primate population in such small and isolated human dominated habitat is strongly correlated with habitat loss and fragmentation due to reduction of food quality and abundance (Hobbs and Hanley, 1990). In habitats in which the diversity and abundance of plant species has been significantly changed, the main challenge is to overcome dietary needs (Dunn *et al*., 2009; Wei *et al*., 2015). Primates show behavioral flexibility in response to a habitat alteration due to seasonal variation, food availability and scarcity of preferred food (Addisu Mekonnen *et al*., 2018; Jarvey *et al*., 2018). Dietary responses of non-human primates to habitat degradation are varied, including consumption of abundant low-quality food items ("fallback foods") (Marshall *et al*., 2009). The term "fallback food" is a type of diet that exists when preferred foods are scarce (Lambert and Rothman, 2015). Some primate species consume abundant leaves, for example, brown howler monkeys (*Alouatta guariba clamitans*) switch to leaf diet during the period of fruit scarcity (Chaves and Bicca-Marques, 2016). Several bamboo lemurs (*Hapalemur* spp.) are bamboo specialists: however, they can survive in habitats without bamboo, by consuming more species-rich diets in these habitats, including a high percentage of graminoids in the cases of *Hapalemur alaotrensis* (Mutschler, 1999) and *Hapalemur meridionalis* (Eppley *et al*., 2015). But in some cases, fragments are too small or primates lack the ecological plasticity to survive on the food present at fragmented forests, resulting in widespread local extirpation of populations from their former habitats (*Trachypithecus pileatus*, *Macaca assamensis* and *Hoolock hoolock*: Sharma *et al*., 2014). Giant and red pandas are arguably the best known obligate specialist folivores, exploiting diets consisting almost entirely of bamboo. Neither species exhibits an ability to cope with intensive habitat degradation (Schaller, 1995; Nie *et al*., 2015). Among primates, some bamboo lemurs appear to be the most inclined towards extreme specialization. In particular, the greater bamboo lemur (*Prolemur simus*) consumes a diet of 95% bamboo (Tan, 1999a) and does not exist outside of bamboo forest habitats (Wright *et al*., 2008; Olson *et a*l., 2013).

Primates that increase their reliance on “fallback food” increase foraging time at the expense of other activities (travel further to find preferred high quality foods) for energy maximization. On the other hand, having to rest more to save energy while eating lower quality food for energy minimizing (Schoenner, 1971; Hixon, 1982). Activity patterns reveal that the abilities of animals to optimize their nutritional and metabolic requirements against their energy expenditure. Primates selectively feed on high-quality food by traveling long distance (Iwamoto and Dunbar, 1983; Hunter, 2001) or traveling less when energy is limited (Bronikowski and Altmann, 1996). Activity patterns provide valuable insights into how primates organize their lives, elucidating the relative importance of each activity (Clutton-Brock, 1977). Identifying how animals divide their activities throughout the day and the year offers insight into their interaction with the environment and strategies for maximizing energetic and reproductive success (Defler, 1995).

In fragmented habitats when the food is scarce, some primates increase and others decrease their range (Donati *et al*., 2011). Home range size and day path length of macaques decrease during low food availability (Alert *et al*., 2013), while baboons decrease during high food availability (Barton *et al*., 1992). Wallace (2006) found that spider monkeys (*Ateles chamek*) reduce their travel distances when resources become scarce. Lemurs living in degraded habitats reduce their daily path length, probably for energy minimizing strategy (Campera *et al*., 2014).

Understanding the dietary responses of individual species to habitat loss and fragmentation is therefore crucial to design and implement appropriate species-based management strategies (Fan *et al*., 2011), especially for dietary specialists which are expected to be less flexible at coping with degradation of habitats than generalist species (Harcourt *et al*., 2002; Benchimol and Peres, 2013). Only a single research has been conducted to assess the effects of habitat degradation and life in fragments on the feeding strategies of the Bale monkey (*Chlorocebus djamdjamensis*). However, this does not cover my study sites of Sidama highlands (Garamba and Worbadule sites) (Addisu Mekonnen *et al*., 2018). Bale monkey is thought to be at high risk of extirpation because of its specialized niche, small geographic distribution, and the ongoing deforestation occurring across much of its range (Addisu Mekonnen *et al*., 2010a).

The recent discovery of Bale monkey populations in a few dozen heavily-degraded forest fragments, some with little bamboo left and some totally eradicated in Sidama human-dominated highlands (Addisu Mekonnen *et al*., 2012), suggests that the species might be of greater ecological flexibility than previously believed (Addisu Mekonnen *et al*., 2012). This unexpected discovery created the need to evaluate the strategies the monkeys employ in response to habitat loss and degradation in fragments by comparing groups inhabiting fragmented non-bamboo, with bamboo fragmented habitats as well as with those of already published materials in a continuous forest (Addisu Mekonnen *et al*., 2010a, b).

2.4. Conservation threats of Bale monkeys

Human-wildlife conflict is a global problem and is occurring in many countries where human and wildlife requirements overlap. It is one of the most widespread and intractable issues facing conservation today (Dickman, 2010). Habitat loss is one of the main threats for wildlife anywhere in the world. Due to destruction of their natural habitat as a result of rapid population growth and related human activities, a rapid decrease of wildlife in size, species and distribution is observed (Dunbar, 1977; Beehner *et al*., 2007). All the Bale monkeys discovered at forest fragments of southern Ethiopia were found at a matrix of human settlements and cultivation and were undergoing extensive habitat modification. The long-term prospects of the small Bale monkey populations in fragments both with and without bamboo remain severe (Chapman *et al*., 2006; IUCN, 2010).

Habitat loss is the greatest threats that face Bale monkeys in southern Ethiopia (Addisu Mekonnen *et al*., 2012). The dense bamboo forests and mountainous terrain in Ethiopia have for millennia provided home for Bale monkeys. However, the bamboo forests are shrinking due to agricultural land expansion and logging associated with the ever increasing human populations. In addition, bamboo is a versatile material that can be used to produce things like furniture, fences, floors and even cabins. The habitat destruction of bamboo forest for local consumption and commercial purpose is a big threat for the Bale monkeys. According to Twinomugisha and Chapman (2006), the harvesting of bamboo in the same area year after year affects the growth of bamboo resulting in poor yield and low coverage. Habitat alteration and climate change are the major threats of biodiversity conservation, particularly for those specialists, rare species inhabiting small geographical ranges. These species are assumed to be less flexible at adapting to a changing environment than generalist species. Similar to other bamboo specialist mammals, such as giant pandas and bamboo lemurs, Bale monkeys are currently at high risk of extinction because of habitat alteration (Addisu Mekonnen *et al*., 2018).

The second threat placing the newly discovered Bale monkey populations in Oromia and Southern Nation, Nationalities and Peoples Regions (SNNPR), is hunting by local people in response to crop raiding. Bale monkeys were reported to be crop raiders at all sites of newly discovered areas (Addisu Mekonnen *et al*., 2012). Some of the Bale monkeys discovered at new fragmented areas are observed feeding on barley planted near the age of the fragmented forest and others entered agricultural areas to feed on other cereals, vegetables and fruits (Addisu Mekonnen *et al*., 2012). Like other crop raiding primates (Hill, 1997; Lee and Priston, 2005; Warren, 2008), having lost their primary food items (bamboo) by habitat loss and fragmentation, Bale monkeys have extended their diet to accommodate agricultural products found around fragmented forests. This results in conflict with nearby human populations (Cowlishaw and Dunbar, 2000). This human-

Bale monkey conflict forced humans to hunt and kill Bale monkeys permanently by considering them as crop pests.

The third threat to Bale monkeys is hybridization with other more widespread and adaptable *Chlorocebus* species (Kingdon, 1997; Addisu Mekonnen *et al*., 2012). The expansion of human settlement and agriculture drives naturally isolated closely related species to be mixed in fragmented patches. This may lead to extensive competition between species which is thought to be important factor determining the reproductive capacity of species within a community (Cornell and Lawton, 1992). Rates of hybridization and introgression are increasing dramatically worldwide due to habitat modifications by humans (Allendorf *et al*., 2001). Hybridization due to increasing anthropogenic disturbance that urge divergent species that naturally occur in sympatry to be mixed can have a disastrous effect (Roca *et al*., 2005). Such unnatural hybridization may direct the evolutionary adaptive process in the specialization process leading to genetic extinction (fertile hybrids displace one or both parental population: Rhymer, 2006), hybrid swarm (populations or species in which all individuals are hybrids to various degrees: Ward *et al*., 2012) and outbreeding depression (Edmands *et al*., 2005). As Kingdom (1997) suggested, hybridization with grivet monkey and vervet monkey is a real threat facing the Bale monkeys.

3. MATHERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

The study was conducted in Sidama highlands, which is located in Southern Nation’s, Nationalities and People’s Regional Stat, Sidama zone particularly at Arbegona Woreda. Arbegona district is located between 6^{0}35'0" - 6^{0}45'0" N and 38^{0}40'0" - 38^{0}50'0" E (Fig. 1). It is located 261 km south from Addis Ababa and 77 km southeast from Hawassa town. The altitudinal variation of the Woreda is between 2200 to 3775 m asl.

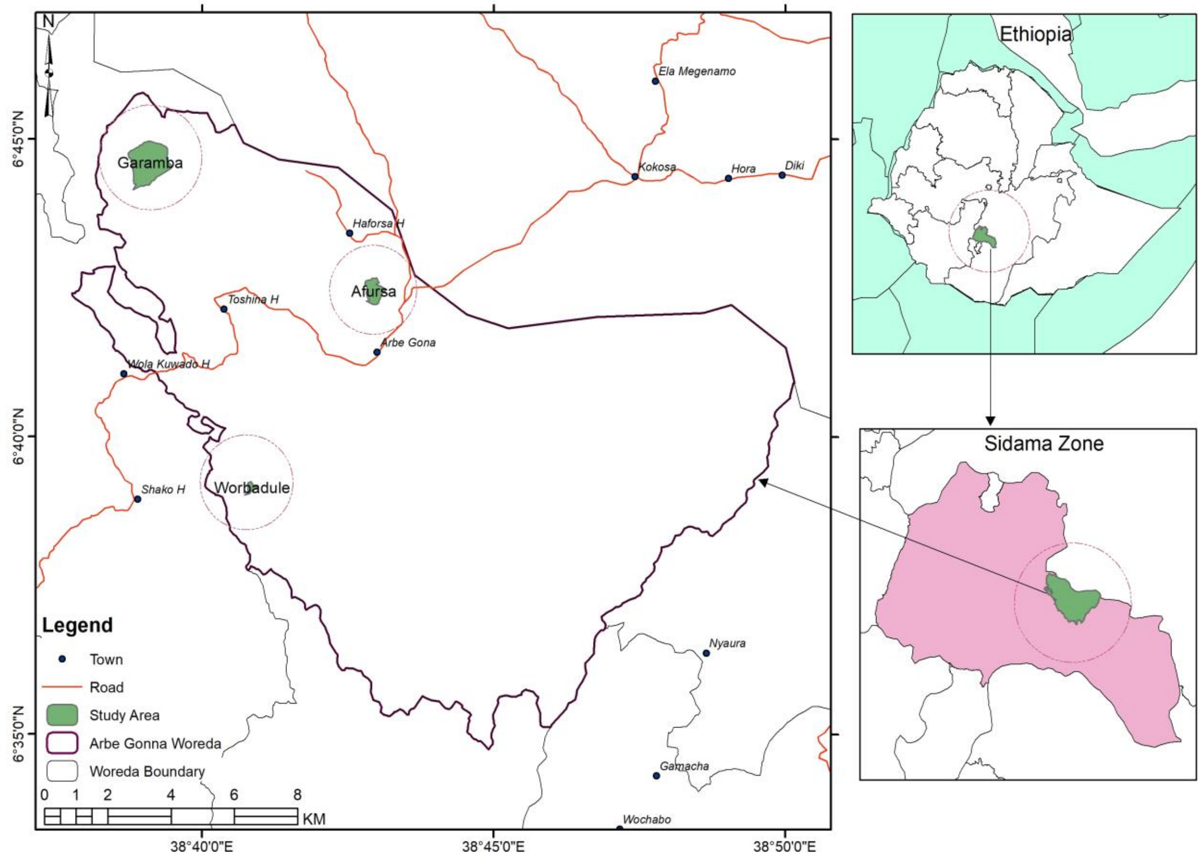

Figure 1. Map of the study area

Behavioral study was conducted in two neighboring administration districts found adjacent to Arbegona town. Intensive agricultural activities are conducted in the area due to high human population growth. The population density of 506/ km^2 makes it one of the highly dense parts of country with the average for Ethiopia being 83 persons (CSA, 2011). Additional new site was reported to study the population size for the first time for the presence of Bale monkey inside the fragmented forest.

Generally, the present study was conducted at Garamba bamboo dominated forest, Afursa fragmented and Worbadule fragmented forest without bamboo. Garamba Forest, relative to the two study sites, contains large forest within which bamboo is relatively abundant. It covers 148 ha at elevation ranging from 2994 to 3775 m asl. Garamba Forest consists of four habitat types: mostly bamboo forest and mixed bamboo forest, tree dominated forest and shrubland as well as it also has small grazing land at the boarder of the forest (Table 1). Cutting of trees and bamboo as well as grazing inside the forest is legally forbidden even if it is a common practice inside the forest. Afursa fragmented forest is located near the Arbegona town and it is very small and very fragmented and the bamboo forest is lost. It only contains a mix of secondary forest, shrubland, *Eucalyptus* plantation with graminoids and forbs inside it (Table 1). It covers an area of 34 hectares at elevation ranging 2357 to 2799 m asl and surrounded by cultivated lands, grazing lands and human settlements. There is no gap between the forest and human settlement and cutting of tree and use of the forest for grazing is forbidden by local government but it is still common phenomena illegally, particularly grazing inside *Eucalyptus* plantation of the forest part.

The two study areas (Afursa and Garamba) are 14 km away from each other (Plate 1). Worbadule natural Shrubland is one of fragmented forests without bamboo in Sidama-human dominated highlands and it is found in Arbenona woreda. It is almost similar to Afursa fragmented forest in all vegetation cover, elevation and human disturbance on the forest. It is the smallest among the three study areas, covers only 28 hectares, and surrounded by cultivated land and human settlement. It is 12 km away from Afursa Forest and 26 km from Garamba Forest.

Table 1. Description of major habitat types of both study areas

Habitat types	**Descriptions**
Bamboo forest	Habitat type composed of mostly indigenous bamboo, *A. alpina*, interspersed with relatively trees and shrubs
Mixed bamboo forest	Habitat type composed of both bamboo and trees in common
Tree dominated forest	Habitat type composed mainly of indigenous trees
Eucalyptus plantation	Habitat type dominated by *Eucalyptus* tree with graminoids and forbs inside it
Shrubland	Habitat type dominated by woody shrubs and herbaceous plants
Grazing land	Occurs at lower parts of the forest is covered by graminoids and forbs during wet season and it surrounds the forest and it is open for grazing

Plate 1. Garamba (left) and Afursa (right) Forest study sites.

Garamba Forest was stratified into three habitat types: modified habitat type along the lower parts of the forest, Alpine bamboo forest in the middle part and sub-Afro-alpine habitat at the top altitude. In Garamba fragmented forest part (modified habitat), this part of the forest is a disturbed habitat with livestock grazing and human disturbance. The alpine bamboo part of the forest covers valley and middle altitude area and dominated by highland bamboo (*Arundinaria alpina*). This habitat was intact and undisturbed compared to other parts of the forest. The sub-alpine covers the top land area of the forest with rugged topography and few remnants of *Erica arborea* at the tip of the mountain and mixed with predominant scattered stand of tree like *Hypericum revolutum*, *Juniperus procera*, *Dombeya torrid* and *Arundinaria alpina* in Garamba Mountain forest. However, Afursa Forest fragment consists of a mix of secondary forest, shrubland and *Eucalyptus* plantation with graminoids and forbs underneath. Bamboo has been eradicated totally and its elevations range from 2357 to 2799 m asl surrounded by an anthropogenic matrix of cultivated lands, pastures and human settlements. The district government forbids cutting of and fragment for grazing. The edge of the fragment, especially the *Eucalyptus* plantation is still used for grazing illegally. This fragmented forest was once dominated by bamboo forest (Addisu Mekonnen *et al*., 2012).

3.1.2. Climate

The climate data was collected from Kokosa Station, at 2534 m asl, which is 9 km from Afursa Forest and 23 km east of Garamba Forest, obtained from National Meteorological Agency (NMA, 2018).

Based on 33 years climate data, 32 (1986-2017) years of climate data obtained from National Meteorological Agency and one year (November 2017 to October 2018) rainfall and temperature data was recorded from the study site, the mean annual rainfall of the study area is 764 mm (NMA, 2019). The distribution of rain fall in the area is characterized by wet season from April to September. The big rain is from July to September. The mean annual temperature of the study area is 17.1 ^{0}C ranging from the mean annual minimum temperature of 10.0 ^{0}C to the mean annual maximum temperature of 25.8 ^{o}C (Fig. 2). The study area falls into two agro-ecological zones, namely Woyina Dega and Dega.

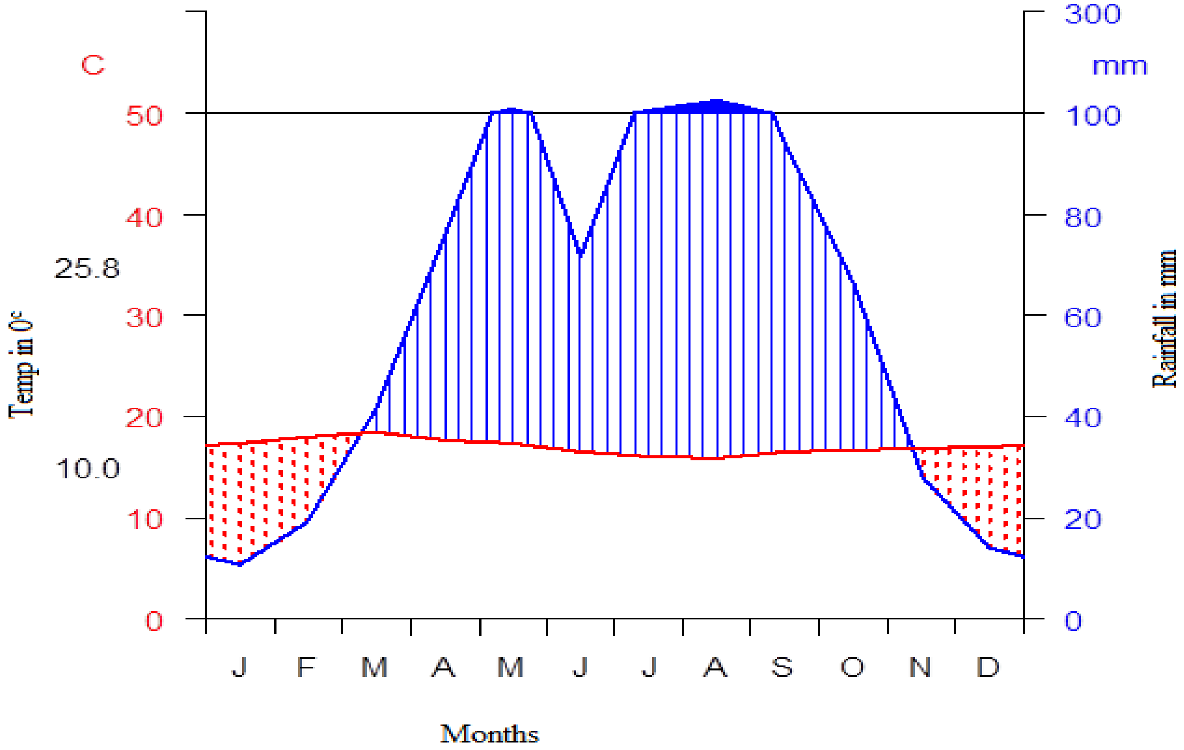

Figure 2. Climate of human-dominated Sidama highland forests (1986-2018) (Source: NMA,
2018).

Soil

The study area comprised mostly chromic Luvisols followed by Humic Nitosols, which is highly eroded and not suitable for cultivation. Soil acidity was stated as a constraint in the study area affecting the productivity of crops. As reported by Ashenafi Mekonnen *et al.* (2017), there was limited practice of liming the acidic soil due to shortage of lime in the area. Due to this low productivity of crops in the area, farmers started shifting from crop production to livestock production.

Fauna and Flora

Sidama highlands are part of the eastern Afromontane Biodiversity Hotspot, and is thus of significant global importance (Burgess *et al*., 2004). It is however neglected for centuries, and many wildlife species including the endangered mountain Nyala in the region have been exterminated (Malcolm and Evangelista, 2002). The area contains numerous fauna and flora although they are under immense human pressure. The Sidama zone has a total area of 10,000 km^2 of which 97.71% is land 2.29% is covered by water. Of the lands, 48.7% is cultivated, 2.29% is forested, 5.04% is shrub and bushland, 17.47% is grazing land, 18.085 is uncultivated, 6.38% is unproductive and 2.1% has other uses. Some of the cultivated lands are undulating escarpment and unsuitable to farming activity. The floras in the study area are *Gainer saxifrage, Hagenia abyssinica, Eucalyptus globules*, *Juniperus procera, Dombeya torrid, Maesa lanceolata, Oleo africana*, *Erica arborea, Ilex mitis, Arundinaria alpina,* shrubs *Rubus aspetalu, Vernonia rueppelli, Bothriocline schimperi, Rhusg lutinesa*, graminoids including *Bothriochloa radicans, Cynodon dactylon, Poa annua* lianas *Oxysstelma bornouense, Cypostemma adenocaule* and forbs *Haplosciadium abyssinica*, *Drymaria cordata* and *Centellia asiatica* (Appendix I).

The study area also harbors large mammals that include: Menelik’s bushbuck (*Tragelaphus s*criptus *Meniliki*), black and white colobus monkey (*Colobus guereza*), common Duiker (*Syvicapra grimmia*), White tailed mongoose (*Ichnumia albicauda*), leopard (*Panthera pardus*), spotted hyena (*Crocuta crocuta*), rock hyrax (*Procavia* *capensis*), and Bale monkey (*Chlorocebus djamdjamensis*). A variety of bird species also occur (Appendix II).

Economic activity

The study area is located in a region which is one of the highly dense populated parts of country and the forests and settlement place is connected without gap between them (CSA, 2011). To large extent, most human settlements are concentrated along the periphery of both study areas and the study areas are surrounded by agricultural land up to its boundary (Plate 2). Cutting of trees and grazing is forbidden by the local government but the local people are still use the forest for grazing and use selective cutting of bamboo for different purposes. Due to agricultural land expansion, logging of bamboo associated with the ever increasing human population, bamboo forests are shrinking and are totally eradicated at one site of the study area, which was densely dominated by bamboo forest before two decays (Addisu Mekonnen *et al*., 2012).

The economic activity in the district is predominantly agriculture. Most of people depend on agricultural products (animals herding, bee keeping, cash crops and food /non-cash crop products). The major food is Enset and the annual crops in the area are maize, barely, wheat and teff. The major cash crop growing in the area is coffee. Livestock rearing is also another major activity in the district. Most areas of the district are highly degraded due to deforestation through expansion of marginal land to farmland and unwise land using practices. This leads to depletion of natural resources, low land productivity and loss of wild animals. The major problems of the highlands are:

deforestation, land degradation, soil erosion, loss of biodiversity, spring dryness, loss of crop productivity, loss of soil fertility and food insecurity.

3.2. METHODS

3.2.1. Preliminary survey

During the reconnaissance survey, habitat types were identified based on the dominant vegetation cover. Two Bale monkey groups were selected; Group A from Afursa fragmented bambooless, tree dominated forest and another Group G from Garamba Forest which contains bamboo forest, mixed-bamboo forest, shrubland and tree dominated forest. The study groups were identified by some individual members that have unique natural markings, coat color, other identifiable features and group size. The groups were also differed in group size, Group-A varied from 25-27 and Group-G varied from 34 to 38 during the study period.

The study groups were habituated to human observers for 2 months by following the groups throughout the day by the researcher and two trained field assistants. Both groups of Bale monkeys were shy at the beginning. They used to avoid observers and hide themselves inside the dense shrubs and upper canopy of the tallest trees of *Hagenia abyssinica, Ilex mitis, Galiniera saxifraga* and *Arundinaria alpina*. Due to this, it was not possible to see Bale monkeys at a distance of more than 50 m away from the observer. After being habituated, they were approached from 5 to 10 m animal observer distance which helped the observer to see the performance of their natural behavior ignoring human presence in their surrounding area. They were observed to forage from 5-10 m distance on the ground and on the tree. During data collection and habituation periods, the observers wore the same matching uniforms of green clothing, so that the bands could distinguish between researchers and local communities more easily. The researcher and assistants always followed and collected data on Group A in one study area at a time followed by Group G in another study area or vice versa. This study included behavioral follows for two different groups of Bale monkeys in two different habitat types. During group follows, we collected behavioral data on the troop throughout the day and conducted equal number of observation days with each troop. In order to minimize the amount of time spent finding the focal groups during the research period; the researcher stayed with each group for five days (a total of approximately sixty hours) before moving on to the another group from other place. To minimize seasonality effects, we distributed observation time for each group approximately equally over each month.

The reconnaissance study was conducted to categorize habitat types and identify the focal groups before the main research data collection. The study groups were habituated for two months (September and October, 2016) on daily basis before starting data collection. Data on behavior ecology and population size of Bale monkeys were collected during both the wet and the dry seasons.

3.2.2. Vegetation Composition and Food Availability

Vegetation surveys were conducted within each group’s home range from randomly selected vegetation transects. These surveys were conducted at the end of each month behavioral study, when the boundaries of each group's home range were known. To examine whether the diet of Bale monkeys was influenced by resource availability, food availability was investigated using measures of phenological assessment and vegetation cover. Temporal change in availability of potential food resources of Bale monkeys were assessed on plant phenology in the home range of the study groups (A and G). Monthly phenological records on the selected food tree, shrub and bamboo were carried out.

A total of 500 m long and 10 m wide vegetation transects were laid out within the study group's (A and G) home ranges and adequately sampled the diversity of big tree ≥ 10 cm DBH (Teelen, 2007; Wong and Sicotte, 2007). All big tree with DBH ≥ 10 cm and all plants with ≥ 2 m were recorded, identified and measured along with species identity, number DBH (in cm) using tape measure, height (m) (Plate 3). Visual inspection was made to estimate plant height after some tree measurements were taken for some trees as standing estimators. To sample all plant species ≥ 10 cm DBH, a total of 5, 50 × 10 m vegetation enumeration quadrats were sampled from the vegetation transects in the home range of each of the study groups. Plant species were identified and recorded in situ if known while unidentified species were collected, named by local names, pressed and taken to Addis Ababa University National Herbarium for further taxonomic identification.

The mean monthly phenological scores of young leaves, mature leaves, fruits and flowers were calculated for each individual plant species. The proportion of monitored trees bearing each of the phenophase every month was calculated (Yeager, 1989; Yiming, 2006). The temporal variations of monthly and seasonal changes in availability of potential food resources were calculated. The vegetation quadrats and transects were used to quantify the overall vegetation composition of the study area and differences in forest composition between the two study groups home range habitat types. The density of each plant species of ≥ 10 cm DBH was calculated by dividing the total number of individuals of certain species recorded per unit area. Accordingly, density was computed by converting the count for the total quadrats in the home range of each group on hectare basis. In the study areas, the plant species diversity of big trees ≥ 10 cm DBH was calculated using the Shannon-Wiener index of diversity, H', Simpson's Dominance index, D, and evenness index, J (Krebs, 1999) to determine whether the dietary species are evenly distributed or not in the home ranges of the study groups. Shannon's index accounts for both abundance and evenness of species present. Species diversity is quantified by the formula:

$$H = - s\sum^{S}{}_{i=1} (Pi * \ln Pi)$$

Where S is the number of species, and pi is the proportion of the total number of individuals represented by i^{th} species to total abundance value; pi = ni/Ni. Plant species evenness index is computed by the formula: $J = H^1 / H^{max}$, where $H^{max} = \ln S$, H^1 is Shannon-Wiener's diversity index, H^{max} is the maximum value of H^1 and S is species richness. Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. It is an index of dominance and hence inversely related to evenness and richness. Simpson's dominance index was calculated by the formula: $D = \sum ni\ (ni-1)/N\ (N-1)$, Where, ni = the total number of individual trees of each plant species and N = the total number of individual trees of all plant species. Using transects quadrat data, basic habitat variables were calculated for each group's home range. Plant species richness and similarity were also assessed between the home range of the two groups. The dietary similarity was compared in the respective habitats (Krebs, 1999). Similarity of species in the dietary composition of the two groups was compared across the two habitats.

Sørensen's Index is one of a most commonly used to quantify tree species similarity between pairs of home ranges or more communities (Krebs, 1999). Thus, the dietary similarity of the two Bale monkey groups was compared in their respective habitats by using the Sørensen's Index of Similarity (Ss). These indices are calculated using the following formulas:

$$S_s = 2a/\ (2a + b + c)$$ (Krebs, 1999).

Where a is number of species occurring at both sites, b is the number of species occurring only at site 1, and c is the number of species occurring only at sit 2 (Kent and Coker, 1992). Coefficient ranged from 0 to 1 with zero representing no species shared (no similarity) and one representing all species shared (complete similarity).

The basal area (BA) of each tree species was calculated to estimate the biomass of each tree within the home range of Bale monkey (Fashing, 2001; Felton *et al*., 2008; Chaves *et al*., 2012). Basal area (BA) calculations were made on the diameter measurements of the stem with DBH of ≥ 10 cm using the formula: $BA = ([0.5 \times DBH]^2 \pi)$ (Fashing, 2001). There is direct relationship between DBH and BA, as $BA = \pi (d/2)^2$, where d= DBH. BA is expressed in cm^2/ha (Hutchings, 1986). BA per hectare was used to estimate the biomass of each tree species in the home range of each study species (Kool, 1989) and to determine dominant tree species in the home range.

A phenological assessment was carried out in the home range of the two species (A and G) over an annual cycle for selected food plant species. Tree species selected for phenological assessments were determined after approximately two months of habituation of each group. After habituation of the study groups, 10 individuals of the food plant species including tree (DBH ≥ 10 cm), shrubs and bamboo (DBH ≥ 5 cm) were marked and identified. Phenological data of marked trees in the home range of the study groups were collected monthly for 1 or 2 days after behavioral data was collected. Each marked tree, shrubs and bamboo were assessed for relative abundance of young leaves, mature leaves, flowers and fruits using visual inspection or binoculars (Fashing, 2001; Xiang *et al*., 2007, Suarez, 2013). Each plant part was assigned to a relative abundance value (score) ranging from 1 to 4 at interval of 1 (Amera Moges, 2019). An abundance score 0 indicates that a tree or shrub exhibited 0% (item absent from plant), 1-

25% = 1, 26-50% = 2, 51-75% = 3 of its potential abundance of that phytophase during the assessment and 4 indicates 76-100% (plant fully laden with the item).

Phenological data were collected from 8 species: five tree species consumed by the study species including *Galiniera saxifraga*, *Hagenia abyssinica*, *Ilex mitis*, *Dombeya torrida*, *Maesa lanceolata* and two shrubs *Rubus apetalus* and *Bothriocline schimperi* as well as *Arundinaria alpina* After visual inspection, individual plant was estimated for a relative abundance score for each of its potential food items (young/mature leaves, flowers/fruits) (Riley, 2007; Addisu Mekonnen *et al*., 2017). Food availability was analyzed from the average availability scores of food item categories of each marked tree, shrub and bamboo species.

The monthly phenology of score of young leaves, mature leaves, flowers and fruits were averaged for each plant species as well as for all plant species in each study group. Monthly food availability index (FAI) for each plant part was calculated by multiplying the mean phenology scores of species i with the mean basal area of species i or density of the corresponding species i per ha (Fashing, 2001). Density is defined as the number of plants of a certain species per unit area. Thus, both phonological and vegetation survey data were used to calculate monthly indices of availability for young leaves, mature leaves, flowers and fruits. A monthly Food Availability Index (FAI) was obtained for each plant species using the following formula:

$$\text{FAIi} = \text{BAi} \times \text{PIS pi}$$

Where FAIi is the food availability index of species i, BAi is the basal area (cm^2/ha) of species i obtained by the vegetation survey data, and PISi is the monthly phonological index of the species i (Zunino *et al*., 2001). The monthly total FAI for each phenophase was calculated by adding FAIi indices across plant food species, as follows:

$$\text{Total FAI} = \sum^{s}{}_{i=1} \text{FAIi}$$

Where Total FAI is the monthly total food availability index of each phenophase, $\sum^{s}{}_{i=1}$ is the sum of all species starting from the first to the end, FAIi is food availability index of species i.

3.2.3. Population Estimate

Population estimate of Bale monkeys was conducted in three study sites (Garamba, Afursa and Worbadule Forests). Population census of Bale monkey was conducted using total count method, which effectively helps to manage species inhibiting small areas and open terrestrial habitats (Beehner *et al*., 2007; Kumara *et al*., 2014). Block method was used to determine distribution pattern and population size of Bale monkeys. Two field assistants and the researcher were moving parallel to each other forward in continuous blocks to avoid double counting. Population censuses were conducted in three sites of Sidama zone.

Based on habitat use of Bale monkeys in the range of shrubland, bamboo forest, mixed bamboo forest, tree dominated forest, *Eucalyptus* plantation and grasslands (Addisu

Mekonnen *et al*., 2017). The Bale monkey potential sites were divided into a total of 16 blocks (Garamba= 8, Afursa= 4 and Worbadule= 4 blocks) to estimate the distribution patterns and population size of Bale monkeys by using geographical appearance, roads and natural remarks at the forest. Two replicate walks were made across each block following permanent routes at diagonal to each block. The survey was conducted by the researcher with the help of a trained field assistants as well as forest guards who are familiar with the areas. A uniform sampling effort of 1-2 km/h was spent along a diagonal of each block.

Each block was censused 6 - 8 times in total, during both the dry (December, 2017 – January, 2018) and wet (August – September, 2018) seasons. Censuses were conducted on blocks from 06:30 to 10:45 in the morning and from 14:00 to 18:00 in the afternoon (Press, 1999; Addisu Mekonnen *et al*., 2010b; Chagas and Ferrari, 2011) when the monkeys were typically active. Data collection was interrupted whenever atmospheric conditions (wind, rain) reduced visibility significantly. Blocks walked at an average speed of 1 km/hr pausing at regular intervals to scan the forest and listen for calls and movements in the forest and canopy in an attempt to locate Bale monkeys and other mammals (Wallace *et al*., 1998; Peres, 1999; Ciani *et al*., 2001).

During the block walk, once Bale monkeys were encountered, a standard set of data was collected, including group size or estimated number of individuals, which is the number of individuals counted during a maximum of 10-15 min observation in each group (Rovero *et al*., 2006; Lwanga *et al*., 2011), GPS location, group spread, age-sex categories, estimated animal observer distance, the height of animal on the tree when first detected, and habitat type where the group is spotted (Rovero *et al*., 2006; Marshall *et al*., 2008; Mammides *et al*., 2009; Lwanga *et al*., 2011; Rovero *et al*., 2012).

Group compositions of Bale monkeys were assessed from each study site where the survey was conducted. Abundance was calculated in mean group encounter rate for each study sites from the encounters during the two replicate censuses. The mean value of Bale monkeys was determined from each study site to calculate group encounter per km^2. Density was calculated by dividing the group size of Bale monkeys per study site area where counting was conducted. The total population size of Bale monkeys was divided by the total area covered during the census.

3.2.4. Activity pattern and Time budgets

After habituation, activity data were collected from randomly selected two study groups for 5 days in every month, covering both wet and dry seasons on a bimonthly basis for each band living on different study sites. During each scan, the activity data were recorded for the first 3-5 visible individuals, excluding very small infants as they are dependant for everything on their mother, for up to 5 minute duration every 15 min sampling gap by using instantaneous scan sampling method (Altmann, 1974) from dawn to dusk. During each sampling, care was taken to avoid sampling the same individuals more than once in a given group scan, but the same individuals could be sampled successive scans. Activity recorded for each individual was the first activity that was lasted for more than 3 seconds once it became into view. The activities were recorded by scanning the group from left to right or vice versa depending of the position of the observer to avoid possible bias towards eye-catching activities such as grooming, fighting, moving and mating (Fashing, 2001; Addisu Mekonnen *et al*., 2010a, Dereje Yazezew, 2018).

During each scan sampling, individual activities were recorded as the following behavioral categories: feeding (when the Bale monkeys were picking, grazing, handling, foraging, chewing or actively searching for or processing food items towards the mouth, masticated and swallowed); resting (when the Bale monkeys were motionless, whether standing, lying, sleeping and sitting); moving (when the Bale monkeys change their spatial position or show any locomotor behavior, including running, walking, leaping, climbing or descending and when Bale monkey was not engaged in feeding, resting or any form of social activity); socializing (when Bale monkeys interacted between two or more individuals and performing activities including playing, copulation, aggression and allogroomig), and “others” (when Bale monkey was observed performing activities such as vocalization, defection, drinking, looking towards the observer and other activities that do not fit in any of the above categories (Fashing, 2001; Zhou *et al*., 2007; Addisu Mekonnen *et al*., 2010a; Eustace *et al*., 2015; Addisu Mekonnen *et al*., 2017). At each scan habitat type and age-sex class of individuals were recorded. The scanned individual was recorded and assigned to one of the following classes: Adult male, adult female, sub-adult male, sub-adult female and juvenile but not infants (Fashing, 2001; Harris and Chapman, 2007).

To calculate the proportion of time in each activity, the number of records of each activity category was divided by the total number of activity records, multiplied by 100 (Vasey, 2005). Hourly time budgets were calculated by averaging scan budgets in an hour to avoid biases. The average percentage of time allocated to each main activity was calculated in hourly classes from dawn to dusk to express the diurnal activity patterns. Behavior of the study groups was used to calculate the activity budgets for every day and averaged every month to construct monthly activity budget of the study groups (Zhou *et al.*, 2007, Addisu Mekonnen *et al.*, 2010a; Fashing *et al.*, 2014, Dereje Yazezew *et al.*, 2018).

3.2.5. Feeding Ecology of Bale monkeys

Each day scan sampling started by arriving at the group's sleeping site that was located at the previous evening. At the time of each activity, dietary data were collected, when an individual Bale monkey was engaged in feeding. During scans, when a Bale monkey was observed feeding, we recorded the type of food item, growth form and species. Commonly known food plants were identified in the field using background knowledge of the researcher and using plant guide including lists of plants in the local district office plant identification key. The food items were recorded as bamboo young leaves, non-bamboo young leaves (from all species other than bamboo), bamboo shoots, bamboo branchlets (young and thin stems emerging from branches), flowers, fruits, stems, petioles and insects. Feeding was recorded when an individual Bale monkey manipulated food items such as plucked food items, passing food items towards the mouth, masticated and swallowed (De Oliveira *et al*., 2014; Eustace *et al*., 2015; Pinheiro *et al*, 2015).

Plant growth form as tree, bamboo, shrub, liana (including climbers and epiphytes), forbs and graminoids (grass or sedge) were recorded. Although most food species consumed were identified in the field, species that could not be identified were collected for taxonomic identification at the National Herbarium in Addis Ababa. We recorded a food item as insects when the monkey was observed manipulating tree bark, searching through dead leaves or directly consuming insects (Addisu Mekonnen *et al*., 2010a). Dietary composition was evaluated by determining the proportion of different dietary items and plant species consumed by Bale monkeys. Food items and species consumed by study groups were summed within each month to construct monthly proportion of food items and species consumed. The monthly proportion of each food item in scans was calculated as the total number of monthly individual scans for each food item divided by total number of individual scans for all food items and multiplied by 100 (Felton *et al*., 2008; Addisu Mekonnen *et al*., 2010a).

To determine the dietary preference or selection ratio of Bale monkeys on specific plant species, the percentage of a specific species in the diet was divided by the percentage of that species in the transect sample enumerated. Ratios above one indicates selectivity, ratios of approximately one indicates no selection (i.e. feeding as expected based on the species' relative abundance within the home range), and ratios below one indicates avoidance (Fashing *et al*., 2014; Addisu Mekonnen *et al*., 2018). When resources are used more than expected based on availability, there is a selection for that resource (Johnson, 1980). As part of habitat selection, an accessible habitat defined by the traditional home range concept which is 100% Minimum Convex Polygon (MCP) is used as available habitat. As part of spacing pattern however, MCP is criticized for over estimating the size of home range due to outlying fixes (Harris *et al*., 1990). Consequently, 95% MCP is used to overcome the limitation by eliminating the most distant locations. The most intensively used portions of a home range is estimated as core area, i.e. areas where individuals are found with greater probability within the home range by 95% Kernels Density Estimate (Dahl, 2005) or 50% fixed MCP method (Harris *et al*., 1990). Habitat preference was carried out on home range level. At home range level, habitat preference was estimated based on observations recorded during the scan sampling. Habitat preference was carried out based on the number of sightings of Bale monkey from each habitat types.

3.2.6. Ranging ecology

Ranging data on the two study groups were collected during the five full-days follow of each group every month from dawn to dusk during behavioral and ecological data collection period (Di Fiore, 2003; Addisu Mekonnen, *et al*., 2017). During instantaneous scan sampling, the GPS locations of the geographic center of the study groups were recorded at 15-minute intervals using a handheld Garmin GPS Map 72s. The GPS locations of the group recorded used to estimate the average daily traveled distance (DTD) and the home range utilized (Di Fiore, 2003).

A mean daily length for each month of both study sites was calculated by adding up the mean 15-minute distances traveled during the day. The GPS locations of the groups recorded were used to estimate daily travel distances and home range areas utilized by the group using ArcGIS. The day travel lengths and home range sizes of each group were calculated using ranges 7 (Anatrack Ltd.) and mapped by ArcGPS version 10.3 software. The home range sizes of the study groups were determined by using Minimum Complex Polygon (MCP) method with harmonic means centers as well as fixed Kernel Density Estimates (KDEs) (Fashing *et a*l., 2007). To estimate the home range, all day ranges were combined to generate 100%, 95%, 90% and 50% MCPs, and 95% and 50% KDE estimates (Seaman and Powell, 1996; Boyle *et al*., 2009).

The available microhabitat types of each study site were recorded every 15 minutes throughout the daily follows for each study group. Five microhabitat types were identified at Garamba Forest site (G) and classified as bamboo dominated forest (BDF), mixed bamboo dominated forest (MBDF), tree dominated forest (TDF) and shrubland (SL) and grazing land (GL). At Afursa Forest site, another four microhabitat types were identified within the home range of group A. These were classified as tree dominated forest (TDF), shrubland (SL), Eucalyptus plantation (EP) and grazing land (GL). Habitat use was expressed as the percentage of monthly location records occurring in each habitat and the annual habitat use was obtained by averaging the monthly percentages

(Zhou *et al.*, 2013). Habitat use of the study groups were analyzed from habitat types recorded during scan sampling by the proportion of use of areas with respect to availability of habitat types. Patterns of habitat use were quantified as the percentage of the total location records that fell into each habitat type for each group of Bale monkeys (Gómez-Posada *et al.*, 2007; Zhou *et al.*, 2013). Thus, the habitat use of Bale monkeys was calculated by the proportion of the number of scans where each group spends with the respective available habitat types in their home ranges (Riley, 2008). Data were compared across months and annually to identify temporal habitat use differences. Selection ratio is calculated as observed use in percent divided by expected use in percent. A habitat selection ratio close to 1 indicates no selection for that habitat, < 1 indicates a habitat is avoided and > 1 indicates a habitat is selected.

3.2.7. Data analysis

All statistical analysis was performed using SPSS version 24, and data were presented with P- values and confidence intervals set at 95%. Data were tested for normality using Shapiro- Wilk test and homogeneity of variances using the Levene test ($P > 0.05$). Independent T-test and One-Way ANOVA were used for parametric tests. Mann-Whitney U test and Kruskal-Wallis H test were used for non-parametric tests. The Monthly Food Availability was tested using non-parametric test, Mann-Whitney U test. Diet selection by each study group was determined from the relative proportions of the number of scans spent feeding on different food items and plant species in the diet. Dietary preference for different food species by the study groups was also calculated as the proportion of annual feeding time spent on certain species i divided by the density of that species i in the study group's home range (Fashing, 2001, Xiag *et al*., 2007, Addisu Mekonnen *et al*., 2010a). Dietary diversity and evenness were calculated using the Shannon-Wiener index, H' and the evenness *J* (Krebs, 1999), respectively.

Group size and age-sex composition of Bale monkey differences among study sites were compared using One-Way ANOVA test. Mean Group size of Bale monkey was compared during the two census periods using Mann-Whitney U test. Mann-Whitney U test was used to examine the age-sex composition between wet and dry season surveys and dietary items distribution in the two study areas. Kruskal-Wallis H test was used for differences in activity budgets of Bale monkeys and feeding activity, on food items and growth forms of different food species, between the two study areas. Mann-Whitney U test and Kruskal-Wallis H test were used to test differences in activity budget of Bale monkeys between seasons and across months, respectively. Kruskal-Wallis H test was used to test activities among age-sex categories and diurnal cyclic activities during the study period. The daily travel distance (DTD) was determined by measuring the straight line distance between consecutive GPS locations scored during group follows and averaged the values on monthly basis. The mean hourly movement rate (MVR) was estimated by dividing the mean monthly DTD by the mean monthly number of hours of observation per day (Fashing *et al*., 2007). Minimum Convex Polygon (MCP) and the best home range estimator technique (Fixed Kernel) methods were used to determine the home range size and daily travel distance by GIS software Arc GIS version 10.0 (Fashing *et al*., 2007; Addisu Mekonnen *et al*., 2010a). Mann-Whitney U test was used to test DTD and movement rate (MVR) between the two groups of Bale monkeys and Kruskal-Wallis H test was used to test monthly MVR across months.

4. RESULTS

The results of this thesis are generally grouped into seven sections. The first section deals with resource availability followed by phenology, population size, activity budget, feeding ecology, dietary preference and ranging ecology. Each of the results of those sections is presented separately as follows:

4.1. Habitat descreption and resource availability

A total of 49 plant species grouped in 30 families were found to exist in the home range of Bale monkeys of the two sites. Plant species richness in the range of Bale monkey groups inhabiting Afursa Forest was more diverse (40 species) than in Garamba Forest (21 species). Afursa Forest group (A) had 40 species grouped in 24 families, 8 trees, 7 shrubs, 4 lianas, 4 graminoids and 17 forbs species. Garamba Forest Group (G) had 21 species grouped in 19 families, 9 trees, 4 shrubs, 2 graminoids, 5 forbs and one bamboo species (Appendix I). Plant species with DBH ≥ 10 cm in the range of Garamba Forest group had higher stem density (768 stems/ha) than Afursa group's (624 stems/ha) (Table 2). *Hypericum revolutum, Dombeya torrida* and *Maesa lanceolata* were very common in the ranges of Garamba Forest but did not occur in the ranges of Afursa Forest group whereas *Eucalyptus globules* and *Discopondium penninervium* were common in group-A ranges but not in group-G range. Regarding basal area, *Galiniera saxifraga* and *Hagenia abyssinica* were the highest ranking in Group-G while *Eucalyptus globules* and *Ilex mitis* were the highest ranking in Group-A range (Table 2).

Table 2. Results of plants ≥ 10 cm DBH in the quadrats of transects within the home range of both Garamba and Afursa Forest groups.

Groups	Rank of abundance	Species	No. of trees	No. of trees per ha	% of total trees	Basal area/ha (cm^2/ha)
Afursa Forest (A)	1	*Eucalyptus globules*	61	244	39.1	14949.50
	2	*Juniperus procera*	24	96	15.4	4069.40
	3	*Ilex mitis*	18	72	11.5	10563.00
	4	*Discopondium penninervium*	17	68	10.9	1256.00
	5	*Hagenia abyssinica*	12	48	7.7	2461.80
	6	*Galiniera saxifraga*	10	40	6.4	9498.50
	7	*Ritchiea albersii*	8	32	5.1	1256.00
	8	*Canthium oligocarpum*	6	24	3.9	1017. 40
Total			156	624	100	

Garamba Forest (G)

	1	*Hypericum revolutum*	35	140	18.2	1256.00
	2	*Dombeya torrida*	32	128	16.7	2826.00
	3	*Hagenia abyssinica*	30	120	15.6	9156.24
	4	*Juniperus procera*	29	116	15.1	3419.46
	5	*Maesa lanceolata*	24	96	12.5	2461.76
	6	*Olea africana*	12	48	6.25	3215.36
	7	*Erica arborea*	12	48	6.25	1256.00
	8	*Acokanthera schimperi*	10	40	5.2	1519.76
	9	*Galiniera saxifraga*	8	32	4.2	13266.50
Total			192	768	100	

Plant species diversity and evenness were higher and dominance was lower in fragmented Afursa Forest than Garamba Forest (Table 3). Bamboo dominated more than 75 % from all stems ≥ 2 m tall in Garamba Forest, but accounted 0% of stem density (totally eradicated) in fragmented Afursa Forest. Large trees (≥ 10 cm DBH) were also more abundant in Garamba Forest (768 stems/ha) than in fragmented Afursa Forest (624 stems/ha). However, shrubs were far more abundant in Afursa fragmented Forest (4360 stems/ha) than in Garamba Forest (1288 stems/ha) (Table 3). The basal area of large food trees (≥ 10 cm DBH) was higher in Garamba Forest (6226 cm^2/ha) than in fragmented Afursa Forest (4850 cm^2/ha) (Table 3).

Shannon-Wiener diversity index (H') of large trees with DBH ≥ 10 cm was 1.8 in Afursa Forest while it was 2.1 in Garamba Forest habitat. However, Mann-Whitney U test showed that there was no significant difference in the diversity of big trees between the two study habitat types ($P>0.05$). There was no overlap between home ranges of the two groups. Sørensen (S_s coefficient) index analysis (12 of 61 species; Ss = 0.281) showed that there were no more similarity in the number of plants species shared between the home ranges of Bale monkey groups in the two study areas.

Table 3. Characteristics of Bale monkey study sites, groups, habitats and home range.

Characteristics	Afursa Forest (Group-A)	Garamba Forest (Group-G)
Forest size (ha)	34	148
Group size	25	34
Mean elevation (m asl) (range)	2697(2357 -2799)	3210 (2994-3775)
Total area surveyed for vegetation composition analysis	0.25 ha	0.25 ha
Habitat quality (variables)		
Total species richness ≥ 2m tall	19	14
Total plant species diversity index, Shannon-Wiener H'	2.14	1.10
All plant species evenness index, J	0.45	0.22
All plant species dominance index, D	0.1968	0.5773
Large tree stem density per ha ≥ 10 cm DBH	624	768
Large tree species richness ≥ 10 cm DBH	8	9
Simpson's species diversity index of large tree species [N(N-1)/ sum n (n-1)]	1. 8	2.1

Large tree species evenness, J ≥ 10 cm DBH	0.75	0.89
Large tree species dominance index, D ≥ 10 cm DBH (Simpson’s dominance index)	0.22	0.13
Shrub stem density per ha	4360	1288
Bamboo stem density per ha	0	6312
DBH of bamboo	-	4.12 ± 0.03
Liana density per ha	792	0
Total stem density per ha (N)	5776	8368
Characteristics of home range (large trees ≥ 10 cm DBH, mean ± SD		
Number of large trees measured	156	192
DBH of food trees (cm)	36.2±16.9	38.8± 16.2
Basal area (cm^2/ha) of large trees	5634 ± 5320.7	4664.1 ± 4149.3
Basal area of food trees (cm^2/ha)	4850.8 ± 4156.8	6226 ± 4789.6
DBH of large tree species surveyed	38 ± 20	33.8 ±15.6

4.2. Phenology

The monthly food availability index (FAI) analysis revealed that there was variation in plant parts based on monthly abundance (Table 4). Young and mature leaves were the most abundant part of the plant throughout the year while fruits and flowers were least abundant and they did not occur throughout the year. Fruits and flowers occurred in some months (Fig. 3).

Food availability of all plant parts like young leaves, mature leaves, fruits and flowers were more abundant in Garamba Forest than the fragmented Afursa Forest. Monthly food availability index of matured leaves was the most continuously abundant food item in both study groups and were available in large quantities throughout the year compared to young leaves. Fruits were relatively high from February to June in both groups. Mann-Whitney U test showed that monthly food availability index of young leaves ($P < 0.05$) and matured leaves ($P < 0.05$) was significantly higher in Garamba Forest than Afursa fragmented forest across months. Higher FAI was observed in Garamba Forest than in the Afursa Forest habitat. However, there were no significant differences in FAI of flowers ($P > 0.05$) and fruits ($P > 0.05$) between the two groups across months even though the differences among months vary. Flower were at peak during November and October in Garamba and December and November in Afursa group ranges while flowers were totally absent during July and August in both Afursa and Garamba group ranges. Fruits were also at peak during February and March while totally absent in August - October in both Garamba and Afursa group ranges (Fig. 3).

Table 4. Monthly food availability indices (FAI units/ha) for groups of Afursa and Garamba Forests

	Young leaves		Mature leaves		Fruits		Flowers	
Months	A	G	A	G	A	G	A	G
Nov-16	38509	60558	4263	6620	13230	13021	41453	70351
Dec-16	53639	81902	20783	44220	10092	15663	42991	59207
Jan-16	38120	64205	16316	35362	22349	28543	16835	26075
Feb-16	38073	57271	24427	46013	49723	73817	17597	28265
Mar-16	16046	24971	29196	38914	49723	73817	16575	28265
Apr-16	16196	24971	29083	38914	29799	41531	9576	25491
May-16	16218	23984	38302	69408	29909	41531	4616	8589
Jun-16	17802	29677	38310	69408	25295	49995	1539	1527
July-16	19311	29877	36771	67202	3079	1737	0	0
Aug-16	37978	57278	24806	41133	0	0	0	0
Sept-16	38509	64205	17420	35362	0	0	5722	7753
Oct-16	53575	81902	20666	44220	0	0	30722	69953

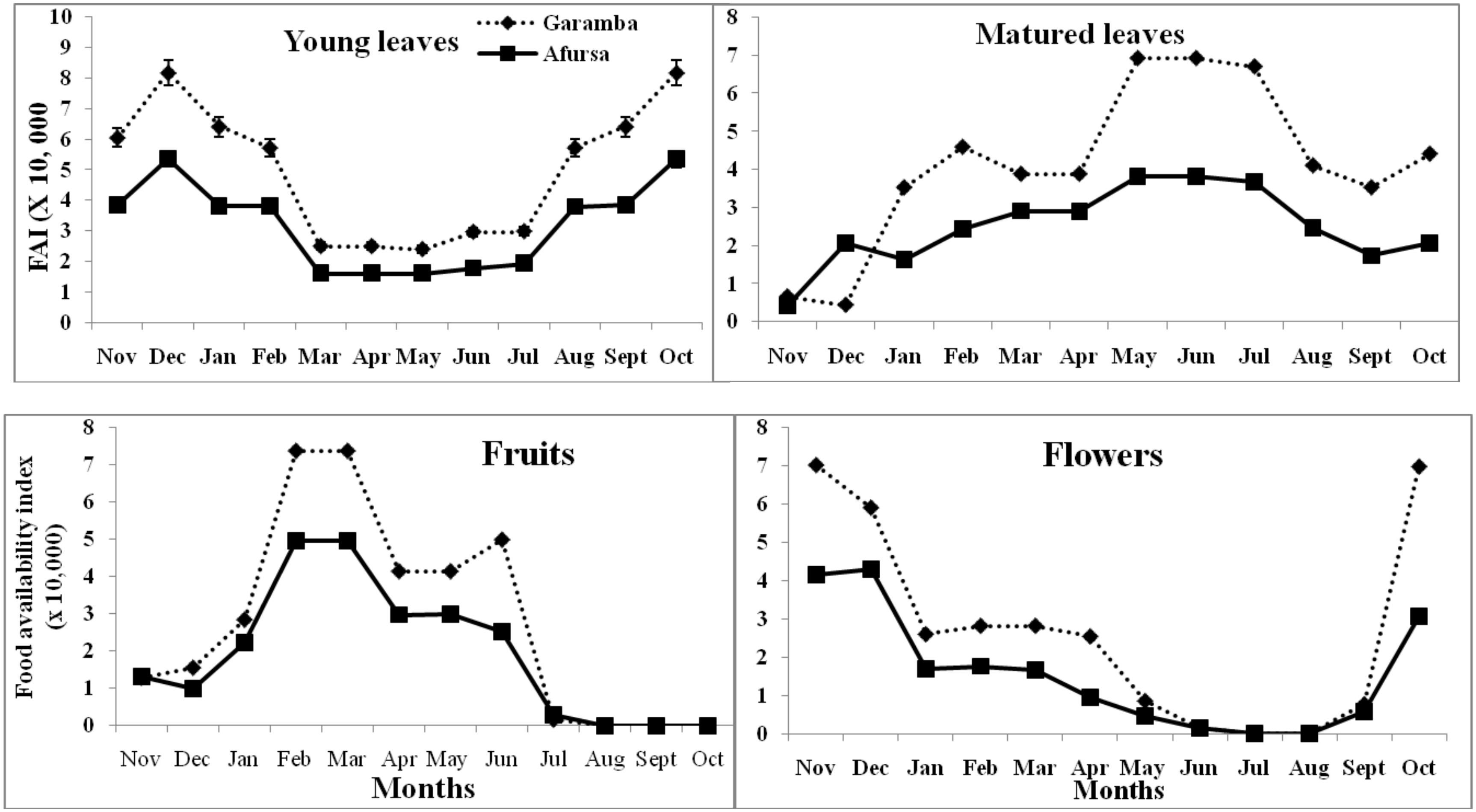

Figure 3. Differences in monthly FAI (units/ha) of major food Items between Bale monkey groups in Garamba and Afursa Forests.

4.3. Population size

On average, 8 groups with a mean of 225 ± 8.42 individual Bale monkeys were recorded from different sites in the three surveyed sites. Bale monkeys inhabited mainly bamboo forests, shrublands and tree dominated forests at elevation ranging 2357 – 3775 m asl. The highest mean population size 133 (59.11%) was recorded from Garamba Forest. The second highest mean number 51 (22.67%) was recorded from Afursa fragmented forest. The lowest mean population size 41 (18.22%) was recorded in Worbadule natural shrubland highland (Table 5).

Table 5. Population size of Bale monkeys during the two season censuses (wet and dry) in three study sites during the study period.

Season	Study sites			Total
	Garamba	Afursa	Worbadule	
Wet	141	53	44	238
Dry	125	49	38	212
Mean	133	51	41	225
Percent	59.11	22.67	18.22	100
SD	11.31	2.81	4.24	8.42

A total of 238 individuals of Bale monkeys were counted from all survey sites during the wet season census. The highest number 141 (59.24%) was recorded in Garamba Forest. Afursa comprised the second 53 (22.27%). The lowest number 44 (18.49%) was recorded in Worbadule Forest. Adult females comprised the highest number, 72 (30.25%) and sub-adult males accounted the lowest 23 (9.66%) during the wet season census. A total of 212 Bale monkeys were recorded from all sites during the dry season census. The highest number 125 (58.96%) was recorded in Garamba Forest and the lowest 38 (17.92%) in Worbadule Forest. Adult female comprised the highest number 77 (36.32%) followed by adult males 34 (16.04%). Sub-adult males were the least 17 (8.02) of the total population during the dry season census (Table 6). There was no significant difference in population size between wet and dry season ($U= 8.5$, $Z= -0.84$, $P> 0.05$).

Table 6. Count and age-sex composition of Bale monkeys in 3 sites during both wet and dry season censuses (AM= adult male, AF= adult female, SAM= sub-adult male, SAF= sub-adult female, Juv.= juvenile, INF..= infant)

Seasons	Census Sites	Groups	Total group size	AM	AF	SAM	SAF	Juv.	INF.	Percent (%)
Wet	Garamba	4	141	22	44	15	18	16	26	59.24
	Afursa	2	53	6	16	3	6	11	11	22.27
	Worbadule	2	44	7	12	5	7	7	6	18.49
	Total	8	238	35	72	23	31	34	43	100
Dry	Garamba	4	125	21	47	10	16	12	19	58.96
	Afursa	2	49	7	17	4	7	8	6	23.11
	Worbadule	2	38	6	13	3	8	5	3	17.92
	Total	8	212	34	77	17	31	25	28	100

Bale monkeys were counted from all census sites of forests at human dominated Sidama highlands. During each census, fluctuations of individuals were recorded in each study sites. From the distribution pattern of Bale monkeys, on average, adult females comprised the highest number 74.5 (33.11 %), followed by infants 35.5 (15.78 %) while sub- adult males were the least 20 (8.89 %) population of the total (Table 7). Mann-Whitney U test showed no significant difference among age groups during the two census (U=12, Z= -0.96, P> 0.05).

Table 7. Mean group size and age-sex composition of Bale monkeys during the wet and dry seasons (AM= adult male, AF= adult female, SAM= sub-adult male, SAF= sub-adult female, Juv. = juvenile, INF= infant).

Surveys	Groups	Group size	AM	AF	SAM	SAF	Juv.	IFN.
Wet season	8	238	35	72	23	31	34	43
Dry season	8	212	34	77	17	31	25	28
Mean	8	225	34.5	74.5	20	31	29.5	35.5
Mean %		100	15.33	33.11	8.89	13.78	13.11	15.78

Population size of Bale monkeys showed slight but insignificant fluctuations during the census. The largest mean population (mean = 133, SD ± 11.31) were recorded in Garamba Forest during the two censuses. Worbadule was the lowest (mean = 41, SD ±

4.24) (Fig. 4). There was a significant difference in mean population size of Bale monkeys at different census sites during the surveys (F = 99, df = 2, P< 0.05).

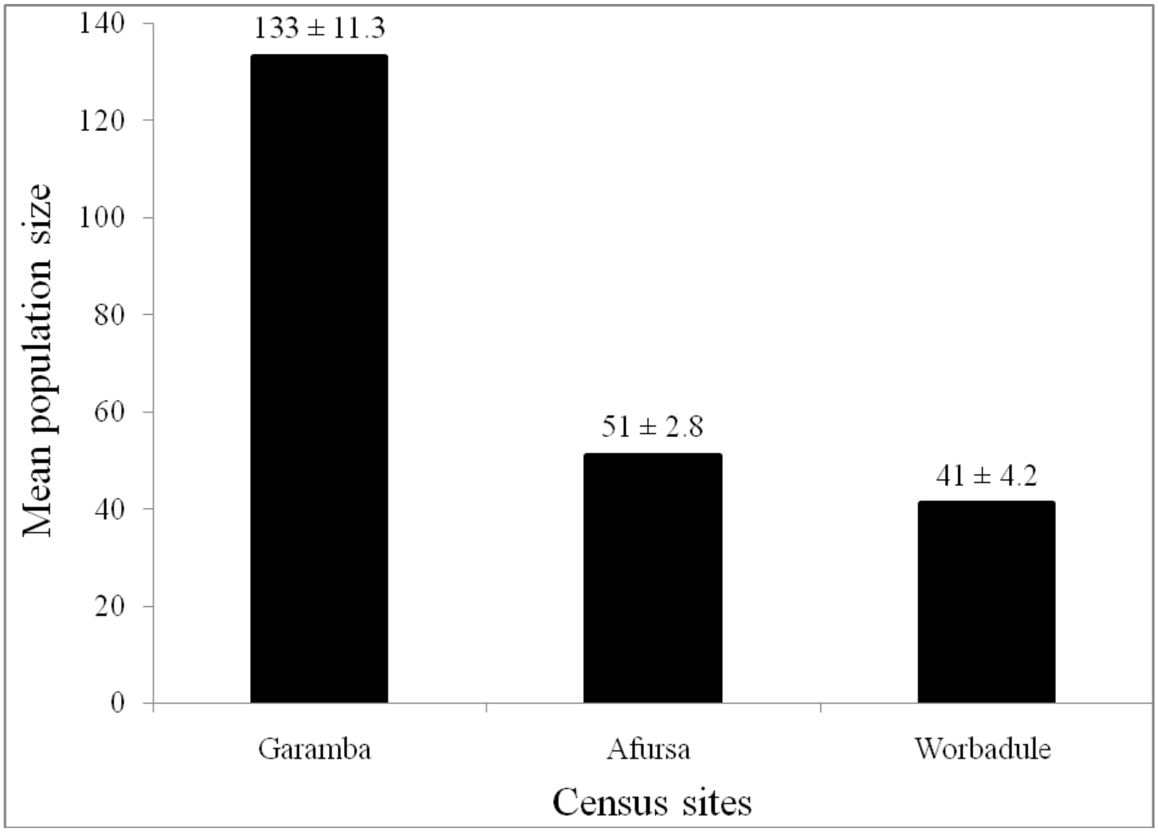

Figure 4. Population size of Bale monkeys in each survey sites (Mean ± SD).

The percentage of age-structure of Bale monkeys comprised adult females (33.11%), sub-adults (22.67%), infants (15.78%) and juveniles (13.11%). There were significant differences among different age groups of Bale monkeys counted in different study sites (F= 18, df= 4, P< 0.05). Group composition by age-sex categories of Bale monkeys included adult females (74.5 ± 3.54), adult males (34. 5 ± 0.71), juveniles of both sexes (29.5 ± 6.36) and sub-adults of both sexes (51 ± 4.24) (Table 8). Mean number of adult females was comprised greater number of individuals during the first census of the dry season. The others comprised high number of individuals in the second census of the wet season.

Table 8. Percentage and mean age-sex structure of Bale monkeys during the two censuses

Age-sex	Dry season	Wet season	Mean	Percent (%)	SD
Adult Females	77	72	74.5	33.11	3.54
Adult males	34	35	34.5	15.33	0.71
Sub-adults	48	54	51	22.67	4.24
Juveniles	25	34	29.5	13.11	6.36
Infants	28	43	35.5	15.78	10.61
Total	212	238	225	100	17.88

The mean ratio of Bale monkeys from all census sites showed that the mean ratio of adult males to adult females was 1:2.2. The mean ratio of both sexes of immature (including both juveniles and infants) to adults was 1:1.7. The mean ratio of immature to adult females was 1:1.2. The ratio of infants of both sexes to adult females was 1:2.1 (Table 9).

Table 9. Age-sex ratios of Bale monkeys in the whole populations in Sidama highlands and among different sites during the study period (AM= adult male, AF= adult female, AD= adults, IMM= immature, Juv. = juvenile, INF. = infant).

Sites	AM:AF	IMM:AD	INF:AD	IMM:AF	INF.: AF	Juv.: AF	Juv.: INF.
All Sidama	1:2.2	1:1.7	1:3.1	1:1.1	1:2.1	1:2.5	1:1.2
Garamba	1:2.1	1:1.8	1:3	1:1.2	1:2	1:3.3	1:1.6
Afursa	1:2.5	1:1.3	1:2.7	1:1	1:1.9	1:1.7	1:1
Worbadule	1:1.9	1:1.2	1:4.2	1:1	1:2.8	1:2.1	1:1

A total of 8 groups of Bale monkeys was recorded with an average group size of 26.5 ± 5.76 animals (range 18 – 34 individuals) from all census sites during the first census (dry season) and 8 groups with an average group size of 29.75 ± 6.48 animals (range 21-38 individuals) during the second census (wet season). The highest mean group density of (7.1 groups/km^2) was recorded in Worbadule, followed by Afursa (5.9 groups/km^2). The number of group encounter rate (group density) varied from 2.7 to 7.1 per km^2. The highest mean population density (157.1 ± 15.1 individuals per km^2) was recorded in Worbadule followed by Afursa (150 ± 8.3 individuals per km^2) during the census. The average density was 128.8 ± 31.3 per km^2 (84.5 – 157.1) (Table 10).

Table 10. Encounter rates and density estimates of Bale monkeys in three different sites.

Census Sites	Census Section	Total area (km^2)	Group observed	Mean group size	Encounter rate ($group/km^2$)	Population density ($indiv./km^2$)
Garamba	I	1.48	4	35.25	2.7	84.5
	II	1.48	4	31.25	2.7	95.3
	Mean	1.48	4	33.25	2.7	89.9
Afursa	I	0.34	2	26.5	5.9	144.1
	II	0.34	2	24.5	5.9	155.9
	Mean	0.34	2	25.5	5.9	150
Worbadule	I	0.28	2	22	7.1	135.7
	II	0.28	2	19	7.1	157.1
	Mean	0.28	2	20.5	7.1	146.4

4.4. Activity budget

A total of 16047 individual behavioral observations were recorded from 4860 instantaneous group scans during 1215 hrs in 120 total observation days (60 days for each study sites) for 12 consecutive months. From the total behavioral observations, 8364 was for Afursa and 7683 was for Garamba study sites. Based on the total study groups of the two study sites (group A and G), on average Bale monkeys spent the largest portion of their time on feeding 55.7% ± 3.29 (54.1% - 57.3%) followed by moving 20.55% ± 2.75 (range =19 - 22.1%), resting 15.2% ± 2.68 (range = 13.2 – 17.2%), socializing 6.9 % ± 2.15 (range = 5.1 – 8.7 %) and ‘others’ 1.65% ± 0.86 (range 1-2.3 %) (Fig. 5).

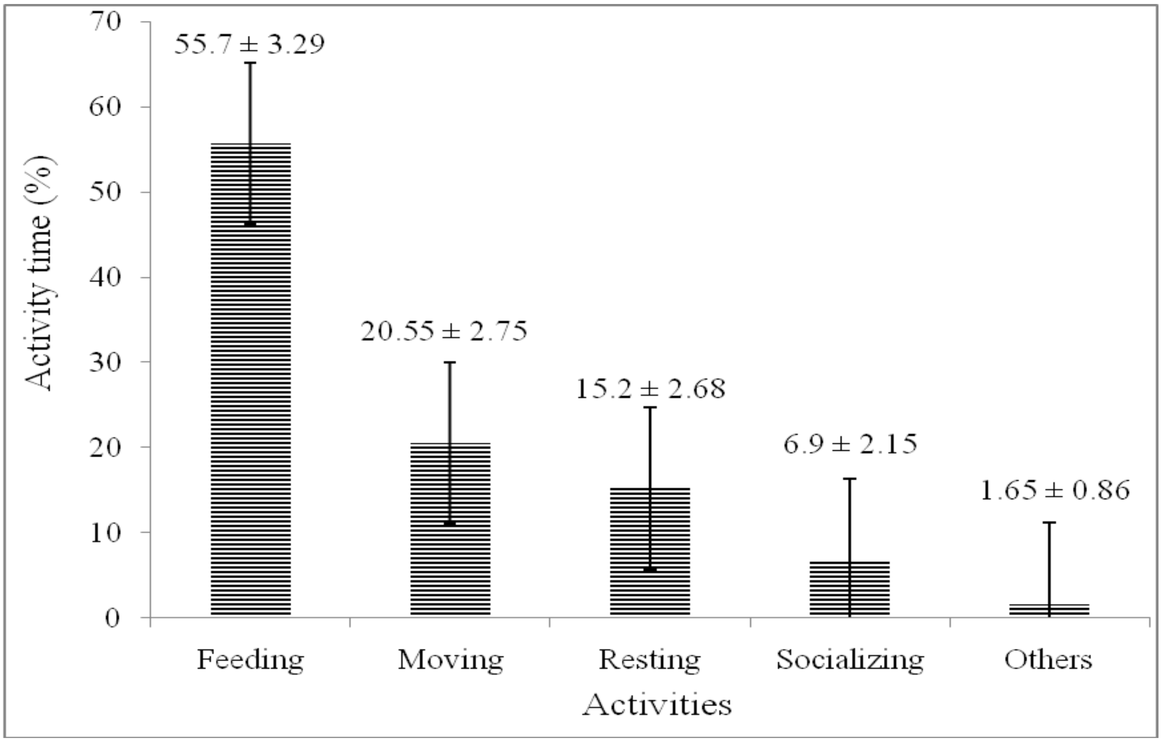

Figure 5. Activity time budget of Bale monkeys at Sidama highlands (Mean ± SD).

Kruskal-Wallis H test showed that, the Bale monkey group in Garamba Forest spent singnificantly more time in feeding (57.3% vs 54.1%; x^2= 5.88, df=1, P< 0.05), moving (22.1% vs 19%; x^2= 7.53, df =1, P< 0.05) and ‘other’ activities (2.3% vs 1%; x^2= 15.45, df= 1, P< 0.05) and significantly less time for resting (13.2% vs 17.2%; x^2=13.66, df =1, P< 0.05), and socializing (5.1% vs 8.7%; x^2= 16.88, df= 1, P< 0.05) than groups in Afursa Forest (Fig. 6).

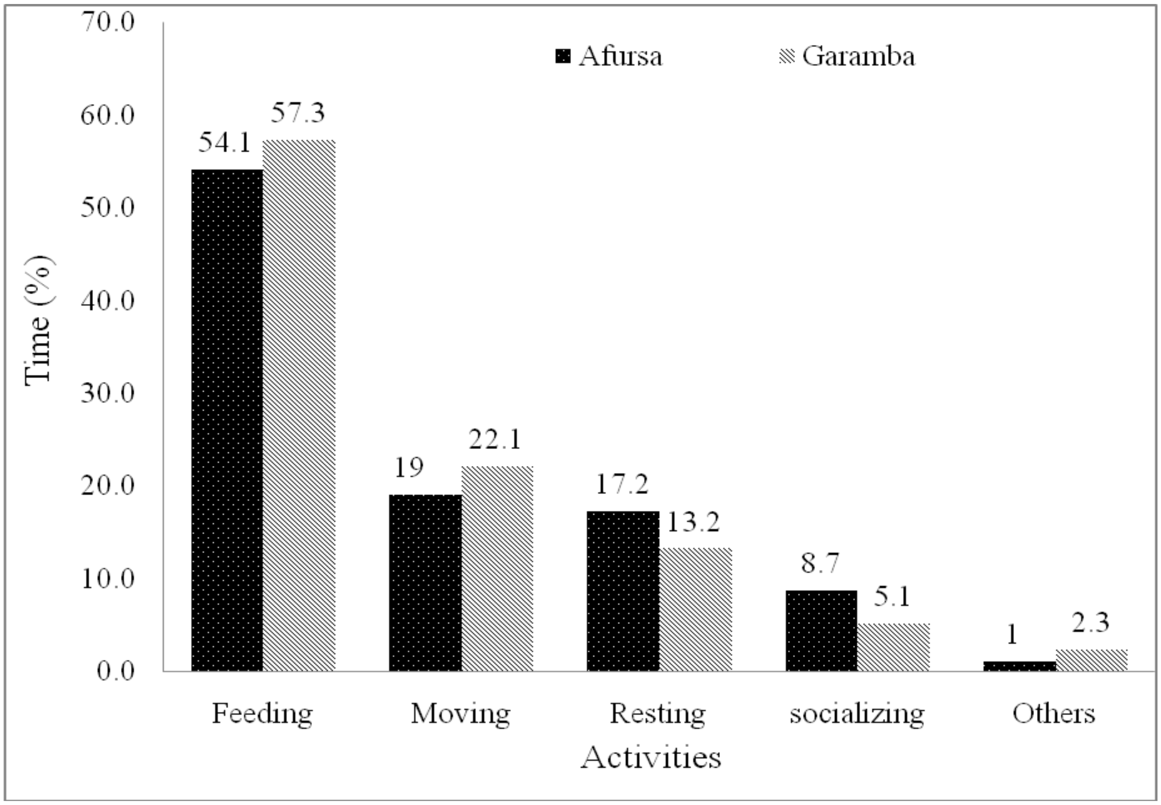

Figure 6. Proportion of annual activity time budget of both Bale monkey study groups (for A, n= 8364 and G, n=7683) in Sidama highlands.

Monthly time budget for feeding during the study period varied across months ranging from 50.31 % during February to 60.07 % during November. Moving ranged from 16.28 % in November to 23.94% in February (Fig. 7). Kruskal-Wallis H test showed that there were no statistically significant differences in percentage of time budget for different activities across months ($x^2 = 0.12$, df =11, P> 0.05).

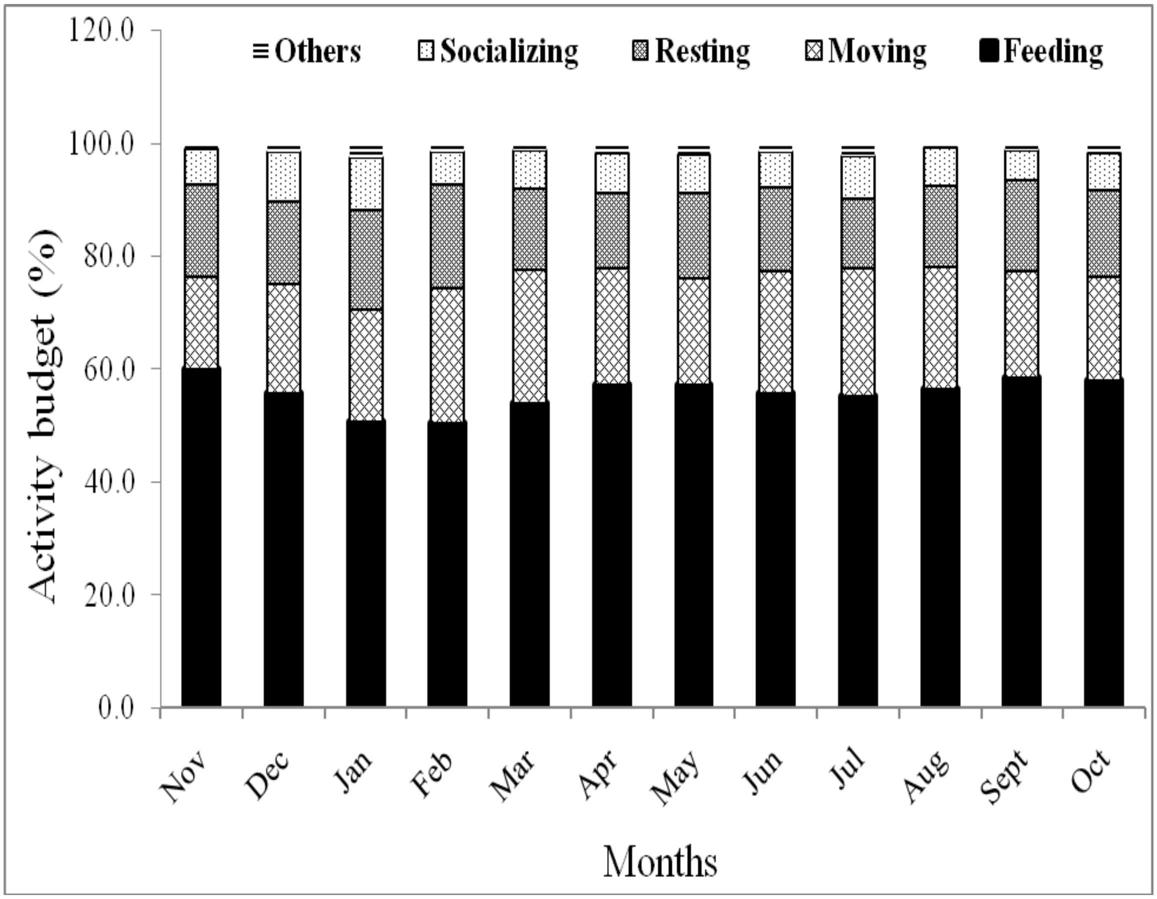

Figure 7. Monthly percentage proportion of time budget of Bale monkeys during the study period.

Bale monkeys experienced minimum variations in all activities during the wet and dry seasons. There was no significant difference among the activity budgets during the wet and dry seasons (Mann-Whitney test, U= 445.5, Z= 0.07, P> 0.05). Feeding constituted higher activity budget than others. Time spent on feeding was higher during the wet season than the dry season. Bale monkeys spent slightly higher time on feeding (56.7% ± 1.2%) during the wet season than the dry season (54.7% ± 3.9%) but there was no significant difference time spent on feeding between wet and dry seasons (U=33, Z= -0.96, P> 0.05). Time spent on socializing was higher during the dry season than the wet season. Bale monkeys spent higher time on socializing (16.1% ± 1.7%) during the dry season than the wet season (14.3% ± 1.3%) but there was no significant difference between them (Fig. 8). Seasonal feeding pattern of Bale monkeys was the highest during both the wet and dry seasons. Feeding pattern was peak during late dry season, during the short rain and before the beginning of the the dry season while decreasing progressingly across the dry season reaching the lowest during the mid-dry saeson. Moving was the second highest activity during the study period. Moving pattern was reduced at the beginning of the dry season and increase during the last two months of dry season.

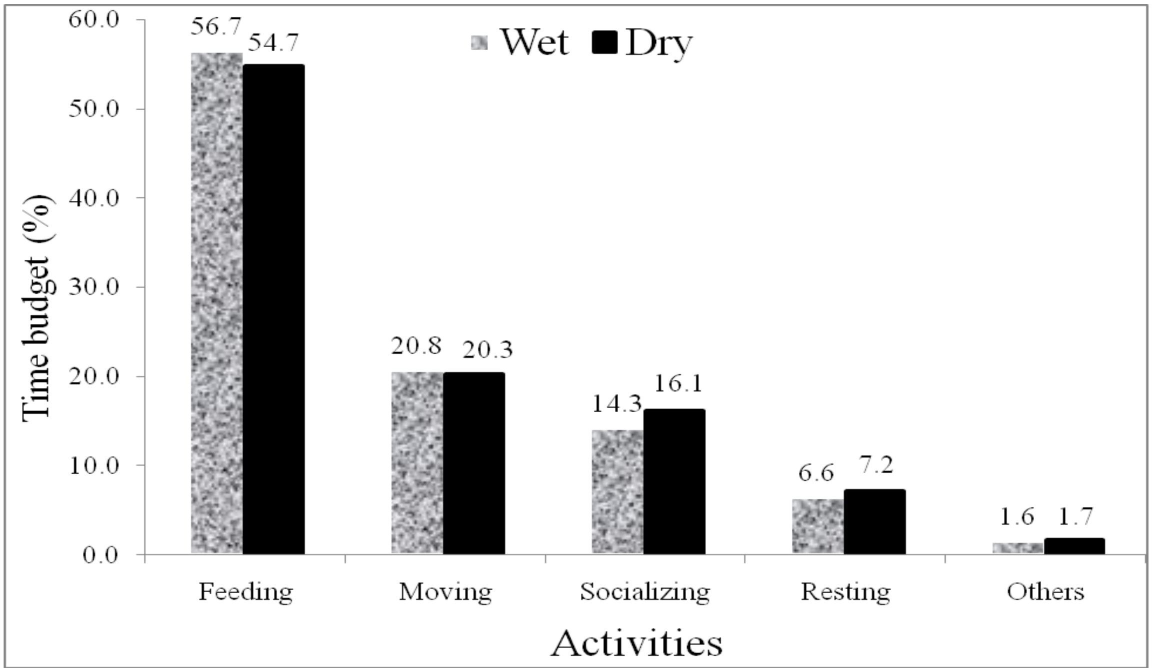

Figure 8. Activity time budget of Bale monkeys during the wet and dry seasons.

4.5. Activity time budget in age-sex catagories

Different budget utilization in age-sex of Bale monkey catagories was observed. The activities of Adult femals and sub-adult females were similar. Due to this, adult females means the sum of both adult females and sub-adult females. Adult females spent the highest (58.2%) time feeding, followed by sub-adult males (57.2%) while adult males recorded the lowest (51.8%). Adult males spent the highest in moving (25.8%) followed by sub-adult males (23.2%). The lowest (11.3%) was observed in juveniles. Resting was recorded as the highest (19.3%) time budget in adult males, followed by adult females (14.8%) and the lowest was (13.1%) in juveniles. Regarding to socializing juveniles recorded the highest (18.6%) time budget, followed by sub-adult males (4.3%) (Fig 9).

Kruskal-Wallis H test showed statistical differences in time budget of Bale monkeys in

Kruskal-Wallis H test showed statistical differences in time budget of Bale monkeys in

each activity among age-sex categories (P< 0.05). Feeding (x^2 = 25.67, df=3, P<0.05), moving(x^2= 37.55, df= 3, P< 0.05), resting (x^2= 31.31, df= 3, P< 0.05), socializing (x^2 = 33.31, df= 3 , P< 0.05) and others (x^2= 34.86, df= 3 , P< 0.05).

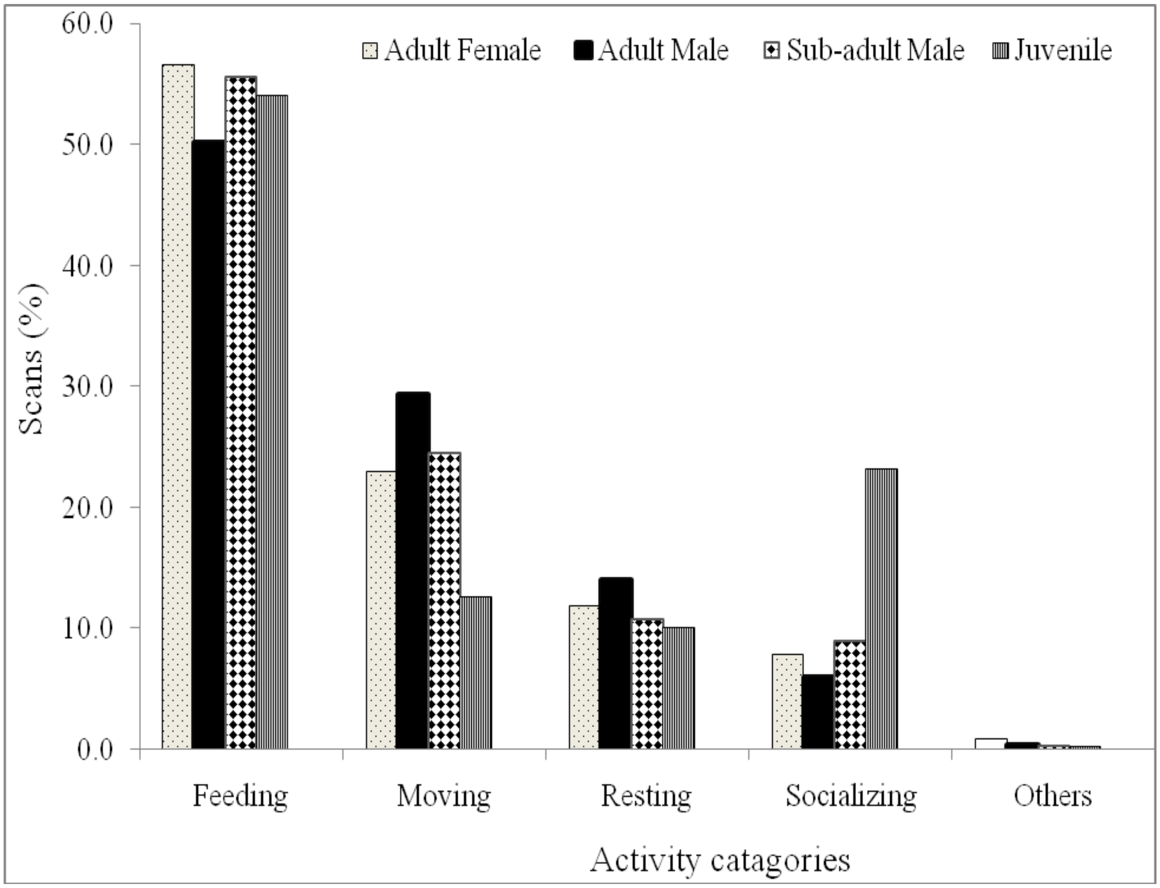

Figure 9. Activity budgets in age-sex categories among study groups of Bale monkeys.

Bale monkes started their diurnal activities early in the morning (0700 h) but active until dusk before they return to their sleeping sites. Socializing was peak early in the morning

(0700 – 0800 h) before the group started other activities. The time devoted for feeding was less in the mornning. Moving was peak in the mornig (0800-1000 h) and in the afternoon (1600-1700 h). Kruska – Wallis H test, (x^2 = 46.79, df = 4, P< 0.05) showed that there were significant differences in diurnal cyclic activities during the study period. Diural feeding activity of Bale monkeys was highest (51.4%) during the afternoon (1600 – 1700 h) (Fig. 10).

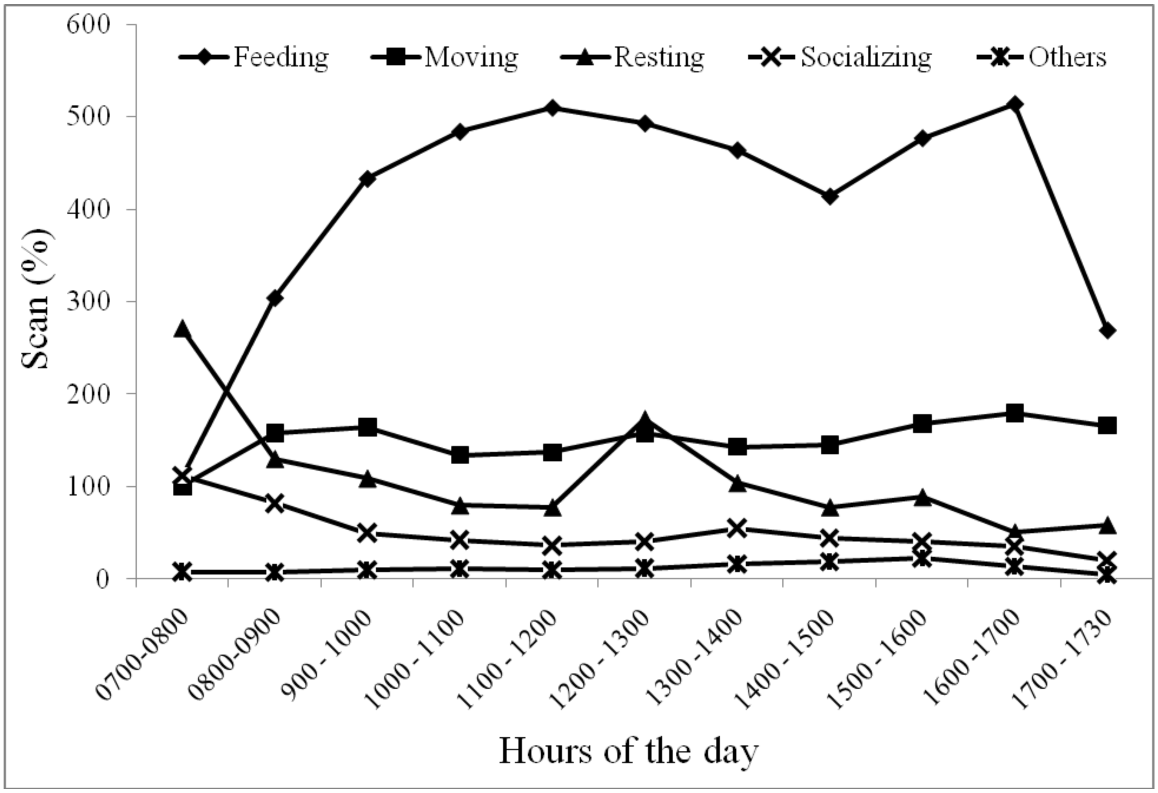

Figure 10. Hourly activities budget of Bale monkeys in the study area.

4.6. Feeding ecology

A total of 8927 feeding behavioral observations were recorded, 4525 (Afursa Forest group) and 4402 (Garamba Forest group). The total number of dietary plant species identified as food for Bale monkes in human dominated Sidama highlands was 46, of which 32 were in the Afurasa Forest group and 14 were in Garamba Forest group. Bale monkeys were observed feeding on plant species belonging to 30 families. The food sources of Bale monkeys in Afursa Forest were 6 trees, 3 shrubs, 2 lianas, 4 graminoids, 17 forbs and diferent insect species whereas in Garamba Forest only 5 trees, one shrub, 2 graminoids, 5 forbs, one bamboo and different insect species. Food plant species similarity index between the groups is very low (Ss= 0.28, 9 of 46 species). Cumulative percentage of the annual diet of Bale monkeys accounted for by the top five plant species was higher in groups inhabiting Garamba Forest (87.22%) than the group in Afursa fragment (58.87%) (Table 11).

The time spent feeding on different growth forms of plant species by Garamba and Afursa Forest groups varied. Kruskal Wallis test revealed that Garamba Forest group spent significantly more time on feeding bamboo (63.49% vs 0%, x^2= 19.76, df= 1, $P< 0.05$) and spent significantly less time feeding on liana (3.45% vs 0%, x^2= 19.74, df= 1, $P< 0.05$), shrubs (4.87% vs 19.28%; x^2= 13.23, df= 1, $P< 0.05$), gramioids (1.94% vs 19.60 %, x^2 = 17.33, df= 1, $P< 0.05$) and forbs (1.23% vs 17.34%; x^2 = 17.30, df= 1, $P< 0.05$) than groups in Afursa Forest. However, there was no significant difference in the consumption of tree (24.67% vs 27.98%; $x^2 = 2.61$, df= 1, $P > 0.05$) between Gatamba and Afursa Forest groups (Fig. 11).

Table 11. Percentage of feeding records on different food items from each plant species between the two Bale monkey groups (Afursa, n= 4525; Garamba, n= 4402).

			Percentage of feeding on each food items									
Family	Species consumed	Growth form	BYL	NBYL	FR	FL	BSH	PT	ST	IN	OS	Total
Garamba (G)												
Poaceae	*Arundinaria alpina*	Bamboo	51.02	-	-	-	12.15	-	-	-	0.32	63.49
Sterculiaceae	*Dombeya torrida*	Tree	-	-	-	9.18	-	-	-	-	-	9.18
Myrsinaceae	*Maesa lanceolata*	Tree	-	-	4.82		-	-	0.36	-	-	5.18
Rosaceae	*Rubus apetalus*	Shrub	-	-	4.02	-	-	-	0.85	-	-	4.87
Uriticaceae	*Hagenia abyssinica*	Tree	-	0.7	-	-	-	2.8	1.00	-	-	4.5
Rubiaceae	*Galiniera saxifraga*	Tree	-	-	2	-	-	-	1.75	-	-	3.75

Cupressaceae	*Juniperus procera*	Tree	-	-	2.06							2.06
Poaceae	*Bothriochloa radicans*	Graminoid	-	1.24	-	-	-	-	-	-	0.08	1.32
Caryophyllaceae	*Drymaria cordata*	Forb	-	0.5	-	-	-	-	0.2	-	-	0.7
Poaceae	*Cynodon dactylon*	Graminoid	-	0.62	-	-	-	-	-	-	-	0.62
Rubiaceae	*Galium spurium*	Forb	-	0.28	-	-	-	-	-	-	-	0.28
Asteraceae	*Carduus schimperi*	Forb	-	-	-	0.08	-	-	0.09	-	-	0.17
Acanthopale	*Acanthopale pubescens*	Forb	-	0.04	-	-	-	-	-	-	-	0.04
Crassulaceae	*Crossula alsinoides*	Forb	-	0.04	-	-	-	-	-	-	-	0.04
	Insect		-	-	-	-	-	-	-	3.8	-	3.8
	Total		51.02	3.42	12.9	9.26	12.15	2.8	4.25	3.8	0.4	100

Afursa (A)

Family	Species consumed	Growth form	BYL	NBYL	FR	FL	BSH	PT	ST	IN	OS	Total
Poaceae	*Bothriochloa radicans*	Graminoid	-	17.03	-	-	-	-	-	-	-	17.03
Rubiaceae	*Galiniera saxifraga*	Tree	-	-	12.31	-	-	-	0.57	-	-	12.88
Rosaceae	*Rubus apetalus*	Shrub	-	-	8.8	-	-	-	3.21	-	-	12.01
Rosaceae	*Hagenia abyssinica*	Tree	-	1.42	-	-	-	6.39	2.33	-	-	10.14
Asteraceae	*Bothriocline schimperi*	Shrub	-	-	-	-	-	-	6.81	-	-	6.81
Apiaceae	*Centellia asiatica*	Forb	-	6.75	-	-	-	-	-	-	-	6.75
Aquifoliaceae	*Ilex mitis*	Tree	-	0.8	-	2.06		-	1.42	-	-	4.28

Urticaceae	*Urera hypselodendron*	Liana	-	-	0.92	-	-	-	2.29	-	-	3.21
Apiaceae	*Hyplosciadium abyssinicum*	Forb	-	3.12	-	-	-	-	-	-	-	3.12
Poaceae	*Cynodon dactylon*	Graminoid	-	1.36	-	-	-	-	-	-	-	1.36
Apiaceae	*Agrocharis melanantha*	Forb	-	1.18	-	-	-	-	-	-	-	1.18
Commelinaceae	*Commelina sp.*	Forb	-	0.24	-	-	-	-	0.87	-	-	1.11
Asteraceae	*Crassocephalum macropappus*	Forb	-	0.86	-	-	-	-	0.22	-	-	1.08
Fabaceae	*Trifolium tembense*	Forb	-	1.00	-	-	-	-	-	-	-	1.00
Poaceae	*Poa annua*	Graminoid	-	0.99	-	-	-	-	-	-	-	0.99
Lamiaceae	*Plectranthus alpinus*	Forb	-	0.2	-	0.06	-	-	0.49	-	-	0.75
Urticaceae	*Pilea rivularis*	Forb	-	0.2	-	-	-	-	0.39	-	-	0.59

Polygonaeceae	*Rumex nepalensis*	Forb	-	0.57	-	-	-	-	-	-	-	0.57
Cupressaceae	*Juniperus procera*	Tree	-	-	0.5	-	-	-	-	-	-	0.50
Asteraceae	*Vernonia rueppelli*	Shrub	-	0.18	-	-	-	-	0.28	-	-	0.46
Balsaminaceae	*Impatiens hochstetteri*	Forb	-	-	-	0.04	-	-	0.38	-	-	0.42
Caryophyllaceae	*Drymaria cordata*	Forb	-	0.2	-	-	-	-	0.06	-	-	0.26
Asteraceae	*Mikaniopsis clematoides*	Liana	-	0.07	-	-	-	-	0.17	-	-	0.24
Poaceae	*Zea mays*	Graminoid	-	0.22	-	-	-	-	-	-	-	0.22
Asteraceae	*Carduus schimperi*	Forb	-	-	-	0.11	-	-	0.06	-	-	0.17
Solanaceae	*Discopondium penninervium*	Tree	-	0.04	-	0.07	-	-	-	-	-	0.11
Rosaceae	*Alchemilla fischeri*	Forb	-	0.10	-	-	-	-	-	-	-	0.10

Asteraceae	*Echinops sp.*	Forb	-	-	-	-	-	-	0.08	-	-	0.08
Urticaceae	*Girardinia bullosa*	Forb	-	0.07	-	-	-	-	-	-	-	0.07
Capparaceae	*Ritchiea albersii*	Tree	-	-	-	-	-	0.07	-	-	-	0.07
Urticaceae	*Urtica simensis*	Forb	-	0.05	-	-	-	-	-	-	-	0.05
Crassulaceae	*Crassula alsinoides*	Forb	-	0.04	-	-	-	-	-	-	-	0.04
	Insects		-	-	-	-	-	-	-	12.35	-	12.35
		Total	0	36.69	22.53	2.34	0	6.46	19.63	12.35	0	100

BYL= bamboo young leaves, NBYL= non-bamboo young leaves, FR= fruits, FL= flowers, BSH= bamboo shoots, PT= petioles, ST= stems, IN= insects, OS= others

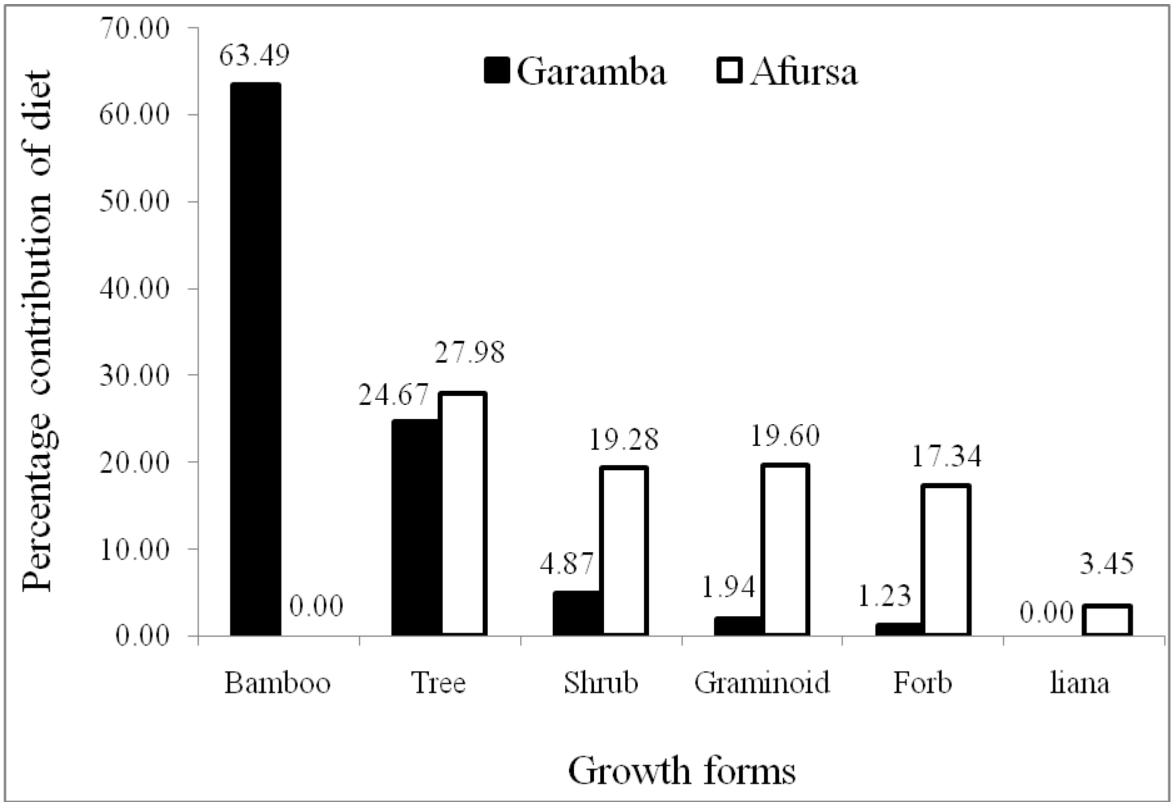

Figure 11. Percentage contribution of each growth forms in the diet of Bale monkey groups.

Bamboo (*A. alpina*) was the top food plant item consumed by Garamba Forest groups (63.49%) but it is not found in Afursat Forest. Instead, in Afursa Forest, grass, *Bothriochloa radicans* (17.03%) and tree *Galiniera saxifraga* (12.88%) were the two top plant species in their diet. *Bothriochloa radicans* and *G. saxifraga* only comprised least (1.32%, 3.75%), respectivelly in the dietary species of Garamba Forest group. A shrub *Rubus apetalus* was the third most frequent food source in Afursa Forest (12.01%) and it is the fourth most frequent food source in Garamba Forest group (4.87%). *Dombeya* *torrida* tree was the second most frequent food source in Garamba Forest group while it was absent in Afursa Forest group (Table 11).

Bamboo young leaves comprised the major diet composition in Garamba Forest (51.02%) whereas it comprised 0% in Afursa Forest group. Non-bamboo young leaves comprised the major diet composition of Afursa Forest group (36.69%) while this covered only 3.42% in Garamba Forest (Fig. 12). Kruskal Wallis test revealed that Garamba Forest group spent significantly more time feeding on bamboo young leaves (51.02% vs 0%; x^2= 19.73, df= 1, P< 0.05), bamboo shoots (12.15% vs 0%; x^2= 14.96, df= 1, P< 0.05) and flowers (9.26% vs 2.34%; x^2= 9.74, df= 1, P< 0.05) while singnificantly less time feeding on non-bamboo young leaves (3.42% vs 36.69%; x^2= 17.28, df= 1, P< 0.05), insects (3.8 % vs 12.35%, x^2= 16.37, df= 1, P< 0.05), fruits (12.90% vs 22.53%; x^2= 7.05, df= 1, P< 0.05) and stems (4.25% vs 19.63%; x^2= 17.28, df= 1, P< 0.05) than Afursa Forest group. However, there was no significant difference between Garamba and Afursa groups in time spent feeding on petioles (2.8% vs 6.46%; x^2= 3.12, df= 1, P> 0.05).

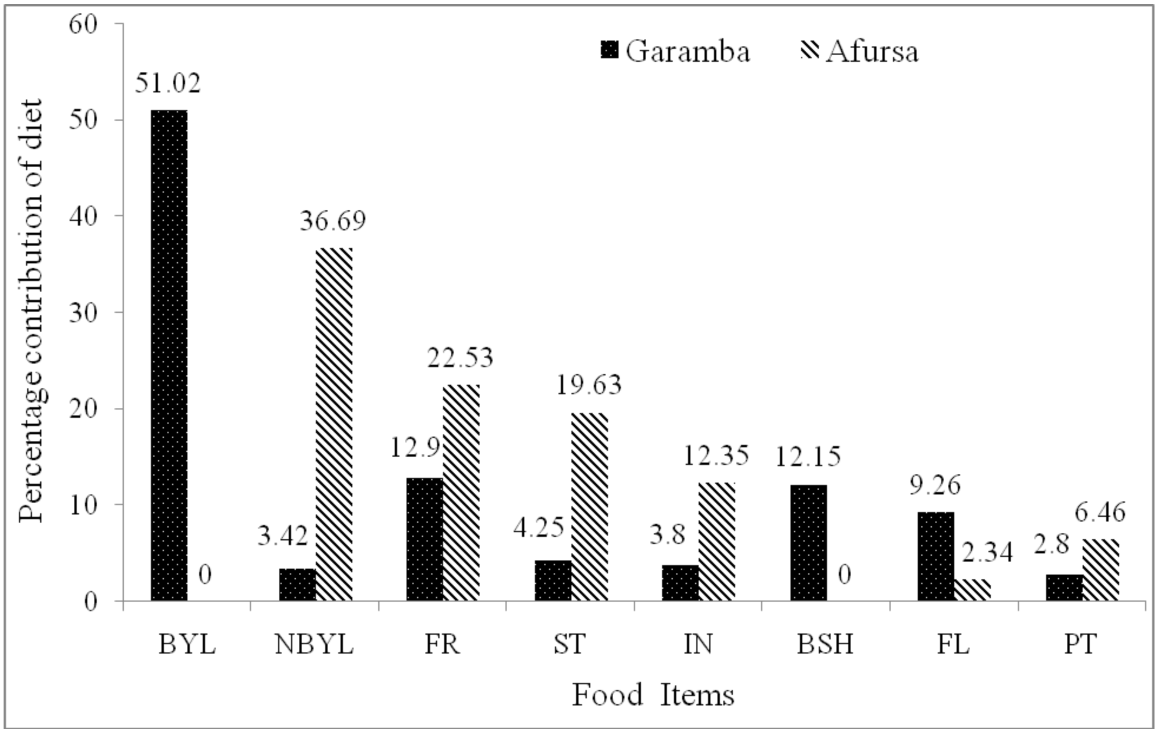

Figure 12. Percentage contribution of each food item in the diet of Bale monkey groups. BYL: bamboo young leaves, NBYL: non-bamboo young leaves, FR: fruits, ST: stems, IN: insects, BSH: bamboo shoots, FL: flower, PT: petioles.

Bamboo young leaves contributed 25% (ranged 11.5% - 33.4%) of Bale monkey's monthly diet. The peak of bamboo young leaves contribution was recorded in September and December while lowest was in May. The average monthly contribution of fruits in the diet was 17.7% (ranged 5.3% - 30.6%) in September and March, respectively. Stems also contributed 12% (ranged 6.8% - 22.5%) in March and September, respectively in the diet of Bale monkeys (Fig. 13)

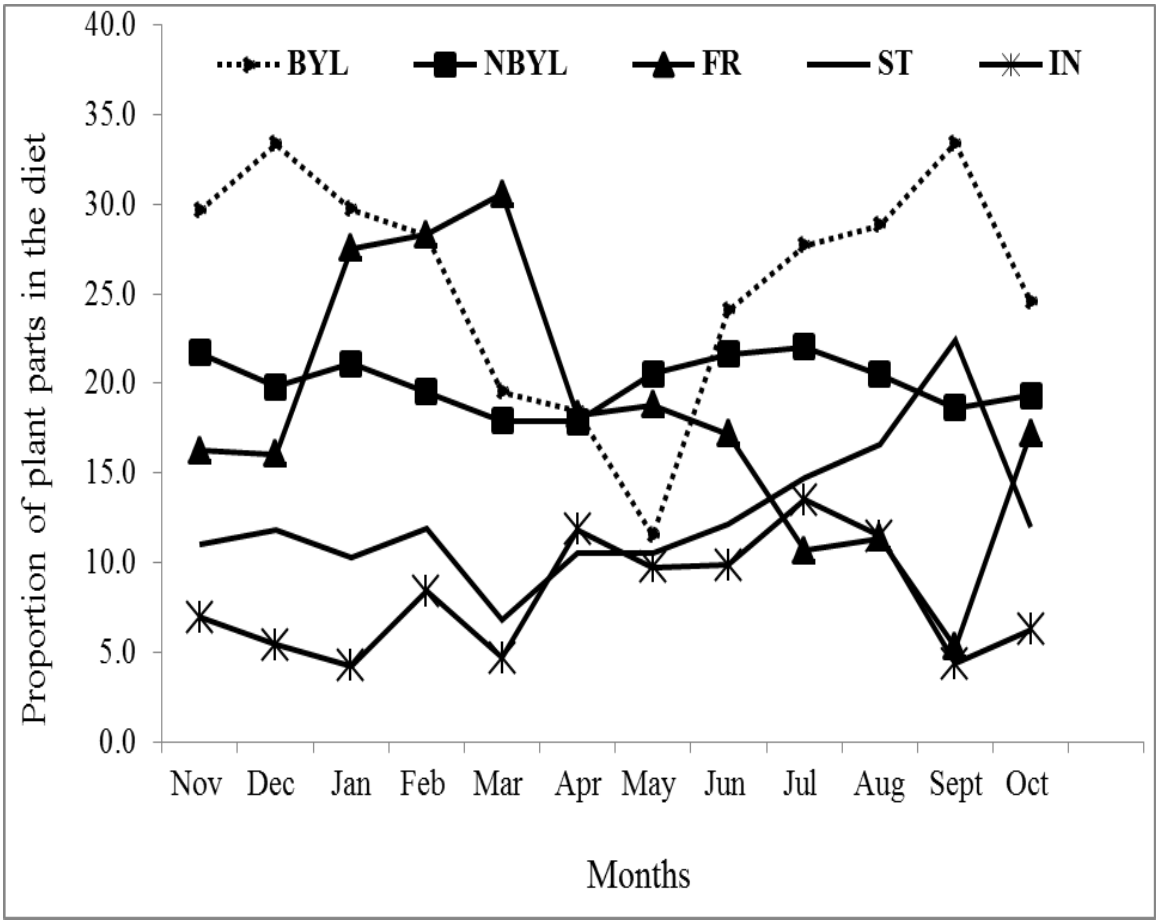

Figure 13. Monthly changes in the proportion of plant parts in the diet of Bale monkeys during the study period.

The monthly dietary diversity over 12 months as calculated by the Shannon-Wiener H', for Bale monkeys in Afursa Group-A) and Garamba (Group-G) were 2.53 (range 2.41 – 2.60) and 1.37 (range 1.23 – 1.53), respectively. Mann-Whitney U test showed that there was a higher monthly dietary diversity in the Afursa Forest group than it was in Gramba Forest ($P <0.05$). Dietary diversity was high in September, November, December and April and it was low in August for Group-A. It was highest in September and lowest in April for Group-G (Table 12). The mean monthly dietary evenness index, J, for Bale monkeys of Garamba and Afursa were 0.32 (range 0.25 – 0.42) and 0.46 (range 0.42 - 0.55), respectively. Mann Whitney U test showed that dietary items were significantly evenly distributed in Afursa Forest group than it was in Garamba Forest ($P<0.05$). Mean monthly food plant species dominance, D, was significantly higher for groups inhebiting Garamba Forest (0.43) than in Afursa Forest (0.11) ($P< 0.05$).

Table 12. Food species diversity, evenness and dominance indices for the 12 month study period from Afursa and Garamba Forests.

Months	Shannon-Wiener diversity index, H'		Evenness index, J		Dominance, D	
	Group-G	Group-A	Group-G	Group-A	Group- G	Group-A
Nov	1.47	**2.6**	0.36	0.5	0.39	0.1
Dec	1.39	**2.6**	0.34	0.47	0.42	0.1
Jan	1.49	2.57	0.32	0.45	0.39	0.11
Feb	1.47	2.58	0.36	0.45	0.35	0.1
Mar	1.35	2.45	**0.42**	0.43	0.35	0.12
Apr	**1.23**	**2.6**	0.32	**0.55**	0.45	0.1
May	1.28	2.52	0.28	0.49	0.48	0.11
Jun	1.28	2.42	0.3	0.47	0.48	0.12
Jul	1.27	2.42	**0.25**	0.45	0.48	0.12
Aug	1.25	**2.41**	0.29	0.43	0.48	0.12
Sept	**1.53**	**2.6**	0.26	**0.42**	0.49	0.12
Oct	1.46	2.53	0.3	0.44	0.39	0.1
Mean	**1.37**	**2.53**	**0.32**	**0.46**	**0.43**	**0.11**

The top 6 plant species comprised 70% of their diet. Their presence in the diet is highly variable from month to month. Some plant species like *Arundinaria alpina* are consumed during every month of the study period while others like *Dombeya torrida* were consumed during some months and absent in the other months. *Arundinaria alpina* contributed the highest persentage regularly throughout the year ranging from 27.7 during May to 34.4% in September (Table 13). Kruskal-Wallis H tests, on the comparison of plant species contribution across each month showed that there were insignificant differences in the time spent feeding on different plant species ($x^2 = 2.35$, df= 11, $P > 0.05$).

Table 13. Monthly percent variations in the contribution of the top 10 plant species to the diet of Bale monkeys during the study period.

Species consumed	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Mean
Arundinaria alpina	32.8	34.1	33.0	32.2	30.1	29.6	27.7	30.9	32.0	33.2	34.4	30.4	31.7
Bothriochloa radicans	10.5	9.4	9.4	8.2	9.8	6.2	7.9	9.8	10.0	10.0	9.5	9.7	9.2
Rubus apetalus	7.0	10.0	12.6	14.9	16.8	7.6	7.5	2.2	2.3	1.6	13.1	6.9	8.5
Galiniera saxifraga	7.2	6.3	6.7	8.6	6.0	7.7	9.4	11.8	10.4	11.2	5.8	8.7	8.3
Hagenia abyssinica	8.4	8.0	5.3	3.6	11.6	7.0	6.7	7.6	7.0	7.2	7.7	7.8	7.3
Dombeya torrida	8.6	6.9	2.4	1.1	1.0	4.2	4.2	4.5	-	-	5.6	7.5	8.6
Bothriocline schimperi	3.2	5.6	5.8	6.5	2.6	2.4	2.3	1.5	2.3	3.1	2.7	3.3	3.4
Centellia asiatica	3.5	3.4	3.0	3.3	3.4	3.4	3.5	3.4	4.1	3.5	3.3	3.4	3.4
Cynodon dactylon	1.0	0.9	0.9	1.0	0.7	0.9	1.2	1.0	1.0	3.1	1.4	1.0	1.0
Maesa lanceolata	2.1	2.8	6.3	6.5	5.5	2.1	2.4	0.4	0.1	1.3	0.4	1.7	2.6

4.7. Dietary preference

The selection ratio of food plant species including bamboo, tree, shrub and liana species acounted for ≥ 0.5 % of the annual diet during the study period in the home rage of Bale monkey. Based on preference ratio, despite its dominance in the diet of Garamba Forest group, bamboo (*Arundinaria alpina*) has selection ratio of below 1.00 (0.84) owing to its extremely high stem density in this forest type. The most selected plant species by Garamba Forest group was the tree *Galiniera saxifraga* with the selection ratio of 11.36, *Dombeya torrida* with the selection ratio of 6.00 follwed by *Maesa lanceolata* with the selection ratio of 4.50. For Afursa group, the most selected species were the trees *Galiniera saxifraga* (18.67), *Hagenia abyssinica* (12.22) followed by *Ilex mitis* (3.42). However, the top food species in the diet of Afursa group was graminoid species, *Bothriochloa radicans*. Species that exhibited consistant high selection ratios and ranked the first among the top three species for dietary selectivity between groups was the tree *Galiniera saxifraga* (Group-G: 11.36, 1st rank and Group-A: 18.67, 1st rank) which showed that Bale monkeys consume primarly on fruits (Table 14).

Table 14. Selection ratio of food plant species contributing ≥ 0.5% to the diet of the two Bale monkey groups.

Group	Species	Growth form	% of diet	% of stem density	Selection ratio	Rank
Group-G	*Arundinaria alpina*	Bamboo	63.49	75.43	0.84	7
	Dombeya torrida	Tree	9.18	1.53	6.00	2
	Maesa lanceolata	Tree	5.18	1.15	4.50	3
	Rubus apetalus	Shrub	4.87	5.16	0.94	6
	Hagenia abyssinica	tree	4.5	1.43	3.15	4
	Galiniera saxifraga	tree	3.75	0.33	11.36	1
	Juniperus procera	Tree	2.06	1.39	1.48	5
Group-A	*Galiniera saxifraga*	Tree	12.88	0.69	18.67	1
	Rubus apetalus	Shrub	12.01	39.34	0.31	6
	Hagenia abyssinica	Tree	10.14	0.83	12.22	2

Bothriocline schimperi	Shrub	6.18	8.31	0.74	5
Ilex mitis	Tree	4.28	1.25	3.42	3
Urera hypselodendron	Liana	3.21	1.39	2.31	4

4.8. Ranging ecology

A total of 5040 GPS points, 2460 from Garamba Forest group and 2580 from Afursa Forest group in 120 days follow up period were recorded. Bale monkeys showed wide daily fluctuation in daily traveled distance (DTD). The daily path length of Garamba Forest group (G) ranged from 895 to 1837 m. For Afursa Forest group (A), the daily path length ranged from 622 to 1300 m. There was a significant difference in daily travel length between Afursa and Garamba Forest groups (Mann Whitney U test; Z= - 7.56, $P < 0.05$). Afursa forest group traveled 1009 ± 25.5 m and Garamba Forest group moved 1469.2 ± 33.7 each day (Fig. 14)

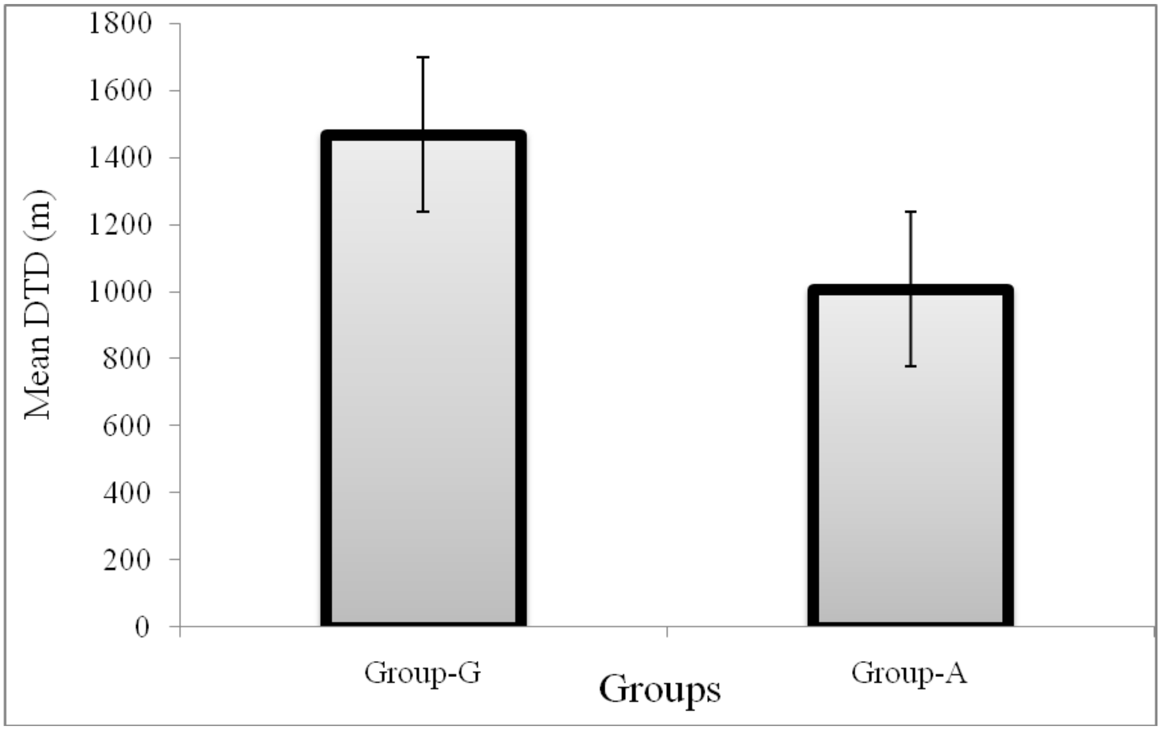

Figure 14. Comparison of daily travel distance (DTD) between the two Bale monkey groups (Mean ± SE).

Mean monthly daily traveled distance (DTD) varied among months in both Garamba and Afursa Forest groups. For group-G, mean monthly path length ranged from 1053 to 1699 m. The longest mean monthly path length was recorded in September, whereas the shortest was in April. Similarly for group-A, the mean monthly path length ranged from 678 to 1220 m. The longest mean monthly path length was recorded in September, while the shortest path length was recorded in May. Analyses of effects of temporal variation and habitat type on mean monthly DTD within each group showed that Bale monkeys in Garamba Forest traveled significantly further than the Group in Afursa Forest (Mann-Whiney test; Z= - 3.47, P < 0.05) (Fig. 15).

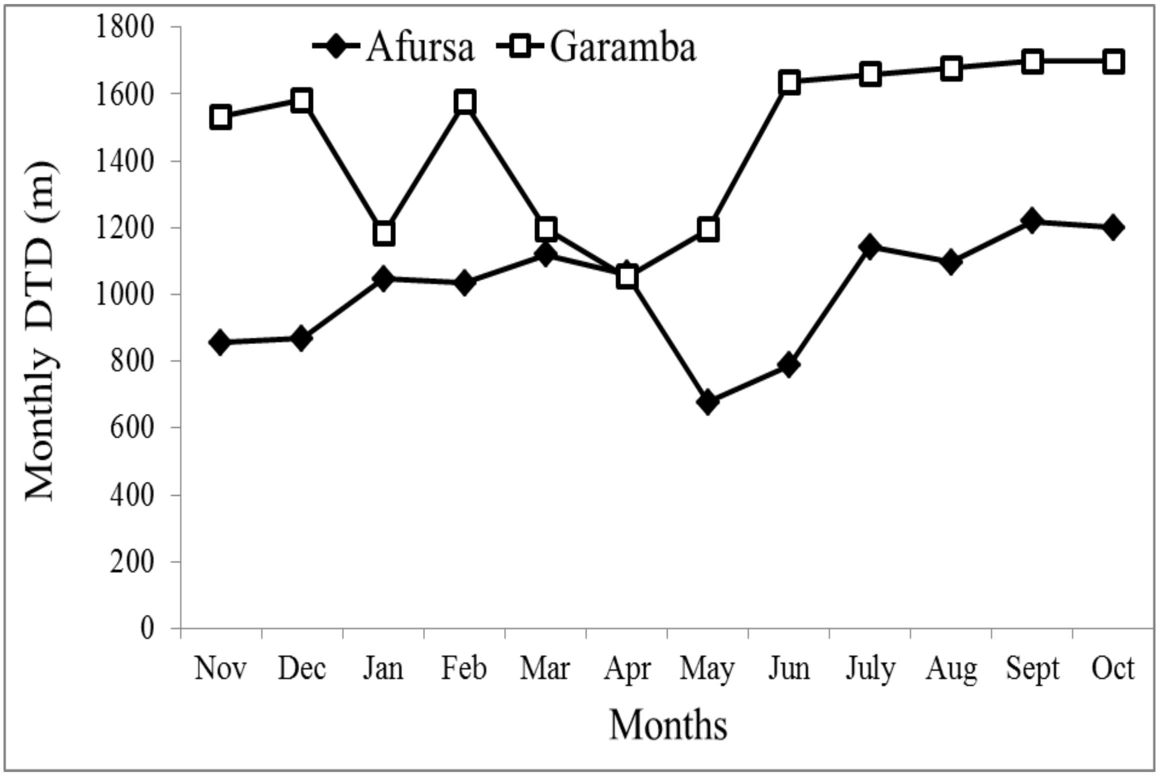

Figure 15. Monthly variation in the DTD between the two groups.

Bale monkeys had significantly higher movement rate (MVR) in Garamba Forest (Mean= 146. 92 ± 3.4 m/hr) than in Afursa Forest (Mean = 95.46 ± 2.6 m/hr) (Mann-Whiney U test; Z= - 8.09, P< 0.05) (Table 15). Kruskal-Wallis H test showed statistical differences in monthly MVR across months in both group-A (x^2 = 42.27, df= 11, P< 0.05) and group-G (x^2 = 41.61, df= 11, P< 0.05).

Table 15. Annual and monthly mean (± SE) and range values of daily travel distance (DTD) and monthly mean (± SE), movement rate (MVR) for the two study groups

Group	Mean No. of GPS points per day	Monthly mean ± SE DTD	Ranges of DTD	Monthly mean ± SE MVR (m/hr)	Ranges of MVR
G	41	1469.2 ± 33.7	895 - 1837	146.9± 3.4	89.5 – 183.7
A	43	1009 ± 25.5	622 - 1300	95.5 ± 2.6	59.3 – 123.8

Annual home range size and core area occupied by both group-G and group-A is presented in Table 16 and Figs. of 16, 17, 18 and 19. Using 100% MCP method, the annual home range size covered by group-G was 32 ha. Similarly, using 95% KDE method, the annual home range size occupied by group-A (16 ha) was smaller than the home range of group-G (26 ha).

Table 16. Annual home range and core area estimated by Minimum Complex Polygon and Kernel density methods occupied by the two Bale monkey groups.

		Annual home range (ha)				Core area (ha)	
Group	No. of GPS points	95% KDE	100% MCP	95% MCP	90% MCP	50% KDE	50% MCP
Group-G	2460	26	32	27.7	24	11	14
Group-A	2580	16	18	16.5	14.2	6.4	6.8

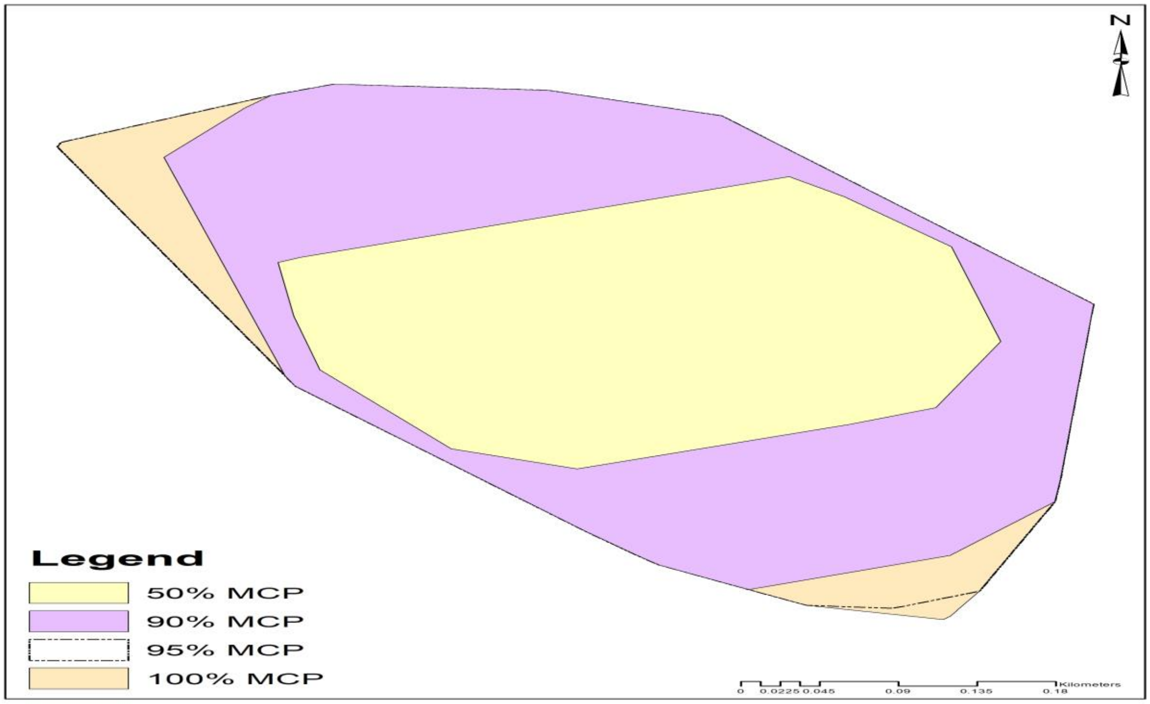

Figure 16. Annual home range size and core area occupied by Group-G using MCP.

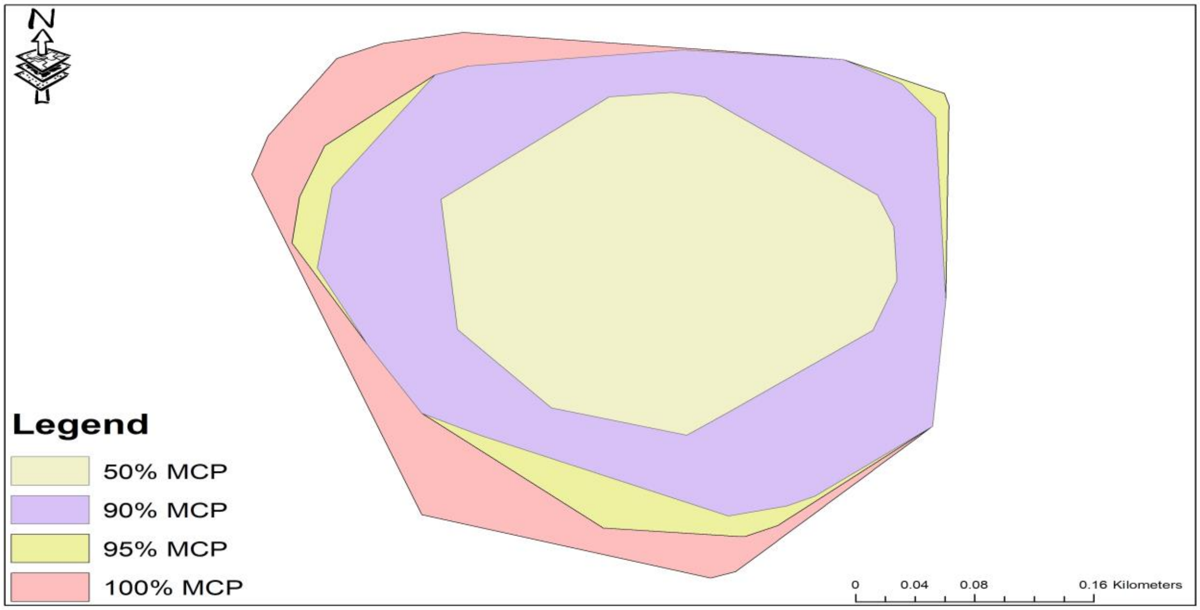

Figure 17. Annual home range size and core area utilizing by Group-A by using MCP method.

Figure 18. Annual home range size and core area of utilized by Group-G using KDE method.

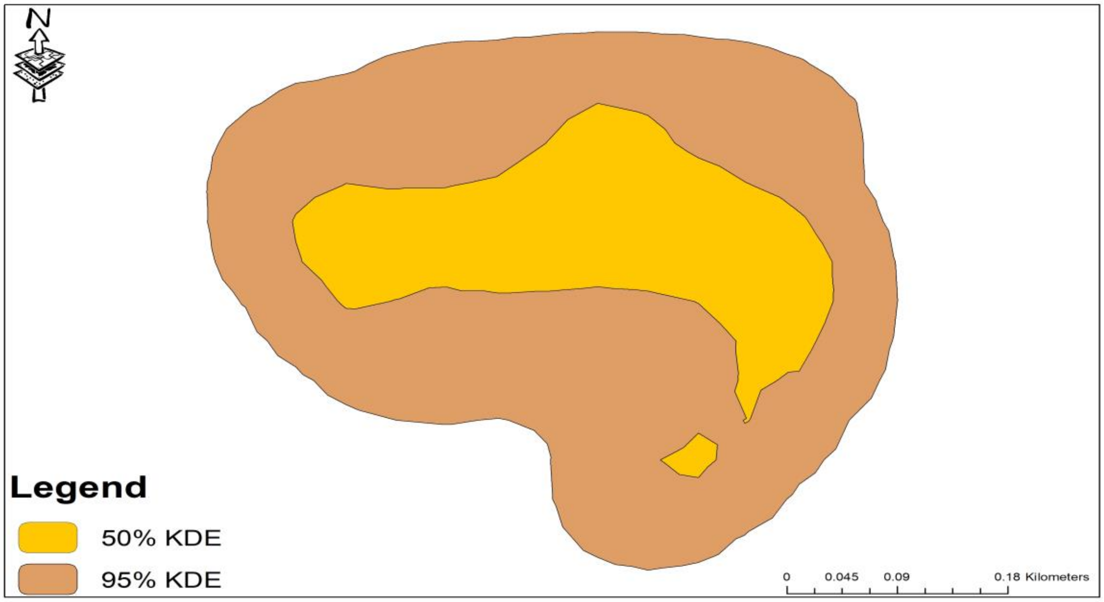

Figure 19. Annual home range and core area utilized by group-A using KDE method.

The home ranges of Garamba Forest group used five habitat types (Fig. 20) while the Afursa Forest group used four habitat types (Fig. 21). Group-G used both mixed bamboo and bamboo forest significantly more than expected based on the percentage representation in the home range. Group-A used tree dominated forest and shrubland more than expected and used grazing land and *Eucalyptus* plantation habitats less than expected (Table 17).

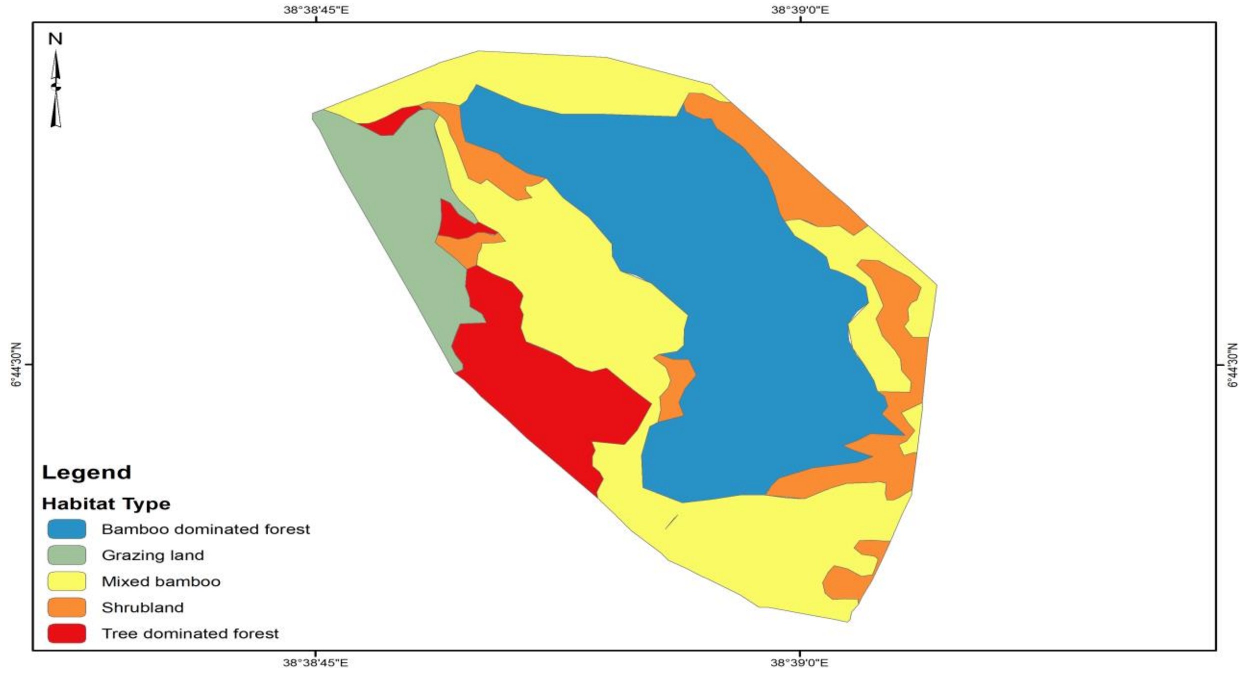

Figure 20. Map of available habitats in the home range of Garamba Forest group Bale monkeys.

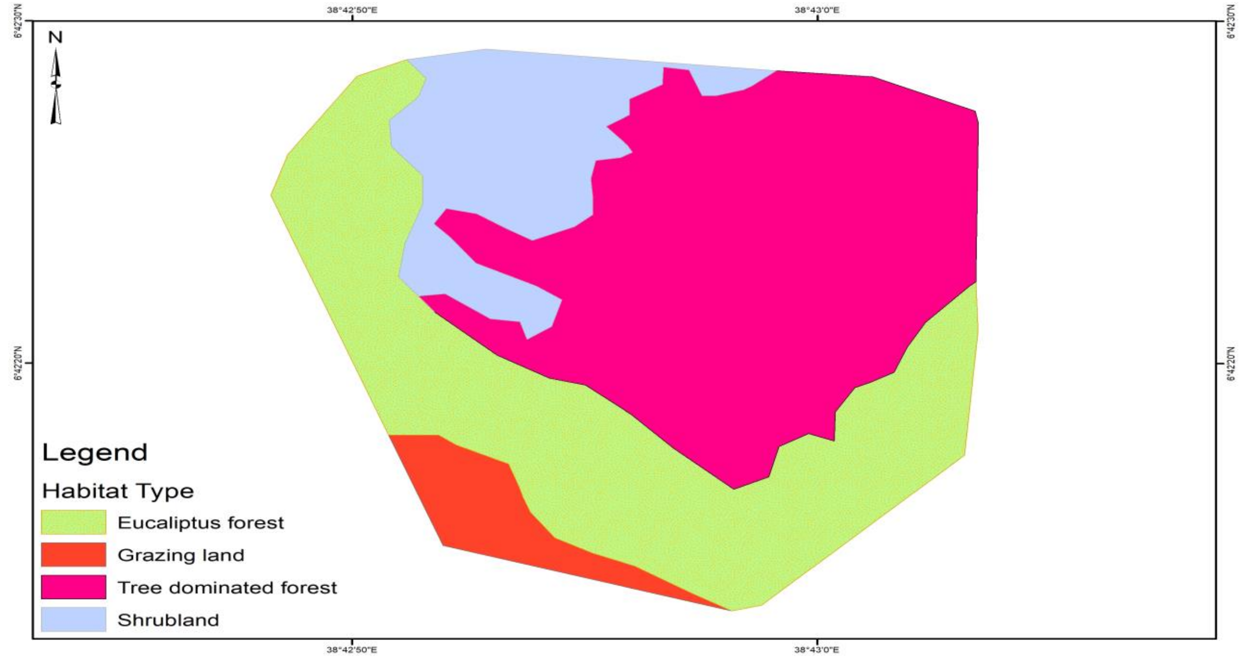

Figure 21. Map of available habitats in the home range of Afursa Forest group Bale monkeys.

Table 17. Differences in the total area of available habitat types (ha) and their percentage representations, observed use (observed number of habitat records), expected use (expected number of habitat records) and selection ratio of each habitat within 95% KDE home range of the study group.

Group	Habitat types	Area (ha)	Area (%)	Observed use	Expected use	Selection ratio	Habitat selection status
Group-G	Bamboo dominated forest	9.46	36.13	987	889	1.11	Selected
	Mixed bamboo	9.26	35.37	1066	870	1.23	Selected
	Tree dominated forest	2.44	9.32	142	229	0.62	Avoided
	Shrubland	2.88	11.00	196	271	0.72	Avoided
	Grazing land	2.14	8.17	69	201	0.34	Avoided
Group-A	Tree dominated forest	7.60	47.15	1446	1216	1.19	Selected
	Eucalyptus forest	5.45	33.81	654	872	0.75	Avoided
	Shrubland	2.16	13.40	422	346	1.22	Selected
	Grazing land	0.91	5.65	58	146	0.40	Avoided

5. DISCUSSION

In this study, many variables like food availability, phenology, population size, activity budget, feeding ecology and ranging ecology were measured and their results were expressed in separate sections. Each of these findings of the parameters is discussed step by step as follows:

Habitat loss and fragmentation resulted in major differences in habitat characteristics, vegetation composition and structure in Sidama highland forest study sites. Plant species that had ≥ 10 cm occurred in greater stem density in the range of Garamba Forest group than in Afursa fragmented forest group. In addition to this, large trees like *Hypericum revolutum*, *Dombeya torrida* and *Maesa lanceolata* were very common in the ranges of Garamba Forest but did not occur in the range of Afursa fragmented forest. The present study results are in line with the report of Dereje Yazezew (2018) stated that selecting cutting of large-sized plant species for timer by illegal loggers and for other construction purposes resulting in the reduction of large trees and domination of the forest by small sized trees/shrubs in disturbed forest than undisturbed forest, and with those from studies of tropical forests elsewhere that showed fragmentation leading to reduction in the availability of large trees, change in tree composition and diversity, and reduction in overall habitat quality (Laurance *et al*., 2000; Arroyo-Rodriguez *et al*., 2007; Addisu Mekonnen *et al*., 2018). This is possibly due to the selective cutting of large-sized tree and bamboo species for timber, other construction purposes illegally by people living around the study area villages of fragmented forest. According to reports of Addisu

Mekonnen *et al*. (2018), bamboo is the main source of food for Bale monkeys and it covers over 80% of diet. Large-sized trees which are food sources for Bale monkeys are facing deforestation, resulting in shrubs and small-sized trees, which will have effects on the sustabability of the forest as well as Bale monkeys.

The Shannon-Wiener species diversity of Bale monkey food plant species in Garamba Forest was lower than Afursa fragmented forest home range. Converslley, the value of Simpson's dominance index was higher for Garamba Forest than that of Afursa fragmented forest providing the lower biodiversity hence the value inverslley related to evenness and richness. In this study, although the fragmented Afursa Forest had high plant species richness, Bale monkey group in Garamba Forest had access to a great abundance of both bamboo and large food tree species, showing that the Garamba Forest had higher habitat quality than Afursa fragmented forest. This finding is similar to the report by Addisu Mekonnen *et al*. (2018) for Bale monkeys where dietary plant species are more diversified in fragments than in continuous forest habitats of southern Ethiopia. Moreover, the finding is also similar to the study in Malagasy forests, which also contain primate bamboo specialists (bamboo lemurs: *Hapalemu* spp.). Habitat destruction has been demonstrated to increase plant species richness, but lower the density of food plants, leading to the reduction in the overall habitat quality for lemurs in forest fragments (Tan, 1999; Grassi, 2006). This finding is contrary to the finding reported by Dereje Yazezew (2018) for guerezas where dietary plant species are diversified in natural forests than in that plantation forest habitats. The possible reason for this difference might be due to

Bale monkeys depending on fast growing pioneer species like fast growing graminoids and forbs rather than large tree species.

The progressive change in resource abundance and availability have fundamental effects on the behavior and ecology of primates (Dunbar, 1988). In this study, food abundance was significantly higher in Garamba Forest than in fragmented Afursa Forest. This might be due to intensive human activity and habitat degradation in fragmented Afursa Forest habitat that led to affect the plant species dominance and structure in the Afursa Forest. This ultimately reduces the availability of food resources and the overall quality of habitats (Tan, 1999; Addisu Mekkonen *et al*., 2018). In the present study, Bale monkeys spent more time feeding on a single plant species *Arundinaria alpina* and less time on graminoid *Bothriochloa radicans* plant species in Garamba Forest while the group of Afursa fragmented forest spent more time feeding on many pioneer species such as graminoids, forbs, shrubs, liana and trees. The graminoids, *Bothriochloa radicans*, species took the largest time compared to all species in fragmented Afursa Forest. This is possibly due to totally eradication of bamboo (*A. alpina*) and large trees which are in turn food sources for Bale monkeys are facing high deforestation, and the forest is dominated by pioneer species like shrubs, graminoids and forbs. This result is in agreement with the reports of Mutschler (1999) and Eppley *et al*. (2015), bamboo specialist *Hapalemur alaotrensis* and *Hapalemur meridionalis* can survive in habitats without bamboo by consuming more species-rich diets in fragments including a high percentage of graminoids. This increased consumption of graminiods by these

Hapalemur species provide an interesting parallel to the Bale monkeys in this study, which also consumed more graminoids at fragmented sites where bamboo is eradicated. This finding suports the hypothesis of this study, when the habitat is fragmented Bale monkeys should adapt new food items.

The present study of population size showed that Bale monkeys occupied three study sites in Sidama highlands. The three study sites differ in altitude and biophysical factors like vegetation compasition. Previous estimates of Bale monkeys were 41 individuals in Garamba, 21 individuals in Afursa, did not list Worbadule Forest of within the site having at Sidama highlands (Addisu Mekonnen *et al*., 2012). In the present study, the actual total count in both historic and new Bale monkey sites showed a mean of 225 ± 8.42 individuals. This result did not show increasing of population size in Sidama highlands rather this study was the first total census made in the study area. The previse study was to check mainly the presence and absence of the species in fragmented highlands of southern Ethiopia. Addisu Mekonnen *et al*. (2012) reported the existence of Bale monkeys in Garamba and Afursa. However, in the present study, new Bale monkeys were recorded in new site at Worbadule natural shrubland.

The density and biomass of many primate species are primarily related to food quality and availability (Chapman and Chapman, 2000; Fashing *et al*., 2007). Reduction in habitat quality due to fragmentation may lower the carring capacity and group size of primates occupying fragmented habitats (Arroyo-Rodriguez and Mandujano, 2006). The finding of this study revealed that the group size of Bale monkeys was high in Garamba

(33.25) than the other two study sites. Group size is associated to food availability (Iwamoto and Dunbar, 1983). Primate groups may split into units when food availability is sparse in a degraded habitat (Iwamoto and Dunbar, 1983). In the present study, small group size of Bale monkeys might be due to the scarcity in food availability (absence of bamboo at Afursa and Worbadule), limited water resource and high human disturbance. Habitat loss, fragmentation and human disturbance might have affected the population size of Bale monkeys in Sidama highlands. Similar findings are reported by Beehner *et al*. (2007) and Arroyo-Rodriguez and Mandujano. (2006), according to their findings, fragmentation-induced reduction in habitat quality may lower carrying capacity and group size, adversely affecting the long term visibility of primates occupying fragments. The findings of this study is comparable with the findings of Addisu Mekonnen *et al*., (2018) who found that the mean group size was high (51.5 individuals per group) in continuouse forests than in fragmented forests (25.5 individuals per group).

Group size in primates is associated with various benefits and costs in relation to food availability and predators (Majolo *et al*., 2008). When group size increases, the chance of individuals to be attacked by predators decreases (Iwamoto, 1979; Majolo *et al*., 2008). However, large groups should face greater competition for food within the group than smaller groups (Majolo *et al*., 2008). Larger groups traveled longer distances per day and spent more time feeding than smaller groups (Iwamoto, 1979; Majolo *et al*., 2008). The mean group size of Bale monkeys was smaller in Worbadule and Afursa than Garamba study site. This may be because of habitat fragmentation and degradation that could not allow the formation of large groups. When habitat becomes fragmented, the availability of resources may not support large group size, leading for the group size to decrease. Onderdonk and Chapman (2000) suggested that the smaller group size of primates in fragments may be due to limitation of resources. Bale monkeys may occupy the available habitat by forming smaller group size at different distances in order to reduce competition over food resources. Thus, the group size in Bale monkeys might be determined by the availability of bamboo forest. Forming small group size might be an adaptation that helps Bale monkeys to survive in human dominated and degraded Sidama highlands as seen in howler monkeys that exist in small isolated habitats as an adaption to form small group size (Ostro *et al*., 1999).

Although there were differences in number of Bale monkeys within a group, the main difference among the present three study sites was the presence of bamboo only at Garamba Forest but all of them are fragmented forests compared to continuous bamboo dominated Bale Mountains Forests. The average group density of Bale monkeys at Sidama highlands was lower than the finding reported by Addisu mekonnen *et al*. (2010b). The relative high density of Bale monkeys in Odobullu Forest may be related to the high abundance and productivity of the main food source, bamboo (Addisu Mekonnen *et al*., 2008). The lower population density and size of Bale monkeys in the current study area might be related to habitat loss and fragmentation, agricultural land expansion and killing of Bale monkeys in response to their crop raiding behavior (Dunbar and Bose, 1991; Kassahun Abie and Afework Bekele, 2017; Kelil Abu *et al*., 2018).

Bale monkeys consist of unequal age-sex ratio with greater number of adult females. The ratio of adult females to Adult males showed with greater number of adult females in all of the study sites compared to adult males. The possible reason may be due to predation pressure and killing adult males causing reduction in male population (Iwamoto *et al*., 1996). At the same time, males depart from their natal groups once they reach sexual maturity (Ohsawa and Dunbar, 1984). The present study is similar with the finding of Dereje Yazezew (2018) and Amera Moges (2019). The presence of accurate data on population count of animals is very crucial for determining future conservation and management of the species (Muoria *et al*., 2003). The current population census of Bale monkeys from Sidama highlands will help to understand the status of Bale monkeys and afforest bamboo forest in the area to ensure the long-term survival of this rare, endemic and endangered primate.

Both groups of Bale monkeys spent most of their time feeding to satisfy their daily energy requirments. The activity budgets resulting from group scan generally are comparable with those of Bale monkey study report by Addisu Mekonnen *et al*. (2018). Bale monkeys in Afursa fragmented forest spent significantly less time feeding and moving while more time resting and travel at a slower rate than the Bale monkey group in Garamba Forest. The present study showed that Bale monkeys in Afursa Forest adopt an energy minimization strategy, in response to the lower overall food availability at fragmented forest. This is in line with the reports of Addisu Mekonnen *et al*. (2018) on

Bale monkeys and Palma *et al*. (2011) on *Alouatta palliata*. This strategy helps cope with the limited abundance and low quality of food resources in fragments.

Diurnal primates allocate their time for different activities as availabile hours of daylight are limited and diurnal primates allocate the day time into feeding, moving, resting, socializing and other activities (Hill *et al*., 2004; Dunbar *et al*., 2009). The present study showed that Bale monkeys at Sidama highlands begin their dirnal cyclic activities early in the morning (0700 h). Feeding pattern peaks late morning and afternoon and resting peaks during morning and mid-day to adapt temprature variation (Zhou *et al*., 2007). This is similar to the findings of Dereje Yazezew (2018) on guerezas, Amera Moges (2019) on Arsi geladas in Ethiopia and other studies reported by Dunbar (1977) and Iwamoto (1993). The present study also showed that Bale monkeys in Sidama highlands move fast late in the mornning, after peak resting and socializing, to feed and during evenning returnning to their sleeping site. Similar findings were reported by Amera Moges (2019) and Dunbar (1978) that geladas always move more when ascending the cliff top in the mornning and descending to their sleeping cliff site early in the evenning.

Activities in age-sex categories of Bale monkeys spent different time budgets. Primates often differ in acivities between males and females (Isbell and Young, 1993). Different studies showed that adult females spent more time feeding than adult males to increase the metabolic demands for pregnancy and lactation (Hunter, 2001). Studies indicate that monkeys with pregnant or lactating females tend to consume more diets (Gautier Hion, 1980; Dunbar *et al*., 2002). Lactating females sent more time feeding than non-lactating females (Dunbar and Dunbar, 1988). Altman (1980) suggested that female primates devote increasing time to feeding to offset the increasing demand of lactation. A lactating mammal must increase her nutritional intake up to two-fold (Randolph *et al*., 1977). Vasey (2005) found that lemur adult females use energetic costs associated with pregnancy and lactation. The present study showed that adult females spend more time feeding and socializing but lower time moving and resting than adult males, similar to the fingings reported by Hunter (2001) and Amera Moges (2019). Socializing time was higher in female than male geladas in Sankaber. Reed *et al*. (1997) mentioned that a leader male in macaque spent more time resting than other males. In the present study juveniles spent high time in socializing, playing in peer within the same group and low time for resting. Similar finding was reported by O'Brien and Kinnaird (1997) that juvenles of macaques spent the highest time in socializing (playing) and lowest time in resting.

Primates can regulate their time budgets in response to seasonal changes at low food availability and climate change (Li and Rogers, 2004). Studies showed that animals are exposed to more stressful conditions during the dry season (Hemingway and Bynum, 2005). Feeding budgets of Bale monkeys in Sidama highlands was high during both wet and dry seasons, suggesting low food quality and availability during both seasons increased feeding time to get the required amout of nutrients. The possible reason that Bale monkeys spent more time feeding than any other activities during the wet season than the dry season in the present study areas maight be, Bale monkeys may require more energy for thermoregulation during the wet season like other primates (*Geladas*: Iwamoto and Dunbar, 1983). Similar fingings were reported by different resaerchers: Felton *et al*., (2008) reported that some primates spent more time feeding during the rainy season. Amera Moges (2019) reported a similar finding that geladas consumed more during cold weather for thermoregulation. A similar finding is also reported by Zewdu Kifle *et al*. (2013) in harsh areas where feeding activity of geladas was low during the dry season. According to their findings, primates required more energy during wet season than dry season for thermoregulation.

In this study, the total number of dietary species identified as food source for Bale monkeys in Sidama highlands were 46 belonging to 30 families. The species richness of primate diet in fragments mostly differs compared to continuous forests. In this study, Bale monkeys showed remarkable dietary diversity in Afursa fragmented forest (32 species) than Garamba Forest (14 species). A comparable finding was reported by Rivera and Calme (2006) who fund that species richness of *Alouatta pigra* diet was higher in the group inhabiting fragmented forest (16 species) than the group inhabiting continouse forest (10 species). Similar finding was also reporded by Dereje Tesfaye *et al*. (2013) on *Cercopithecus mitis boutourlinii*, showed that ditary species richness was higher in the group inside the fragmented forest (33 species) than in the continouse forest (24 species). It is also similar to the finding of Addisu Mekonnen *et al*. (2018), on *Chlorocebus djamdjamensis*, dietary species richness was higher in groups inhabiting forest fragments (patchy area ≥ 47 species, hilltops ≥ 35 species) than groups inhabiting continuous forest (continuous B = 8 species). Habitat loss and fragmentation resulted in major differences in habitat characterstics, vegetation composition and structure in Sidama highland forest study sites. The present findings are similar with those studies of Addisu Mekonnen *et al*. (2018) from southern Ethiopia and studies of tropical forests elsewhere showing that habitat loss and fragmentation lead to reduction in the availability of large food trees, changes in tree composition and diversity as well as reduction in overall habitat quality (Laurance *et al*., 2000; Arroyo-Rodriguez *et al*., 2007).

The bamboo specialist Bale monkeys spent more time feeding on bamboo young leaves and shoots to satisfy their daily energy requirments in continuous forests (Addisu Mekonnen *et al*., 2012). Habitat loss and fragmentation affect plant species richness, diversity and structure of continuouse forests when converted into fragmented forests (Marsh, 2003). In the present study, Bale monkeys in Afursa fragmented forest, in which bamboo is totally eradicated, exploited many of these pioneer species. Broadening their diet to include a great diversity of plant species and growth forms than groups inhabiting Garamba Forest is an adaptation for survival. This finding is similar with the finding reported by Addisu Mekonnen *et al*. (2018) in which Bale monkey groups that live in fragments supplemented their diets with alternative food resources including shrubs, forbs, graminoids, and even cultivated foods. This high level of dietary diversity is an aset for Bale monkeys to cope with fragmented forests and food scarcity which otherwise would make Bale monkeys highly vulnerable.

Primates may select certain foods based on accessibility, economic exploitation, availability throughout the year and nutritional content. Primates living in fragments frequently eat a higher percentage of leaves than groups living in continuous forests (Chaves *et al*., 2012; Chaves and Bicca-Mrques, 2016). Bale monkeys, however, consumed a lower percentage of leaves in Afursa fragmented forest than in Garamba Forest. This is because of the absence of bamboo in Afursa Forest. In Afursa Forest, Bale monkeys modified their diet by increasing consumption of fruits, stems, petioles and insects as well as leaves of many plant species. However, the higher fruit consumption in Afursa Forest occurred despite fruits being highly available in Garamba Forest than in Afursa Forest. This is in line with the finding of Addisu Mekonnen *et al*. (2018), who stated that Bale monkeys in fragments consumed less percentage of leaves than groups inhabiting continuous forests. Bale monkeys in fragments modify their diet by increasing their consumption of fruits, stems, petioles, and insects as well as leaves despite higher fruit consumption in fragmented forests than continuous forests (Addisu Mekonnen *et al*., 2018).

Bale monkeys in Afursa Forest consumed more secondary growth form species, shrubs, graminoids and forbs, getting more than 56% of their diet from these species. This finding is similar to the findings reported by Arroyo-Rodriguez *et al*. (2007), Chaves *et al*. (2012), Dunn *et al*. (2012) and Addisu Mekonnen *et al*. (2018) where more than half of their diet was obtained from secondary growth forms like shrubs, forbs and graminoids. This is also a common dietary response to habitat loss and fragmentation to consume more secondary growth forms (Bicca-Marques, 2003; Grassi, 2006; Irwin, 2008).

When dietary flexibility of Bale monkeys relative to other *Chlorocebus* species is compared, *Chlorocebus* species are well-studied (Willems, 2007). Among *Chlorocebus* species, Bale monkeys (*C. djamdjamensis*) are unique in their diet depending heavily on the young leaves and shoots of bamboo in relatively undisturbed continuous forests (Addisu Mekonnen *et al*., 2018). The present finding showed that *Chlorocebus djamdjamensis* that live in Afursa fragmented forest consumed diets more comparable to those of the other less specialized *Chlorocebus* species than to Garamba Forest and continuous forests of Bale Mountains. The percentage of fruits and graminoids consumed by *C. djamdjamensis* in Afursa Forest was similar to those reported for East African *Chlorocebus pygerythrus* populations (Appendix III), and level of invertebrates (insects) consumed by Afursa Forest group (12.35%) was similar to those reported for West African generalist species of *Chlorocebus sabaeus* (13.1%) than the *C. djamdjamensis* (3.8%) that live in Garamba Forest (Appendix III). This dietary flexibility shown by *C. djamdjamensis* in Afursa Forest may retain some of the ancestral ecological flexibility characteristic of other members of the genus *Chlorocebus*, expressing this plasticity when habitat loss and fragmentation require to diversify diets when bamboo species, the main source of diet, is fragmented or eradicated (Addisu Mekonnen *et al*., 2018).

In the present study, Garamba Forest group made significantly longer daily travel distance (DTD) compared to Afursa Forest group. This might be due to the smaller core area size available in Afursa Forest group surrounded by cultivated lands and human settlements forcing them to have shorter DTD. However, the monkeys did not increase their daily travel distance (DTD), percentage of time moving or their travel rate during the period of low food availability though these variables are expected to force them to visit additional food sources each day. Accordingly, there is no indication that Bale monkeys devoted additional effort for finding more food sources by ranging further or traveling more when food sources are less abundant, as reported by Di Fiore (2003) for woolly monkeys, Dereje Yazezew (2018) for guerezas and Addisu Mekonnen *et al*. (2018) for Bale monkeys, but switched feeding preferences to more available food items and reduced the time spent for moving. This may be due to balance between the energetic benefit of obtaining food and energetic costs of moving longer to obtain food (energy minimization) (Isbell, 1991). In addition to home range size, differences in food abundance and quality across sites, daily ranging may be physiologically constrained in primates due to high consumption of low energy food (Milton, 1980).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Worbadule new site shows that there are still Bale monkey populations that remain unknown by researchers in human-dominated Sidama Mountains. Bale monkeys in Afursa and Worbadule fragmented Sidama highlands are distributed in a limited and fragmented patch with small population size, experiencing low food availability and habitat quality relative to those in Garamba Forest. The small group size populations of Bale monkeys observed in Afursa fragmented forest and Worbadule shrubland may be optimal size in which foraging efficiency is maximized for the habitat as a survival strategy.

The finding of this study also indicates that Bale monkeys can respond to habitat loss and fragmentation by being flexible in their diet, by replacing bamboo with more alternative food items such as graminoids, shrubs, lianas and forbs. They also exploit more other resources in human-altered landscapes. Plasticity in activity budgets and patterns, diets and ranging ecology that helps them to minimize energy, are key factors for the survival strategy of Bale monkeys in fragmented and human-dominated highlands.

The high diversity in consumption of different food species is an adaptation to survive in fragmented and human dominated highlands. Anthropogenic habitat alteration can affect the availability, distribution and quality of food resources. This has directly or indirectly affected Bale monkeys living in human-modified habitats. *Galiniera saxifraga* and *Rubus* *apetalus* are recognized as major fruit resources for Bale monkeys living in Afursa Forest, and the fruiting patterns of both plant species result in a reliable food source for Bale monkeys during dry season for food scarcity. Bale monkeys are the only specialized members of a genus, *Chlorocebus* while the others are ecological generalists, it is hypothesized that Bale monkeys have retained the ancestral *Chlorocebus* ability to fall back on a generalist diet where bamboo is totally eradicated.

6.2. Recommendations

Based on the findings of this study, the following recommendations are forwarded to ensure the sustainable and long term survival of Bale monkeys and their habitats (bamboo forest):

- Bamboos should be afforested and conserved since it contributed more than 80% of Bale monkeys' diet in continuous forests.
- Big trees like *Galiniera saxifraga* and *Dombeya torrida* should be conserved since their fruits and flowers are food sources and sleeping sites of Bale monkeys.
- Regular long-term population monitoring and conservation actions should be carried out to ensure Bale monkeys persistence and to determine their population trend in human- dominated Sidama highlands.
- It is important to test the impacts of predator risk on the habitat selection of Bale monkeys in human-dominated Sidama highlands

- A community-based conservation education and outreach program is essential to improve the awareness of local people and to develop positive attitude towards the conservation of Bale monkeys and their habitats.
- The federal and local governments, rural development and agricultural offices and wildlife authorities should be responsible to prepare conservation strategies to protect the vulnerable and little known Bale monkeys and its habitat.
- The promotion of tourism activities should be undertaken in Sidama highlands to develop positive attitudes and change the perceptions of the local farmers towards Bale monkeys and biodiversity of the area.
- Local people would benefit from new jobs and might be encouraged to participate in the income-generating programs that might improve their socioeconomic conditions.

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Appendices

Appendix I. Commonly found edible and non-edible plant species in the study area (Sidama highlands).

Family	**Species consumed**	**Growth forms**
Poaceae	*Arundinaria alpina*	Bamboo
Sterculiaceae	*Dombeya torrida*	Tree
Myrsinaceae	*Maesa lanceolata*	Tree
Rubiaceae	*Galium spurium*	Forb
Acanthaceae	*Acanthopale pubescens*	Forb
Hypericaceae	*Hypericum revolutum*	tree
Oleaceae	*Olea africana*	tree
Ericaceae	*Erica arborea*	tree
Apocynaceae	*Acokanthera Schimperi*	tree
Poaceae	*Bothriochloa radicans*	Graminoid
Rubiaceae	*Galiniera saxifraga*	Tree
Rosaceae	*Rubus apetalus*	Shrub
Rosaceae	*Hagenia abyssinica*	Tree
Asteraceae	*Bothriocline schimperi*	Shrub
Apiaceae	*Centellia asiatica*	Forb
Aquifoliaceae	*Ilex mitis*	Tree
Urticaceae	*Urera hypselodendron*	Liana
Apiaceae	*Haplosciadium abyssinicum*	Forb

Poaceae	*Cynodon dactylon*	Graminoid
Commelinaceae	*Commelina sp.*	Forb
Asteraceae	*Crassocephalum macropappus*	Forb
Fabaceae	*Trifolium tembense*	Forb
Poaceae	*Poa annua*	Graminoid
Lamiaceae	*Plectranthus alpinus*	Forb
Urticaceae	*Pilea rivularis*	Forb
Cupressaceae	*Juniperus procera*	Tree
Asteraceae	*Vernonia rueppellii*	Shrub
Balsaminaceae	*Impatiens hochstetteri*	Forb
Caryophyllaceae	*Drymaria cordata*	Forb
Asteraceae	*Mikaniopsis clematoides*	Liana
Poaceae	*Zea mays*	Graminoid
Asteraceae	*Carduus schimperi*	Forb
Rosaceae	*Alchemilla fischeri*	Forb
Solanaceae	*Discopodium penninervium*	Tree
Asteraceae	*Echinops sp.*	Forb
Urticaceae	*Girardinia bullosa*	Forb
Capparaceae	*Ritchiea albersii*	Tree
Urticaceae	*Urtica simensis*	Forb
Crassulaceae	*Crassula alsinoides*	Forb

Myrtaceae	*Eucalyptus*	Tree
Rubiaceae	*Canthium oligocarpum*	Tree
Oleaceae	*Jasminum abyssinicum*	Shrub
Balanitaceae	*Balanites aegyptica*	Shrub
Ebenaceae	*Euclea racemosa*	Shrub
Anacardiaceae	*Rhusg lutinesa*	Shrub
Asclepiadaceae	*Oxystelma bornouense*	liana
Vitaceae	*Cypostemma adenocaule*	liana
Apiaceae	*Agrocharis melanantha*	Forb
Polygonaceae	*Rumex nepalensis*	Forb

Appendix II. List of animal species recorded from Sidama highlands during the study period

No.	Common name	Family name	Scientific name	Local name
1.	Common Duiker	Bovidae	*Sylvicapra grimmia*	Mdakua
2.	Crested Porcupine	Hystricidae	*Hystrix cristata*	Jart
3.	Menelik's bushbuck	Bovidae	*Tragelaphus scriptus Meniliki*	Yeminilik Duculla
4.	Rock Hyrax	Hyracoidae	*Procavia capensis*	Shikoko
5.	Starck;s Hare	Leporidae	*Lepus starckii*	Tinchel
6.	Spotted Hyaena	Hyaenidae	*Crocuta crocuta*	Jib
7.	Leopard	Felidae	*Panthera pardus*	Aner
8.	Black and white clobus	Cercopithecidae	*Colobus Guereza*	Gueraza
9.	Common Jackal	Canidae	*Canis aureus*	Tekula
10.	Gelada Baboon	Cercopithecidae	*Theropithecus gelada*	Tikur zinjero
11.	Abyssinian Genet	Herpestidae	*Genetta abyssinica*	Shelemetemat
12.	White tailed mongoose	Herpestidae	*Ichnumia albicauda*	Faro

Appendix III. Percentage of food items consumed by genus *Chlorocebus* populations, from different long-term field studies.

Species	Study period	Group (n/name)	BYL	NB YL	BSH	TL	FR	FL	AP	No. spp.	Site, Country	Reference
Chlorocebus djamdjamensis	12	RCF	51.02	3.42	12.15	66.41	12.9	9.26	3.8	14	Garamba(CF), Ethiopia	This study
Chlorocebus djamdjamensis	12	FF	0	36.7	0	36.7	22.5	2.34	12.35	32	Afursa(FF), Ethiopia	This study
Chlorocebus djamdjamensis	12	CA	57.7	3.1	19.7	81.7	7.5	6.0	3.3	12	Odobullu (CF), Ethiopia	Addisu Mekonnen *et al*., 2018
Chlorocebus djamdjamensis	8	2	73.0	7.2	1.5	82.8	9.6	3.1	2.3	11	Odobullu (CF), Ethiopia	Addisu Mekonnen *et al*., 2010.
C. pygerythrus	9	3	0.0	-	0.0	26.6	13.7	0.0	7.7	-	Amboseli, Kenya	Wrangham and Watterman, 1981

C. pygerythrus	26	1	0.0	-	0.0	8.3	25.4	44.7	0.0	-	Saumburu-Isiolo, Kenya	Whitten,1983
C. sabaeus			0.0	-	0.0	-	63.0	13.0	13.1	-	Mt. Assirik, Senegal	Harrison, 1983
C. tantalus	11	1	0.0	-	0.0	20.5	49.2	5.3	25.1	28	Ngel Nyaki, Nigeria	Agmen *et al*., 2010

BYL= bamboo young leaves, BSH= bamboo shoots, NBYL= non-bamboo young leaves, TL=total leaves FR= fruits, FL=flower, ST= stems, AP= animal prey. Habitat: CF= continuous forest, RCF= relatively continuous forest, FF= fragmented forest.

Plate 2. View of agricultural expansion around Sidama highlands

Plate 3. DBH measuring and height estimate of plants

Plate 4. Different pictures from the field.

Bamboo used for house and fense construction

Sleeping site of researcher and field asistants in Garama Forest study site

Reasearcher with field asistants in the field

Feeding of Bale monkeys in Eculyptus plantation and grazing lands

Bamboos in the market for the source of income and also transported to other areas