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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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Full Length Research Paper

A study on Ichthyofaunal diversity of Sagar lake, Madhya Pradesh, India

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The objective of the present study was to report the ichthyofaunal diversity of Sagar lake Madhya Pradesh, central India. During the study, a total of 21 species of freshwater fishes belonging to 6 orders, 11 families and 17 genera were recorded from the study sites of the lake. Family Cyprinidae, contributing about 48% of the fish diversity of the lake, was found to be the most abundant family of the fishes. According to Conservation Assessment and Management Plan (CAMP) Conservation status among 21 species, 2 are endangered, 5 are vulnerable, 10 are at lower risk- near threatened status, 1 lower risk least concern and 3 non evaluated. The study also shows a tremendous decrease in the ichthyofaunal diversity of the lake during the last decade.

Key words: Fish diversity, conservation status, Sagar lake.

INTRODUCTION

Fish constitute more than a half of the total number of all other vertebrates in the world. Out of 64,000 vertebrates, 32,900 species of fish had been described by November 2014 (Froese and Pauly, 2014). India has offered a large variety of water bodies and habitats to aquatic life. Its coastal marine waters, river systems, streams, different wetlands, lakes and ponds of different water quality, at different altitudes have favoured the development of a species-rich fish fauna with a large variety of adaptations. Therefore, India is today a megadiverse in fish fauna and occupies 9th position in terms of fresh water biodiversity. There are about 2,546 species of fishes (about 11% of the world species) found in Indian waters. Central India harbor a wide variety of freshwater fishes in its diverse water resources such as streams, rivers, reservoirs, sub-terrain aquatic ecosystems, traditional lakes and domestic ponds. Study of fish fauna in Madhya Pradesh started with the work of D' Abrue (1925). Later several workers studied the fish fauna of Madhya Pradesh which include Hora (1938, 1940), Hora and Nair (1941), Dubey and Mehra (1959), Mathur and Mishra (1976), Karmakar and Datta (1988), Desai (1994), Desai et al. (1997), Sharma (2007, 2008, 2009), Thilak (2009, 2011), Vyas et al. (2012), Dongre et al. (2012), Paunikar et al. (2012), and Uchchariya et al. (2012). The suggestions for fish conservation are sure to come out only after the depth study of their biodiversity. The objective of the present study was to document the fish fauna of Sagar lake located almost at the centre of India.

MATERIALS AND METHODS

Sagar lake is situated in the heart of Sagar city (23°50'N 78°45'E 517m) with an area of 82 hectares (Figure 1). The entire lake can be divided into two parts; the main lake occupying an area 68

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Figure 1. Sattelite image of Sagar lake showing three sampling stations. A: chakra ghat area, B: Sanjay drive area, C: Fisheries department area.

hectares and a small wetland of 14 hectares.

The present study was carried out from March 2012 to April 2014. The fish were collected monthly from three sampling sites of the lake (Sanjay drive area, Chakraghat area and Fishery department area) as shown in Figure 1, with the help of local fishermen using cast nets during days and gill nets installed over nights applying the fish collection methods of Arunachalam (2000). The fish samples were then preserved in 4% formalin and brought to laboratory for identification. Systematic identification of the fish species were carried out by using the standard keys of Talwar and Jhingran (1991) and Jayaram (1999). Threat status of each fish was made according to the report on Conservation Assessment and Management Plan (CAMP) for freshwater fishes of India (Molur and Walker, 1998) and Red List of Threatened Species by (IUCN, 2014). The relative abundance of the fish was classified into three categories: Abundant (+++) constitute 71-100% of total catch, Moderate (++) constitute 36-70% of the total catch and Rare (+) constitute 1-35% of the total catch, assuming the fishing efforts constant for each catch.

RESULTS AND DISCUSSION

During the two years of an extensive study, a total of 21 species of freshwater fishes belonging to 6 orders, 11 families and 17 genera were recorded from the study sites of the lake. The species found in the lake, their taxonomic distribution, threat status and relative abundance is given in Table 1. The most abundant family of the fishes, Cyprinidae was represented by 10 species contributing about 48% of the fish diversity in the lake. The percent contribution of other families is shown in Figure 2. According to CAMP report, among 21 species, 2 are endangered, 5 are vulnerable, 10 are at lower risk-near threatened status and according to IUCN 2014 report 3 species are near threatened, 16 are at least concern and 2 are not evaluated.

The previous studies on fish diversity of Sagar lake have mentioned 41 species belonging to 25 genera and 13 different families (Tiwari, 2006). The present data when compared with the earlier data on ichthyofaunal diversity of Sagar lake recorded not more than a decade ago shows a tremendous decrease in the ichthyofaunal diversity of this lake. *Puntius ticto, Puntius conchonius* and *Puntius sophore* are the most abundant species found throughout the lake. All the species were found equally distributed throughout the lake however *P. sophore* was found in abundance in the small wet land portion of the lake. Some species like *Xenentodon cancila, Puntius sarana, Rasbora daniconius* and *Mastacembelus armatus* are very rare and are about at the verge of extinction from the lake. The fish farmers have started to cultivate some species like *Catla catla, Labeo rohita* and *Cirrhinus mrigala* in the lake for economical purposes.

The introduction of exotic fish *Oreochromis niloticus* a decade ago was a great success as it grows widely, but it may be one of the several causes for dwindling of fish biodiversity of the lake. The exotic fish pose a threat to indegenious fish species (Mukherjee et al., 2002). So, continuous monitoring of non-indigenous species should be done to avoid their negative impacts (Galib et al., 2013).

The other reasons for the depletion of the fish species are pollution and indiscriminate exploitation of fish. The pollution of the Sagar lake is a matter of concern, sedimentation and the spread of weeds pose serious threat to the fish fauna of this lake. Therefore there is a

Table 1. List of fish species from Sagar lake with their conservation status and abundance in the lake.

Taxonomical rank	Scientific name	Abundance	CAMP status	IUCN status
1. Order: Siluriformes				
Family : Siluridae	*Ompok bimaculatus*	+	EN	NT
	Wallago attu	+	LR-nt	NT
Family : Bagriidae	*Mystus vittatus*	++	VU	LC
Family : Heteropneustidae	*Heteropneustes fossilis*	++	VU	LC
2. Order: Osteoglossiformes				
Family : Notopteridae	*Notopterus notopterus*	++	EN	LC
3. Order: Synbranchiformes				
Family : Mastacembelidae	*Mastacembelus armatus*	+	VU	LC
4. Order: Cypriniformes				
Family : Cyprinidae	*Puntius conchonius*	+++	LR-nt	LC
	Puntius ticto	+++	LR-nt	LC
	Puntius sarana	+	VU	LC
	Puntius sophore	+++	LR-nt	LC
	Catla catla	*	VU	NE
	Labeo rohita	*	LR-nt	LC
	Cirrhinus mrigala	*	LR-nt	NE
	Rasbora rasbora	+++	LR-nt	LC
	Rasbora daniconius	+	LR-nt	LC
	Chela laubuca	++	LR-lc	LC
Family: Cobitidae	*Lepidocephalichthys guntea*	+++	NE	LC
5. Order: Beloniformes				
Family : Belonidae	*Xenentodon cancila*	+	LR-nt	LC
6. Order: Perciformes				
Family : Gobiidae	*Glossogobius giuris*	+++	LR-nt	LC
Family : Cichlidae	*Oreochromis mossambicus*	+++	NE	NT
Family : Ambassidae	*Parambassis ranga*	++	NE	LC

EN = Endangered; VU = Vulnerable; LR-lc = Lower risk least concern; LR-nt = Lower risk near threatened; NE = Not evaluate; LC = Least concern; NT = Near Threatened; +++ = Abundant ++ = Moderate; + = Rare; * = cultivated in the lake.

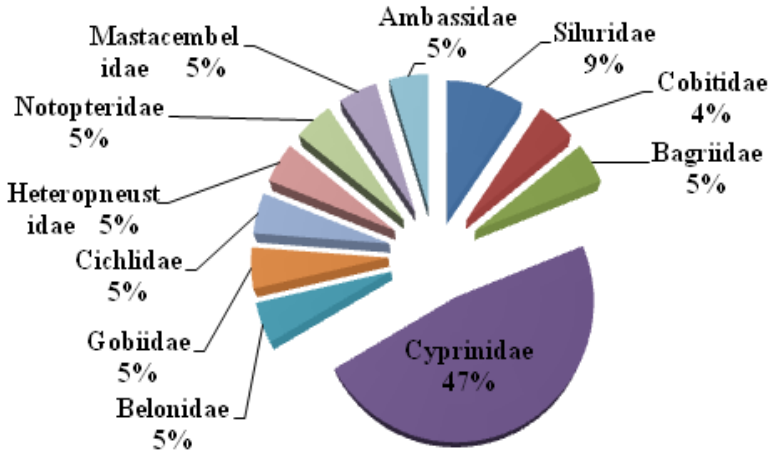

Figure 2. Percent contribution of families towards ichthyofaunal diversity of the lake.

pressing need to give special attention for the conservation of fish diversity of the lake.

Simmilar studies were also reported from two Lakes of Kumaon, Uttarakhand (Negi and Rajput, 2012), Changhoz Dam, Pakistan (Khan and Hassan 2011), Vattakkayal lake (Seethal et al., 2013). These studies are about exploring the ichthyofaunal diversity of different water bodies, present their threat status, abundance and taxonomic distribution. Such studies provide the first hand assessment to understand and conserve the fish diversity of their water bodies.

Conflict of interests

The authors did not declared any conflict of interests.

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Full Length Research Paper

Threats of biodiversity conservation and ecotourism activities in Nechsar National Park, Ethiopia

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This study was carried out on the threats of biodiversity conservation and ecotourism activities in Nechsar National Park (NSNP), Arba Minch, Ethiopia. Data was collected from protection staffs and local communities found in and around the boundary of the national park. Open ended and close ended questionnaires, focused group discussion and field observation were used to collect all the necessary information. Protection staffs interview revealed that illegal fishing (100%), fuel wood collection (100%) and charcoal production (92.0%) were among the major problems of biodiversity in the study area. On the other hand, the data obtained from the villagers showed that 58.5 and 37.8% of them were involved in fuel wood collection and livestock grazing, respectively. Poor salary (96.0%), inadequate staffing (88.0%), lack of equipment (96.0%) and poor infrastructure (96.0%) were also among the major management problems that hinder the motivation of the park management staffs. Based on our research results, we could say that there is a rapid growing ecotourism activity in the study area. However, the long term effects of human threats to biodiversity had resulted and can have negative implications on the ecotourism activities and biodiversity of the study areas in the future.

Key words: Biodiversity threats, conservation, ecotourism, Nechsar national park.

INTRODUCTION

Biodiversity is the variety of life, in all of its many manifestations encompassing all forms, (plants, animals and microorganisms) and at all levels of biological organization which includes genetic diversity, species diversity and ecosystem diversity (Christ et al., 2003; Gaston and Spicer, 2004; Meduna et al., 2009; CBD, 2012). The earth's biodiversity constitutes valuable natural resources in economic, cultural, aesthetic, scientific and educational terms, providing enormous amounts of both monetary and non-monetary benefits to humankind (Groombridge, 1992; Howard et al., 2000; Hockings, 2003; Hockings et al., 2005; Leverington et al., 2010; Kolahi et al., 2012). Nature conservation is among the top priorities of most members of the international community in the 21st century (Kolahi et al., 2012). Their conservation and management are critical to the interests of all nations and governments (Dudgeon et al., 2006). Protected areas (PAs) play critical roles in safeguarding biodiversity and maintaining the crucial services provided by the natural systems. They have an important role in the evolving challenge of maintaining a sustainable world (Borrie et al., 1998; Groombridge, 1992). Currently, more than 161,991 areas have been reported as PAs in the World Database of Protected Areas and the number

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continues to increase (Kolahi et al., 2013). PAs have long been the only way to conserve ecological regions from the other forms of land use (EEA, 2010). For example, they have significantly lower rates of clearing compared to locations outside their boundaries and to conditions before they were gazetted, although clearing is still significant, especially in the African and Asian regions (Leverington et al., 2010; Nagendra, 2008). Protected areas are therefore the cornerstone of most national strategies to protect biodiversity and natural resources (Hockings et al., 2005; Leverington et al., 2010) playing a key role in the sustainable utilization and attainment of natural resources.

There is a growing evidence of critical biodiversity breakdowns both inside and outside of many PAs (Hockings et al., 2002; Dudley et al., 2004; Fischer, 2008; Butchart et al., 2010). Accordingly, many PAs are presently being degraded and destroyed (Hockings, 2003; Dudley et al., 2004). In most developing countries, PAs are under pressure from anthropogenic activities and lack proper management and maintenance (Kolahi et al., 2102). Overpopulation and overconsumption (Eldredge, 2002; Kolahi et al., 2012), habitat loss, fragmentation, and invasive species (Christ et al*.,* 2003; Meduna et al*.,* 2009), associated with socioeconomic problems and policy failures, weak government structure, policy, and legislation, low morale, and inadequate funds are underlying causes of biodiversity loss (Braatz, 1992; Eldredge, 2002).

Ethiopia is known for its faunal and floral diversity with an estimated 6500–7000 species of plants of which 2% are considered endemic (Tewolde Berhan, 1991; Mohammed and Ababu, 2003; Melaku Tefera, 2011). From the total land area coverage of the country, PAs such as national parks, sanctuaries, controlled hunting, open hunting, wildlife reserves and community conservation areas shares about 15% only (BIDNTF, 2010). These include 15 national parks, four wildlife sanctuaries, seven wildlife reserves and 18 controlled hunting grounds (Mohammed and Ababu, 2003; James, 2012). Despite these diversities, there have been many setbacks. The biodiversity of Ethiopia has recently received appropriate recognition. The majority of the country now falls into two Biodiversity Hotspots; the Eastern Afromontane Hotspot comprise over 50% Ethiopian Highlands and the Horn of Africa Hotspot in which greater than 40% of it falls within Ethiopia. However, these areas are among the most threatened Hotspots in the world in that an estimated 97% of the natural vegetation of Ethiopian Highlands has been lost. Consequently, status of protected areas in Ethiopia is reported to be relatively poor, exist on paper only (Jacobs and Schroeder, 2001; Solomon et al., 2012) and severely damaged during or after the civil war that brought the current government to power. Many studies revealed that livestock grazing and poaching are the major problems affecting biodiversity in the protected areas. Besides, insufficient funding for park management and poor salary pay for protection staff could contribute limitations and less attention regarding the conservation of biodiversity (Meduna et al., 2009; Solomon et al., 2012).

Ecotourism has been considered as the impetus and economic investment for management of natural resources (Kolahi et al., 2013). Another important aspect of ecotourism is the encouragement of active participation by the local population in the conservation and education dimensions (Aramde et al., 2012). Currently, ecotourism is becoming the fastest growing segment of tourism. On a global scale, ecotourism is growing because of its international appeal (Lowman, 2004). An estimated 1.035 billion people from all cultures and all walks of life participate in different kinds of tourism, spending over US$ 1.075 trillion (UNWTO, 2013) comprising 11% of world gross national product (GNP) if related activities 'tourism and general travel' are included (Roe et al., 2004).

The basis of Ethiopia's tourism product is cultural, historical and natural sites where the biggest challenge currently is to preserve the historic sites from natural decay and the national parks from degradation by the local communities that live around or inside them (World Bank, 2006). Although, Ethiopia currently ranks 19th among African countries in tourist destination, the long-term vision of the government is to make Ethiopia one of the top ten tourist destinations in Africa by the year 2020, with an emphasis on maximizing the poverty-reducing impacts of tourism, and utilizing tourism to transform the image of the country (World Bank, 2006).

NSNP, incorporates many biodiversity resources as well as supporting the livelihood of both the national and local users, and becoming a tourist destination, the value given for its protection and conservation development is very low. Smallholder farmers and pastoralists use the natural resources of for their livelihoods, mainly grazing land, firewood and fish. This promotes a continuous degradation of the park's ecosystems and its biodiversity. Invasive woody species are overrunning the Nechsar Grassland Plains on which the grazing wild animals depend. The government attempted repeatedly to address the problem by resettling people out of the park and to deter illegal resource utilization through law enforcement. The loss of wildlife and their habitats in the park have continued unabated despite the conservation efforts by the Ethiopian government. This research aims to identify biodiversity conservation problems or threats and their impacts on ecotourism activities in NSNP.

MATERIALS AND METHODS

Study areas

NSNP was established in 1974 covering an area of 514 km^2 (HOA And FFE, 2008), situated in one of the most scenic parts of the Ethiopian rift valley near Arba Minch town, about 500 km southwest of Addis Ababa, of which 85% is land and 15% is water (lakes

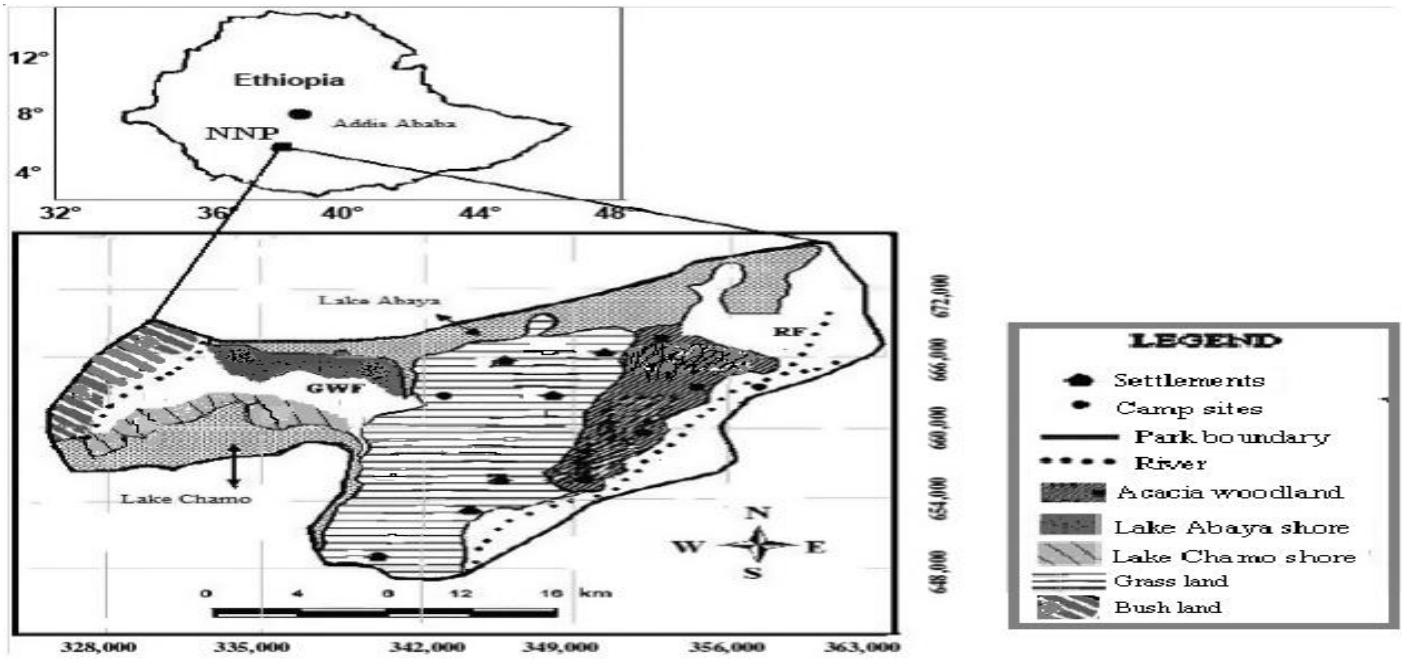

Figure 1. Map of the study area (GWF = ground water forest; RF = riverine forest).

Chamo and Abaya). Although it was designated in 1974, the Park has not yet been formally gazette (Aramde et al., 2012). The park falls within one of the IUCN"s global diversity hotspots (APF, 2007), namely the "Horn of Africa" and the original habitats of the park are highly degraded with only about 5% remaining. Annual rainfall follows a bi-modal system and averages 880 mm, mostly falling in March, April and May, and between September and November. The temperature ranges from 12.2 to 34.3ºC. There is a great diversity of habitats in the park including Acacia woodland, bushland, grassland, ground water forest (with low ground water and diverse floristic make up), riverine forest, Lake Abaya shore and Lake Chamo shore (Duckworth et al., 1992; Yisehak et al., 2007; Sintayehu et al., 2011). Generally, the park is regarded as one of the most degraded hotspots in the world (Figure 1).

Data collection and sampling procedure

Three main techniques of data collection were used for this research. These were, semi structured interviews, questionnaires and focus groups discussions including direct observation. The study area was divided into different villages based on the ranges established by the management of the local Peasant Association (PAs). Two types of questionnaire were designed for the study. The first type was for the villagers, while the second type was for the park protection staffs of the national park. The questionnaire for villagers had two sections: demographic characteristics and checklist of illegal activities that were carried out by them inside or at the boundary of the national park while the questionnaire for staffs comprised the illegal activities that they have encountered in the park (Meduna et al*.,* 2009). A total of seven peasant associations were located at the proximity of namely, Sile in the south west part of the park, Amaro in south east, Guji I and II in eastern part of the park and People at the vicinity of Arba Minch town in the western parts of the park. Each PA is further sub-divided into villages, depending on its size; one association can have 6 to 10 villages. Among those villages, we only selected two villages found at the vicinity of the National park having direct interaction and knowledge on what is going on to the NSNP by the residents of these villages. Then, 10 individuals were interviewed from each village so that a total of 14 villages were represented for this particular research. From each 13 villages, we have interviewed and made discussion with 10 individuals, a total of 130 individuals, except one small village the western boundary of the NSNP, *Sech area*, where we could have got only 5 voluntary people for interview, making our total representative sample to be 135. Additionally, all 25 protection staffs were subjected to questionnaires and interview. Lastly, the record of illegal activities or arrest made and tourism flow from 2002-2011 (10 years) by the park were obtained from the park management office.

RESULTS

The demographic characteristics of villagers interviewed are shown in Table 1. It reveals that 65.2% of the villagers were male while 34.8% were female. Moreover, most of the respondents were farmers/semi-pastoralists (47.4%), civil servants (18.8%) and students (15.6%). This is an indication that the dominant occupations in the study area are farming and livestock herders.

Table 2 shows the results of illegal activities that have been carried out by villagers. Fuel wood collection (58.5%) was recorded as the peak threat to NSNP. There are also major threats to the national park, which includes illegal fire (37.0%), deforestation (37.0%), livestock grazing (37.8%) and charcoal production (28.9%). The study indicates the problems affecting biodiversity conservation in NSNP which were identified by protection

Table 1. The demographic information of the respondents in NSNP (n=135).

Variables	Nechsar NP Percentage
Gender	
Male	65.2
Female	34.8
Occupation	
Farmers/Semi-pastoralists	47.4
Civil servant	18.8
Contract Worker	5.9
Driver	0.7
Merchant	5.2
Student	15.6
Jobless	7.4

Table 2. Comparison of respondents result on the illegal activities to the NSNP carried out by the villagers (n=135) as identified by protection staff (n=25).

	Value in percentage	
Variables	**Protection staff**	**Villagers**
Livestock grazing	76.0	37.8
Illegal fire	84.0	37.0
Deforestation	76.0	37.0
Poaching	80.0	9.6
Fuel wood collection	100.0	58.5
Charcoal Production	92.0	28.9
Settlement	72.0	9.6
Illegal fishing	100.0	44
Grass cutting	88.0	40

n indicates the total number of interviewed respondents.

staff (Table 2). The result has showed that illegal fishing (100%), fuel wood collection (100%), charcoal production (92%) and grass cutting (88%) as the major threats for NSNP.

The illegal acts that have been recorded for the past ten consecutive years (from 2002 to 2011) by protection office are presented in Figure 2. The highest record of illegal acts (90 records) in the National Park was recorded in 2008. This was due to the fact that the 2008 was the final year when the African Parks Network (NGOs) has loosened and left its eight years contract agreement of the park (which was signed in 2005) for its own protection, with the Ethiopian government due the climax threat of the park by the local communities, the Gugi tribes, dwelling and interrupting the health conditions of the park through interference of their massive cattle herd along the wildlife and other illegal activities. Then, the park again has become under the control of federal government and the local administrative

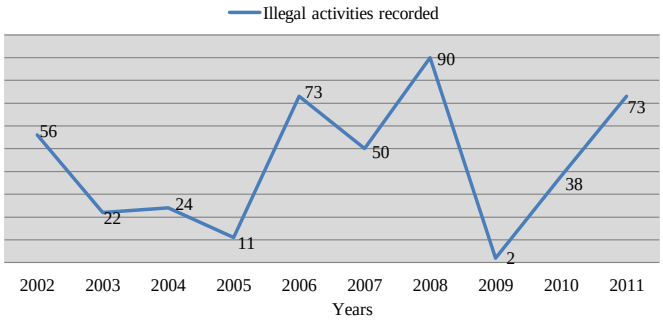

Figure 2. Rate of recurrence of illegal activities recorded by the conservation staff in NSNP (Source: Nechsar National Park annual report, 2012).

zone, Arba Minch in 2009. In this year, the climax was highly reduced (only 2 records) as the result of serious controlling measures taken by the government in collaboration with park management staff, against the illegal acts of the villagers. However, the previous trend of threatening biodiversity of the park has been increasing since 2010, as result of poor managerial activities. The most common management problems affecting biodiversity conservation in the national park are shown in Figure 3. The interview of protection staff indicated that poor salary, lack of equipment and poor infrastructure contributed equal weight (96.0%) as most common management problems affecting biodiversity conservation in the national park and was followed by inadequate staffing (88.0%).

DISCUSSION

Our research finding, on biodiversity conservation threats, which includes and mainly identified in our study as human settlement, deforestation or fuel wood collection and charcoal production, livestock grazing and/or grass cutting, poaching and fishing activities, and their impacts on ecotourism activities, has given emphasis to the information obtained from the respondents of the park's protection staffs and experts which were really concerned about the safety and health condition of the park than to the local people who were rather for the many causes of threats to the biodiversity of NSNP in many aspects. This discussion are based around issues of conditions of NSNP management, information about threats of biodiversity conservation within and their impediment to ecotourism sector.

Regarding conditions of the NSNP, since the time of its designation as a national park in 1974, it has experienced fundamental and repeated changes in its formal organizational status through different regimes of the country. However, the transitional period (after the Derg regime changed in 1991), was the time when the park's natural resource degradation was accelerated most as in

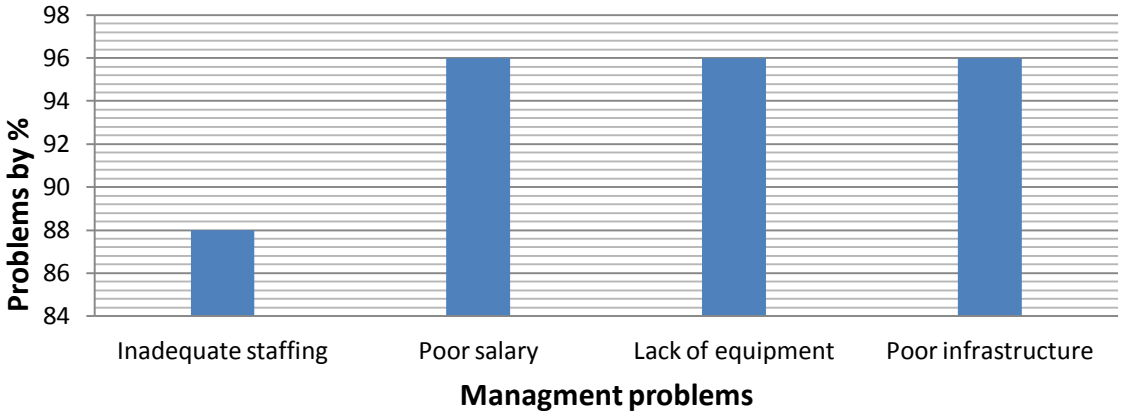

Figure 3. Management problems affecting biodiversity conservation in NSNP identified by protection staffs (n=25).

other protected areas of Ethiopia (Girma Kelboro and Stellmacher, 2012). After a long history of destruction of the NSNP, the responsibility for the technical park management and the establishment of collaborations with stakeholders was handed over to the non-governmental international conservation organization, African Parks Network (APN) or African Parks Foundation in February 2005 for 25 years, based on an agreement signed between the Federal Ministry of Agriculture, the SNSNPRS President's Office and APN. The engagement of APN in NSNP management during 2005 to 2008 led to a dramatic improvement of the human and financial resources which resulted efforts for the reinstallment and restoration of the park (Figure 2). As result, increased personnel capacity and extra payments, particularly of the scouts, had contributed to better control illegal activities in the park. Unfortunately, inability not to resettle the three local groups; Guji, Gamo/Ganta and Kore (Girma Kelboro and Stellmacher, 2012) to areas outside the park boundaries added to the complication of the park's management by APN.

Consequently, APN was unsatisfied by the failure of resettlement and it disrupted the agreement in 2008, stopped all its activities in NSNP and withdrew from Ethiopia. Since then, the biodiversity threats rejuvenate and persist till now (Aramde Fetene. et al., 2012). Very soon, the financial as well as human resources employed for the management of the park has got reduced in the consecutive years later, except some modification in the year 2013 and 2014 as observed during the study of this research (Table 3). Recent studies also showed that the population size of Arba Minch town has greatly increased from 2,830 in 1966 to 72,507 in 2005 (Elias, 2003; CSA, 2005; Aramde Fetene, 2011) which aggravated the threatening condition of the park.

Many studies have revealed that human settlement to natural habitat had a profound impact on wildlife communities. Species richness could decline as the level of development on the surrounding natural habitat has increased (Miller et al., 2003; Meduna et al., 2009) through the modification of vegetation structure and composition. This was the case for NSNP which was surrounded by agricultural communities from its eastern and western boundaries. This made it more vulnerable to settlement which has created worries for 72.0% of protection staffs interviewed (Table 2). These illegal settlements within the park's territory were in fact the main reasons for the failure of the park management agreement (Girma and Stellmacher, 2012).

According to Population Action International (1999) and WHO (2006), more than three billion people worldwide depend on solid fuels, including biomass (wood, dung and agricultural residues) and coal, to meet their most basic energy needs where Ethiopia, with greater than 95 percent of its population is using solid fuels. This is a particular case of developing countries which are primary users of fuel wood thereby contributing 75% of forest harvesting (FAO, 2000). It is a fact that charcoal and fuel woods are the principal traditional fuels in Ethiopia, in general and in the study area in particular. World Bank (2011) reported that production of charcoal and fuel wood is the primary driver of deforestation and subsequent land degradation due to extensive agriculture, and these were the major threats observed in NSNP. The study of Bearer et al. (2008), also showed that fuel wood collection can be potential threat which is capable to dramatically reduce the total amount of forestland around the world.

The result of our study also found the major challenges to NSNP where 58.8% of the villagers were involved. All of the protection staffs (100%) interviewed agreed on seriousness of the threat. Due to its vicinity to Arba Minch town where there was high demand for fuel wood, NSNP is highly vulnerable to fuel wood collection where most of the city residents are dependent on it as energy source for cooking with no other energy source for cooking in the

Table 3. Personnel of NSNP before APN (under government administration), during APN and after APN (under government administration).

Positions of the NSNP personnel	2004	During APN (2005-08)	2009/10	2011/12	2013/14
Warden	1	1	1	1	1
Project coordinator	-	1	-	-	-
Community coordinator	-	1	-	-	-
Expert	1	-	-	1	2
Medium level wildlife and habitats expert	-	-	-	-	1
Junior wildlife and habitats expert	-	-	-	-	1
Community wildlife expert	-	-	-	-	-
Tourism expert	-	-	-	-	1
Scout	25	60	39	40	42
Support	14	19	15	15	17
Total	41	82	58	58	60

Source: NSNP archives.

town.

The present study shows deforestation, through fuel wood collection and charcoal production (for cooking purpose and house building), followed by grass cutting and illegal fire were the prominent threats to NSNP. This was mostly exercised by the poor local communities as a means of their livelihood via selling and this was discussed and agreed by 76.0% of the park experts. Illegal poaching and settlement and domestic animal grazing were additional challenging problems clearly seen in our present study. The widespread use as well as potential harvesting of forest products can have impacts on forested landscapes and wildlife habitats (Bearer et al., 2008). Our findings are supported by the very recent report of Steve Sepp by which in many developing countries, the demand for wood fuel destroys forests around ur ban and semi-urban agglomerations, resulting from unsustainable management practices and inefficient conversion and combustion technologies (Steve, 2014).

Even though charcoal production is an important economic activity and an important source of energy in developing countries (Dawit, 2012), it is being however conducted informally without any license (Million Bekele, 2011) and it was recorded as proved by 92% of the protection staffs (Table 2). According to the result of the study, the local people involved in charcoal production (28.9%), posed a threat which is mainly for commercial purposes. The research done by Mulat et al. (2004), proved that charcoal making and selling is a major non-farm employment along the main roads of the country which exposes the fragile ecosystem for severe deterioration. On the other hand, charcoal is a cheap commodity that requires low-priced, affordable and readily available metal or ceramic stoves in the market as compared to electric and gas stoves for cooking purpose (Luoga et al., 2000). Related studies have also proved that protected areas found near towns can be badly affected (Monela et al., 1993; Steve, 2014) due to the fact that fuel wood products is more economically rewarding near urban areas (Benjamin et al., 2011).

Grass cutting for fodder and house construction (88%) followed by overgrazing (76%) were approved as the third challenging problems diminishing the abundance of wild life forage "*nechsar grass*" there by threatening the grazers biodiversity such as the Burchel's zebra (*Equus burchellii*), and Grant's gazelle (*Gazella granti*) in which NSNP was primarily established and is known for . This event might pose a problem since it results direct resources competition with the wildlife (Table 3). Across the world, there is clear commonality in at least some of the themes being addressed such as the issues of grazing, invasion, growing agricultural demands, climate change and management problems for biodiversity conservation (Watkinson and Ormerod, 2001). The recent study of Aramde et al. (2011) also identified that grazing deteriorates the scenery and the wildlife visibility, diminishing greatly over time, and finally disappeared, putting impediment for the income generating from ecotourism activities. Regarding this, particularly of domestic animal grazing, NSNP was surrounded by agrarian settlements which could alleviate the problem of overgrazing as ascertained by 76 % of protection staff. Huge flocks of cattle were observed grazing together with
wild animals inside the territory of national park. As the result, livestock grazing has put frequent conflicts between the farmers and the park managers in the area.

Illegal fire has effects on biological diversities and ecosystem function by damaging habitats, breeding site and food causing the loss of wildlife, the territorial birds and mammals from their natural homes (Bowman and Murphy, 2010; CBD, 2010). The result of our study also revealed that uncontrolled fire has contributed a potential

conservation challenges, as agreed with 84% of the park management respondents, in the study area.

Poaching was reported by most of the protection staffs (80%) as one of the hard biodiversity threats to control. This is supported by a survey conducted within 2001 parks from different tropical countries of three continents indicated that poaching is the leading among the list of problems in over 85% of the parks (Gubbi, 2003; Dobson and Lynes, 2008; Kolahi et al., 2012). Poaching is also related to the roles of wild animals in some cultural ceremonies and tradition like marriage of the local tribes (Onadeko, 2004). However, the discussion made with local people has agreed on their involvement in poaching for bushmeat as alternative source of protein. The main reasons for poaching can be profits derived from the sale of wildlife parts and obtaining a trophy specimen for personal use thrill killing, necessity of obtaining food, and antagonism toward the government which were also observed in our current study.

Moreover, NSNP is partly consisted of aquatic habitats, lakes Chamo and Abaya, which were vulnerable to uncontrolled fishing activities. The interviews (100%) made with NSNP protection staffs revealed that Illegal fishing was one of the most difficult activities threatening the lakes fish diversity. It creates significant collateral damage to ecosystems which may aggravate bycatch and incidental mortality of aquatic animals (Agnew et al., 2009). It contributes to overexploitation of fish stocks mainly in a region with poor governance and it has often been linked to organized crime (Vaisman, 2001). This was one of the threats for NSNP, which may probably result from weak governance system, causing a continuous, non-selective overexploitation of fishes in both lakes. This has led to the overall weakening of lakes' productivities by affecting the cascade of aquatic trophic dynamics. This situation had not shown significant change in terms of number of arrests made on illegal activities each year in both study areas where the number of arrests made in 2011 was higher than in 2010 (Figure 2).

Correspondingly, annual expenditure on protected areas in many developing countries is extremely low (Jones, 2005; WWF, 2007) and protected areas in tropical regions are under-funded even though they require resources for annual operating budgets, capital investment, staff-training, community development and public aware-ness among a wide range of other activities (Jones, 2005). All these gaps were also seen as a major management challenges for protection staffs of NSNP in our study (Table 2). The work of Ogunjinmi et al. (2009), reported low salary as one of the variables hindering rangers or protection staffs not to be employed in protected areas and satisfied with their job leading them to poor commitment to protection activities.

Over the past six decades, tourism has experienced continued expansion and diversification, becoming one of the largest and fastest-growing economic sectors in the world (UNWTO, 2013). Similarly, ecotourism has shown considerable growth in our study area, NSNP (Table 3) which has a potential to host the ecotourism resourcefulness and a number of international and local tourists are interested to visit the park every year. The number of tourists and the revenue collected has shown considerable increments from year to year (Table 3). It has increased ten times in the last decade from one hundred and fifty three thousand, two hundred and fifty-five Ethiopian birr (153,255ETB) in 2002 to one million, three hundred and thirty one thousand, five hundred and thirteen Ethiopian birr (1,331,513 ETB) in 2011. Besides the increase of ecotourism revenue, the local communities did not receive any incentives, which might pose challenges to protected area and put a limitation on ecotourism as a good alternative for conservation by providing substantial incentives to the host communities (Kolahi et al., 2013).

Conclusion

Current issues related with protected areas in Ethiopia require special attention in the light of the unabated population growth, correlated encroachment and misuse and abuse of natural resources (IBC, 2010). According to UNEP (2010), despite good framework and legislation for natural resource management, the implementation on the ground in Ethiopia was affected by limited participation of stakeholders. NSNP, a jewel in the crown of Ethiopia's National Parks, is valued for its physical beauty, endemic species, and diversity ranging from lakes to mountains. However, there have been disastrous reductions and changes in Ethiopian's ecosystems. In our case study, lack of a suitable PAs information database, limited public participation, inadequate provision of facilities, shortage of protection staff and park experts, poor infrastructure, low salary and persistent local people conflicts between park management officials or the government for settle-ment and other livelihoods were identified as the major problems for biodiversity conservation works in NSNP.

As a result, NSNP biodiversity is being lost by mismanagement, increasing competition for settlement, deforestation (fuel wood collection and charcoal produc-tion), overexploitation (in our case, overgrazing and overfishing), and illegal hunting or poaching, poaching, aggravated by insufficient staff and human resources, and budget constraints. These things had put a pronounced burden to the ecotourism industry. The fact that National Parks in Ethiopia are experiencing low visitation is a pointer to the debilitating effect of these problems on ecotourism activities, economy of the local people and that of the country as a whole. Despite a progress increment in the number of visitors as well as revenue generated from NSNP, for the past decades, there has been a decreased tourist visit record in the past two years (2013 and 2014); this was partially due to frequent conflicts in the utilization of the park resources and a diminished number of wildlife which were meant for

recreation a cause for visit (personal communication with NSNP manager, 2014). These problems emanated from socio-economic cum total dependency of local communities and peoples of Arba Minch town as their livelihood on the park. In addition, low priority is given to conservation programs by the three tiers of government (Federal, State and Local Governments) which means they are not communicated ether in the top-down nor down-top system.

With this fast rate of deforestation, and other threats, the environment will reach to the point where it cannot support the community, the wild animals and ecotourism activities will stop, leaving Arba Minch town to be bounded to face some serious problems in their livelihood. Therefore, integrated forest and wildlife management with the involvement of all stakeholders may be used as a strategy to conserve NSNP and associated resources in a sustainable way.

Recommendation

Ethiopian biodiversity conservation is in dire straits. Neither the federal Ethiopian wildlife conservation authority (EWCA) nor the regional states offices can succeed by themselves to achieve the minimum required programmes to be successful. As a minimum, EWCA and the regional offices could have a joint management commission for the entire EPAS, where they could jointly work out practical solutions to the most urgent problems. The ensuing results of deforestation, grazing cattle, human habitation and overfishing in the park have caused severe stresses and degradation of park's ecosystems, leaving the sustainability of NSNP's resources in question. As result, income generated from the ecotourism is being negatively affected. The income from NSNP in terms of park entrance fee is higher as compared to other national parks with similar management scheme, was very high which is a reflection of its being unique tourist destination place. However, it was only from the park entrance fee, and should also include other income generating opportunities such as accommodation charges, visitors guide fees, food and drinks and from various activities so as to upgrade the park's infrastructures and other management facilities.

National parks management agencies require new strategies to curb illegal activities in the NSNP. It is obvious that the traditional measures such as arrest and prosecution of poachers or fuel wood collectors have failed and therefore, conservation awareness aimed at changing local attitude will go a long way in reducing incessant threat on the integrity of the park's biodiversity. Kohlai et al (2012) supported the public participation, awareness and transparency in decision-making as a great importance in conflict resolution and sustainable management in PAs. Similar researches also approved for the reason that local communities' participation in tourism benefit-sharing is central to tourism development and biodiversity conservation (Kolahi et al., 2012) reinforced by other activities such as creating awareness, training and environmental education (Knapp, 2000; Bettinger et al., 2010). Another important recommendation we should forward is to reconsider or involve, but with a great governmental or regional support not to fail, the international or local NGOs, corporations, conservation trusts, local communities, and the private sector to take over NSNP management duties, for example, as it was tested and successful by APN for some years. This is because, these organizations have more autonomy in finances and decision-making, compared to government bureaucracies, and have proven to be successful models for managing PAs in many parts of the world (ICEM, 2003; Kolahi et al., 2012). This is to mean that the government should negotiate with landowners, pastoralists and other stakeholders inside or around to NSNP, to move outside and resettle them in other areas, through ensuring a commitment to sustainability. A new paradigm of human-centered conservation is becoming a standard approach in many countries (Phillips, 2003) as a tool for social planning and income generation (Locke and Dearden, 2005). Therefore, we can make conservation efforts more systematic and efficient through active management, legal, political and financial support from upper levels of government (Kolahi et al., 2012) to the regional states and local communities where the real protection and management activities takes place through efficient and systematic planning and policy instruments that allow integrated, sustainable ecosystem management. This would fantastically allow the many paper parks of Ethiopia including NSNP to become real working PAs that succeed in biodiversity conservation, as it was supported by the research work of Kolahi et al. (2012) and Kolahi et al. (2013). Moreover, on a local level, establishment of management committee would also be promising, in which local stakeholders would be represented, including one or more representatives from the regional government, local communities, local tourism facilitators (hotels, tour operators) and the biology department of Arba Minch University. The last but not the least we should commend is that because of the need for many studies, research institutions, universities, and students should be encouraged and strengthened with full material, finance and training capacities to conduct more intensive similar researches to assess and narrow problem gaps, the threats to NSNP thereby reassuring ecotourism activities for its long term sustainability.

Conflict of interests

The authors did not declare any conflict of interests.

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Enumeration of lichen diversity in Manaslu Conservation Area and Sagarmatha National Park of Nepal

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An extensive research on deciphering lichen diversity in the high Nepalese Himalaya was undertaken in two subsequent years in Manaslu Conservation Area (MCA) and Sagarmatha National Park (SNP). Altogether, 621 specimens were collected from these two regions, viz., 173 from MCA and 448 from SNP, which resulted in the occurrence of a total of 13 species of lichens from MCA (belonging to 4 families) and 69 species belonging to 15 different families from SNP. Among the lichen families reported from these two study sites, family Parmeliaceae (7 and 29 species from MCA and SNP, respectively) was the dominant one followed by Physciaceae (12 species from SNP) and Cladoniaceae (4 and 8 from MCA and SNP, respectively). Thus, this research work, to some extent, reveals the lichens enrichment in the study region, furnishing much new insights that can be used as a composite signal of environmental quality and future bio-monitoring studies.

Key words: Bio-indicators, endemism, geographical gradients, speciation.

INTRODUCTION

Lichens, frequently called ‘Jhyau’ or ‘Tare’ in Nepal are classified as a cluster of lower life-form of fungi (dual organisms assumed as a single one) and are formed by an intricate and mutualistic combination of both fungal (mycobiont) and algal (phycobiont/cyanobiont) partners (Sharma, 1995; Shah, 2014). Approximately, about 771 species belonging to 167 genera are known to Nepal as of now, of which more than 50 species are endemic (Baniya et al., 2010). However, current estimation of over 2,000 lichen species belonging to Nepal has now been made (Bhuju et al., 2007), but, lack of adequate knowledge continues to keep them undocumented. Though, the Nepalese Himalaya possess enormous pristine glories enriched with higher diversity and a very wide range of eco-climatic zones (Dobremez, 1976), most of its regions remained still unexplored. As it is well known that scientific discourse on ecological and biogeographical patterns and theories of species richness may prove an excellent system in bio-monitoring (Körner, 2002), this contemporary study was designed to abridge the existing gap in understanding and elucidating the diversity of lichens in Nepal.

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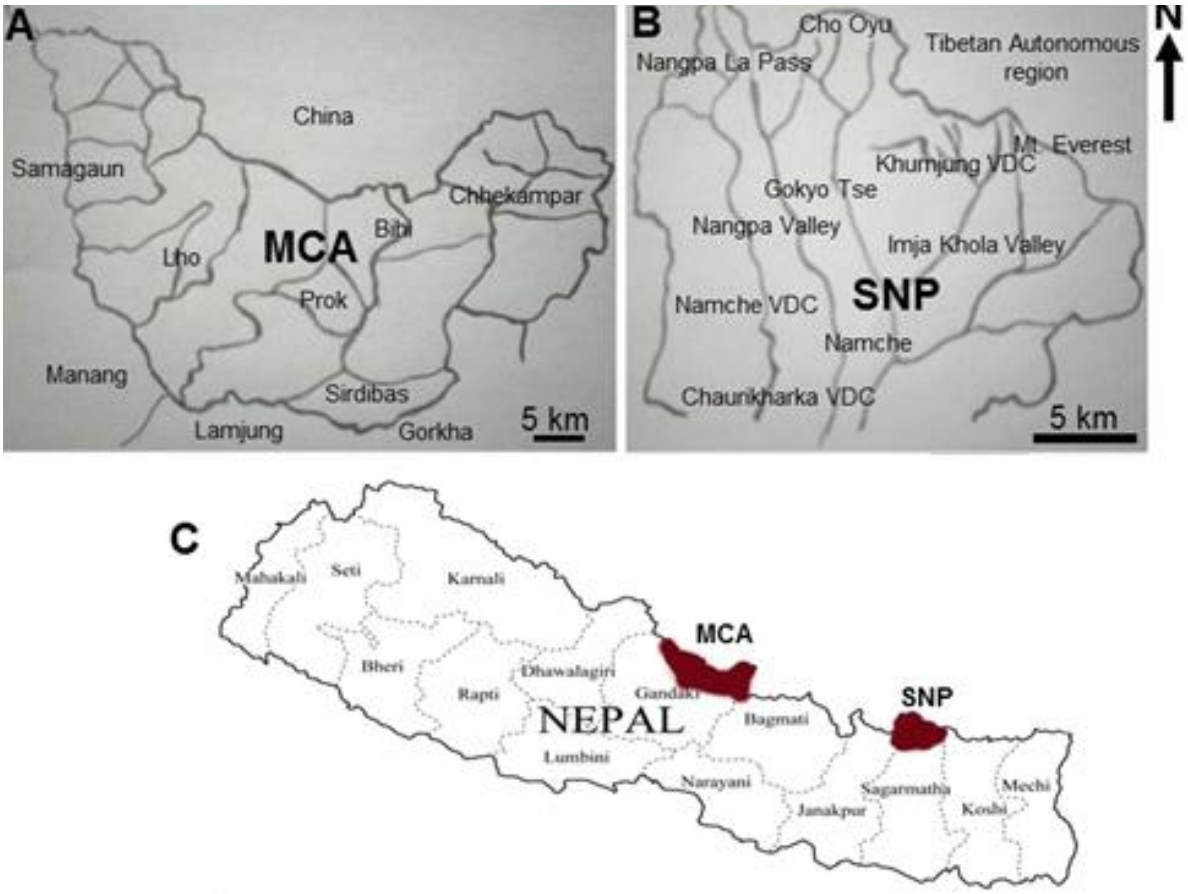

Figure 1. Pictures depicting the sampling area. A. Manaslu Conservation Area, B. Sagarmatha National Park, C. Map of Nepal.

MATERIALS AND METHODS

Topography of the sampling areas

The Manaslu Conservation Area (MCA) lying on the lap of Manaslu Himalaya (Figure 1A), is spread in an area of 1,663 km^2 and has an elevation gradient ranging from 1,400-8,163 m asl. It is bordered by Tibet autonomous region of China to the north and east, while Manang district to the west and Gorkha district to the south. The Sagarmatha National Park (Figure 1B) stretched in an area of 1,148 km^2 lies in the Solukhumbu district and has an elevation gradient ranging from 2,845-8,848 m asl. The dominant tree vegetation in both the study area comprises of species of *Rhododendron, Betula, Quercus* and *Juniperus.*

Lichen sampling

The field trips were executed during 2010 (September-October) in Manaslu Conservation Area (MCA; coordinates Table 1), and in 2012 (April-May) in Sagarmatha National Park (SNP; Mount Everest Region; coordinates Table 2). Lichens growing on different substrata were sampled at an elevation above 2,350 m asl. With the special focus made on higher elevations, the sampling of lichens below 2,300 m asl was not incorporated in the present study. All species of lichens found in the sampling areas were harvested and species that tightly adhered to bark or soil were uprooted with the help of iron scalpels. Immediately after collection, samples were cleansed to eliminate the bark residues and other extraneous materials for their proper identification, followed by storage in air tight zip-lock plastic bags. All specimens were shade dried and the herbaria prepared according to method devised by Nash et al. (1993), was lodged in Nepal Academy of Science and Technology (NAST). All specimens collected were also coded with the British Lichen Society recording code numbers (Coppins, 2002).

The lichen cohort richness patterns in the studied areas were performed at different altitudinal ranges. Random-samplings were performed according to the availability of the lichens and the lichens found were harvested and the geographical co-ordinates and substratum were recorded. The specimens were identified through examination of their morphology, anatomy and habitation as per published floras (Awasthi, 2007).

RESULTS AND DISCUSSION

The two studied areas (Figure 1) possess an ample

Table 1. Diversity of lichens in MCA.

Family	Latin name	Substratum	Co-ordinates		Elevation (m asl)
			Latitude	Longitude	
Parmeliaceae	*Hypogymnia physodes* (L.) Nyl.	*Rhododendron* sp.	27°39'15.7" N	85°18'43.4" E	2,859
	Everniastrum nepalense (Taylor) Hale ex Sipman	*Malus domestica*	27°39'15.7" N	85°18'43.4" E	2,353
	Parmotrema reticulatum (Taylor) M. Choisy	*R. campanulatum*	27°39'15.7" N	85°18'43.4" E	2,727
	Usnea aciculifera Vain.	*Quercus* sp.	27°39'15.7" N	85°18'43.4" E	3,115
	Usnea arizonica Mot.	*Rhododendron* sp.	27°39'15.7" N	85°18'43.4" E	2,829
	Usnea longissima Ach.	*Quercus* sp.	27°39'15.7" N	85°18'43.4" E	3,079
	Usnea rubicunda Stirt.	*R. campanulatum*	27°39'15.7" N	85°18'43.4" E	2,927
Cladoniaceae	*Cladonia cristatella* Tuck.	*Quercus* sp.	27°39'15.7" N	85°18'43.4" E	3,086
	Cladonia cariosa var. cariosa (Ach.) Spreng.	Usually on rocks but sometimes on the trees bark	27°39'15.7" N	85°18'43.4" E	3,115
	Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.	*R. campanulatum*	27°39'15.7" N	85°18'43.4" E	2,833
	Cladonia ramulosa (With.) Laundon	Rocks along with mosses	27°39'15.7" N	85°18'43.4" E	2,829
Coccocarpiaceae	*Coccocarpia* sp.	*Malus domestica*	27°39'15.7" N	85°18'43.4" E	2,727
Lobariaceae	*Lobaria pindarensis* Räsänen	Rocks along with mosses	27°39'15.7" N	85°18'43.4" E	2,829

amount of lichens diversity, which are summarized in Tables 1 and 2. Through this discourse, we traced a total of 621 lichens specimen from the studied areas, viz., 173 from MCA and 448 from SNP. Altogether, 13 species of lichens from MCA (lying on 4 families) and 69 different species lying on 15 different families from SNP were identified, among which family Parmeliaceae (7 and 29 species from MCA and SNP, respectively) was largest followed by Physciaceae (12 species from SNP) and Cladoniaceae (4 and 8 from MCA and SNP, respectively) (Figure 2). From the study, the high altitudinal lichens located on the studied areas were *Leptogium indicum* (3,900 m asl) and *Cladonia coniocraea* (3,803 m asl). Lichens enrichment was found to be maximum in the range of 2,800 m asl in MCA, while the species richness were found to be maximum at an elevation of 2,700 m asl in SNP.

Most of the lichen species traced in the present study have previously been reported from the adjacent regions, such as India, Pakistan and Bhutan (Kumar et al., 2011) and also other parts of Nepal (Baniya et al., 2010). Thirty-three percentage of the total lichens reported in the present study were found above the tree line (> 4,300 m asl) of which 53% were endemic. This number seems to be enormous which suggests that the environmental conditions are quite favorable for the luxuriant growth of lichens and the topography and varied altitude somehow contribute towards rich lichen diversity and endemism in the study sites. But, it would be too early to predict that the results of the present study are somewhat similar to that of Baniya et al. (2010) who traced altogether 525 species of Nepalese lichen distributed between elevations of 200-7,400 m asl and documented 55 species endemic to Nepal, because, in the present study, lichens sampling was done up to the elevation of 4,200 m asl. The members of the *Parmelioid* clade belonging to lichen family Parmeliaceae were dominant in the study sites and are followed by the *Usneoid* clade of the same family. This study corresponds to the findings of Thell et al. (2012) who mentions that the Parmeliaceae is the largest family across the globe and till date includes 79 genera and *ca.* 2,726 spp. belonging to 5-main clades, *viz*., *Parmelioid, Cetrarioid, Usneoid, Alectorioid* and *Hypogymnioid.*

At high elevation, lichens of either in foliose or fructicose forms are found and they exhibit maximum species diversity value (Sipman, 1989), while crustose forms of lichens prevail greatly in lower altitude. The ubiquitous lichen species tend to establish and colonize early on every microhabitat occupying a larger chunk of area (Rose and Wolseley, 1984). The diversity of the epiphytic lichens may vary with tree species, age of the tree, bark pH and tree health status (Herk, 2001; Hauck and Runge, 2002; Nascimbene et al., 2013). However, actual

Table 2. Diversity of lichens in SNP.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Collemataceae	*Leptogium trichophorum* Müll. Arg.	Rock	Chhuthawa	27°44'32.6" N	86°42'47.8" E	2,672
	Leptogium delavayi Hue	*R. campylocarpum* and other trees	Phakding	27°45'20.4" N	86°42'37.1" E	2,729
	Leptogium adpressum Nyl.	Trees bark	Chhuthawa	27°44'05.8" N	86°42'43.6" E	2,566
	Leptogium indicum D.D. Awasthi & Akhatar	*Rhododendron* sp.	Near Khunde	27°48'56.4" N	86°42'36.6" E	3,900
	Leptogium lacerum (Sw.) Gray	*Malus* sp.	Ghat	27°43'59.8" N	86°42'46.3" E	2,750
Cladoniaceae	*Cladonia cariosa* var. cariosa (Ach.) Spreng.	Usually in rocks, but sometimes on the trees bark	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
	Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.	Rocks	Near Larza	27°47'09.7" N	86°43'17" E	2,860
	Cladonia portentosa (Dufour) Coem.	*Quercus* sp.	Jorsalle	27°46'50.4" N	86°43'19" E	2,994
	Cladonia coniocraea (Flörke) Spreng.	On roots of woods and tree bases, rarely on bare soil	Syanboche	27°48'45.2" N	86°42'38.9" E	3,803
	Cladonia cristatella Tuck.	*Malus* sp., *Rhododendron* sp.	Larza bridge	27°47'24" N	86°43'03.8" E	2,910
	Cladonia ramulosa (With.) J.R. Laundon	Rocks along with mosses	Phakding	27°45'20.4" N	86°42'37.1" E	2,728
	Cladonia rangiferina (L.) Weber ex F.H. Wigg.	*Rhododendron* sp.	Toktok	27°45'21.3" N	86°42'36.3" E	2,710
	Cladonia rangiformis Hoffm.	Rocks	Jorsalle	27°46'28.7" N	86°43'19" E	2,812
Parmeliaceae	*Anzia colpodes* (Ach.) Stizenb.	Trees bark	Toktok	27°45'20.4" N	86°42'37.1" E	2,729
	Bulbothrix sp.	Trees bark	Near Phakding	27°44'05.8" N	86°42'46.6" E	2,566
	Canoparmelia texana (Tuck.) Elix & Hale	Rocks and barely on barks	Chhuthawa	27°44'56.2" N	86°42'44.6" E	2,687
	Cetraria sp.	Rocks	Syanboche to Khunde	27°48'57" N	86°42'36" E	3,850
	Everniastrum nepalense (Taylor) Hale ex Shipman	*R. arboretum* and other trees	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
	Flavoparmelia caperata (L.) Hale	Trees bark	Ghat	27°42'49.7" N	86°42'50.9" E	2,614
	Flavoparmelia soredians (Nyl.) Hale	Rocks	Larza bridge	27°47'22.9" N	86°43'07.1" E	3,123
	Hypogymnia sp.	Trees bark	Phakding	27°44'05.8" N	86°42'46.6" E	2,566
	Parmelaria thomsonii (Stirt.) D.D. Awasthi.	*Malus domestica*	Manjo	27°46'10.9" N	86°43'25.7" E	2,810
	Parmelia nepalensis Taylor	Trees bark	Manjo	27°44'03.5" N	86°42'42.6" E	2,860
	Parmelia nilgherrensis Nyl.	*Quercus* sp.	Mislung	27°47'56.8" N	86°42'47.4" E	3,340
	Parmelia reticulata Taylor	Trees bark	Khunde	27°49'09.6" N	86°42'29.2" E	4,110

Table 2. Contd.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Parmeliaceae	*Parmelia sancti-angelii* Lynge	Trees bark	Namche	27°48’45.1" N	86°42’38.7" E	3,450
	Parmelia squarrosa Hale	Tree barks	Larza bridge	27°47’22.9" N	86°43’07.1" E	3,123
	Parmelia stuppea Taylor	Trees bark	Chhuthawa	27°43’44.5" N	86°42’48.3" E	2,600
	Parmelia sulcata Taylor	Trees bark	Thamu	27°49’16.1" N	86°40’52.4" E	3,450
	Parmelia wallichiana Taylor	*Malus domestica*	These	27°48’54.5" N	86°41’11" E	3,480
	Parmotrema sp.	Trees bark	Benkar	27°45’41.6" N	86°42’45.7" E	2,757
	Parmotrema tinctorum (Delise ex Nyl.) Hale	Trees bark	Phurte	27°48’45.8" N	86°41’31.1" E	3,400
	Pseudevernia furfuracea (L.) Zopf	Trees bark	Jorsalle	27°46’50.4" N	86°43’19" E	2,993
	Punctelia borreri (Sm.) Krog	Trees Bark	Phakding	27°45’55.7" N	86°43’23.3" E	2,809
	Punctelia subrudecta (Nyl.) Krog	Tree bark	Manjo	27°46’10.9" N	86°43’25.7" E	2,810
	Usnea aciculifera Vain.	*Quercus* sp.	Toktok	27°45’20.4" N	86°42’37.1" E	2,729
	Usnea longissima Ach.	Trees bark	Phakding	27°44’05.8" N	86°42’46.6" E	2,566
	Usnea orientalis Motyka	Trees and sometimes on rocks	Chhuthawa	27°44’56.2" N	86°42’44.6" E	2,687
	Usnea rubicunda Stirt.	Trees bark	Benkar	27°45’41.6" N	86°42’45.7" E	2,757
	Usnea sp.	Trees bark	Manjo	27°46’10.9" N	86°43’25.7" E	2,810
	Usnea trichodeoides Motyka	*Betula* sp.	Mislung	27°47’52" N	86°42’41.5" E	3,477
	Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw	Tree barks and rocks	Benkar	27°45’41.6" N	86°42’45.7" E	2,757
Gyalectaceae	*Pachyphiale himalayensis* Vezda & Poelt	*Malus domestica*	Kyanjuma	27°48’58.3" N	86°43’50.6" E	3,583
Caliciaceae	*Dirinaria confluens* (Fr.) D.D. Awasthi	Trees bark	Kyanjuma	27°48’58.3" N	86°43’50.6" E	3,583
Coccocarpiaceae	*Coccocarpia* sp.	*Malus* sp.	Ghat	27°42’49.7" N	86°42’50.9" E	2,613
Lecanoraceae	*Lecanora himalayae* Poelt	*Malus domestica*	Toktok	27°45’06.4" N	86°42’37.4" E	2,743
Graphidaceae	*Phaeographina nepalensis* D.D. Awasthi & Kam. P. Singh	Moist soil and rocks	Phakding	27°45’20.4" N	86°42’37.1" E	2,728

mapping of lichens render difficulties at times. More often, the seemingly chaotic mingling of lichen species provides falsification to their actual identification and classification. Moreover, the implication of the molecular tools for their actual identification at the genomic level is needed, which decreases the falsified misinterpretations regarding the taxonomic classification. Thus, on such prevailing scenario, scare ongoing effort to document the lichen population in Nepal is below the threshold, and hence species identification via molecular studies may prove to be an effective milestone to know more about this charismatic group of organism in Himalayan

Table 2. Contd.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Physciaceae	*Heterodermia corallophora* (Taylor) Skorepa	Trees barks	Toktok	27°45’21.3" N	86°42’36.3" E	2,710
	Heterodermia diademata (Taylor) D.D. Awasthi	Trees bark	Chhuthawa	27°43’ 44.5" N	86°42’48.3" E	2,600
	Heterodermia dissecta (Kurok.) D.D. Awasthi	Several trees	Phakding	27°45’55.7" N	86°43’23.3" E	2,809
	Heterodermia incana (Stirt.) D.D. Awasthi	Trees barks	Chhuthawa	27°44’25.8" N	86°42’43.6" E	2,566
	Heterodermia leucomela (L.) Poelt	Trees bark	Chhuthawa	27°44’05.8" N	86°42’43.6" E	2,567
	Heterodermia pseudospeciosa (Kurok) W. Culb.	Rocks	Benkar	27°45’41.6" N	86°42’45.7" E	2,757
	Heterodermia punctifera (Kurok.) D.D. Awasthi	*R. arboretum* and on rocks along with mosses	Jorsalle	27°46’28.7" N	86°43’19" E	2,812
	Heterodermia sp.	Barks and sometimes on rocks	Chhuthawa	27°44’25.8" N	86°42’43.6" E	2,566
	Heterodermia upretti	Rocks and barks of several trees	Jorsalle	27°46’46.6" N	86°43’17.8" E	3,111
	Phaeophyscia hispidula (Ach.) Essl.	*Rhododendron* sp.	Mislung	27°47’56.8" N	86°42’47.4" E	3,340
	Physcia caesia (Hoffm.) Fürnr.	Trees bark	Phakding	27°44’56.2" N	86°42’44.6" E	2,688
	Physconia enteroxantha (Nyl.) Poelt	Tree barks and on rocks	Phakding	27°44’05.8" N	86°42’46.6" E	2,566
Ramalinaceae	*Ramalina fraxinea* (L.) Ach.	Trees bark	Mislung	27°47’52" N	86°42’41.5" E	3,477
	Ramalina sinensis Jatta	*Betula* sp.	Jorsalle	27°46’50.4" N	86°43’19" E	2,993
	Ramalina sp.	Trees bark	Ghat	27°42’49.7" N	86°42’50.9" E	2,614
	Ramalina usnea (L.) R.H. Howe	Rocks along with some mosses	Syanboche	27°48’45.2" N	86°42’38.9" E	3,803
Peltigeraceae	*Peltigera polydactyla* (Neck.) Hoffm.	Rocks, barks and rarely on soil	Toktok	27°45’06.4" N	86°42’37.4" E	2,741
Stereocaulaceae	*Stereocaulon coniophyllum* Lamb	Rocks and soil	Larza bridge	27°47’22.9" N	86°43’07.1" E	3,123
Chrysothricaceae	*Chrysothrix chlorina* (Ach.) J.R. Laundon	Rocks and soil	Jorsalle	27°46’46.6" N	86°43’17.8" E	3,111
Lecideaceae	*Lecidea khumbuensis* Hertel	*R. hogsonii*	Manjo	27°47’11.3" N	86°43’13.2" E	2,960
Lobariaceae	*Lobaria amplissima* (Scop.) Forssell	On overhangs of siliceous rocks	Toktok	27°45’06.4" N	86°42’37.4" E	2,741
	Lobaria pindarensis Räsänen	*R. hogsonii*	Manjo	27°47’11.3" N	86°43’13.2" E	2,960

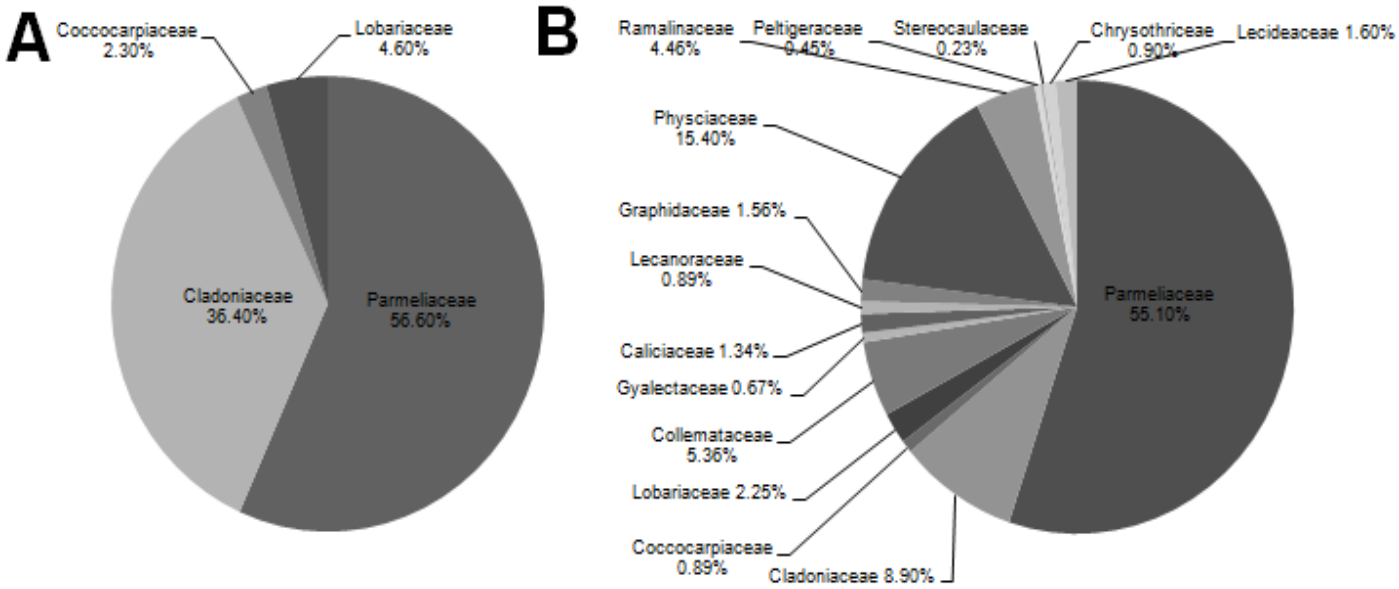

Figure 2. Frequency distribution of the lichen families in the studied areas, A. Lichens found in MCA, B. Lichens found in SNP.

ecozone.

Conclusion

The Nepalese Himalayas still harbors clusters of lichens that are not well-identified, so this study furnishes a preliminary finding about the diversity of lichens in some new localities of Nepal which may somehow be helpful in developing a general framework on the exploration of lichens in other regions of Nepal, and also to conduct future bio-monitoring studies by utilizing this baseline data.

Conflict of interests

The author declares there is no conflict of interest whatsoever.

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Conservation of plant biodiversity of Namatimbili forest in the southern coastal forests of Tanzania

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The aim of this study was to determine the ecological characteristic of Namatimbili Forest in terms of plant species composition, stem size class structure, stand biomass, diversity, and distribution and identify endemic and threatened plant species that are found within the forest. Data were sampled by using transect method that were established in various habitats within the forest. A total of 312 plant species were found in 62 families, where Fabaceae (51 species) was the highly represented of all families. Of all plant species recorded, 26 are cited under IUCN red list and 36 are endemic species of East African Coastal Forests.The woodlands were more diverse with a Shannon's index of 2.72 ± 0.21 followed by the riverine forest (1.64 ± 0.19), coral rags (2.28 ± 0.32) and closed canopy evergreen forest (2.32± 0.17) and this pattern was also applied to the species evenness and the difference among vegetation types was significant. The DCA ordination revealed a major variation at DCA-Axis1 where samples from riverine forest separated quite clearly and positioned on the right side of the ordination space. The coral rag habitat extended widely overlapping with other habitats because of high similarity in plant species composition. The woodland habitats separated from the evergreen forest habitat at DCA Axis 3 because of plant species composition differences between them, such that closed canopy trees and the understorey species characterized the evergreen habitats. The riverine forest had a density of 136 stems/ha with the DBH sizes between 41 and 292.99 cm and the stand biomass ranged from 0.1 to 876.06 m^3/ha. However, high density of trees with DBH sizes beyond 90 cm was observed in the riverine forest, regardless of all the vegetation typeshaving individual stems beyond this size class. The coral rag vegetation had 42 stems/ha, with diameter at breast height (DBH) sizes ranging from 41 to 95.5 cm and stand biomass in a range from 0.1 to 59 m^3/ha. The woodlands had 28 stems/ha with the DBH sizes between 41 and 77.38 cm with denser stems at the size class of 10-14 cm DBH and stand biomass in a range from 0.06 to 127.4 m^3/ha. There were 31 stems/ha in the evergreen forest with the DBH sizes from 41.40 to 108.28 cm and stand biomass between 0.06 and 64.42 m^3/ha. A significant difference exists in stand biomass, basal area, but no difference in crown cover among vegetation types. It can be concluded that, the heterogeneous habitat characteristics in Namatimbili Forest favour the performance of diverse plant species and determine their natural distribution patterns. Large proportion of plant species found in the forest is endemic to the East African Coastal Forests and some of these have been cited under various IUCN threat categories. However, exploitation of timber trees, fire, and clearance for cultivation negatively affected the plant species diversity, distribution and vegetation community structure in this forest. Based on the ecological importance of Namatimbili Forest, the forest need to be considered for gazetting for protection from habitat degradation caused by anthropogenic activities and it should be included in the natural resource management plans of the southern coastal forests of Tanzania.

Key words: Namatimbili forest, coastal forests, endemic, habitas, threats, IUCN, anthropogenic disturbance.

INTRODUCTION

Namatimbli is among natural forests found in Lindi region in the southern coast of Tanzania. The forest forms part of the Eastern African coastal forest mosaic with a number of fragments that are characterized by high biological diversity and are also very rich in species localized in available unique habitats that has resulted in their restricted distribution pattern (Burgess and Clarke, 2000). Efforts to identify and classify the coastal forests mosaic of Tanzania in combination with the adjacent Eastern Arc Mountains to be among important biodiversity conservation centers, date back to 1999 where the two ecoregions together were recognized as one of the 25 Global Biodiversity "Hotspots" because of their exceptionally high levels of biological diversity and endemism (Mittermeier et al. 1999). Revision of global biodiversity centers has continued over time where more ecoregions qualified the assessment criteria. To date the number of conservation centers has increased to 34 hotspots covering 15.7% of the Earth's land surface (Myers et al., 2000) and the coastal forests may stand as a Hotspot in its own right (Mittermeier et a., 2004). The Tanzanian coastal forests being part of the aforementioned hotspots are the leading among the world hotspots in terms of the plant species endemism per unit area and eighth in terms of levels of threat (Brooks et al., 2002; Brooks, 2010). Despite the position the coastal forests hold among the global biodiversity centers, many of the forest fragments' conservation status in the ecoregion is less known in terms of the plant species distribution patterns and their habitat characteristics and the level of protection. A number of forest fragments in the southern coast of Tanzania including the Namatimbili forest have no conservation status and hence not protected. This forest forms part of the 21 coastal forest fragments covering about 145 km^2 in Tanzania with unknown conservation status (Hall et al., 2004). The promotion of the conservation status of most coastal forests in Tanzania through gazetting into forest reserves was carried out before 1961 (during colonial periods). It appears that the process was not exhaustive to include a large part of the land cover that left behind many fragments including Namatimbili fragment ungazzetted. These forest fragments have diverse habitats harboring high plant species diversity and a number of the plant species are coastal endemic and threatened by anthropogenic activities (WWF 2012). One of the common habitats in the coastal forests include woodlands that form the largest vegetation cover interconnecting the various other habitats, including the closed canopy evergreen forest in the southern Tanzania coastal forest ecosystem. Many of the typical coastal forest fragments are less than 20 km^2 and widely scattered, but buffered by the adjacent continuum of woodlands (Hall, 2004).

The various habitats common in coastal forests favor an overlapping plant species assemblage with high ecological conservation value wealth protection. Regardless of the ecological conservation significance of most coastal forests of Tanzania, including the Namatimbili forest, they are threatened by a number of uncontrolled human activities. These activities include illegal exploitation of wood resource, clearance for farming, kaolin and gypsum rock mining, bush fire assisted hunting. These activities have continued illegally in many coastal forests including the Kilwa landscape where Namatimbili Forest is a part. While the northern part of the coastal forest in Tanzania (Tanga Region including Dar es-Salaam) have been cleared for agriculture and sisal estates that significantly reduced the coastal forest cover, some parts in the southern coastal forests particularly in Lindi Region were not largely affected by the large clearance for similar purposes with exceptions of a few small scale clearance for subsistence farming under shifting cultivation and reckless fires being a common phenomenon in the area accelerating the depletion of large cover of coastal forest. As forest loss continues across the coastal forest belt in Tanzania, the species confined to forest habitats including endemic species (Burgess et al., 1998; Burgess and Clarke 2000), will decline in their distribution range and population sizes overtime (Tabor, 2010). There has been a consistent land cover change in the coastal region overtime with increasing woodland and decreasing evergreen forest cover (Prins and Clarke 2007; Tabor et al., 2010). These changes have been accompanied with loss of species habitat that affects the plant populations and species distribution within the coastal forests. Namatimbili Forest being part of the coastal forests is also characterized with various attributes that determine its ecological values and the diverse habitats for biodiversity conservation. These ecological values and various attributes are important to draw an alarm for consideration of changing the conservation status of Namatimbili Forest. The aim of this study was to evaluate the ecological characteristic of Namatimbili Forest in terms of plant species composition; trees vertical size structure, biomass, diversity and distribution and identify plant species of ecological conservation value (threatened and endemic)

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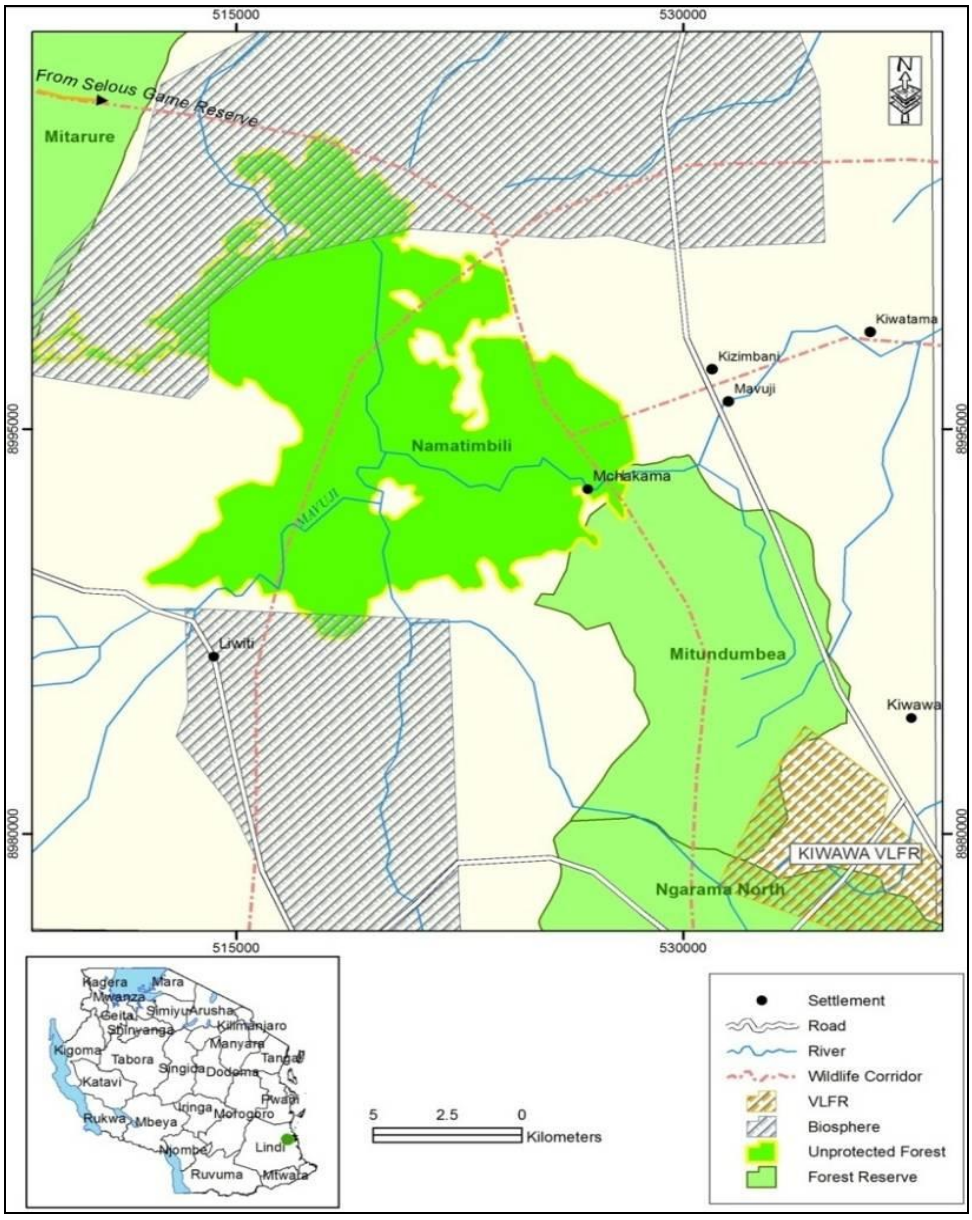

Figure 1. Location of Namatimbili Forest in Lind Region, southern coast in Tanzania.

found within the diverse habitats in this forest. Data on the ecological attributes that covered woodlands, riverine forest, coral rags and closed canopy evergreen forest provide the picture for the need to conserve and gazette Namatimbili Forest.

MATERIALS AND METHODS

The location and description of the Namatimbili Forest

Namatimbili forest is located in Kilwa District, Lind Region in the southern part of Tanzania (Figure 1). It is part of the Kilwa biodiversity landscape that has been regarded as local center of endemism in Tanzania and is the second from that found in the border between Tanzania and Kenya (Clarke, 2001). It is located south-west of Kilwa town and about 6 km from the Mavuji village on the western side of the main road to Lindi and the immediate human settlement adjacent to it being Mchakama village (Figure 1). The Namatimbili Forest lies between longitudes 39° 5' and 39° 16' E and latitudes 9° 0' and 9° 10' S, covering approximately a surface area of 16,033 ha, based on the georeferenced map within an altitudinal range of between 136 and 164 above sea level (Figure 1). The forest is found on the southeastern side of the Mitarure Forest Reserve where a biosphere reserve separates between them. Namatimbili Forest borders Mitundumbeya Forest Reserve to the southern part as well as the biosphere reserve. The

Plate 1. The Namatimbili Gorge that provides a unique characteristics of Namatimbili forest.

forest is bisected by the Mavuji River, which meanders through the valley bottoms that narrows in the Namatimbili Gorge, an ancient coral rag escarpment where the river eventually leaves the forest through Mchakama village.

Namatimbili forest differs significantly in structure from the surrounding vegetation types due to diverse habitats that include the coral rags a unique feature in the coastal forests of the southern coast of Tanzania; apart from the woodland and evergreen forest that are commonly distributed among many coastal forest fragments in Tanzania (Burges and Clarke, 2000). Habitat complexity in this forest makes it support various types of vegetation communities. It is also characterized by undulating landscape with hilltops, valley slopes, valley bottoms, rocky cliffs that forms the unique feature of the Namatimbili Forest "Namatimbili Gorge" (Plate 1) and coral rags with characteristic plant species composition. The closed canopy evergreen forest (also known as Uchungwa) is relatively a pristine patch of natural vegetation on the southwest within Namatimbili Forest. Since all habitats are in a continuous matrix of a typical East African coastal forest vegetation characteristics, the evergreen forest begins as a mixed forest type in the southern part of Namatimbili Hills covering an approximate surface area of 1,000 ha. The woodland covers the largest portion of the Namatimbili on ridge tops, steep and gentle slopes of the rocky hills extending from the north to the southern parts in a matrix with small habitat characterized by bushes, thickets and scrub forest patches. The scrub habitats are scattered throughout the woodlands excluding the riverine, evergreen forest types and *Brachystegia* woodlands. The thickets or scrub forms are characterized by annual burns that provide the template of the scrub habitats. The woodlands begin as scattered trees in an open woodland structure with large grassland patches and then form closed woodland/bushland with juxtaposed patches of evergreen vegetation types. The woodland, therefore, consists of heterogeneous communities that are characterized by diverse plant species associations in the Namatimbili Forest. The coral rag habitat is found on the hillsides of the gorge and on the hilltops in most hills in the central part of the forest. This habitat extends to the eastern part from the Namatimbili hills and the nearby forests including the Mitindumbeya Forest Reserve. Riverine vegetation is found along Mavuji River and along the moist tributaries draining to the Mavuji River system and this represents the best-developed riverine forest in Coastal Tanzania. The Mavuji River supports the most critical riparian habitat and to date the river being sole important for the livelihoods of people in Mchakama village, including the inhabitants upstream. Currently, Namatimbili Forest is not gazetted as a conserved forest reserve such that people from the surrounding areas have full access and exploits the forest woody products from the forest including poaching and logging.

Vegetation sampling Procedure

A preliminary survey was done to identify and characterize the various habitats existing in the forest and this was followed by sampling of vegetation data. Based on the preliminary survey, four identifiable habitats were characterized and a total of four transects were established in Namatimbili Forest. The first transect was established from the Namatimbili Forest hilltop to the northern direction for representing the woodland and bushland habitats. The second transect was running from the Namatimbili hilltop to the western side to represent the closed canopy evergreen habitats and the third transect was established from the same starting point where other transect originated to the eastern direction across the Namatimbili River scarps representing the coral rag habitat. Each of the three transects established cut across various microhabitat conditions, including the hilltops, valley slope and valley bottom. The fourth transect was established following the direction of the Mavuji River system to represent riparian and wetland habitats. Along each transect, a series of nested plots as recommended by Stohlgren et al. (1995) were systematically established at the interval of 200 m. The sampling plots were positioned by alternating on the sides along transects following the method of Kasenene (1987). A plot of size 20 x 50 m was used to sample trees with >10 cm diameter at breast height (DBH), a plot of size 5 m x 2m nested in the larger plot was used for sampling of shrubs together with tree poles and saplings and a plot of size 2 m x 0.5 m nested in the 5 x 2m was used for assessment of herbs, seedling and grasses. The information recorded in the field were the plant species names, diameter at breast height (DBH) for trees, number of shrubs, poles and saplings and the percentage cover for grasses and herbs in relation to the plot sizes. Most plants were identified to species level in the field and those that were difficult to identify, specimen were collected, pressed and taken to the herbarium in the Department of Botany, University of Dar Es Salaam for identification by matching with herbarium specimens.

Data analysis

The trees were summarized in terms of the number of stems per hectare at different DBH size classes, stand biomass, height classes

Table 1. Plant species diversity, evenness and abundance among habitats in Namatimbili Forest.

Vegetation type	Shannon's Diversity	Simpsons' Diversity	Richness	Evenness
Woodland	2.72 ± 0.21	17.08 ± 5.30	240 ± 50	0.52 ± 0.04
Evergreen forest	2.32 ± 0.17	10.19 ± 1.99	160 ±27	0.45 ± 0.03
Coral Rag vegetation	2.28 ± 0.32	11.35 ± 3.91	170 ± 47	0.44 ± 0.06
Riverine forest	1.64 ± 0.19	4.57 ± 0.63	80 ± 17	0.31 ± 0.04
ANOVA	F = 3.76	F = 2.03	F = 2.59	F = 3.76
	P = 0.029	P = 0.145	P = 0.08	P = 0.029
	Significant	*Not signif.*	*Marginal*	*Significant*

and crown cover by species and these were compared among habitats using Analysis of Variance (ANOVA) (GraphpadInstat, 2003). Species diversity index was calculated from the composite plant species data based on Shannon and Wiener Diversity Index (Shannon and Wiener, 1948), and Simpson's diversity index. Species diversity indices including richness and evenness were then compared among habitat types in the Namatimbili Forest. The plant species distribution pattern was assessed by using Detrended Correspondence Analysis (DCA), an indirect gradient analysis (ter Braak and Smilauer, 2005). DCA was employed in this analysis on the assumption that plant species distribution patterns are determined by environmental variables. Furthermore DCA was used because the size of the forest is very small and the ranges of the environmental gradients captured were so small that the response might be colinear.

RESULTS

Plant species composition, diversity, richness and evenness among habitats in Namatimbili forest

A total of 312 plant species were recorded in Namatimbili Forest distributed among 62 families and a great variation was observed among forest habitat types (Appendix 1). Of these, 62 plant species have high conservation status, and 26 plant species are listed in IUCN red list and 36 are purely East African coastal forest endemic species. The most highly represented families were Fabaceae (51 species), Rubiaceae (21 species), Poaceae (18 species), Annonaceae (16 species) and other families had less than 14 plant species (Appendix 1). Species diversity (Shannon–Wiener diversity index, H^1), richness and evenness followed the order of Woodland > Evergreen forest > Coral Rags > Riverine forest (Table 1). Plant species diversity was in a range between 1.45 and 2.93 and the difference among habitats was significant based on single factor analysis of Variance ($P<0.05$). The plant species in woodlands had more evenly distributed individuals, followed by evergreen closed canopy forest, coral rags and the lowest was observed in the riverine forest. Among habitats, the woodland had the highest species composition among habitats with a richness of 240 plant species. Although species richness was highest in woodlands, than other habitats, the difference was significantly marginal based on one-way analysis of variance ($F = 259$, $P = 0.08$). The evergreen forest plant species richness was 160 species, which was lower than that in the coral rag habitat regardless of higher species diversity than the later. The lowest plant species richness was recorded in the riverine forest (80 species) and so did the species diversity, which was significantly lower than that in woodlands based on the Analysis of Variance ($F = 3.76$, $P = 0.029$) (Table 1).

The plant species distribution among habitats in Namatimbili forest

Ordination analysis showed decreasing variation in species composition among habitats from DCA-axis 1 to DCA-axis 4 (90.50, 64.36, 46.17 and 25.87% in that order). The major variation was depicted by DCA axis 1 where samples from riverine forest separated quite clearly and positioned at the highest gradient (7.8 eucledian units) on the right side of the ordination space than the rest of the habitats (Figure 2). The coral rag habitat extended widely in the forests overlapping with other habitats in terms of species composition. The woodland habitats separated from the evergreen forest habitat at DCA axis 3 (Figure 2), and this may be because of plant species composition differences between them, such that the evergreen habitats are characterized by closed canopy trees and the understorey species such that, plant species confined to this habitat are forest dependent.

Species composition in the riverine were characterized by moist dependent plants where the upper canopy layer was represented by Pteryogotaperrieri, Parkia filicoides, Uvariodendron gorgonis, Lettowianthus stellatus, Milicia excelsa, Khaya anthotheca, Ficus sur and Garcinia livingstonei whereas Barringtonia racemosa, Sorindeia madagascariensis, Newtonia paucijuga, Pachystella brevispica, Baphia kirkii, Ziziphus mucronata, Drypetes arguta, Diospyros kabuyeana, Drypetes natalensis and Breonardia salicina were the commonly represented

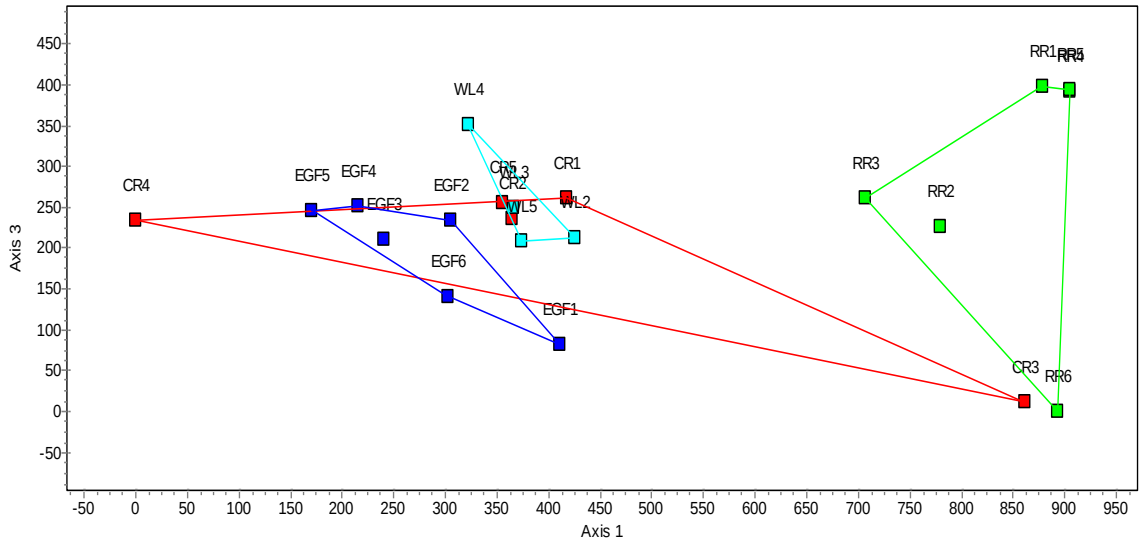

Figure 2. DCA ordination analysis showing the clusters of sites from difference habitats (1-6 = plot numbers, RR= riverine, CR= coral rag, EG= evergreen, WL= Woodland and the polygons marks the clusters of site samples).

understorey species. Within the riverine habitat Encephalartos hildebrandtii was an abundant shrub on *the basement of the cliffs of the Namatimbili Gorge and the understorey parts in riverine forest. Namatimbili forest represents the southernmost habitats threshold favourable for survival and performance of the cycad Encephalartos hildebrandtii. The permanently inundated area along Mavuji River, Phragmites mauritianus, Cyperus denudatus, Polysphaeria multiflora, Culcasiaorientalis* and *Syzygium guineense* were commonly widespread species. However, these species species are vulnerable to being cleared for the wetland cultivation and some of the quality timber trees (*Khaya anthotheca* and *Milicia excelsa*) have been selectively exploited from the riverine habitat. In the closed canopy evergreen forest, *Dialium holtzii*, *Haplocoeluminopleum*, *Hymenaea verrucosa, Strychnos henningsii, Markhamia zanzibarica, Vitex zanzibarensis, Pericopsis angolensis* and *Memecylon sanzibaricum* dominated the upper canopy tree layer and *Dichapetalum mosambicense, Baphia kirkii, Drypetes arguta, Tetracera litoralis, Dichapetalum stuhlmannii, Salacia madagascariensis, Salacia leptoclada* and *Uvaria acuminata* dominated in the understorey. There were small evergreen forest patches on the Namatimbili hillsides and on rocky outcrop escarpment where *Erythrina schliebenii* and *Cynometra gilmanii* were common co-existing with *Cynometra webberi, Cynometra suaheliensis* and *Tessmania stuhlmannii* which are coastal endemic species and vulnerable.

Plant species that were common in the woodland included *Eleodendron buchananii, Sterculia appendiculata, Sterculia quinqueloba, Pterocarpus angolensis, Pteleopsis myrtifolia, Salacia madagascariensis, Mkilua fragrans,* with a few individuals of the scattered *Erythrina sacleuxi*. On the other hand, *Millettia stuhlmannii*, *Brachystegia spiciformis, Pterocarpus angolensis, Afzelia quanzensis, Strychnos henningsii, Lannea stuhlmannii, Haplocoelum inopleum, Vitex zanzibariensis* and *Ochna holstii* had densely packed stems in some parts in the woodlands. The valuable timber trees (*A. quanzensis, P. tinctorius* and *P. angolensis*) have been selectively exploited in the woodlands to some extent, which may have contributed to negative effect on their population structure and relative abundance. The coral rag habitat was characterized by rocky outcrops in many parts with scattered trees between them. *Cynometra gilmanii, Erythrina sacleuxi, Cola greenwayi, Erythrina schliebenii, Strychnos henningsii* and *Codyla africana* dominated the uppermost layer whereas the understorey habitat was dominated by *Encephalartos hildebrandtii*, *Monodora grandidieri, M. hastipetala* and *Drypetes reticulata***.** Observation showed a high level overlap among habitat generalist plant species and the discrimination among study sites through ordination was a function of habitat specialist plant species within the forest and this is because DCA is sensitive to habitat specialist plant species.

Population structure and size class distribution of trees among habitat in Namatimbili forest

The curves displaying the population size class structure for trees in most habitats were skewed to high size classes with high density progressively decreasing to large size classes (Figure 2). Among habitats, woodlands

Table 2. The basal area, woody biomass and crown cover among habitats in Namatimbili Forest (Mean ± SE).

Habitat type	Biomass(m^3/ha)	Basal Area (m^2/ha)	Canopy cover (m^2/ha)
Woodland	333 ± 153	20.4 ± 8.3	102700 ± 30100.3
Evergreen forest	492.2 ± 72	23.9 ± 3.3	113355 ± 12890
Coral rag vegetation	633.1 ± 248	21.0 ± 4.8	107754 ± 28748
Riverine forest	2917.6± 983	73.8 ± 21.5	1056010 ± 884400
F-ratio	5.05	4.41	0.5954
P-value	0.010	0.017	0.626
Conclusion	significant	significant	not significant

were represented by high density of stems of size class 10-14 cm DBH and this pattern was the same as in other habitats. The riverine habitat had high representation of individuals beyond DBH sizes of 90 cm, regardless of all the habitats with individual representation beyond this size class (Figure 2). Most tree stems in the woodland habitat had lower than 50cm DBH sizes but lower than 60 cm DBH from trees in evergreen closed canopy habitats. However, trees in coral rags and riverine forest had large number of individuals with DHB sizes of 70cm and 90cm respectively and had trees represented in most of the classified size classes in Namatimbili Forest.

The riverine forest had a total of 136 stems/ha where individuals had DBH sizes between 41 and 292.99 cm. *Khaya anthotheca* had high density of stem with large DBH sizes whereas other trees had individuals with DBH sizes below this range. The coral rag vegetation had a density of 42 stems/ha where *Bombax rhodognaphalon, Cordyla africana, Cynometra webberi, Khaya anthotheca, Pteleopsis myrtifolia, Scorodophloeus fischeri, Terminalia zambeziaca* and *Xerroderis stuhlmannii* had DBH sizes ranging from 41 to 95.5 cm while trees had DBH sizes below this range. The observed 28 stems/ha in woodlands were represented by trees with the DBH sizes between 41 and 77.38 cm. There were 31 stems/ha in the evergreen forest, which was represented by trees with the DBH sizes between 41.40, and 108.28 cm and many trees had DBH sizes lower than this ranges.

Basal area, stand biomass, height and crown cover in various habitats in Namatimbili forests reserve

The biomass in the woodlands ranged from 0.06 to 127.4 m^3/ha where trees that contributed large amount were *A. digitata, A. quanzensis, B. rhodognaphalon, D. hispidula, P. myrtifolia, S. birrea, T. zambeziaca* and *X. stuhlmannii* with the biomass in a range between 3.55 and 127.40 m^3/ha. In the evergreen forest, the range of biomass was between 0.06 and 64.42 m^3/ha where *Afzelia quanzensis, Cleistanhtus schlechteri, Combretum adenogonum, Hymenaea verrucosa, Dialium holtzii, Diospyros mesipliformis, Manilkara bicolor, Maytenus undata, Millettia stuhlmannii, Strychnos heningsii, Strychnos occoranum, Terminalia zambeziaca*and *Vitex zanzibariensis* contributed more of the total biomass in a range from 4.12 to 64.42 m^3/ha. The coral rag vegetation had a biomass in a range from 0.1 to 59 m^3/ha, and the major contribution was from trees with large DBH sizes including *Bombax rhodognaphalon, Cordyla africana, Cynometra webberi, Pteleopsis myrtifolia, Terminalia zambeziaca* and *Xerroderis stuhlmannii* with biomass between 4.64 and 59.72 m^3/ha. Trees in the riverine had the highest biomass than it was in other habitats (Table 2) that ranged from 0.1 to 876.06 m^3/ha whereas *Baringtonia racemosa, Ficus sur, Garcinia livingstonei, Khaya anthotheca, Milicia exelsa, Mimusops kummer, Pteleopsis myrtifolia, Sclerocarya birrea, Sorindeia madagascariensis*, *Sterculia appendiculata, Syzygium guineense* and *Terminalia zambeziaca* contributed more biomass between 4.64 and 876.06 m^3/ha such that, *S. appendiculata* had the highest contribution (876.06 m^3/ha) and other trees contributed below 216.48 m^3/ha. Analysis of Variance (ANOVA) showed significant difference in the overall biomass accumulation among habitats (Table 2). Regardless of low density, based on students t-test, the riverine habitat had more biomass than the woodlands (LSD = 258.42, q = 4.65, $p<0.05$), evergreen forest habitats (LSD = 242.54, q =4.53, $p<0.05$) and coral rag habitat (LSD = 228.45, q = 4.074, $p<0.05$). Similar pattern was observed for the trees basal area where the difference was significant among habitats (F= 4.41, P = 0.017) where the riverine habitat had significantly higher basal areas than the woodlands (LSD = 53.43, q = 4.17, $P<0.05$), evergreen forest habitat (LSD = 49.98, q = 4.09, $P<0.05$) and coral rag habitat (LSD = 52.83, q = 4.13, $P<0.05$).

Although biomass was high in trees of the coral rags than that in evergreen forest habitat, the trees basal area on average was lower than the aforementioned habitats. Trees in riverine habitat had extensive crown cover followed by that in evergreen forest habitat but the difference based on ANOVA was not significant ($P>0.05$) (Table 2). Most trees were in the height sizes between 6 and 25 m among habitats except in the riverine habitats where some trees were 55 m tall. The woodlands and

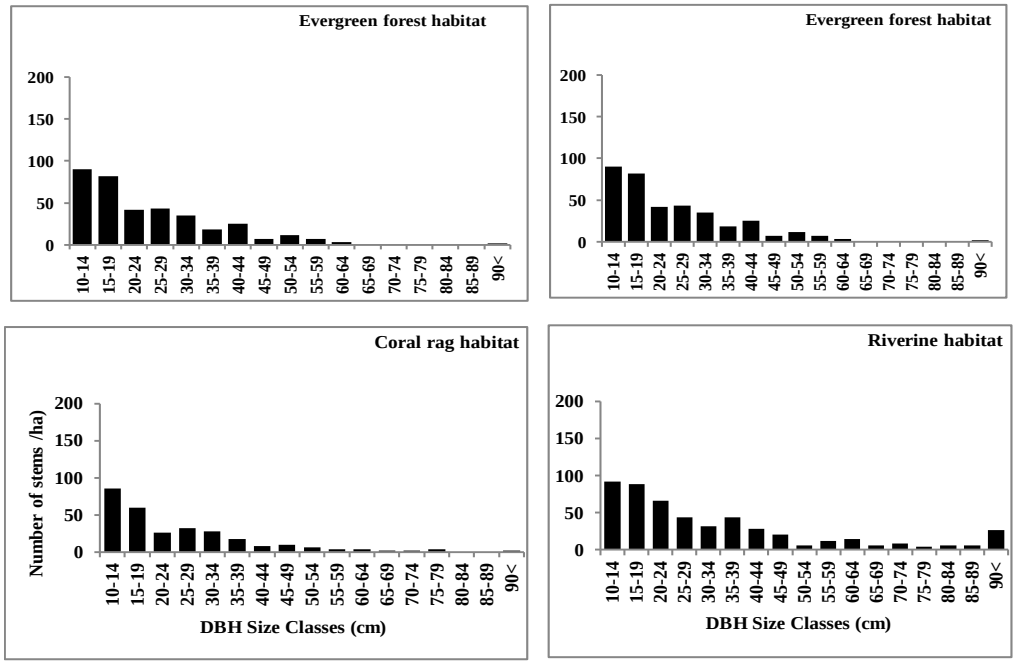

Figure 3. Size class distribution of trees in various habitats in Namatimbili Forest.

evergreen forest habitats had equal representation at the maximum height classes (Figure 3). The tree height classes beyond the aforementioned habitats were recorded in both coral rag and riverine habitats (Figure 3). The trees with the tallest stems in woodland were *Adansoniadigitata, P. myrtifolia, S. birrea, T. zambeziaca* and *X. stuhlmannii* with a range of heights between 20 and 25 m. The tallest trees in the evergreen forest included *D. holtzii, H. verrucosa, M. bicolor, N. paucijuga, T. zambeziaca* and *V. zanzibariensis* with the height between 21 and 25 m. The tallest trees in coral rag habitat were *C. webberi, K. anthotheca, B. rhodognaphalon, C. africana* and *S. fischeri* with heights from 51 to 55 m. In the riverine habitats *A. glaberrima, B. racemosa, K. anthotheca, Milicia exelsa, S. appendiculata* and *S. gueneense* had similar range of heights as those in some parts in coral rag vegetation.

DISCUSSION

Plant species composition, diversity and richness in Namatimbili forest

The variation in plant species composition among habitats in Namatimbili Forest implies that the vegetation communities need conservation attention like any other coastal forest in Tanzania. Clarke et al. (2000) pointed out that variation in plant species assemblage is determined by anthropogenic factors, rainfall patterns and soil characteristics. Also, Hall et al. (2004) pointed out that soil, geology and landscape characteristics might have significant impacts on the community structure of the vegetation in the coastal forests. Silt red, greyish and mixed soils were soil physical characteristics that determined the complex vegetation communities in the woodlands in Namatimbili Forest. The woodland habitat was characterized by diverse microhabitats in a matrix composed of bushland, shrublands, evergreen patches in a range of topographic positions (hilltops, hill slopes, valley bottom) that determined plant species preference in various organized communities. Plant species composition difference among communities is the outcome of the aforementioned landscape attributes found in Namatimbili forest. Some parts in the woodland are characterized by large cover of coral rag rocky outcrops which are widely distributed in most parts of the forests. The coral rag vegetation provides a unique characteristic of Namatimbili Forest and many other coastal forests in Lindi Region. Utumi (2002) reported high densities of *Encephalartos hildebrandtii* and endemic trees such as *Cynometra filifera*, *Cynometra gillmannii* and *Erythrina schliebenii* in the coral rag in the forests of Kilwa and Lindi districts, which is similar to the observation, made in this study. Few plant species may survive in certain habitats only and are regarded as habitat specialists whereas many plant species are habitat generalists.

According to Burgess et al. (2000), the dominance of ecologically generalist plants in coastal forests is attributed

to small sized patches surrounded by mosaic habitats, which are generally dry for an extended period of the year. The riverine, evergreen, woodland and coral rags are habitats for both habitat specific and generalist species. The highest species evenness in woodlands implies high composition of generalist species because of unlimited habitat preference. Howell et al. (2012) pointed out that, *Pteleopsis myrtifolia, Terminalia zambesiaca, Strychnos heningsii, Millettia stuhlmannii* and *Zanthoxylum chalybeum* are habitat generalist species. The distribution of these species overlap among communities is because of of the similarity in their habitat conditions found within Namatimbili Forest. Similar observation was reported by Clarke (2011) in the study of the vegetation ecology of the coastal forests in Palma and Nangade District of Mozambique that a huge overlap exists in species composition among habitats and vegetation communities. Since this study was carried out in one of coastal forest fragments, the habitat types identified in Namatimbili Forest reflect the characteristic vegetation community types found in most coastal forests in Tanzania (Clarke and Robertson, 2000). The woodland, riverine, coral rag and evergreen forest are distinct habitat characteristics with well-represented vegetation communities in Namatimbili Forest. The woodland habitat has more evenly distributed species, which are continuously at wider scale than other habitats that are more fragmented with uneven distribution of individual trees. This is because random distribution of individuals and spatial heterogeneity of light resources created by various tree size classes offers an opportunity for multiple species co-existence as supported by Kohyana (1994). However, low evenness implies the existence of species microhabitat preference in habitats in Namatimbili Forest. Low evenness in the riverine vegetation may be contributed by discontinuity of habitat that supports similar kind of species. This causes the fragmented species distribution in some sections in the Mavuji River system that may have resulted into lowest evenness among habitats. The presence of floodplains which support *Khaya anthotheca, Milicia excels* and *Syzygium guineense,* differs from the rocky cliffs that support *Erythrina schliebenii* and *Encephalartos hildebrandtii*, and clay rich river banks in the upstream that supports heterogeneous vegetation communities commonly represented by *S. guineense, A. polyacantha* and *M. excelsa*. Each microhabita supports different community composition and that is why plant species are less evenly distributed along the riverine than in other habitats.

Species diversity is the most important ecological parameters determined for the purpose of designing and deliberating an area for biodiversity conservation purposes. *Alpha* diversity in Namatimbili forest was determined so as to scale out the importance of plant biodiversity conservation in the southern coastal Tanzania. Kent and Coker (1992) pointed out that, most habitats have Shannon's diversity index between 1.5 and 3.5, whereas Murali et al. (1996) pointed out that a habitat with diversity index between 2.56 and 2.86 as diverse. The diversity indices for Namatimbili Forest were between 1.45 and 2.93 which implies that high species diversity exists among habitats in this forest. The *alpha* diversity indices suggest a high species richness within habitats that is at the same level as those indicated by Kent and Coker (1992). This implies that diverse plant species assemblages exist among diverse habitats in the Namatimbili Forest that worth high conservation attention. Disturbance cannot be put outside the framework of discussing the conservation values of the southern coastal forests of Tanzania. Plant species diversity may be influenced by habitat heterogeneity and the varying levels of anthropogenic disturbances (Mligo et al., 2011) and this affects microsites for plant diversity (Hobbs, 1992). Although the woodland is selectively logged, the dominance of few trees may be reduced giving room for unrepresented species to expand in their distribution range. Halpern and Spies (1995) reported that the heavily disturbed habitats through logging favour dominance by ruderal species. However, Namatimbili Forest can be regarded as less disturbed except in some few areas such that the indigenous trees are responding to such disturbance in the same way as it occurs under natural vegetation dynamics in a forest. High level of disturbance lowers species richness (Armesto and Pickett, 1985). However, low species richness in the riverine habitat contributed by the dominance of a few trees that prevent light resource for other species. The environmental stress may only favour plant species that are capable of surviving by using the meagerly captured resources (Grime, 1979). A number of light stress tolerant plant species co-existed in the understorey within trees of the uppermost layer in the closed canopy evergreen forest and riverine habitats contributing to their current richness.

Mavuji River is important to the ecosystem as it provides permanent moist conditions in the riverine habitat, which favour continuous growth of plants and hence high biomass accumulation than in other habitats whose trees biomass are characterized by seasonal growth. The riverine condition favour plant species that are performing under perennial moist conditions where many of them are endemic to the Swahilian region. These conditions however are very rare in the coastal forests in general (Clarke and Robertson, 2000) and localized within the drainage system in the region, but may extend downstream according to the duration of the flows. There are substantial heterogeneous microhabitats in the woodlands, including scrub, bushland and thickets that do not correspond directly with the classification by Clarke and Robertson (2000). The habitat categories in Namatimbili Forest are the outcome of analysis of

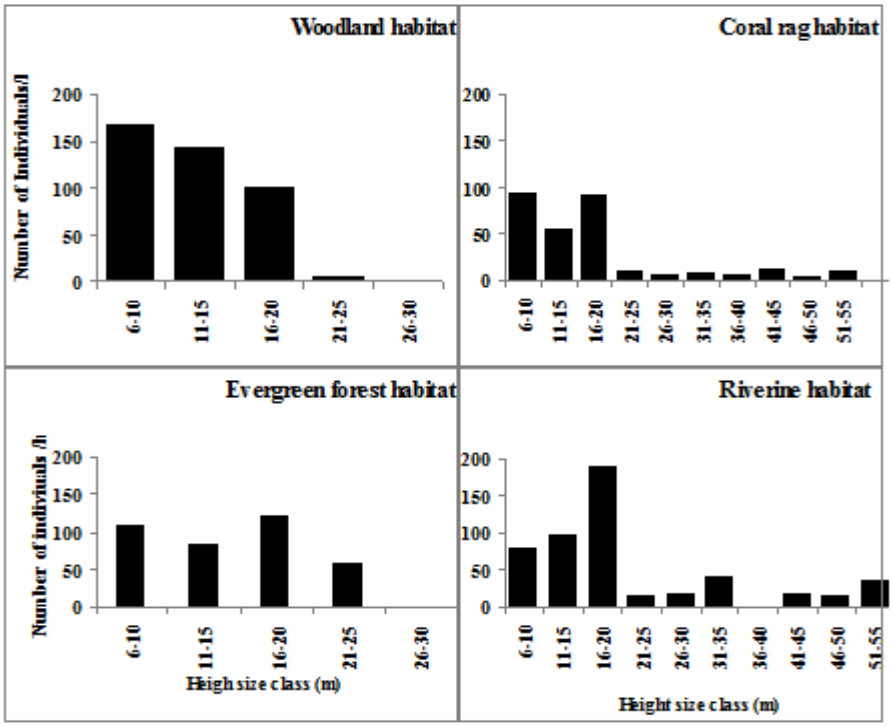

Figure 4. Variation in heght size distribution of trees among vegetation types.

complexity of vegetation community types under heterogeneous habitat conditions. This output provides simplicity in classifying habitats for understanding of the ecological characteristics of many coastal forest fragments that are found in Kilwa biodiversity conservation landscape.

Variation in plant population structure, basal area, biomass, height stratification and crown cover among habitats in Namatimbili forest

Tree population structures play an important role in the dynamics of forest ecosystem (Kohyama, 1994). It was considered that analyzing DBH size class distribution of trees among habitats could provide an understanding of population structure in Namatimbili Forest. According to Deb and Sandrily (2008); Kohira and Ninomiya (2003), tree size class distribution is associated with population trends; and this is an adequate measure of population dynamics (Kohyana, 1994; Bin, 2012). Because Namatimbili Forest is accrued with diverse local and regional endemic plant species, its future stability will depend on active recruitment under the influence of environmental factors in combination with anthropogenic activities. The difference in maximum DBH size classes of trees among habitats is a reflection of variation in microhabitat conditions where tree species adapt differently.

Some trees in woodland and evergreen forest do not grow beyond 25 cm DBH size classes (Figure 4) and this has been contributed by variation in habitats conditions where the riverine is favoured by perennial moist conditions than the intermittent conditions in the other habitats. Kumlachew et al. (2003) pointed out that, small sized individuals in a given population function as a significant reserve for replacing older individuals. A skewed curve to lower DBH size classes is an indication of community succession (Diekman, 1994). DBH size class variations among habitats show that tree populations are expanding with active recruitment at lower size classes that will replace ageing or dying trees in the forest. High representation of trees with large size classes among habitats was due to limited anthropogenic pressure in combination with their survival tactics under various environmental influences and these represent relics of the previous vegetation communities. Converting the forest to a reserve will prevent anthropogenic pressure and the vegetation community structure will be stable and provide ecosystem services under new conservation status. Regardless of the selective exploitation of trees in Namatimbili Forest, their populations are still stable and the level of degradation is considered low and therefore merits to be included among conserved reserves within the Kilwa biodiversity landscape. The patterns of DBH size class distribution in

the study forest were contributed much by plant species from families Sapotaceae, Caesalpiniaceae, Sapindaceae, Fabaceae and Combretaceae. This means that plant species from these families play a big role in characterizing vegetation community structure, functions and dynamics among habitats in Namatimbili Forest. Although there is illegal and licensed chain sawing in the Namtimbili Forest and the nearby forest patches, the tree population size class distribution showed little indication of negative impacts of exploitation that may be affecting natural regeneration. For the purpose of forest conservation, trees are the most important life form to monitor because they determine the microhabitat conditions suitable for forest biodiversity. Being a dominant life form, trees are easy to locate precisely and count (Condit et al., 1998) and are also relatively better known taxonomically (Gentry, 1987). The diameter size class distribution determines the amount of stem, basal area and biomass accumulated by the tree species in the forest. The basal area was presented because it provides an understanding of the forest- wildlife habitat relationship and helps to determine the conservation and protection decision since it is in close proximity to the Selous Game Reserve and therefore a habitat buffer zone to the wildlife sanctuary in the southern coastal region of Tanzania. Microhabitat variation among habitat may be the cause of variation in biomass accumulation of individual tree species in Namatimbili Forest. The growth of trees in habitats with a constant supply of moisture, nutrient, and light are likely to continue. Trees with large DBH size classes are consistently intercepting large amount of light to accumulate large amounts of biomass. This may be the cause of extensively tall trees in the riverine where some stems had heights beyond 50 m and the understorey were trees adapted to diffuse light conditions. Because of these the richness was lower than other habitat and the riverine community was characterized by a large number of individuals represented only by few species. Trees with large biomass, basal area and crown cover that were found in the riverine habitat were contributed by the stable moist conditions caused by the presence of perennial flows from Mavuji River. The dominant trees that contributed largely to the basal area, biomass and crown cover included *Khaya anthotheca, M. excelsa, B. racemosa, S. guineense, P. filicoides, S. appendiculata* and *A. glaberrima*. These trees benefited from the favorable habitat conditions contributed by the flow dynamics in the river system.

The impacts of human activities on distribution of plant species in Namatimbili Forest

Species distribution in Namatimbili Forest is largely contributed by the existing habitat characteristics in combination with the anthropogenic activities. *Erythrina schliebenii, Cynometra webberi, Encephalators hildebrandtii* and *Cynometra gulmanii* are commonly found in the forest coral rag habitats and *Scorodophloeus fischeri, Coffea pseudozanguebarica, Leptactina papyrphloea* and *Vitex zanzibariensis* were common in habitats with silt loam and reddish soils in the hillslopes. On the sandy soils of the floodplains were found *Milicia excelsa*, *Khaya anthotheca*, *Sorindeia madagascariensis* and *Polysphaeria parvifolia*. However, observation showed that both natural and anthropogenic disturbances play a big role in shaping the vegetation community structural organization among habitats in the Namatimbili Forest. Hall et al. (2004) pointed out that anthropogenic activities result in scrub, wooded grassland, grassland and forest edge habitats in coastal forests. Disturbance is known to affect microsites for plant diversity (Hobbs 1992). Part of the evergreen closed canopy is being transformed to other habitat types including woodlands and bushlands. Open canopy allows colonization by short lived and opportunistic species that accumulate combustible fuel in a short period and favor fire occurrence. Frequent burning reverts the forest into woodland and grassland, but fire controlled habitat can recover to woodland (Peterson, 2001). The already affected areas may revert to woodland and lost coastal forest characteristics if Namatimbili Forest is gazetted and protected.

A number of anthropogenic activities are transforming the forest into a degraded habitat where the evergreen forests are changing into scrubs, bush lands and thicketed wooded grasslands. The frequent fires that emanate from the forest surrounding villages may be the cause of increased grassland patches and scrub in woodlands. The reserve is surrounded by various kinds of land use types including crop cultivation in the Mavuji riparian habitat. This is an important agricultural area for production of vegetables for livelihood of Mchakama villagers and the surrounding communities. Intrusion to the natural habitat upstream has been a common phenomenon. Logging, pole extraction and exploitation for timber are among the ongoing illegal activities in this forest that is targeting important timber species including *K. anthotheca, A. gummifera, P. angolensis, D. melanoxylon, M. excelsa, P. tinctorius, A. quanzensis* and *M. stuhlmannii.* Some of the evergreen forest parts are now reduced to patchy bushland with only few less valuable timber tree species remaining in the fragments. The riparian trees were still dominated by *K. anthotheca* but low density of large sized *M. excelsa*. The area is close to human settlement and contains regenerating *Scorodophloeus fischeri* and *Cynometra webberi* that are highly prized for use as building poles and if not gazetted and protected will be depleted following the increased demand that aggravated intensive exploitation.

The existing variation in vegetation community structure within forests partly was contributed by logging that depleted the populations of the target species that might have lead to the present conditions in the forest. When large timber trees are removed the forest canopy is opened up thereby enabling more widespread species to regenerate and making the forest more vulnerable to fire. Although woodlands are usually tolerant to low temperature fires, most forest species are sensitive to fire and easily destroyed by fire. This makes all the forest habitats destroyed by fire that affects species diversity and distribution patterns.

The impact of habitat degradation on the plant species with high ecological conservation status inNamatimbili Forest

There are various habitats identified in this forest where species with high conservation status have been found, securing survival resources, maintaining their minimum population sizes through interacting with both biotic and abiotic resources. The best conservation management option is that which takes into account of preserving species habitats to maintain the population stability. While both natural and anthropogenic disturbance are the major concerns for the species habitat loss, the latter is more stringent and have negative impacts to habitat with species of high conservation concern. Expanding agri-culture provides threat to the Namatimbili forests' natural habitats because of clearance of pristine parts that causes habitat destruction. The closed canopy evergreen and riverine habitats have fertile soils and therefore more vulnerable than in the woodlands. *Sesamum indicum* cultivation has rapidly grown within the last three years (2011-2014) following the availability of potential market where the previous practiced subsistence farming has changed to agribusiness. This has been accompanied by opening up of large land areas for the said crop cultivation and large part of Namatimbili Forest has been encroached. The ongoing clearance of the forest contributed to the current degradation of the potential natural habitats that accommodate endemic and threatened species. With a particularly heavy logging in Kilwa and Lindi Districts, Namatimbili Forest may not be exceptional making it unfavorable for forest dependent plant species. The impact of logging particularly was observed in the woodlands (*D. melanoxylon*, *A. quanzensis*, *P. angolensis*), riverine (*M. excelsa* and *K. anthotheca*) and closed canopy evergreen forest with selective removal of large trees that affects the plant species co-existence and degraded the habitats.

Fire impact is a common phenomenon in Namatimbili forest, which affects biodiversity habitat. It may escape during land clearance or ignited deliberately by illegal hunters to drive animals for easy hunting in the woodlands. The availability of wildlife has been possible because Namatimbili Forest is in close proximity with Selous Game Reserve and animals are unaware of the landscape borders. The habitat for the forest dependent plant species may undergo total destruction affecting species that are not adapted to fire. The degraded habitat remains behind with only fire-adapted species and the previously evergreen forests may change to woodlands and grasslands. The expanding woodlands cover in the east southern Namatimbili Forest is a result of frequent burning accelerated by exploitation of woody resources and hunting. The unprotected Namatimbili Forest will result into negative effect to plant species with restricted habitat requirements (endemic) and threatened plant species. The identified threatened plant species included *C. gilmanii, C. webberi, C. suaheliensis*, *T. stuhlmannii* and *V. zanzibarensis* in evergreen vegetation; *Uvariodendron gorgonis, Lettowianthus stellatus, Milicia excelsa*, *Khaya anthotheca, Newtonia paucijuga, Baphia kirkii* and *Encephalartos hildebrandtii* in the riverine; *Zanthoxylum chalybeum*, *Monanthotaxis trichantha, Ophrypetalum odoratum, Erythrina sacleuxi, Vitex zanzibariensis* in the woodlands and *Cynometra gilmanii, Erythrina sacleuxi,Cola greenwayi* and *Erythrina schliebenii* to mention a few in the coral rag vegetation. These species are coastal forest endemics and are also cited under various IUCN threat categories (IUCN, 2011). While *Cynometra gillmannii*, *Erythrina schliebenii* are the IUCN critically endangered species, *Vismia pauciflora, Uvariodendron gorgonis*, *Tessmannia densiflora*; *Uvariodendron gorgonis* are endangered species. On the other hand, the vulnerable plant species are *Erythrina sacleuxii, Khaya anthotheca, Baphia kirkii, Cynometra webberi, Mkilua fragrans, Vitex zanzibarensis, Zanthoxylum holtzianum, Dialium holtzii, Ophrypetalum odoratum, Khaya anthotheca, Newtonia pucijuga, Coffea pseudozanguebariae, Gardenia transvenulosa, Vitex zanzibarensis* and the near threatened are *Encephalartos hildebrandtii, Milicia excelsa* and *Lettowianthus stellatus* (Appendix 1). The identified threatended plant species from Namatimbili Forest forms 8.33% of the total number of plant species recorded in this forest. Since many plant species are coastal forests endemics (Appendix 1), in total they formed 11.53% of all the plant species recorded in Namatimbili Forest. Because of the unprotected nature of Namatimbili Forest, the habitats of threatened species will be degraded and destroyed, consequently resulting into decrease of their population sizes. This will affect further their already restricted distribution pattern in the coast forest ecosystem and their genetic diversity within populations. The ongoing anthropogenic disturbance may negatively affect populations of *K. anthotheca, B. kirkii, C. webberi, V. zanzibarensis* and *M. excelsa* through timber production and the rest may be cleared for agricultural or

destroyed by fire. Exploitation of canopy trees for timber may expose the understorey species to new environment that are not the habitat attribute for their performance and therefore fail to survive. Also, the microclimatic conditions that could be maintained by the upper most tree layer in the vegetation stand cannot be available to understorey layer and hence the community can be interrupted in favour of pioneer, invasive and sun loving plants. Clarke (2001); Prins and Clarke (2007) reported a number of local endemics in Kilwa Landscape, to include *Trichilia lovettii, Baphia keniensis* and *Leptactina oxyloba.* Perkin et al. (2008) pointed out *E. schliebenii, M. trichantha*, *C. gillmannii*, *C. filifera*, *C. pulchella* and *D. magogoana* as endemic to the Lindi landscape. Based on the data in Appendix 1 on this study, 36 plant species were coastal endemic and their habitats are frequently burnt, degraded through exploitation of timber trees and destroyed through clearance for cultivation. However, the discrepancy of data among the afore-mentioned studies shows insufficient information to conclude about actual distribution pattern of plant species with high ecological conservation value within the landscape and the difficulty to quantify the magnitude of threat to endemic plant species from the ongoing anthropogenic activities. There is heavy extraction of timber in the nearby forest reserve such as the Mitarure (Ball, 2004), such that this may not rule out the impacts of the same in Namatimbili Forest which is in close proximity to Dar es salaam- Lindi main road and easily accessible. The significant threat comes from the recent inclusion of the northern part of the Uchungwa/Namatimbili forest to be a potential site for bio-fuel farming (Perkin et al. 2008), where large proportion of the forest may be cleared for *Jatropha curcas* farming. It is expected that a large portion of the woodland habitats of Namatimbili Forest to be converted to a plantation and this is expected to be potential threat to conservation of biodiversity in the Kilwa Landscape.

With the existing limited information available so far describing the conservation management status for most of the southern Tanzania coastal forest fragments, data on the unprotected Namatimbili Forest fragment adds up to the existing knowledge gap regarding the current ecological conservation value. The ecological conditions of the forest fragment, particularly linking the diverse habitat and vegetation community structure among habitats in the forests forms the basis for the protection of ecological values present in the forest. Clarke *et al.,* (2000) pointed out that the conservation value of most coastal forests is because of richness in species with restricted distribution. Namatimbili Forest fragment can be recognized of high conservation value because of high proportion of endemic species. Also, the presence of large proportion of plant species under various IUCN threat categories may highlight the ecological importance of protection of Namatimbili Forest.

Conservation management implication of Namatimbili forest

Namtimbili Forest is currently not in any conservation and management ownership from either local community or the central government authority to guarantee its protection where the resources are extracted illegally. Although the pressure on forest resources and the encroachment of the forest has not been quantified, observation in the field confirmed the existence of degraded forest habitats. Blomley *et al.,* (2008) pointed out that participatory forest management is the strongest technique for biodiversity conservation in coastal forests of Tanzania. However, the local communities are not conscious enough to play their role in the conservation of the Namatimbili forest. This is because there is no available organ to establish agreement among parts to share efforts in conserving the forest that involve local community participation which may prevent further forest degradation. The anthropogenic activities that have negative impacts on species with specialized habitats in Namatimbili Forest include the extraction of forest resources such as building poles, timber, illegal wildlife poaching, clearance of the pristine forest for crop cultivation and reckless fires. Since there are no forest boundaries that may be used to prevent access to the forest resources; clearance of land for crop farming may continue unlimited. With gradual increase in cultivation of *Sesamum indicum* and opening up biofuel crop plantations'*Jatropha curcas"* for external market purposes more clearance of the pristine forest is expected unless the forest is gazetted, boundaries are clearly marked and the local community is well educated enough to recognize that forest resources need to be conserved or sustain ably utilized if possible. The future of the southern coastal forests of Tanzania including Namatimbili Forest rests on the efforts to demarcate boundaries from forest encroachment and protection of habitat and gazzeting it as conserved forest reserve. A map used in this article may provide the base for establishment of boundaries along the already predetermined boundaries of the forest reserve since this forest is among many forest patches in southeastern Tanzania that are not gazetted and therefore unprotected.

Namatimbili Forest, including the neighbouring forest patches have "charismatic" plant species assemblages which make them being of high biodiversity conservation importance in the southern coast of Tanzania. For appropriate protection of Namatimbili Forest, it needs to be part of the conserved southern coastal forest ecosystem covering habitats with relatively closed canopy evergreen habitats, the unique coral rag (of the southern coastal forests) and the integrated riverine forest within Kilwa Landscape of the southern coast of Tanzania. The existence of vegetation communities with

a large number of coastal forest endemic plant species and threatened plant species signify the conservation importance of the Namatimbili Forest fragment and other fragments in Kilwa biodiversity landscape. Conserving plant populations in this forest will contribute to the preserving genetic diversity remaining in the southern coast of Tanzania. Since a large part of the coastal forest cover has now gone, the decision to conserve and protect the remaining few fragments of which Namatimbili Forest is part that needs to be prioritised. This will make the forest habitat in the Kilwa-Lindi landscape thoroughly connected for conservation of high species richness and this may have high conservation implications to forest dependent species that require a large dynamic area for performance. The study forest is among interconnected valuable coastal forest fragments to include the Mitundumbeya, Mineature, biospheres, Mbarawala and Ngarama and the mangrove populations in a continuous matrix. The interconnected habitats may have been the cause of the existing wildlife corridors and Namatimbili Forest being the junction for these corridors in Kilwa-Lindi landscape, where wildlife migrate among the inter-connected coastal forests and Selous Game Reserve in Lindi Region. The major wildlife corridor originates from the southern part of Selous Game Reserve through Mitarure FR and biospheres to Namatimbili Forest. The corridor then radiates to the south, forming two arms that go through Mbarawala plateaus to Pindiro Forest Reserve. One sub corridor is a few kilometres north of Mavuji River-bridge, the second is located at Mavuji Bridge and the third passes south of Hoteli tatu up to Namakongoro in the Mangrove forest. Therefore, conservation management by protecting Namatimbili Forest will maintain the existing wildlife corridors among forest patches and Selous Game Reserve. Also increasing the matrix of conserved forest fragments within Kilwa-landscape provides adequate dynamic areas to various biodiversity components in the southern coastal ecoregion of Tanzania.

On the other hand, protecting Namatimbili Forest will ensure preservation of landscape values based on the observed plant biodiversity potentials and the forest gorge. The magnificence of the Namatimbili forest gorge provides a unique landscape feature that is unparalleled along the entire eastern African coast that increases the forests' conservation value. The presence of the forest gorge and a well-developed riparian forest cover along Mavuji River provide a unique characteristic of Namatimbili Forest in comparison with other coastal forests in Tanzania. Namatimbili forest gorge and caves under the coral rag limestone rocks in combination with the sacred forest with the hippo pool at Nyange River in Makangaga village provide long-term tourist potentials in the Kilwa landscape. The easy accessibility of the gorge from the main road increases its potential as a tourist destination linking between the coastal cities of Kilwa Kivinje, the ruins of Kilwa Kisiwani and the wildlife of the Selous Game Reserve which together increase the ecotourism potential of the Namatimbili forest and the Kilwa Landscape.

Conclusion

Namatimbili Forest has a number of habitats harbouring diverse plant species compositions. Although the woodland had high plant species diversity, it was represented by forest generalist species that were more evenly distributed than in the riverine and coral rag that had habitat specialist species with large biomass. The tree size class distributions are related to the habitat types and their performance are determined by respective habitat conditions in the forest. Bin (2012) pointed out that tree size distribution has long being of interest to ecologists and foresters because they reflect fundamental demographic processes. Although plant size class structures may provide insufficient basis for conservation management decisions (Virillo et al., 2010), the information gathered showed the presence of various size classes at different demographic levels, which gives a sufficient criterion for categorization of Namatimili as a forest reserve with adequately conserved and protected habitats. The size class distributions among the forest habitats reflect shade tolerance strategies and indicated that many populations were stable because of the limited major disturbance events within Namatimbili Forest. Wright et al. (2003) pointed out that shade-tolerance, demographic traits (fecundity, seedling mortality, recruit-ment, sapling growth and sapling mortality rates) is related to population size structure. However, Virillo et al. (2010) found no empirical evidence that population size structures are related to changes in population size. This implies that individuals of a cohort that begins at the same level of growth structure may pattern in a very different growth direction with time and growth resources resulting in different vegetation community structures. Multiple vegetation community structure in an ecosystem provides refuge to a number of species with different ecological requirements that has been portrayed in Namatimbili Forest. A successful biodiversity conservation model is that which takes into consideration of preservation of diverse habitats that are found in Namatimbili Forest similar to the adjacent coastal forests within Kilwa- Lindi landscape. The habitats in Namatimbili Forest are natural and therefore depict similar characteristics of the ecological rich coastal forest region making it of high conservation concern. From the ecological and biodiversity conservation context, the forest cannot be separated from the efforts to conserve the whole Kilwa-Lindi landscape and southern coastal forest. Based on

findings from this study, the responsible organs may use this data in combination with various guidelines, including the biodiversity conservation convention of 2010 in strategic planning for protecting Namatimbili Forest. The appropriate zoning of all the unprotected fragments, including Namtimbili Forest as forest reserve by gazetting them will be assured of its protection under the regulation of forest reserves. This will minimize unsustainable conservation practices that have been operating in Kilwa landscape. The most effective and least expensive way of preserving biodiversity is by maintaining native species in their habitats where there is a greater chance of success in ensuring the long-term conservation (Rodrigues et al., 2007). Tanzania is currently limited of conserved forest reserves and this need promoting the unprotected forests to a conserved status so that biodiversity conservation objectives can be met. Like any other coastal forest in Tanzania, Namatimbili Forest cannot be treated in isolation rather the conservation efforts in the region should be inclusive with other forests adjacent to it. Regardless of the available information on the general characteristics of the southern coastal forests of Tanzania (Frontier, 2001; UTUMI, 2002; Howell et al., 2012), some forest patches are yet exhaustive. Based on the detailed characteristics of Namatimbili Forest highlighted, the diverse ecological attributes may contribute to the decision to conserve aforementioned coastal forest fragments. The minimum area required for protecting endemic species in the coastal forests needs to include multiple habitat types along the southern coastal strip of Tanzania. Protecting the threatened, endemic and the near-endemic species require a matrix of interconnected patches with properly managed corridors and habitats. This should involve prioritisation of patches that are close to each other in one landscape for easy management. Namatimbili Forest is connected to the rest of the forest patches and hence the inclusion of this patch among conserved forests would benefit from the overall conservation of the southern coastal forest ecosystem of Tanzania. Species at greatest risk are those with restricted range and narrow habitat preference. Some species that were previously documented as extinct such as *Karomia gigas* and *Erythrina schliebenii* have been rediscovered in the Kilwa landscape (Clarke et al., 2011). The distribution of both species faces immediate negative fire impacts and human activities that points out the importance of habitat conservation in the region. *Karomiagigas* is more threatened because its habitats are directly affected by human activities than those of *Erythrina schliebenii* that are threatened by fire impacts (Howell et al., 2012). Consideration of biodiversity conservation should be regional specific because of the nature of the distribution pattern of plant species that are characterized by the high level of localized habitats. The principles that can be developed to conserve any ecological regions should not apply to the coastal forest conservation. This is because of the existing fragmented forests that are sufficiently isolated from one another and some of the plant species are localized within these forest patches resulting into low evenness for forest dependent species. Conservation in coastal forest should be holistic that takes into consideration of the interconnected habitats in a landscape. This will guarantee the protection of many species that are localized within some of the fragments, including those species that might have not been in contact with scientist eyes in the course of scanning the coastal forest biodiversity and demarcating biospheres for conservation in Tanzania. The conservation consideration should target the largest cover that is inclusive of the existing fragments within the landscape.

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Appendix 1. Plant species composition and distribution among habitats in Namatimbili forest.

S/N				Conservation status		Woodland habitat	Evergreen Forest	Coral rag Habitat	Riverine Habitat
	Family	Plant species names	Author	Endemism	IUCN Thtreat				
1	Acanthaceae	*Asystasia gangetica*	(L) T Anderson			x	x		X
2	Acanthaceae	*Barleria spinulosa*	Klotzsch			x	x		
3	Acanthaceae	*Blepharis affinis*	Lindau			x			
4	Acanthaceae	*Blepharis ciliaris*	(L) B L Burtt			x	x		
5	Acanthaceae	*Dicliptera aculeata*	C B Clarke			x		x	X
6	Acanthaceae	*Justicia stachytarphetoides*	(Lindau) C B Clarke			x	x	x	X
7	Adiantaceae	*Acrostichum aureum*	L			x		x	
8	Anacardiaceae	*Lannea stuhlmannii*	(Engl) Engl			x	x		
9	Anacardiaceae	*Lannea schimperi*	(A Rich) Engl			x	x	x	
10	Anacardiaceae	*Rhus glaucescens*	A Rich			x			
11	Anacardiaceae	*Rhus natalensis*	Krauss			x			
12	Anacardiaceae	*Sclerocarya birrea*	A Rich			x			
13	Anacardiaceae	*Sorindeia madagascariensis*	DC			x			X
14	Annonaceae	*Annona senegalensis*	Pers			x	x		X
15	Annonaceae	*Asteranthe asterias*	(S Moore) Engel & Diels	√	NT	x	x		
16	Annonaceae	*Asteranthe lutea*	Vollesen			x	x	x	
17	Annonaceae	*Cleistochlamys kirkii*	(Benth) Oliv			x		x	
18	Annonaceae	*Lettowianthus stellatus*	Diels	√	NT	x		x	x
19	Annonaceae	*Monanthotaxis buchananii*	(Engl) Verdc			x		x	
20	Annonaceae	*Monanthotaxis trichocarpa*	(Diels & Engl) Verdc	√	LC	x	x	x	
21	Annonaceae	*Monanthotaxis trichantha*	(Diels) Verdc	√	Vu	x	x	x	
22	Annonaceae	*Mkilua fragrans*	Verdc	√	vu	x	x		x
23	Annonaceae	*Monodora grandidieri*	Baill			x	x		
24	Annonaceae	*Ophrypetalum odoratum*	Diels	√	vu	x	x	x	x
25	Annonaceae	*Uvaria acuminata*	Oliv	√	LC	x	x		
26	Annonaceae	*Uvaria kirkii*	Hook f	√	NT	x	x		
27	Annonaceae	*Uvaria lucida*	Benth			x	x		
28	Annonaceae	*Uvariodendron gorgonis*	Verdc	√	en	x	x	x	x
29	Annonaceae	*Xylopia latipetala*	Verdc	√		x	x		
30	Amaryllidaceae	*Boophone disticha*	(L f) Herb			x		x	
31	Apocynaceae	*Ancylobothrya petersiana*	(Kl) Piarre			x			
32	Apocynaceae	*Diplorhynchys condylocarpon*	(Mull Arg) Pichon			x			

33	Apocynaceae	*Holarrhena pubescens*	G Don			x		x	
34	Apocynaceae	*Landolphia buchananii*	(Hallier f) Stapf				x		
35	Apocynaceae	*Landolphia kirkii*	Dyer			x	x		
36	Apocynaceae	*Pleiocarpa pycnantha*	(K Schum) Stapf			x	x		
37	Apocynaceae	*Saba comorensis*	(A DC) Pichon				x		x
38	Apocynaceae	*Strophanthus kombe*	Oliv			x	x	x	
39	Araliaceae	*Cussonia arborea*	A Rich				x		x
40	Araceae	*Zamioculcas zamiifolia*	(Lodd) Engl				x		
41	Asclepidiaceae	*Secamone parvifolia*	(Oliv) Bullock			x		x	
42	Asclepidiaceae	*Parquetina nigrescens*	(Afz) Bullock				x		
43	Liliaceae	*Asparagus africanus*	Lam			x	x	x	
44	Liliaceae	*Asparagus falcatus*	Lam			x	x	x	
45	Liliaceae	*Asparagus aethiopicus*	Lam			x	x		
46	Balanitaceae	*Balanites aegyptiaca*	(L) Delile			x			
47	Balanitaceae	*Balanites maughamii*	Sprague	√		x	x		
48	Baringtoniceae	*Baringtonia racemosa*	(L) Spreng			x			x
49	Bignoniaceae	*Kigelia africana*	(Lam) Benth			x			
50	Bignoniaceae	*Markhamia lutea*	(Benth) K Schum			x			
51	Bignoniaceae	*Markhamia obtusifolia*	(Baker) Sprague			x	x		
52	Bignoniaceae	*Markhamia zanzibarica*	(DC) K Schum			x			
53	Bignoniaceae	*Stereospermum kunthianum*	Cham			x		x	
54	Bombacaceae	*Adansonia digitata*	Lim			x		x	
55	Bombacaceae	*Bombax rhodognaphalon*	K Schum			x	x	x	
56	Burseraceae	*Commiphora africana*	(A Rich) Engl			x		x	
57	Burseraceae	*Commiphora madagascariensis*	Jacq			x	x		
58	Burseraceae	*Commiphora zanzabarica*	(Baill) Engl			x			
59	Capparaceae	*Boscia salicifolia*	A Rich			x			x
60	Capparaceae	*Boscia angustifolia*	A Rich			x	x	x	
61	Capparaceae	*Pseudocladosternon kirkii*	Oliv Pax & Gilg			x	x		
62	Capparaceae	*Maerua angolensis*	DC			x			x
63	Capparaceae	*Maerua grantii*	Oliv			x	x		
64	Capparaceae	*Maerua triphylla*	A Rich			x	x		
65	Capparaceae	*Thylachium densiflorum*	Gilg-Ben & Benedict			x		x	
66	Capparaceae	*Capparis tomentosa*	Lam			x			
67	Capparaceae	*Capparis fascicularis*	DC			x	x		
68	Celastraceae	*Elaeodendron buchananii*	(Loes) Loes			x		x	
69	Celastraceae	*Maytenus undata*	(Thunb) Blakelock			x		x	

70	Celastraceae	*Maytenus mossambicensis*	(Klotzsch) Blakelock			x		x	
71	Celastraceae	*Mystroxylon aethiopicum*	(Thunb) Loes			x			x
72	Celastraceae	*Salacia elegans*	Oliv			x			x
73	Celastraceae	*Salacia leptoclada*	Tul			x	x		x
74	Celastraceae	*Salacia madagascariensis*	(Lam) DC			x	x		
75	Chrysobalanaceae	*Parinari curatellifolia*	Planch ex Benth			x			
76	Combretaceae	*Combretum aculeatum*	Vent			x		x	
77	Combretaceae	*Combretum fragrans*	F Hoffm			x			
78	Combretaceae	*Combretum collinum*	Fresen			x		x	
79	Combretaceae	*Combretum constrictum*	(Benth) M A Lawson			x			x
80	Combretaceae	*Combretum apiculatum*	Sond			x			x
81	Combretaceae	*Combretum hereroense*	Schinz			x			
82	Combretaceae	*Combretum molle*	G Don			x			
83	Combretaceae	*Combretum zeyheri*	Sond			x		x	
84	Combretaceae	*Terminalia kaiserana*	F Hoffm			x		x	
85	Combretaceae	*Terminalia sambesiaca*	Engl & Diels			x		x	
86	Combretaceae	*Terminalia sericea*	DC			x			
87	Combretaceae	*Terminalia boivinii*	Tul			x		x	
88	Commelinaceae	*Commelina benghalensis*	Wall			x	x	x	x
89	Commelinaceae	*Commelina africana*	L			x	x	x	x
90	Commelinaceae	*Cyanotis foecunda*	Hassk			x	x		x
91	Compositae	*Aspilia mossambicensis*	(Oliv) Wild			x	x		
92	Compositae	*Brachylaena huillensis*	O Hoffm			x	x		
93	Compositae	*Bidens pilosa*	L			x			x
94	Compositae	*Dichrocephala integrifolia*	(L f)Kuntze			x	x		
95	Compositae	*Dicoma tomentosa*	Cass			x		x	
96	Compositae	*Ethulia conyzoides*	L f			x	x		
97	Compositae	*Pluchea dioscorides*	(L) DC			x			x
98	Compositae	*Sphaeranthus suaveolens*	(Forsk) DC			x			x
99	Compositae	*Tridax procumbens*	L			x			x
100	Compositae	*Vernonia perrottetii*	Sch Bip ex Walp			x			x
101	Compositae	*Vernonia glabra*	(Steetz) Vatke			x			x
102	Compositae	*Vernonia amygdalina*	Delile			x			x
103	Convolvulaceae	*Ipomoea obscura*	(L) KerGawl			x			x
104	Crassulaceae	*Kalanchoe lanceolata*	(Forssk) Pers			x		x	
105	Cycadaceae	*Encephalartos hildebrandtii*	A Br & Bouche var	√	NT	x	x	x	
106	Cyperaceae	*Cyperus alopecuroides*	Rottb			x	x	x	x

107	Cyperaceae	*Cyperus alternifolia*	L			x			x
108	Cyperaceae	*Cyperus exaltatus*	Retz			x			x
109	Dichapetalaceae	*Dichapetalum mossambicense*	(Klotzsch) Engl			x	x		x
110	Dichapetalaceae	*Dichapetalum macrocarpum*	M Krause			x	x		x
111	Dichapetalaceae	*Dichapetalum stuhlmannii*	Engl			x	x		
112	Dichapetalaceae	*Dichapetalum braunii*	Engl & K Krause	√		x			x
113	Dilleniaceae	*Tetracera boiviniana*	Baill			x	x	x	
114	Dilleniaceae	*Tetracera litoralis*	Gilg	√		x	x		
115	Ebenaceae	*Diospyros consolatae*	Chiov			x	x		
116	Ebenaceae	*Diospyros mespiliforms*	A DC			x	x		
117	Ebenaceae	*Diospyros squarrosa*	Klotzsch			x	x		
118	Ebenaceae	*Diospyros kirkii*	Hiern			x	x		
119	Ebenaceae	*Diospyros mafiensis*	FWhite			x	x		
120	Ebenaceae	*Euclea natalensis*	A DC			x	x		
121	Ebenaceae	*Euclea racemosa*	(A DC) F White			x			
122	Euphorbiaceae	*Alchornea hirtella*	Benth			x		x	
123	Euphorbiaceae	*Alchornea laxiflora*	(Benth) Pax & K Hoffm			x	x		
124	Euphorbiaceae	*Antidesma venosum*	Tul			x	x		
125	Euphorbiaceae	*Bridelia cathartica*	G Bertol			x	x		
126	Euphorbiaceae	*Croton megalocarpoides*	Friis & Gilbert			x			
127	Euphorbiaceae	*Drypetes arguta*	(Müll Arg) Hutch			x			x
128	Euphorbiaceae	*Drypetes natalensis*	(Harv) Hutch			x	x		
129	Euphorbiaceae	*Drypetes usambarica*	(Pax) Hutch			x			x
130	Euphorbiaceae	*Euphorbia candelabrum*	Kotschy			x		x	
131	Euphorbiaceae	*Euphoribia grantii*	Oliv			x		x	
132	Euphorbiaceae	*Flueggea virosa*	(Willd) Voigt			x			x
133	Euphorbiaceae	*Spirostachys africana*	Sond			x			x
134	Euphorbiaceae	*Suregada zanzibariensis*	Baill			x	x		
135	Euphorbiaceae	*Uapaca nitida*	Mull Arg			x			
136	Fabaceae	*Abrus precatorius*	L			x			x
137	Fabaceae	*Acacia polyacantha*	(A Rich) Brenan			x			x
138	Fabaceae	*Acacia sieberiana*	DC			x			
139	Fabaceae	*Afzelia quanzensis*	Welw			x			
140	Fabaceae	*Albizia glaberrima*	Schum & Thomm			x			x
141	Fabaceae	*Albizia versicolor*	Welwex Oliv			x			x
142	Fabaceae	*Baphia wollastonii*	Bak f			x	x		
143	Fabaceae	*Baphia punctulata*	Harms			x	x		

144	Fabaceae	*Baphia kirkii*	Baker	√	vu		x		x
145	Fabaceae	*Tylosema fassoglensis*	(Schweinf) Torre & Hillc			x			
146	Fabaceae	*Bauhinia tomentosa*	L			x		x	
147	Fabaceae	*Brachystegia boehmii*	Taub			x			
148	Fabaceae	*Brachystegia microphylla*	Harms			x			
149	Fabaceae	*Burkea Africana*	Hook			x			
150	Fabaceae	*Cassia abbreviata*	Oliv	√		x			
151	Fabaceae	*Cassia astrofistula*	(Holmes) Brenan			x			
152	Fabaceae	*Cordyla africana*	Lour			x			
153	Fabaceae	*Craibia brevicaudata*	(Vatke) Dunn			x			
154	Fabaceae	*Crotalaria goodiiformis*	Vatke			x			x
155	Fabaceae	*Cynometra webberi*	Baker f	√	Vu	x		x	
156	Fabaceae	*Cynometra gillmanii*	J Leonard	√	Cr		x		
157	Fabceae	*Cynometra greenweyi*	Brenan	√			x	x	
158	Fabaceae	*Dalbergia arbusifolia*	Baker			x			
159	Fabaceae	*Dalbergia nitidula*	Baker			x			
160	Fabaceae	*Dialium holtzii*	Harms	√	vu	x			
161	Fabaceae	*Dolichos oliveri*	Schweinf			x			
162	Fabaceae	*Entada abyssinica*	Steud			x	x		
163	Fabaceae	*Erythrina sacleuxii*	Hua	√	vu	x		x	
164	Fabaceae	*Erythrina schliebenii*	Harms	√	ex	x		x	
165	Fabaceae	*Erythrophleum suaveolens*	(Guill & Perr) Brenan			x		x	
166	Fabaceae	*Macrotyloma axillare*	(E Mey) Verdc			x	x		
167	Fabaceae	*Lonchocarpus bussei*	Harms			x			
168	Fabaceae	*Lonchocarpus capassa*	Rolfe			x			
169	Fabaceae	*Millettia impressa*	Harms			x	x		
170	Fabaceae	*Mundulea sericea*	(Willd) A Chev			x	x		
171	Fabaceae	*Newtonia paucijuga*	(Harms) Brenan	√	vu	x	x		x
172	Fabaceae	*Parkia filicoides*	Oliv			x	x		
173	Fabaceae	*Pilliostigma thonningii*	Schumach			x			
174	Fabaceae	*Pterocarpus angolensis*	DC		LR/nt	x			
175	Fabaceae	*Pterocarpus rotundifolius*	(Sond) Druce			x			
176	Fabaceae	*Rhynchosia hirta*	(Andr) Meikle & Verdc			x			x
177	Fabaceae	*Rhynchosia minima*	(L) DC			x	x		x
178	Fabaceae	*Scorodophloeus fischeri*	(Taub) J Leonard	√		x	x		x
179	Fabaceae	*Senna singueana*	(Del) Lock	√		x			x
180	Fabaceae	*Sesbania sesban*	L			x			x

181	Fabaceae	*Tamarindus indica*	L			x			
182	Fabaceae	*Tessmania densiflora*	Harms	√	en	x	x		
183	Fabaceae	*Xerroderis stuhlmannii*	(Thau) Mendonca & Sousa			x	x		
184	Fabaceae	*Dichrostachys cinerea*	(L) Wight & Arm			x			
185	Fabaceae	*Millettia usaramensis*	Lam	√		x	x		
186	Flacourtiaceae	*Apodytes dimidiata*	E Mey ex Arn			x			
187	Flacourtiaceae	*Casearia engleri*	Gilg			x		x	
188	Flacourtiaceae	*Caloncoba welwitschii*	(Oliv) Gilg			x	x		x
189	Flacourtiaceae	*Dovyalis hispidula*	Wild			x			
190	Flacourtiaceae	*Flacourtia indica*	(Burm f) Merr			x	x		
191	Flacourtiaceae	*Homalium abdessammadii*	Asch & Schweinf			x	x		
192	Flacourtiaceae	*Xylotheca tettensis*	(Klotzsch) Gilg	√		x			
193	Flagellariaceae	*Flagellaria guineensis*	Schumach			x			
194	Gramineae	*Bambusa vulgaris*	Wenell			x		x	
195	Gramineae	*Chloris virgata*	Sw			x			x
196	Gramineae	*Echinochloa colona*	(L) Link			x			x
197	Gramineae	*Echinochloa haploclada*	(Stapf) Stapf			x			x
198	Gramineae	*Eleusine indica*	(Kenn-O'Byrne) SMPhillips			x			
199	Gramineae	*Eragrostis aspera*	(Jacq) Nees			x			x
200	Gramineae	*Hyparrhenia variabilis*	Stapf			x			x
201	Gramineae	*Heteropogon contortus*	(L) Roen & Schult			x		x	
202	Gramineae	*Imperata cylindrica*	(L) Raeusch			x			x
203	Gramineae	*Loudetia simplex*	(Nees) C E Habb			x	x		
204	Gramineae	*Panicum maximum*	Jacq			x			x
205	Gramineae	*Panicum trichocladum*	K Schum			x			x
206	Gramineae	*Pennisetum purpureum*	Schumach			x			x
207	Gramineae	*Setaria sphacelata*	(Schum) M B Moss ex Stapf & C E Hubb			x			x
208	Gramineae	*Themeda triandra*	Forssk			x			
209	Guttiferae	*Garcinia livingstonei*	T Anderson			x			
210	Guttiferae	*Garcinia volkensii*	Engl			x			x
211	Guttiferae	*Vismia pauciflora*	Milne-Redh	√	en	x	x		x
212	Guttiferae	*Psorospermum febrifugum*	Spach			x		x	
213	Lamiaceae	*Basilicum polystachyon*	(L) Moench			x		x	
214	Lamiaceae	*Hoslundia opposita*	Vahl			x			x

215	Lamiaceae	*Plectranthus seretii*	(De Wild) Vollesen			x			x
216	Liliaceae	*Sansevieria gracilis*	N B E Br			x		x	
217	Liliaceae	*Drimiopsis perfoliata*	Baker			x	x		
218	Liliaceae	*Dracaena mannii*	Baker			x	x		
219	Liliaceae	*Sansevieria fischeri*	DC			x		x	
220	Linaceae	*Hugonia grandiflora*	N Robson			x	x		x
221	Loganiaceae	*Strychnos cocculoides*	Baker			x			
222	Loganiaceae	*Strychnos henningsii*	Gilg			x			
223	Loganiaceae	*Strychnos innocua*	Del			x			
224	Loganiaceae	*Strychnos madagascariensis*	Poir			x			
225	Loganiaceae	*Strychnos pototorum*	Lf			x			
226	Malvaceae	*Azanza garckeana*	(FHoffm) Exell & Hillc			x	x		
227	Melastomataceae	*Memecylon sansibaricum*	Taub			x			
228	Meliaceae	*Khaya anthotheca*	(Welw) CDC	√	vu				x
229	Moraceae	*Ficus lutea*	Vahl						x
230	Moraceae	*Ficus exasperata*	Vahl						x
231	Moraceae	*Ficus ingens*	(Miq) Miq						x
232	Moraceae	*Ficus natalensis*	Hochst						x
233	Moraceae	*Milicia excelsa*	(Welw) Benth & Hook f	√	Ln/nt			x	x
234	Myrtaceae	*Syzygium guineense*	(Welw) CC Berg						x
235	Ochnaceae	*Ochna holstii*	Engl				x		
236	Ochnaceae	*Ochna mossambicensis*	Klotzsch				x		
237	Olacaceae	*Olax dissitiflora*	Oliv				x		
238	Olacaceae	*Olax petandra*	Sleumer				x		
239	Olacaceae	*Ximenia americana*	L			x			
240	Onagraceae	*Ludwigia stolonifera*	(Gill & Perr) P H Raven						x
241	Orchidaceae	*Microcoelia exilis*	Lindl						x
242	Palmae	*Borasuss aethiopum*	Mart						x
243	Palmae	*Phoenix reclinata*	Jacq			x			x
244	Palmae	*Hyphaene compressa*	HWandl						
245	Passifloraceae	*Schlechterina mitostemmatoides*	Harms			x	x		
246	Rhamnaceae	*Ziziphus mucronata*	Willd			x			
247	Rubiaceae	*Chassalia umbreticola*	Vatke			x	x		
248	Rubiaceae	*Catunaregam spinosa*	(Thunb) Tirvengadum			x			
249	Rubiaceae	*Coffea sessiliflora*	Bridson	√		x	x		
250	Rubiaceae	*Coffea pseudozanguebaricae*	Hiern	√	vu		x		
251	Rubiaceae	*Crossopteryx febrifuga*	(G Don) Benth			x	x		

252	Rubiaceae	*Gardenia transvenulosa*	Verdc	√	vu	x	x		
253	Rubiaceae	*Hymenodictyon parvifolium*	Oliv			x	x		
254	Rubiaceae	*Keetia venosa*	(Oliv) Bridson			x	x		
255	Rubiaceae	*Keetia zanzibarica*	(Klotzsch) Brindson			x	x	x	
256	Rubiaceae	*Lamprothamnus zanguebaricus*	Hiern			x			
257	Rubiaceae	*Leptactina platyphylla*	(Hern)Wernham					x	
258	Rubiaceae	*Leptactina delagoensis*	K Schum			x		x	
259	Rubiaceae	*Leptactina papyrophloea*	Verdc			x			
260	Rubiaceae	*Mitragyna rubrostipulata*	(K Schum) Havil			x			
261	Rubiaceae	*Oxyanthus pyriformis*	(Hochst) Skeels			x	x		
262	Rubiaceae	*Oxyanthus speciosus*	DC			x	x		
263	Rubiaceae	*Polysphaeria multiflora*	Hiern						x
264	Rubiaceae	*Rothmania whitfieldii*	(Lindl) Dandy				x		x
265	Rubiaceae	*Rystignia decussata*	(K Schum) Robyns				x		
266	Rubiaceae	*Uncaria africana*	G Don						x
267	Rubiaceae	*Vangueria infausta*	Burch			x			
268	Rutaceae	*Vepris lanceolata*	(Lam) G Don			x			
269	Rutaceae	*Vepris nobilis*	(Delile) Mziray			x	x		
270	Rutaceae	*Vepris glomerata*	(F Hoffm) Engl			x	x		
271	Rutaceae	*Clausina anisata*	(Willd) Benth			x			
272	Rutaceae	*Teclea nobilis*	Delile			x			
273	Rutaceae	*Teclea simplicifolia*	(Engl) Verd			x			
274	Rutaceae	*Zanthoxylum chalybeum*	Engl			x			
275	Rutaceae	*Zanthoxylum holtzianum*	(Engl) PGWaterman	√	vu	x			
276	Salvadoraceae	*Dobera loranthifolia*	(Warb) Harms			x			
277	Sapindaceae	*Allophyllus africanus*	P Beauv			x			x
278	Sapindaceae	*Deinbollia borbonica*	Scheff			x			
279	Sapindaceae	*Haplocoelum inopleum*	Radlk			x	x		
280	Sapindaceae	*Haplocoelum foliosum*	(Hiern) Bullock			x	x		
281	Sapindaceae	*Lepisanthes senegalensis*	(Poir) Leenh			x			
282	Sapindaceae	*Macphersonia gracilis*	O Hoffm			x			
283	Sapindaceae	*Majidea zanguebarica*	JKirk			x			
284	Sapindaceae	*Pancovia golungensis*	(Hiern) Exell & Mendonça			x	x		
285	Sapindaceae	*Paullinia pinnata*	L			x	x		
286	Sapindaceae	*Zanha africana*	(Radlk) Exell			x			
287	Sapotaceae	*Englerophytum natalense*	(Sond) T D Penn			x			

288	Sapotaceae	*Malacantha alnifolia*	(Baker) Pierre			x	x		
289	Sapotaceae	*Manilkara discolor*	(Sond) J H Hemsl			x			
290	Sapotaceae	*Manilkara sansibarensis*	engl			x	x		
291	Sapotaceae	*Mimusops fruticosa*	Lam			x	x		
292	Sapotaceae	*Mimusops kummer*	A DC			x	x		
293	Sapotaceae	*Mimusops schliebenii*	Mildbr & G M Schulze			x			
294	Sapotaceae	*Synsepalum brevipes*	(Baker) Pennington			x	x		
295	Schizaeaceae	*Lygodium microphyllum*	(Cav) R Br			x			
296	Simaroubaceae	*Harrisonia abyssinica*	Oliv			x			x
297	Sterculiaceae	*Cola discoglyoremnophylla*	Brenan & A P D Jones					x	
298	Sterculiaceae	*Cola greenwayi*	Brenan					x	
299	Sterculiaceae	*Dombeya rotundifolia*	(Hochst) Planch			x	x		
300	Sterculiaceae	*Dombeya shupangae*	K Schum			x			
301	Sterculiaceae	*Pterygota perrieri*	Hochr			x			
302	Sterculiaceae	*Sterculia appendiculata*	K Schum ex Engl			x			
303	Sterculiaceae	*Sterculia quinqueloba*	(Garcke) K Schum			x			
304	Tiliaceae	*Grewia bicolor*	A Juss			x			
305	Tiliaceae	*Grewia conocarpa*	K Schum			x			
306	Tiliaceae	*Grewia microcarpa*	K Schum			x			
307	Tiliaceae	*Grewia platyclada*	Mast			x			
308	Tiliaceae	*Grewia similis*	K Schum			x			
309	Tiliaceae	*Triumfetta rhomboidea*	Jacq						x
310	Ulmaceae	*Trema orientalis*	(L) Blume			x			
311	Verbenaceae	*Vitex mombassae*	Vatke			x	x		
312	Verbenaceae	*Vitex zanzibariensis*	Vatke	√	vu	x	x		
				36	26	281	122	62	85

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The flora of holy Mecca district, Saudi Arabia

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The flora of Mecca city district, Saudi Arabia has been recently studied between March and July, 2014. Four hundred and thirty three (433) specimens were collected from the study area. The specimens were found to belong to forty four (44) families, one hundred twenty five (125) genera and one hundred and eighty four (184) species. In this work and for the first time, four new species (unidentified, possibly new) were collected with specimen's numbers: 40, 175, 279 and 415. Besides, the study came out with nine rare species to the flora of Saudi Arabia: *Tribulus arabicus Atriplex farinosa, Cyperus rotundus*, *Datura innoxia*, *Emex spinosus*, *Heliotropium crispum*, *Kohautia caespitosa*, *Launaea nudicaulis* and *Plantago ciliata*. It was found that the largest family in Mecca is *Poaceae* represented by 17% followed by *Fabaceae* with a percentage of 13%. The most prevalent species was *Calotropis procera.* From the analysis of species, the most chorotype prevalent was Saharo-Arabian with 27.70%. In addition, the most life-forms prevalent is the Therophytes with 41%. On the other hand, most of the species of high percentage 24.57% are used for medicinal purpose.

Key words: Flora, mecca, Saudi Arabia.

INTRODUCTION

Saudi Arabia represents almost 80% of the Arabian Peninsula with an area of about 2.25 million km^2 (Almazroui et al., 2012). It extends between latitude 16' 83° N 32'43° N and longitude 34' 36° E 56°E (Meelad, 2006; Al-Amri, 2007). It is an important source of biodiversity and contains about 2250 species. Moreover, the number of species increased from approximately 1500 to almost 2300 (Alfarhan et al., 2005; Masrahi et al., 2012).

Overall, the most dominant families are *Fabaceae* and *Poaceae* due to arid and extreme arid climate adaptation (Chaudhary, 1989). The vegetation cover in the area is xerophytic (El-Ghanim et al., 2010).

Alshareef, (1984) reported that Mecca is located in Wadis between the mountainous region of the west of Saudi Arabia. Moreover, it is located in a fragile system (Abdel Khalik et al., 2013). More specifically, the temperature in Mecca ranges between 40-49°C (Ashrae, 2005). The rate of rainfall ranges between 50-80 mm / year and most of precipitation is in winter that causes reduced vegetative cover.

The study area is a rangeland in Western of Saudi Arabia along with the coast of Red Sea, including major rangeland sites in Mecca Province (Daur, 2012).
Broadly, Mecca is specialized by different types of plants and great species diversity(Al-Said, 1993; Rahman et al., 2004).

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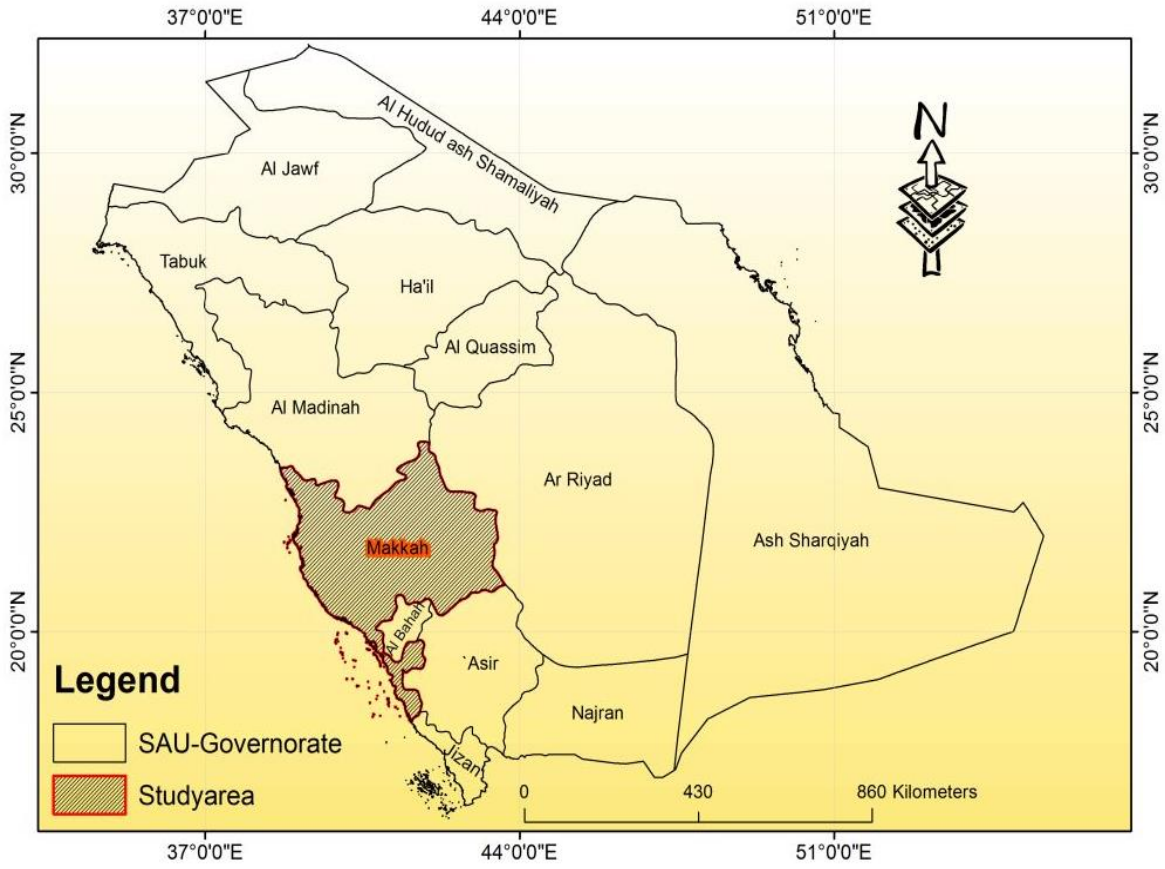

Figure 1. Mecca district in Saudi Arabia.

Apparently, so many species have been playing a vital part of healthcare since the past days to the present day (Sher and Aldosari, 2013), for example, some of the flora elements are beneficial to human being used in folk medicine in the past (El-Ghazali et al., 2010). In addition, El-Ghazali and Al-Soqeer (2013) believed that other flora elemnts can cause a lot of losses in crops such as weeds flora. Besides, *Lamiaceae* medicinal plants are most abundant in Saudi Arabia (Rahman et al., 2004).

Fundamentally, the interesting fact about Mecca is the overlapping with Hail, based on its loacation as being in a wadi between two mountain ranges Aja and Salma. The major types of plants in wadi Rimah-Hail region are *Acacia* and some of *Senna* (Al-Turki and Al-Olayan, 2003).

The flora of Saudi Arabia has been extensively studied (Zohary, 1957); the most important studies is given by Mighaid (1974) *'Flora of Saudia Arabia'* and published for four times, the last edition was published in 1996. Furthermore, three volumes about *'Flora of the Kingdom of Saudi Arabia Illustrated'* was written by Chaudhary (1999, 2000, 2001). Moreover, a book was written by Chaudhary and Al-Jowaid (1999, 2013) titled *Vegetation of the Kingdom of Saudi Arabia* as published for two times. Large number of articles have discussed this topic such as *Contribution to the Flora of Saudi Arabia: Hail Region* by Al-Turki and Al-Olayan (2003), *A floristic account on Raudhat Khraim Central province, Saudi Arabia* by Alfarhan (2011) and *Diversity Of Perennial Plants At Ibex Reserve In Saudi Arabia* by Al-Khamis et al. (2012).

The main objectives of this study were collecting and identifying of the flowering plants species in Mecca, mapping the geographical distribution of the recorded species based on GIS recording and analysis of the flora components

MATERIALS AND METHODS

Study area

In April 2014, a floristic survey was carried out in Mecca Province. Mecca is located in western part of Saudi Arabia and western Arabian Peninsula. In particular, it is in the valley area between Hijaz mountain at the intersection of degree latitudes 27/19 N longitude 40/39 E, about 80 km from Jeddah on the Red Sea coast (Figure 1). Mecca is bound by Al-Gamom on the north, Al- Lith in the south, Taif in the east and the Red Sea coast and Jeddah in the west. In addition, it is characterised by high temperature ranges between 40-49°C, low rain fall (50-80 mm/year), high light intensity

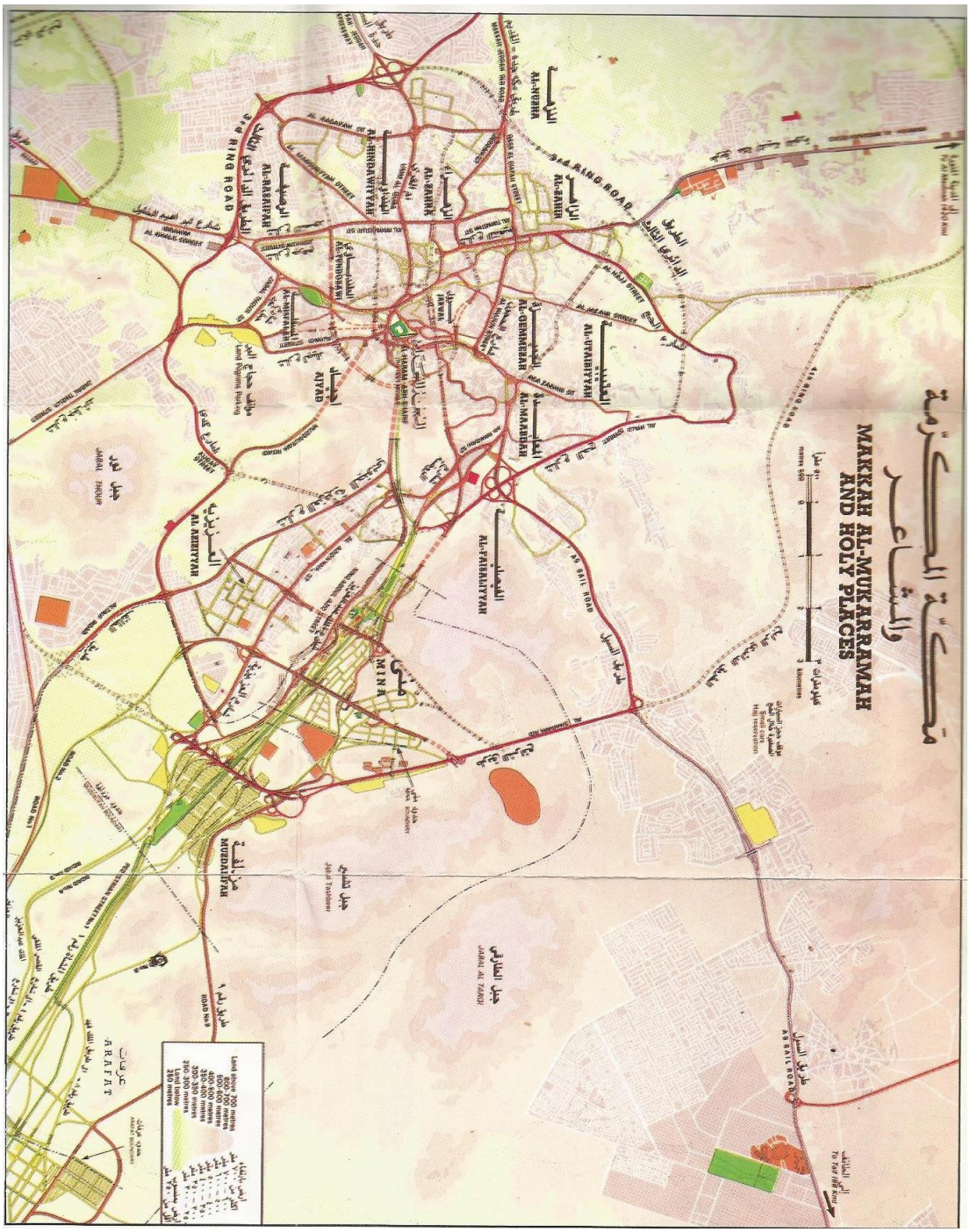

Figure 2. The detailed district of Mecca, Saudi Arabia.

and low humidity (Al- Khalif et al., 1430). Moreover, it consists of several regions (Arafat, Mina, Muzdalifah, Mount Thour, Mount Alnoor, Kuday, Al-Zahir, Al-Utaibiyyah, Al-Nuzha, Alzama, Al-Sharaai (Mount Tashbeer), Valley Numan, Al-Maabdah and Al-Abdeeah) (Figures 1 and 2).

Some of those regions are valleys below 250 m and others are mountainous areas above 700 m. Besides, Mecca contains very solid granitic rocks, as well as, it rises above the sea level about 330 m (Figures 3 and 4). Thus, the heights in Mecca ranges from 250-700 m with the most common height of about 330 or 350 m.

Survey procedure

To cover and satisfy the research objectives as well as to gather the needed information, two trips to Saudi Arabia (Mecca) were

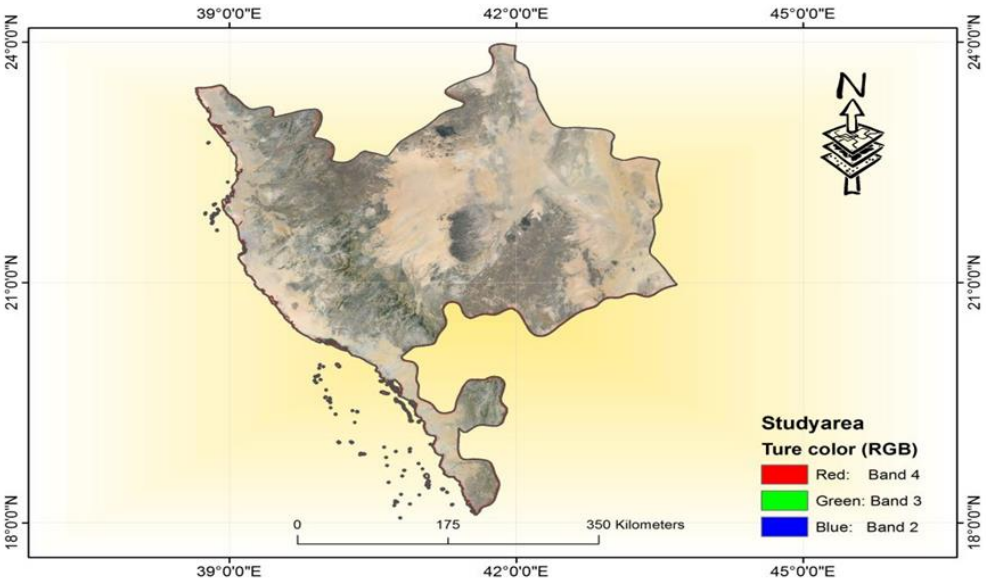

Figure 3. Isolation of study area Mecca district.

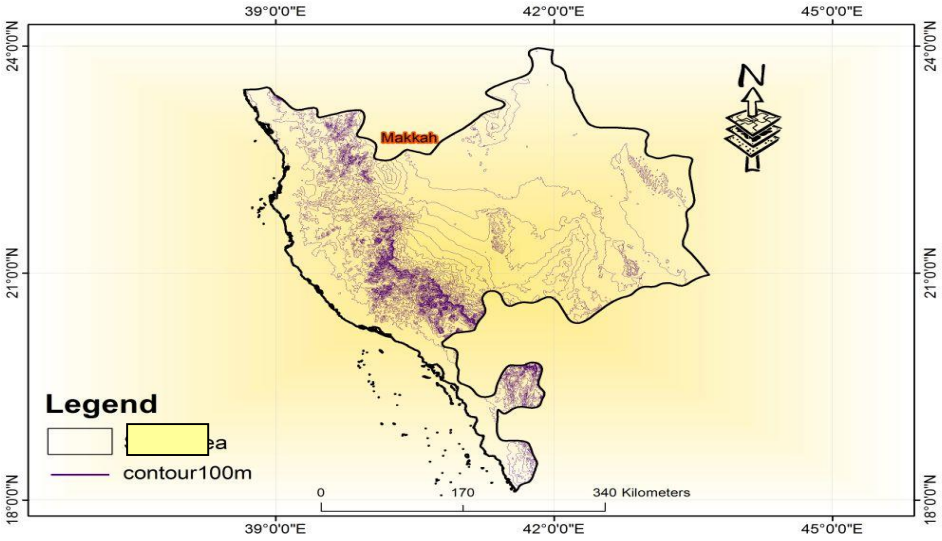

Figure 4. Contour of study area Mecca district.

conducted. The first trip was conducted during the growing season at the beginning of April, 2014 and consisted of 48 localities as showed in the study area. Furthermore, localities were recorded by determining the locations using Global Positioning System (GPS).

Plant material

Tools used for collection

The data were collected through samples taken from daily field trips during April as it was representing in forty-eight sites were determined using (GPS). The samples were collected using secateurs to cut plant parts and then put them in various sizes of plastic bags. Moreover, duplicates for each sample were taken depending on plant availability. Pictures using camera (Nikon D3100) for each plant samples was taken.

By the end of the field trip, these samples were taken to the herbarium at The University of Jordan, Department of Biological Sciences, Amman-Jordan (AMM) for poisoning mounting, identifying and preservation as herbarium specimens.

Preparation of plant specimens

Several steps were used to prepare the plant specimens.

Collection

The collecting of specimens was done by random stops in various

areas of Mecca region depending on the existence of the plants. Then the collected plants were put in plastic bags with numeric numbers mentioned in the Table 1.

Pressing and drying

The collected material of plant specimens were pressed using wooden board presses, old newspaper, drying paper and filter paper to drying the specimens, every day filter paper were changed for a week up to ten days until specimens were dried.

Poisoning

A mixture of 150 g of mercuric chloride ($HgCl_2$) and 350 g of ammonium chloride (NH_4Cl) was dissolved in as little needed water as possible until the solution had no residue and became transparent. The solution was prepared using automating stirrer. Then the solution was added to 10 L of commercial alcohol (96% ethanol) and used for every specimen.

Filling

Arrangement and insersion of collected specimen to the herbarium, Department of Biological Science, Faculty of Science, The University of Jordan (AMM) was done.

Method of identification

Basically, the collected plant specimens were identified and named by Prof. Al-Eisawi, using references for Flora of Saudi Arabia, Flora Palaestine and Flora of Egypt (Bouls, 1999-2005; Chaudhary, 1989; Chaudhary, 1999-2001; Chaudhary and Al-Jowaid, 1999; Chaudhary and Zawawi, 1983; Feinburn-Dothan, 1978 and 1986; Migahid, 1978 and 1988; Migahid and Hammouda, 1974; Migahid et al., 1977; Zohary, 1966, 1972).

Species life-forms were determined according to the location of regenerative buds and the parts shed during the unfavorable season (Raunkier, 1934). A chronological analysis of the floristic categories of species was made to assign the recorded species to world geographical groups, according to Chaudhary (2001) and Zohary (1966, 1972).

RESULTS

List of the flora of Mecca

A number of 433 plant specimens was colleced. The total number of species is one hundred and eighty four (184) species belonging to one hundred and twenty five genera (125) and forty four (44) families (Table 1). It was found that these plants share characteristics with flora of Saharo-Arabian and Irano–Turranean (Al-Turki and Al-Olayan, 2003).

Moreover, forty eight (48) locations were found to have little diversity in general terms of biodiversity assessments due to the reason that there is limited change among these locations in terms of light intensity, relative humidity and topography.

Rare and unrecorded species

More significantly, the research has ended up with four new species considered as unknown and most probably new species to sciences. We could not confirm their identity at the time, waiting for new plant collection which has more details of the plant characteristic, specially, mature fruit. These specimens have the specimen numbers 40, 175, 279 and 415 (Table 2). There are nine species recorded as rare species to the flora of Saudi Arabia (Table 3).

Number and percentage of families and species in flora of Mecca

It was found that there are forty four (44) families in the flora of Mecca and the most prevalent one is *Poaceae* with 16.94% followed by *Fabaceae* with a percentage of 13.11% and *Amaranthaceae* with 4.92% while the lowest plant families are *Apiaceae, Malvaceae Menispermaceae, Meliaceae, Moringaceae, Molluginaceae, Neuradaceae, Oleaceae, Plantaginaceae, Plumbaginaceae, Portulacaceae, Rhaminaceae, Rosaceae* and *Tamaricaceae* with a percentage of 0.56% (Figure 5).

In relation to all species collected from Mecca, the most prevalent species are *Calotropis procera* with percentage 4.21% followed by *Aerva javanica* with percentage 3.93%, *Dipterygium glaucum* and *Panicum turgidum* both with percentage 3.37% and *Abutilon hirtum* with percentage 2.81% while the lowest recorded percentage is 0.28% in the following species *Peristrophe paniculata*, *Ruellia malacosperma, Trianthema protulacaotrum, Trianthema crystallinum, Aerva persica, Alternanthera bettzickiana, Alternanthera pungens, Amaranthus graecizans, Amaranthus hybridus, Pulicaria schimperi, Steinheilia radicans, Periploca visciformis, Odontanthera radians* etc.

Chorotype of taxa

The analysis of flora is necessary to display the chorotypes of the species, Saharo-Arabian (SA); Sudano-Zambezian (SU); Sudanian territories (ST); Irano-Turanian (IT); Mediterranean (ME); Tropical (TR); Cosmopolitan (COSM); Panotropic (PAN); American (AM); Euro-Siberian (ES);, W Europe (WE); Africa (AF); and Asia (SI).

The largest number of chorotype groups is the Saharo-Arabian with a percentage of 27.70%, then Irano-Turanian with a percentage of 17.91% and followed by Sudano-Zambezian with a percentage of 16.22%, while the least number are Sudanian territories, Sahalian Somali and Madagascar with a percentage of 0.34% (Table 4 and Figure 6). This percentage of plant chorotype groups agrees with the results found in this study since no records for American and W Europe or Euro-Siberian, since the study area does not fall within

Table 1. Overall list of plants in Mecca district showing family, genus, species, coordinates and locality.

Specimens number	Family	Scientific name	Coordinates	Locality	Date
326, 361		*Blepharis ciliaris* (L.) B. L. Burtt	N21◦24.051' E039◦54.913'	18	04/18/14
84		*Blepharis ciliaris* (L.) B. L. Burtt	N21◦27.039' E039◦57.254'	19	04/18/14
83, 84		*Blepharis ciliaris* (L.) B. L. Burtt	N21◦27.331' E039◦51.710'	24	04/19/14
211, 379		*Blepharis ciliaris* (L.) B. L. Burtt	N21◦24.595' E039◦52.210'	30	04/21/14
347	*Acanthaceae*	*Blepharis ciliaris* (L.) B. L. Burtt	N21◦36.738' E040◦06.913'	43	04/25/14
169, 171		*Blepharis ciliaris (*L.) B. L. Burtt	N21◦32.103' E040◦07.671'	45	04/25/14
210		*Peristrophe paniculata* (Forssk.) Brummitt	N21◦27.039' E039◦57.254'	19	04/18/14
232		*Ruellia malacosperma* Greenman	N21◦23.042' E039◦52.144'	46	04/26/14
4		*Sesuvium verrucosum* Raf.	N21◦23.042' E039◦52.144'	46	04/26/14
232		*Sesuvium verrucosum* Raf.	N21◦19.464' E040◦02.992'	4	04/08/14
389	*Aizoaceae*	*Sesuvium verrucosum* Raf.	N21◦20.463' E039◦57.379'	13	04/13/14
155		*Trianthema protulacaotrum* L.	N21◦20.463' E039◦57.379'	13	04/13/14
423		*Trianthema crystallinum* (Forssk.) Vahl	N21◦20.463' E039◦57.379'	13	04/13/14
317		*Aerva javanica* (Burm. f.) Juss.	N21◦20.401' E039◦56.933'	11	04/13/14
32, 351		*Aerva javanica* (Burm. f.) Juss.	N21◦54.560' E039◦16.807'	8	04/12/14
249, 402		*Aerva javanica* (Burm. f.) Juss.	N21◦24.051' E039◦54.913'	18	04/18/14
87		*Aerva javanica* (Burm. f.) Juss.	N21◦27.449' E039◦57.361'	20	04/18/14
128, 255		*Aerva javanica* (Burm. f.) Juss.	N21◦25.199' E039◦53.070'	22	04/19/14
103		*Aerva javanica* (Burm. f.) Juss.	N21◦26.313' E039◦51.374'	23	04/19/14
203, 256		*Aerva javanica* (Burm. f.) Juss.	N21◦23.212' E039◦51.136'	27	04/21/14
378		*Aerva javanica* (Burm. f.) Juss.	N21◦22.639' E039◦52.258'	31	04/22/14
51		*Aerva javanica* (Burm. f.) Juss.	N21◦21.122' E039◦52.270'	33	04/22/14
77		*Aerva javanica* (Burm. f.) Juss.	N21◦19.347' E039◦53.034'	34	04/22/14
149		*Aerva javanica* (Burm. f.) Juss.	N21◦23.620' E039◦49.535'	40	04/24/14
381		*Aerva javanica* (Burm. f.) Juss.	N21◦36.738' E040◦06.913'	43	04/25/14
176, 184, 185		*Aerva javanica* (Burm. f.) Juss.	N21◦32.103' E040◦07.671'	45	04/25/14
403		*Aerva javanica* (Burm. f.) Juss.	N21◦26.754' E039◦45.199'	47	04/27/14
419		*Aerva persica* (Bunm. f.) Merr.	N21◦19.650' E040◦01.286'	3	04/08/14
303	*Amaranthaceae*	*Alternanthera bettzickiana* (Regel.) Voss.	N21◦19.464' E040◦02.992'	4	04/08/14
79, 411		*Alternathera pungens* Kunth	N21◦19.347' E039◦53.034'	34	04/22/14
403		*Amaranthus albus* L.	N21◦20.463' E039◦57.379'	13	04/13/14
98		*Amaranthus graecizans* L.	N21◦27.331' E039◦51.710'	24	04/19/14
402		*Amaranthus graecizans* L.	N21◦20.463' E039◦57.379'	13	04/13/14
114		*Amaranthus hybridus* L.	N21◦23.204' E039◦52.041'	21	04/19/14
252		*Amaranthus hybridus* L.	N21◦26.150' E039◦46.046'	48	04/27/14
177, 192		*Amaranthus lividus* L.V.	N21◦32.103' E040◦07.671'	45	04/25/14
363, 386		*Amaranthus lividus* L.V.	N21◦20.463' E039◦57.379'	13	04/13/14
107		*Amaranthus lividus* L.V.	N21◦27.039' E039◦57.254'	19	04/18/14
372		*Amaranthus lividus* L.V.	N21◦25.199' E039◦53.070'	22	04/19/14
332		*Amaranthus lividus* L.V.	N21◦20.493' E039◦52.401'	32	04/22/14
38, 132, 133		*Amaranthus lividus* L.V.	N21◦26.609' E039◦47.611'	36	04/24/14
288		*Amaranthus lividus* L.V.	N21◦26.807' E039◦48.560'	37	04/24/14
371		*Amaranthus lividus* L.V.	N21◦26.572' E039◦46.758'	38	04/24/14
287		*Amaranthus lividus* L.V.	N21◦26.363' E039◦49.002'	39	04/24/14
233	*Apiaceae*	Anethum graveolens L.	N21◦26.363' E039◦49.002'	39	04/24/14

Table 1. Contd.

101		*Catharathus roseus* G. Don	N21◦27.331' E039◦51.710'	24	04/19/14
237		*Catharathus roseus* G. Don	N21◦23.042' E039◦52.144'	46	04/26/14
157, 159		*Rhazya stricta* Decne.	N21◦22.801' E039◦49.812'	41	04/24/14
8, 355	*Apocynaceae*	*Rhazya stricta* Decne.	N21◦19.650' E040◦01.286'	3	04/08/14
125		*Rhazya stricta* Decne.	N21◦20.590' E039◦44.101'	15	04/16/14
119		*Rhazya stricta* Decne.	N21◦20.903' E039◦41.694'	16	04/16/14
360		*Rhazya stricta* Decne.	N21◦20.456' E039◦41.559'	17	04/16/14
91		*Rhazya stricta* Decne.	N21◦27.331' E039◦51.710'	24	04/19/14
17		*Calotropis procera* (Ait.) Ait. f.	N21◦19.464' E040◦02.992'	4	04/08/14
134		*Calotropis procera* (Ait.) Ait. f.	N21◦20.401' E039◦56.933'	11	04/13/14
173		*Calotropis procera* (Ait.) Ait. f.	N21◦20.456' E039◦41.559'	17	04/16/14
127		*Calotropis procera* (Ait.) Ait. f.	N21◦26.313' E039◦51.374'	23	04/19/14
122		*Calotropis procera* (Ait.) Ait. f.	N21◦27.331' E039◦51.710'	24	04/19/14
267		*Calotropis procera* (Ait.) Ait. f.	N21◦23.212' E039◦51.136'	27	04/21/14
331		*Calotropis procera* (Ait.) Ait. f.	N21◦20.493' E039◦52.401'	32	04/22/14
55		*Calotropis procera* (Ait.) Ait. f.	N21◦21.122' E039◦52.270'	33	04/22/14
66		*Calotropis procera* (Ait.) Ait. f.	N21◦19.347' E039◦53.034'	34	04/22/14
67		*Calotropis procera* (Ait.) Ait. f.	N21◦26.609' E039◦47.611'	36	04/24/14
325		*Calotropis procera* (Ait.) Ait. f.	N21◦26.807' E039◦48.560'	37	04/24/14
354		*Calotropis procera* (Ait.) Ait. f.	N21◦36.738' E040◦06.913'	43	04/25/14
241		*Calotropis procera* (Ait.) Ait. f.	N21◦23.042' E039◦52.144'	46	04/26/14
397		*Glossonema varians* Benth. ex Hook. f.	N21◦54.560' E039◦16.807'	8	04/12/14
6		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦19.448' E039◦58.002'	2	04/08/14
34, 29	*Asclepidaceae*	*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦56.220' E039◦01.617'	7	04/12/14
295		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦54.560' E039◦16.807'	8	04/12/14
93		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦27.331' E039◦51.710'	24	04/19/14
92		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦22.639' E039◦52.258'	31	04/22/14
153		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦22.801' E039◦49.812'	41	04/24/14
250		*Leptadenia pyrotechnica* (Forssk.) Decne.	N21◦26.754' E039◦45.199'	47	04/27/14
34		*Odontanthera radians*(Forssk.) D. V. Field	N21◦54.560' E039◦16.807'	8	04/12/14
89, 104		*Pergularia tomentosa* L.	N21◦27.331' E039◦51.710'	24	04/19/14
34		*Pergularia tomentosa* L.	N21◦54.560' E039◦16.807'	8	04/12/14
329		*Periploca visciformis* K. Schum.	N21◦24.051' E039◦54.913'	18	04/18/14
406		*Steinheilia radicans* Decne.	N21◦54.560' E039◦16.807'	8	04/12/14
73		*Arnebia decumbens* (Vent.) Coss. and Kral.	N21◦21.122' E039◦52.270'	33	04/22/14
180		*Gastrocotyle hispida* (Forssk) Bunge	N21◦20.463' E039◦57.379'	13	04/13/14
227		*Heliotropium bacciferum* Forssk.	N21◦27.449' E039◦57.361'	20	04/18/14
312	*Boraginaceaa*	*Heliotropium bacciferum* Forssk.	N21◦24.946' E039◦59.447'	14	04/13/14
348		*Heliotropium bacciferum* Forssk.	N21◦36.738' E040◦06.913'	43	04/25/14
23		*Heliotropium crispum* Desf.	N21◦19.464' E040◦02.992'	4	04/08/14
58		*Heliotropium crispum* Desf.	N21◦23.620' E039◦49.535'	40	04/24/14
168		*Heliotropium crispum* Desf.	N21◦32.103' E040◦07.671'	45	04/25/14

Table 1. Contd.

78		*Heliotropium crispum* Desf.	N21◦19.347' E039◦53.034'	34	04/22/14
24		*Heliotropium europaeum* L.V.	N21◦19.464' E040◦02.992'	4	04/08/14
416		*Heliotropium digynum* Desf.	N21◦30.993' E040◦02.958'	42	04/25/14
175		*Heliotropium supinum* L.	N21◦32.103' E040◦07.671'	45	04/25/14
220		*Trichodesma africanum* (L.) R. Br.	N21◦27.039' E039◦57.254'	19	04/18/14
1		*Dipterygium glaucum* Decne.	N21◦21.313' E039◦55.503'	1	04/08/14
29		*Dipterygium glaucum* Decne.	N21◦56.607' E039◦01.742'	5	04/12/14
309, 314		*Dipterygium glaucum* Decne.	N21◦24.946' E039◦59.447'	14	04/13/14
121		*Dipterygium glaucum* Decne.	N21◦20.590' E039◦44.101'	15	04/16/14
166		*Dipterygium glaucum* Decne.	N21◦20.456' E039◦41.559'	17	04/16/14
225		*Dipterygium glaucum* Decne.	N21◦27.449' E039◦57.361'	20	04/18/14
269	*Capparaceae*	*Dipterygium glaucum* Decne.	N21◦23.160' E039◦50.086'	28	04/21/14
296		*Dipterygium glaucum* Decne.	N21◦22.639' E039◦52.258'	31	04/22/14
156		*Dipterygium glaucum* Decne.	N21◦22.801' E039◦49.812'	41	04/24/14
165, 345		*Dipterygium glaucum* Decne.	N21◦32.103' E040◦07.671'	45	04/25/14
251		*Dipterygium glaucum* Decne.	N21◦26.754' E039◦45.199'	47	04/27/14
188		*Maerua crassifolia* Forssk.	N21◦56.220' E039◦01.617'	7	04/12/14
431, 294, 421		*Maerua crassifolia* Forssk.	N21◦22.639' E039◦52.258'	31	04/22/14
183, 189		*Maerua crassifolia* Forssk.	N21◦36.738' E040◦06.913'	43	04/25/14
159, 180, 196		*Maerua oblongifolia* (Forssk.) A. Rich	N21◦36.767' E040◦05.869'	44	04/25/14
313		*Loaflingia hispanica* L.	N21◦24.946' E039◦59.447'	14	04/13/14
413		*Minuartia hybrida* (Vill.) Schischk.	N21◦19.464' E040◦02.992'	4	04/08/14
308		*Polycarpae repens* (Forssk.) Aschers. Schweinf.	N21◦19.650' E040◦01.286'	3	04/08/14
303	*Caryophyllaceae*	*Polycarpon tetraphyllum* L.	N21◦27.449' E039◦57.361'	20	04/18/14
41		*Polycarpea robbaire* Kuntze.	N21◦23.160' E039◦50.086'	28	04/21/14
307		*Spergularia diandra* (Guss.) Boiss.	N21◦19.650' E040◦01.286'	3	04/08/14
68		*Spergularia diandra* (Guss.) Boiss.	N21◦26.572' E039◦46.758'	38	04/24/14
73		*Telephium sphaerospermum* Boiss.	N21◦26.572' E039◦46.758'	38	04/24/14
144		*Atriplex farinosa* Forssk.	N21◦20.463' E039◦57.379'	13	04/13/14
138		*Chenopodium album* L.	N21◦20.463' E039◦57.379'	13	04/13/14
414	*Chenopodiaceae*	*Chenopodium murale* L.	N21◦22.801' E039◦49.812'	41	04/24/14
30		*Halocnemum strobilaceum* (Pak.) M. B	N21◦56.607' E039◦01.742'	5	04/12/14
35		*Salsola vermiculata* L.	N21◦56.607' E039◦01.742'	5	04/12/14
69, 70		*Suaeda aegyptiaca* (Hasselq.) Zohary	N21◦19.347' E039◦53.034'	34	04/22/14
367		*Launaea capitata* (Spreng.) Dandy	N21◦26.363' E039◦49.002'	39	04/24/14
41, 42, 367		*Launaea intybacea* Beauverd	N21◦56.607' E039◦01.742'	5	04/12/14
368		*Launaea nudicaulis* (L.) Hook. f.	N21◦26.363' E039◦49.002'	39	04/24/14
370		*Launaea procumbens* (Roxb.) Ram. and Rajg.	N21◦26.363' E039◦49.002'	39	04/24/14
112	*Compositea*	*Pulicaria schimperi* D. C.	N21◦25.199' E039◦53.070'	22	04/19/14
4		*Senecio flavus* (Decne.) Sch. Bip.	N21◦21.313' E039◦55.503'	1	04/08/14
151		*Sonchus oleraceus* L.	N21◦26.363' E039◦49.002'	39	04/24/14
369, 405		*Urospermum picroides* (L.) F. W. Schmidt	N21◦26.363' E039◦49.002'	39	04/24/14
262, 412, 427	*Brassicaceae*	*Farsetia stylosa* R. Br. Sehweinf.	N21◦54.560' E039◦16.807'	8	04/12/14

Table 1. Contd.

179		*Morettia parviflora* Boiss.	N21◦32.103' E040◦07.671'	45	04/25/14
100		*Schouwia purpurea* (Forssk.) Muschl.	N21◦23.212' E039◦51.136'	27	04/21/14
16, 400		*Citrullus colocynthis* (L.) Schrad.	N21◦19.464' E040◦02.992'	4	04/08/14
167, 399		*Citrullus colocynthis* (L.) Schrad.	N21◦32.103' E040◦07.671'	45	04/25/14
80	*Cucurbitaceae*	*Cucumis prophetarum* L.	N21◦27.331' E039◦51.710'	24	04/19/14
271		*Momordica balsamina L.*	N21◦23.160' E039◦50.086'	28	04/21/14
430		*Momordica charantia* L.	N21◦23.160' E039◦50.086'	28	04/21/14
418		*Cyperus bulbosus* Vahl	N21◦54.560' E039◦16.807'	8	04/12/14
30		*Cyperus conglomeratus* Rott.	N21◦56.607' E039◦01.742'	5	04/12/14
56	*Cyperaceae*	*Cyperus longus* L.	N21◦54.560' E039◦16.807'	8	04/12/14
27		*Cyperus rotundus* Benth.	N21◦21.9' E040◦11.10'	10	04/10/14
44, 45		*Cyperus schimperianus* Spreng.	N21◦21.122' E039◦52.270'	33	04/22/14
28		*Euphorbia cuneata* (Vahl) P.V.Heath	N21◦54.560' E039◦16.807'	8	04/12/14
25		*Euphorbia granulata* Forssk.	N21◦19.464' E040◦02.992'	4	04/08/14
219		*Euphorbia hirta* L.	N21◦26.572' E039◦46.758'	38	04/24/14
305	*Euphorbiaceae*	*Chrozophora oblongifolia* (Del.) A. Juss.	N21◦19.464' E040◦02.992'	4	04/08/14
431		*Chrozophora oblongifolia* (Del.) A. Juss.	N21◦54.560' E039◦16.807'	8	04/12/14
373		*Euphorbia serpens* Kunth.	N21◦32.103' E040◦07.671'	45	04/25/14
12		*Aristida adscensionis* Walter	N21◦19.650' E040◦01.286'	3	04/08/14
390		*Aristida adscensionis* Walter	N21◦20.463' E039◦57.379'	13	04/13/14
275		*Aristida adscensionis* Walter	N21◦24.595' E039◦52.210'	30	04/21/14
248, 273		*Arundo donax* L.	N21◦23.160' E039◦50.086'	28	04/21/14
222		*Cenchrus biflorus* Roxb.	N21◦23.160' E039◦50.086'	28	04/21/14
62		*Cenchrus ciliaris* L.	N21◦21.122' E039◦52.270'	33	04/22/14
152		*Cenchrus ciliaris* L.	N21◦23.620' E039◦49.535'	40	04/24/14
182		*Cenchrus echinatus* L.	N21◦36.738' E040◦06.913'	43	04/25/14
3		*Cenchrus setigerus* Vahl	N21◦21.313' E039◦55.503'	1	04/08/14
61		*Cenchrus setigerus* Vahl	N21◦21.122' E039◦52.270'	33	04/22/14
382		*Chloris barbata* Sw.	N21◦20.401' E039◦56.933'	11	04/13/14
226		*Cynodon dactylon* (L.) Pers.	N21◦27.449' E039◦57.361'	20	04/18/14
88		*Cynodon dactylon* (L.) Pers.	N21◦26.807' E039◦48.560'	37	04/24/14
81	*Poaceae*	*Cynodon dactylon* (L.) Pers.	N21◦26.363' E039◦49.002'	39	04/24/14
44		*Cynodon dactylon* (L.) Pers.	N21◦21.122' E039◦52.270'	33	04/22/14
129		*Dactyloctenium aegyptium* (L.) P. Beauv.	N21◦27.331' E039◦51.710'	24	04/19/14
320		*Dactyloctenium aegyptium* (L.) P. Beauv.	N21◦20.401' E039◦56.933'	11	04/13/14
75		*Dactyloctenium aegyptium* (L.) P. Beauv.	N21◦19.347' E039◦53.034'	34	04/22/14
224		*Dactyloctenium aegyptium* (L.) P. Beauv.	N21◦21.122' E039◦52.270'	33	04/22/14
321		*Dichanthium annulatum* (Forssk.) Stapf	N21◦20.401' E039◦56.933'	11	04/13/14
52		*Dichanthium annulatum* (Forssk.) Stapf	N21◦21.122' E039◦52.270'	33	04/22/14
139, 140, 141		*Eleusine indica* (L.) Gaertn	N21◦26.609' E039◦47.611'	36	04/24/14
333		*Eleusine indica* (L.) Gaertn	N21◦26.572' E039◦46.758'	38	04/24/14

Table 1. Contd.

392		*Echinochloa colonum* (L.) Link	N21◦20.401' E039◦56.933'	11	04/13/14
254		*Echinochloa colonum* (L.) Link	N21◦26.150' E039◦46.046'	48	04/27/14
137, 408		*Eragrostis barrelieri* Dav.	N21◦20.672' E039◦57.247'	12	04/13/14
53, 54		*Eragrostis japonca* Tunb.	N21◦21.122' E039◦52.270'	33	04/22/14
394		*Parapholis incurva* L.	N21◦54.560' E039◦16.807'	8	04/12/14
154,155		*Panicum turgidum* Forssk.	N21◦22.801' E039◦49.812'	41	04/24/14
13		*Panicum turgidum* Forssk.	N21◦19.650' E040◦01.286'	3	04/08/14
24, 31		*Panicum turgidum* Forssk.	N21◦56.607' E039◦01.742'	5	04/12/14
115, 123		*Panicum turgidum* Forssk.	N21◦20.590' E039◦44.101'	15	04/16/14
311, 207		*Panicum turgidum* Forssk.	N21◦20.456' E039◦41.559'	17	04/16/14
213		*Panicum turgidum* Forssk.	N21◦27.449' E039◦57.361'	20	04/18/14
127		*Panicum turgidum* Forssk.	N21◦25.199' E039◦53.070'	22	04/19/14
302		*Panicum turgidum* Forssk.	N21◦23.202' E039◦50.836'	25	04/20/14
74		*Panicum repens* L.	N21◦19.347' E039◦53.034'	34	04/22/14
65		*Pennisetum ciliare* (L.) Link	N21◦21.122' E039◦52.270'	33	04/22/14
383		*Pennisetum ciliare* (L.) Link	N21◦20.401' E039◦56.933'	11	04/13/14
425		*Pennisetum ciliare* (L.) Link	N21◦20.672' E039◦57.247'	12	04/13/14
210		*Pennisetum ciliare* (L.) Link	N21◦25.199' E039◦53.070'	22	04/19/14
108		*Pennisetum ciliare* (L.) Link	N21◦26.313' E039◦51.374'	23	04/19/14
21		*Pennisetum divisum* (J. F. Gmel.) Henrard	N21◦19.464' E040◦02.992'	4	04/08/14
328		*Pennisetum divisum* (J. F. Gmel.) Henrard	N21◦24.051' E039◦54.913'	18	04/18/14
208		*Pennisetum divisum* (J. F. Gmel.) Henrard	N21◦27.039' E039◦57.254'	19	04/18/14
130		*Pennisetum divisum* (J. F. Gmel.) Henrard	N21◦27.331' E039◦51.710'	24	04/19/14
57		*Leptochloa fusca* (L.) Kunth	N21◦25.199' E039◦53.070'	22	04/19/14
36, 417		*Phragmites australis* (Cav.) Steud.	N21◦54.560' E039◦16.807'	8	04/12/14
276, 277		*Rostraria pumila* (Desf.) Tzvelev	N21◦24.595' E039◦52.210'	30	04/21/14
248, 273		*Sorghum bicolor* (L.) Moench	N21◦23.160' E039◦50.086'	28	04/21/14
422		*Stipa capillata* Hook.	N21◦36.738' E040◦06.913'	43	04/25/14
67		*Stipa tenacissima* L.	N21◦36.767' E040◦05.869'	44	04/25/14
323		*Stipa capensis* Thunb.	N21◦32.103' E040◦07.671'	45	04/25/14
324		*Stipa capensis* Thunb.	N21◦32.103' E040◦07.671'	45	04/25/14
207		*Stipagrostis ciliata* (Desf.) De Winter	N21◦27.039' E039◦57.254'	19	04/18/14
82		*Stipagrostis hirtigluma* (Steud.) De Winter	N21◦27.331' E039◦51.710'	24	04/19/14
392		*Stipagrostis hirtigluma* (Steud.) De Winter	N21◦20.463' E039◦57.379'	13	04/13/14
409		*Stipagrostis hirtigluma* (Steud.) De Winter	N21◦22.801' E039◦49.812'	41	04/24/14
22		*Stipagrostis raddiana* (Savi) De Winter	N21◦21.9' E040◦11.10'	10	04/10/14
222		*Stipagrostis raddiana* (Savi) De Winter	N21◦27.039' E039◦57.254'	19	04/18/14
270		*Setaria verticillate* (L.) P. Beauv.	N21◦23.160' E039◦50.086'	28	04/21/14
76		*Setaria verticillate* (L.) P. Beauv.	N21◦19.347' E039◦53.034'	34	04/22/14
10		*Tragus racemosus* (L.) All	N21◦19.650' E040◦01.286'	3	04/08/14
148, 374		*Ociumum basilicum* L.	N21◦23.620' E039◦49.535'	40	04/24/14
289		*Ociumum basilicum* L.	N21◦26.609' E039◦47.611'	36	04/24/14
97	*Lamiaceae*	*Ociumum canum* Sims	N21◦27.331' E039◦51.710'	24	04/19/14
315		*Plectranthus arabicus* E. A. Bruce	N21◦20.672' E039◦57.247'	12	04/13/14
282		*Plectranthus asirensis* J. R. I. Wood	N21◦24.595' E039◦52.210'	30	04/21/14

Table 1. Contd.

300		*Acacia ehrenbergiana* Hayne	N21◦23.202' E039◦50.836'	25	04/20/14
205		*Acacia ehrenbergiana* Hayne	N21◦23.149' E039◦51.791'	29	04/21/14
335		*Acacia ehrenbergiana* Hayne	N21◦22.639' E039◦52.258'	31	04/22/14
198		*Acacia ehrenbergiana* Hayne	N21◦36.738' E040◦06.913'	43	04/25/14
373		*Acacia ehrenbergiana* Hayne	N21◦36.767' E040◦05.869'	44	04/25/14
338		*Acacia ehrenbergiana* Hayne	N21◦20.672' E039◦57.247'	12	04/13/14
384		*Acacia ehrenbergiana* Hayne	N21◦20.401' E039◦56.933'	11	04/13/14
327		*Acacia ehrenbergiana* Hayne	N21◦24.051' E039◦54.913'	18	04/18/14
398		*Acacia gerrardii* Benth.	N21◦55.507' E039◦18.707'	9	04/12/14
116		*Acacia gerrardii* Benth.	N21◦20.903' E039◦41.694'	16	04/16/14
88		*Acacia hamulosa* Benth.	N21◦27.331' E039◦51.710'	24	04/19/14
35		*Acacia tortilis* Hayne	N21◦56.220' E039◦01.617'	7	04/12/14
40		*Acacia tortilis* Hayne	N21◦19.650' E040◦01.286'	3	04/08/14
12		*Aristida adscensionis* Walter	N21◦19.650' E040◦01.286'	3	04/08/14
390		*Aristida adscensionis* Walter	N21◦20.463' E039◦57.379'	13	04/13/14
275		*Aristida adscensionis* Walter	N21◦24.595' E039◦52.210'	30	04/21/14
217		*Colutea istria* Miller	N21◦26.572' E039◦46.758'	38	04/24/14
19		*Clitoria ternatea* L.	N21◦19.464' E040◦02.992'	4	04/08/14
218, 283		*Delonix elata* (Torner) Gamble	N21◦23.620' E039◦49.535'	40	04/24/14
63, 405		*Indigofera spinosa* Forssk.	N21◦21.122' E039◦52.270'	33	04/22/14
298, 375		*Leucaena leucocephala* (Lam.) de Wit	N21◦23.248' E039◦51.796'	26	04/20/14
266		*Leucaena leucocephala* (Lam.) de Wit	N21◦23.212' E039◦51.136'	27	04/21/14
142		*Mimosa senegalensis* Forssk.	N21◦26.572' E039◦46.758'	38	04/24/14
330		*Onobrychis ptolemaica* (Del.) DC.	N21◦24.051' E039◦54.913'	18	04/18/14
330		*Onobrychis ptolemaica* (Del.) DC.	N21◦21.122' E039◦52.270'	33	04/22/14
365	*Fabaceae*	*Pithecellobium dulce* Benth.	N21◦26.363' E039◦49.002'	39	04/24/14
280, 283,		*Pithecellobium dulce* Benth.	N21◦24.595' E039◦52.210'	30	04/21/14
7		*Prosopis juliflora* D. C.	N21◦19.448' E039◦58.002'	2	04/08/14
9,		*Prosopis juliflora* D. C.	N21◦19.650' E040◦01.286'	3	04/08/14
33		*Prosopis juliflora* D. C.	N21◦56.528' E039◦02.402'	6	04/12/14
385		*Prosopis juliflora* D. C.	N21◦20.401' E039◦56.933'	11	04/13/14
135		*Prosopis juliflora* D. C.	N21◦20.672' E039◦57.247'	12	04/13/14
120		*Prosopis juliflora* D. C.	N21◦20.590' E039◦44.101'	15	04/16/14
117, 120		*Prosopis juliflora* D. C.	N21◦20.903' E039◦41.694'	16	04/16/14
179		*Prosopis juliflora* D. C.	N21◦20.456' E039◦41.559'	17	04/16/14
49, 50, 71		*Prosopis juliflora* D. C.	N21◦21.122' E039◦52.270'	33	04/22/14
260, 264		*Rhynchosia minima* (L.) DC.	N21◦23.212' E039◦51.136'	27	04/21/14
217		*Rhynchosia minima* (L.) DC.	N21◦23.212' E039◦51.136'	27	04/21/14
33, 395		*Rhynchosia schimperi* Hochst. ex Boiss.	N21◦54.560' E039◦16.807'	8	04/12/14
5, 352		*Senna alexandrina* Miller	N21◦21.313' E039◦55.503'	1	04/08/14
215		*Senna alexandrina* Miller	N21◦55.507' E039◦18.707'	9	04/12/14
118		*Senna alexandrina* Miller	N21◦20.456' E039◦41.559'	17	04/16/14
229		*Senna alexandrina* Miller	N21◦27.449' E039◦57.361'	20	04/18/14
72, 64		*Senna holosericea* (Fresen) Garsault	N21◦19.347' E039◦53.034'	34	04/22/14
336		*Senna italica* Miller	N21◦22.639' E039◦52.258'	31	04/22/14
178		*Senna italica* Miller	N21◦30.993' E040◦02.958'	42	04/25/14
11		*Senna italica* Miller	N21◦19.650' E040◦01.286'	3	04/08/14
278		*Senna italica* Miller	N21◦24.051' E039◦54.913'	18	04/18/14
95		*Senna italica* Miller	N21◦27.331' E039◦51.710'	24	04/19/14
57, 110		*Tephrosia nubica* (Bioss) Baker	N21◦25.199' E039◦53.070'	22	04/19/14

Table 1. Contd.

85		*Tephrosia nubica* (Bioss) Baker	N21◦27.331’ E039◦51.710’	24	04/19/14
301		*Tephrosia nubica* (Bioss) Baker	N21◦23.202’ E039◦50.836’	25	04/20/14
20		*Tephrosia purpurea* (L.) Pers.	N21◦19.464’ E040◦02.992’	4	04/08/14
60		*Tephrosia villosa* (L.) Pers	N21◦21.122’ E039◦52.270’	33	04/22/14
126	*Lilaceae*	*Aloe vera* L.	N21◦20.456’ E039◦41.559’	17	04/16/14
37, 341		*Abutilon hirtum* (Lamk.) Sweet	N21◦54.560’ E039◦16.807’	8	04/12/14
13, 14		*Abutilon hirtum* (Lamk.) Sweet	N21◦19.650’ E040◦01.286’	3	04/08/14
340		*Abutilon hirtum* (Lamk.) Sweet	N21◦36.767’ E040◦05.869’	44	04/25/14
231		*Abutilon hirtum* (Lamk.) Sweet	N21◦36.738’ E040◦06.913’	43	04/25/14
286	*Malvaceae*	*Abutilon hirtum* (Lamk.) Sweet	N21◦26.182’ E039◦48.718’	35	04/24/14
337		*Abutilon hirtum* (Lamk.) Sweet	N21◦22.639’ E039◦52.258’	31	04/22/14
259, 263		*Abutilon hirtum* (Lamk.) Sweet	N21◦23.212’ E039◦51.136’	27	04/21/14
230		*Abutilon hirtum* (Lamk.) Sweet	N21◦27.449’ E039◦57.361’	20	04/18/14
204		*Abutilon hirtum* (Lamk.) Sweet	N21◦23.202’ E039◦50.836’	25	04/20/14
187		*Azadirachta indica* A. Juss.	N21◦36.767’ E040◦05.869’	44	04/25/14
246, 247		*Azadirachta indica* A. Juss.	N21◦26.807’ E039◦48.560’	37	
202	*Meliaceae*	*Azadirachta indica* A. Juss.	N21◦23.212’ E039◦51.136’	27	04/21/14
199		*Azadirachta indica* A. Juss.	N21◦23.248’ E039◦51.796’	26	04/20/14
353, 386		*Azadirachta indica* A. Juss.	N21◦20.401’ E039◦56.933’	11	04/13/14
268	*Moraceae*	*Ficus carica* L.	N21◦23.160’ E039◦50.086’	28	04/21/14
137		*Ficus elastica* Roxb.	N21◦26.609’ E039◦47.611’	36	04/24/14
334	*Moringaceae*	*Moringa oleifera* Lam.	N21◦20.493’ E039◦52.401’	32	04/22/14
73	*Molluginaceae*	*Telephium sphaerospermum* Boiss.	N21◦19.347’ E039◦53.034’	34	04/22/14
404	*Neuradaaceae*	*Neurada procumbens* L.	N21◦54.560’ E039◦16.807’	8	04/12/14
242, 243, 244, 245	*Nyctaginaceae*	*Bougainvillea spectabilis* Willd.	N21◦26.807’ E039◦48.560’	37	04/24/14
150		*Boerhavia diffuser* L.	N21◦26.572’ E039◦46.758’	38	04/24/14
415		*Commicarpus africanus* Lour.	N21◦21.313’ E039◦55.503’	1	04/08/14
238	*Oleaceae*	*Jasminum sambac* (L.) Aiton	N21◦23.042’ E039◦52.144’	46	04/26/14
265		*Phoenix caespitosa* Chiov.	N21◦23.248’ E039◦51.796’	26	04/20/14
39	*Palmae*	*Phoenix caespitosa* Chiov.	N21◦26.363’ E039◦49.002’	39	04/24/14
200		*Hyphaene thebaica* (L.) Mart.	N21◦23.212’ E039◦51.136’	27	04/21/14
43		*Washingtonia robusta* H. Wendl.	N21◦24.595’ E039◦52.210’	30	04/21/14
113	*Plantaginaceae*	*Plantago ciliata* Desf.	N21◦25.199’ E039◦53.070’	22	04/19/14
304	*Plumbaginaceae*	*Limonium axillare* (Forssk.) O. Kuntze	N21◦19.464’ E040◦02.992’	4	04/08/14
209		*Emex spinosus* L.	N21◦27.039’ E039◦57.254’	19	04/18/14
376	*Polygonaceae*	*Rumex cyprius* Murb.	N21◦27.039’ E039◦57.254’	19	04/18/14
201		*Rumex vesicarius* L.	N21◦27.039’ E039◦57.254’	19	04/18/14
235,236	*Portulacaceae*	*Portulaca oleraceae* L.	N21◦23.042’ E039◦52.144’	46	04/26/14
46	*Polygalaceae*	*Polygala negevensis* Danin	N21◦21.122’ E039◦52.270’	33	04/22/14
206		*Ziziphus spina- christi* (L.) Willd.	N21◦23.149’ E039◦51.791’	29	04/21/14
65		*Ziziphus spina- christi* (L.) Willd.	N21◦23.248’ E039◦51.796’	26	04/20/14
223		*Ziziphus spina- christi* (L.) Willd.	N21◦27.449’ E039◦57.361’	20	04/18/14
158, 160	*Rhaminaceae*	*Ziziphus spina- christi* (L.) Willd.	N21◦22.801’ E039◦49.812’	41	04/24/14
284		*Ziziphus spina- christi* (L.) Willd.	N21◦26.609’ E039◦47.611’	36	04/24/14
291		*Ziziphus spina- christi* (L.) Willd.	N21◦26.182’ E039◦48.718’	35	04/24/15
285		*Ziziphus spina- christi* (L.) Willd.	N21◦24.595’ E039◦52.210’	30	04/21/14
146, 147	*Rosaceae*	*Rubus sanctus* Schreber. Icon.	N21◦26.572’ E039◦46.758’	38	04/24/14
346	*Rubiaceae*	*Kohautia caespitosa* Schnizl.	N21◦36.738’ E040◦06.913’	43	04/25/14
172		*Kohautia caespitosa* Schnizl.	N21◦32.103’ E040◦07.671’	45	04/25/14

Table 1. Contd.

414		*Oldenlandia capensis* L. fil.	N21◦26.572' E039◦46.758'	38	04/24/14
433	*Scrophulariaceae*	*Schweinfurthia pterosperma* A. Braun	N21◦23.620' E039◦49.535'	40	04/24/14
339	*Solanaceae*	*Datura innoxia* Mill	N21◦30.993' E040◦02.958'	42	04/25/14
102		*Hyoscyamus deserforum* L.	N21◦27.331' E039◦51.710'	24	04/19/14
359	*Tamaricaceae*	*Tamarix aphylla* (L.) H. Karst.	N21◦23.248' E039◦51.796'	26	04/20/14
60		*Tamarix aphylla* (L.) H. Karst.	N21◦21.122' E039◦52.270'	33	04/22/14
191, 190, 193		*Tamarix aphylla* (L.) H. Karst.	N21◦36.767' E040◦05.869'	44	04/25/14
316		*Tamarix aphylla* (L.) H. Karst.	N21◦24.946' E039◦59.447'	14	04/13/14
391	*Typhaceae*	*Typha domingensis* Pers.	N21◦20.463' E039◦57.379'	13	04/13/14
111, 366	*Urticaceae*	*Forsskaolea tenacissima* L.	N21◦25.199' E039◦53.070'	22	04/19/14
96		*Forsskaolea tenacissima* L.	N21◦27.331' E039◦51.710'	24	04/19/14
257		*Forsskaolea tenacissima* L.	N21◦23.212' E039◦51.136'	27	04/21/14
279		*Urtica pilulifera* L.	N21◦24.595' E039◦52.210'	30	04/21/14
2, 228	*Zygophyllaceae*	*Fagonia bruguiei* DC.	N21◦21.313' E039◦55.503'	1	04/08/14
18		*Fagonia indica* Burnm. f.	N21◦19.464' E040◦02.992'	4	04/08/14
345		*Fagonia indica* Burnm. f.	N21◦32.103' E040◦07.671'	45	04/25/14
145, 393		*Fagonia indica* Burnm. f.	N21◦20.463' E039◦57.379'	13	04/13/14
36		*Fagonia olivieri* DC.	N21◦54.560' E039◦16.807'	8	04/12/14
193, 194		*Fagonia olivieri* DC.	N21◦36.767' E040◦05.869'	44	04/25/14
214, 434		*Fagonia simplex* L.	N21◦27.039' E039◦57.254'	19	04/18/14
318		*Tribulus arabicus* H. Hosni	N21◦20.672' E039◦57.247'	12	04/13/14
128		*Tribulus arabicus* H. Hosni	N21◦24.051' E039◦54.913'	18	04/18/14
124		*Tribulus terrestris* L.	N21◦20.590' E039◦44.101'	15	04/16/14
221		*Tribulus terrestris* L.	N21◦27.039' E039◦57.254'	19	04/18/14
26, 306		*Tribulus terrestris* L.	N21◦19.464' E040◦02.992'	4	04/08/14
86, 94, 106		*Tribulus terrestris* L.	N21◦27.331' E039◦51.710'	24	04/19/14
162		*Maerua oblongifolia* (Forssk.) A. Rich	N21◦32.103' E040◦07.671'	45	04/25/14
99		*Tribulus terrestris* L.	N21◦25.199' E039◦53.070'	22	04/19/14
32		*Zygophyllum mandavillei* Hadidi	N21◦56.607' E039◦01.742'	5	04/12/14
90		*Zygophyllum simplex* L.	N21◦21.313' E039◦55.503'	1	04/08/14
181		*Zygophyllum simplex* L.	N21◦36.767' E040◦05.869'	44	04/25/14
46, 47		*Zygophyllum simplex L.*	N21◦21.122' E039◦52.270'	33	04/22/14
258		*Zygophyllum simplex* L.	N21◦23.212' E039◦51.136'	27	04/21/14
105, 109		*Zygophyllum simplex* L.	N21◦25.199' E039◦53.070'	22	04/19/14
131		*Zygophyllum simplex* L.	N21◦20.401' E039◦56.933'	11	04/13/14

Table 2. New species.

Specimens number	Family	Genus
40	*Asteraceae*	*Launaea sp.*
175	*Boraginaceae*	----------
279	*Nyctaginaceae*	*Commicarpus sp*
415	*Lamiaceae*	----------

these terretories.

Life-form of all species and uses of plants

In the current study, the Life-forms of all species in Mecca district follow Raunkiaer scale as shown in Figure 8, whereas each species will be presented by its initial such as: H, hemicryptophyte; Ch, chamaephytes; GH, geophytes-helophytes; Ph, phanerophytes; Th, therophytes and He, helophyte. In relation to all species collected from Mecca, the most prevalent life-forms are therophytes with 41% followed by chamaephytes with 34% followed by phanerophytes with 11% (Figure 7).

In short conclusion the flora species and components in general are very important science; it deals with differenttypes of plants (medicinal, aromatic, poisonous... etc). This classification is very important and practical regarding human social structure and behavior and it is usually given the term of ethnobotanical uses of local communities which really affect their life style and the

Table 3. Rare species in Mecca district.

Family	Species
Boraginaceaa	*Heliotropium crispum* Desf.
Chenopdiceae	*Atriplex farinosa* Forssk.
Asteraceae	*Launaea nudicaulis* (L.) Hook. f.
Cyperaceae	*Cyperus rotundus* Benth.
Plantaginaceae	*Plantago ciliata* Desf
Polygonaceae	*Emex spinosus* (L.)
Solanaceae	*Datura innoxia* Mill
Rubiaceae	*Kohautia caespitosa* Schnizl.
Zygophyllaceae	*Tribulus arabicus* Hosni

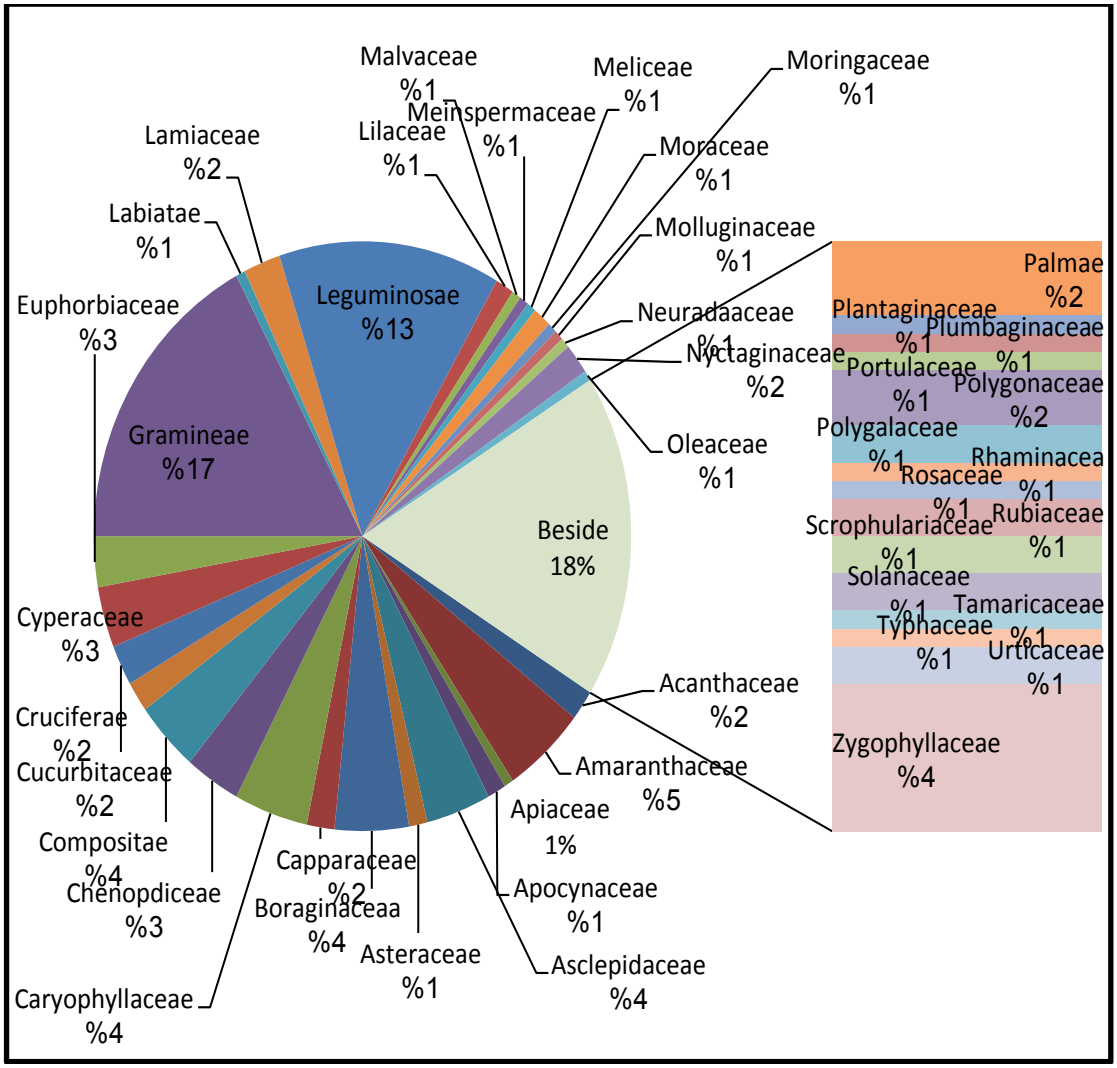

Figure 5. Distribution of taxa in relation to their families.

sustainable use of their resources (Oran, 2014; Oran and Al-Eisawi, 2014).

Overall, during the identification of the collected samples of plants in relation to their usages, they can be classified

Table 4. Chorotype the total and percentage of taxa.

Corotype	SA	SU	ST	IT	ME	TR	COSM	PAN	AM	SE	WE	SM	IN	EU	AF	SI
Total	82	48	1	53	30	17	12	3	6	7	2	1	10	4	14	5
Percentage	27.70	16.22	0.34	17.91	10.14	5.74	4.05	1.01	2.03	2.36	0.68	0.34	3.38	1.35	4.73	1.69

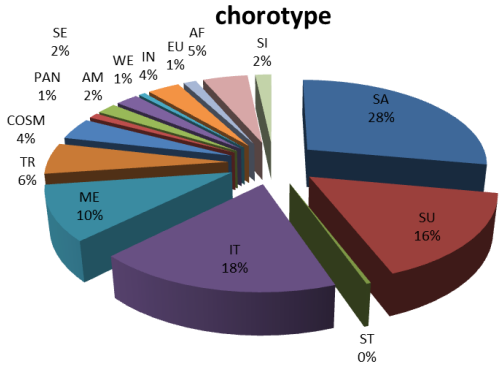

Figure 6. Graph showing the percentage of chorotype.

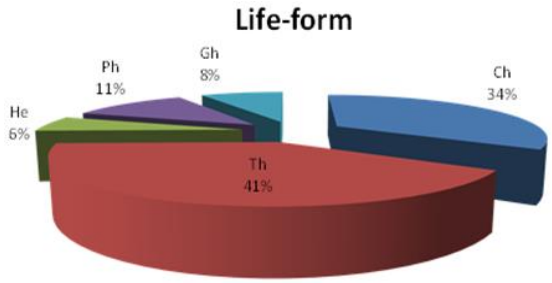

Figure 7. Percentage of Life- form in Mecca district. H= hemicryptophyte; Ch= chamaephytes; GH= geophytes-helophytes; Ph= phanerophytes; Th= therophytes and He= helophyte.

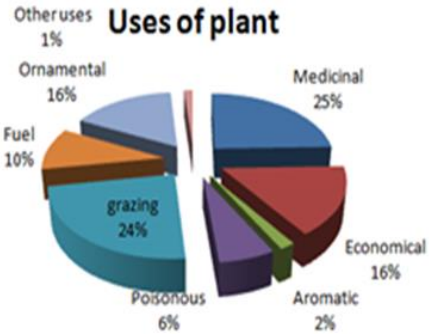

Figure 8. Graph of uses of species of Mecca district.

into medicinal plants representing 71 species, species economical plants, 46 species; aromatic plants, 5 species; poisonous plants, 18 species; range grasses (fodder grasses) plants, 69 species; ornamental plants, almost 47 species; wood (fuel) plants, 29 species; other uses, about 4 species (Table 5, Figure 8). The most popular medical plant in Mecca is *Senna italica* Miller, which is used as laxative. *Senna* is a very well-known universal plant laxative used in medical industry as well as herbal medicine known in Arabic Language as *Sanamekka*; as clearly shown, the scientific name of the plant seems as originally taken from its old, local Arabic name. The plant at present is commonly used in the study area, Saudi Arabia, the Arabian Peninsula, Majority of the Arab World and India (Michael et al., 1999).

DISCUSSION

Saudi Arabia as mentioned earlier is a huge country with variable biogeographic regions. Therefore, it is very rich in biodiversity and special groups at the generic level such as *Alloe, Caralluma, Acacia*, or at the family level, such as Resedaceae, Leguminosae (Fabaceae) and Amaranthaceae.

The number of the recorded species in general in Saudi Arabia is increasing day after day based on new field trips and biodiversity surveys. As an indicator of that; is the first number 1500 species which was recorded by Migahid between the years 1974-1988. Later on the number was raised to reach 2300 within a period of about 30 years; this is based on the records given in the Flora of Saudi Arabia (Chaudhary, 1999-2001; Alfarhan et al., 2005; Masrahi et al., 2012). This is very true for the Flora of Egypt which was recorded to be less than 1700 species by Täckholm (1974) and raised to over than 2000 species by Bolous (1999-2005) in the new flora of Egypt. The same thing applies to Jordan, in the First Checklist of Vascular Plants of Jordan 2087 species (Al-Eisawi, 1982); recently a new checklist for the flora of Jordan was produced including 2545 species (Al-Eisawi, 2013). All of these examples indicate that the flora and biodiversity in the Arab world is not really extensively studied, in fact it is still very much under studied and needs further surveys in a wide field of biodiversity knowledge especially, insects and invertebrate biology.

However, this study is restricted to specific part of Saudi Arabia which is Holy Mecca. Accordingly, Mecca district is located in the west of Saudi Arabia in an arid zone of Saudi Arabia. Mecca is a restricted area for foreign visitors, therefore, it has been very little times investigated and thoroughly studied. Accordingly, it was

selected for investigation using a local resident person who knows the various parts and has access and local help to survey the study are.

Based on this study where 184 species were collected and identified from this restricted area, it shows that it contains 8.48% of species from the total flora of Saudi Arabia. In this study, 80 more species have been recorded as additional species to the Flora of Mecca since the publication of the paper by Abdel Khalik et al. (2013). They recorded only 104 species. It is more likely that intensive collection at the year around would possibly discover more species. Mecca is considered to be poorly investigated since it is a restricted area to nonmuslim visitors. The most prevalent species recorded in this study are *Calotropis procera*, *Aerva javacica* which typical species of dry subtropical ecosystem, similar to conditions prevailing in Jordan Rift Valley, Southern Egypt, and Sudan and extending to the Indian peninsula (Al-Eisawi, 1996).

In terms of floristic and vegetation composition in the studied area *Poaceae* and *Fabaceae* are represented by the highest number of species (31 and 24, respectively). The dominance of members of *Poaceae* and *Fabaceae* coincides with the findings reported by Al-Turki and Al-Olayan (2003), El-Ghanem et al. (2010) and Abdel Khalik *et al.* (2013).

The results show that the most chorotype distribution in the study area is Saharo-Arabian (27.70%), followed by Irano-Turanian (17.91%) and then Sudano-Zambezian (16.22%). A floristic analysis shows that the majority life-form of plants in the study area is therophytes followed by chamaephytes, phanerophytes as a result of adaption to the hot dry climate.

The study shows also that the most highly percentage for uses of plants was used as medicinal plants with a percentage of 24.57% followed by grazing plants with percentage of 23.88% while the least percentage was a aromatic plants with a percentage of 1.73%. It is worth mentioning here that the aim of this study was only survey of biodiversity, then classifying plant uses without working on their chemical constituents, but based on their records in previous literature (Al-Eisawi, 2014, 2015; Oran and Al-Eisawi, 2014, Oran, 2014).

The plants in Mecca region are predominately arid zone plants, where the leaves are covered with a waxy layer and have large roots and branched which came as a result of the increase in the rate of photosynthesis and search for water (Michael et al. 1999).

During this research, differences in the thickness of leaves and waxy layer of plant *Calotropis procera* was observed; the thickness of leaves and waxy layer is related to the water availability. When water is available the thickness of leaves and waxy layer will decrease and vice versa.

In conclusion, it is expected that further studies on the biodiversity of organisms will take place, in addition to vegetation and ecophysiology parameters. The vegetation in general and dry ecosystem in particular, extremely varies from year to year based on environmental conditions especially, rainfall and prevailing temperature.

Conflict of interests

The author(s) have not declared any conflict of interests.

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Determining the potential for introducing and sustaining participatory forest management: A case study of South Nandi Forest of Western Kenya

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The South Nandi Forest is the most important site for the conservation of the globally threatened *Eremomela turneri*. The growing human population is the main threat to its biodiversity and the forests provision of ecosystem services. In order to address the above threat, Kenya Forest Service and partners perceived that the introduction of participatory forest management would mitigate the challenge. This study was conducted to provide socio-economic baseline information about the forest adjacent community members and other forest stakeholders who are the key blocks upon which the joint management strategies and programmes would be anchored. Information was gathered using participatory rural appraisal tools such as mapping, transect walks, focused group discussions, respondents recall and the livelihood framework analysis. Firewood was the most accessed forest product with the others being poles and posts. Even the very presence of the forest in the midst of the community presented several livelihood improvement opportunities within the settlement areas such as on-farm tree growing, fish farming, grazing and microclimate for high agricultural production. It was noted that the community were highly interested in participating in forest management (93.7%). The key challenge was that the forest adjacent community perceived South Nandi forest resources to be on the decline. This shall have to be converted into an opportunity that would be utilized to introduce and implement PFM in South Nandi.

Key words: Wellbeing, participatory forest management, livelihoods, opportunity and interest.

INTRODUCTION

Forests are being depleted at an alarming rate in recent decades in developing countries (World Bank, 2009). The depletion has been witnessed to be higher in forests which are centrally managed by the state because of low capacity and limited incentives to protect and manage the forests. Community forestry among many management approaches has been adopted more widely as it has shown that it can lead to better forest management and improved community livelihoods which are dual incentives for government and community to support the approach which addresses their needs. This is premised on the current theory and narrative that decentralization of forest management leads to sustainable forest management and improved livelihoods (Tacconi et al., 2006).

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This is based on three assumptions that (i) democratic decentralization is a means of institutionalizing and scaling up community based natural resource management (ii) If rural people benefit from the forest they shall conserve it (iii) the success of decen-tralization can be measured by lack of (or lower rates of) deforestation.

In Kenya, indigenous forests which are state managed have undergone a decade of degradation between 1980s up to mid-1990s. As noted by Otsuka and Pokharel (2014), the state lacks the resources to protect forests and the motivation to manage trees hence it cannot manage the forests sustainably. Though the government reacted by declaring a ban on utilization of indigenous trees, this was not very successful. In 1997, a pilot on community forestry was started buoyed by the success in other parts of the globe especially Nepal. This should be viewed against a review of the Kenya's history which reveals that the country has for the better part of its independent life been a unitary state with a highly centralized government that has had overbearing control over the sub national government and the other arms of the government, namely the legislature and the judiciary (Institute of Economic Affairs, 2010). It is against this background that the country does not have a long experience with decentre-lization of natural resources. Despite this, the stakeholders planned to introduce participatory forest management (PFM) in South Nandi forest.

Together with Kakamega and North Nandi forests, South Nandi forest forms part of the Western rainforest region, and the Eastern most fragment of the Guinea – Congolian phyto-geographical region. The area occupied by the forest was once extensive, but has steadily declined due to high population pressure and inadequate manage-ment which was centralized with no formal community participation. The forest has been under the state management through Kenya Forest Service (KFS) formerly Forest Department (FD).

South Nandi forest is almost certainly the most important site in the world for the threatened *Eremomela turneri* (Otieno et al., 2011). The area supports exceptionally high densities of this little-known species. South Nandi forest has a total of 70 species of butterflies, majority of which are forest species of Western Kenya. South Nandi forest was heavily logged in the past and this affected the vegetation structure severely resulting in some of the areas getting reverted to thickets. Currently, the common trees include *Tabernaemontana stapfiana*, *Macaranga kilimandscharica*, *Croton megalocarpus*, *Croton macrostachyus, Drypetes gerrardii*, *Celtis africana*, *Prunus africana*, *Neoboutonia macrocalyx* and *Albizia gummifera*. This justifies the need to implement PFM which is expected to enhance conservation of these flora and fauna.

Forest adjacent communities continued to use the forest resources due to exacerbated decline of forestry products on their farms. The community use of the forest remains the single largest threat to the forest's conservation. Additionally, the increasing human population coupled with the commercialization of forest products whose demand is increasing places extreme pressure on the forest whose management is poorly resourced. This has made the management of the forest by Kenya Forest Service (KFS) ineffective thereby the need to have other stakeholders participate in the management of the forest. This has started with the participation of several local, national and regional stakeholders who are contributing in diverse ways towards the management and use of the forest.

In line with the Forest Act 2005, and PFM guidelines which provides the framework under which stakeholders especially communities should participate in forest management, KFS through support from development partners has been initiating PFM. Through this approach, communities and other stakeholders participate in forest management under a framework that also supports livelihood. This new management approach is at infancy and it is a pre requisite that the partners get a very good understanding of the community: their needs, interests and how they would wish to be involved in the management of the forest. This shall be complimented by a good assessment of the resources available so as to determine the demand and supply with a view of proposing a partnership framework that shall ensure that partnership is sustained, the resource is sustainably managed and the community needs are met through regulated access and provision of goods from other sources including their farms to supplement unmet demand.

This management shift is premised on the evidence that: "when forests are managed by the state, population pressure create a higher demand for firewood and agricultural and grazing land, which results in deforestation, whereas favourable market access lead to the felling of large trees for sale. The assumption is that once the forest is handed over to the community forest user groups (CFA in Kenya), the larger the demand for forest resources, the greater becomes the incentives to manage the forests, thereby leading to faster rehabilitation of the forest condition through the regeneration of young trees" (Rajpoudel, 2014). The evidence from other countries has pushed many countries to start implementing some form of community forestry which has been referred to as PFM in Kenya (KFS, 2007).

The SNF forest adjacent communities are mostly farmers engaged in the growing of tea and maize as cash crops. They also keep dairy cows in their homesteads and rear beef cattle which graze in the forest for a fee. The average land holding by forest adjacent households is 2.5 acres. In 2008, the population of Nandi South was 150,335 people with a sex ratio of approximately 1:1. Forestry contribution to the economy is through products such as timber (48%), firewood (40%) and poles (18%). There are a few people (8%) engaged in forest related activities such as saw milling and carpentry (GoK, 2008).

Problem statement

The forest was under intense use by the forest adjacent community but was not adequately managed by KFS. The increased demand of forestry resources and increasing population poses a challenge. The community and other stakeholders' needs were not known and the modes of their involvement in forest management were not available though it is supported by the policy.

Justification

Management of forest resources globally is changing from state management to management by various stakeholders but with the state playing a regulatory role. South Nandi forest was facing management challenges and it was perceived that the involvement of forest adjacent communities and other stakeholders through PFM would mitigate the challenges. The study was to provide baseline information and status necessary for planning and implementing the approach in South Nandi forest which would be applicable in other forests with similar socio ecological conditions.

Study questions

1. What does the community use from the forest?
2. How does the community wish to be involved in the management of the forest?
3. What is the status of the forest products from the forest and the farms?
4. What are the challenges and how do they wish to have them mitigated?

Study/research objectives

1. To undertake social mapping of the forest adjacent community and stakeholders
2. To determine community forest resources' needs
3. To determine the on farm resource status
4. To determine the most feasible forest management institutional arrangement
5. To develop a baseline for monitoring the impact of community involvement in forest management on forest conservation and community livelihoods.

METHODOLOGY

Study site

South Nandi Forest is located in Western Kenya and is one of the main fragments of a contiguous forest block that included the North Nandi and Kakamega. The forest is located approximately between longitude 37°05 E to 37°23' E and at latitude 0°18' N and 0°32 N (Figure 1). It became a legally protected area in 1936 on gazettement as a Trust Forest as per legal notice number 76 of 1936 and defined by boundary plan no.75/68 LN 89 of 1937. It has a total area of 49,880 ha which later reduced to 24,683 ha through excisions. The forest is managed under two stations namely Kobujoi with 17,960 ha and Kimondi with 6,723 ha. The excised forest areas were for settlement (2,200 ha), a buffer zone of tea plantations (340 ha) and plantations of fast growing exotic trees (1,400 ha). Of the current stand of South Nandi forest trees, at most 13,000 ha is closed-canopy forest, the rest being shrubs, grassland or cultivated area. Its altitude ranges from 1,700 - 2,000 m with a mean annual rainfall ranging from 1,600 – 2,000 mm per year (Njunge and Mugo, 2011).

The forest is drained by the Kimondi and Sirua Rivers, which merge to form the Yala River flowing into Lake Victoria. The landscape is gently undulating and underlain by granitic and basement complex rocks, which weather to give deep, well-drained, moderately fertile soils.

Sample size

South Nandi Forest is surrounded by 18 administrative locations overseen by a chief. The communities listed the 18 locations, followed by listing of the sub location in each location. The villages in each sub location were listed and the key socio ecological factors were also listed through focused group discussion with local knowledgeable persons. A socio-ecological representative sub location was selected from each location to provide the village for sampling. One village was selected from each of the 18 forest adjacent locations giving a total of 18 selected villages which were representative of the socio-economy of the villages in each forest adjacent locations. The selection was done by a team of forestry stakeholders who were well conversant with the local area. Each village represented several villages determined by the local population size and physical features. Households interviewed were randomly selected from each village ensuring that the four wellbeing categories (very rich, rich, poor and very poor) are well represented in each village. A total of 1278 respondents were interviewed in all the villages selected.

Data collection instruments

FGD was used to list household in each village with community selecting locally knowledgeable people who included: old men, women, youth (both male and female), local leaders and staff of development organizations. These were individuals with vast understanding of the village and the community. The households were clustered into four well-being categories from A to D with A representing a well off household and D the least well off.

In each village, representative households were interviewed guided by set of socio-economic parameters. This was precedent by community led FGD where participatory household well-being characterization through community criteria was done including getting information on perceived community resource status trends and management trends over time.

Questionnaires were administered to respondents of randomly selected households in the identified villages.

RESULTS AND DISCUSSION

Socio-economic factors influencing community interest in PFM

Well-being characterization

This focused on characterization of well-being status of

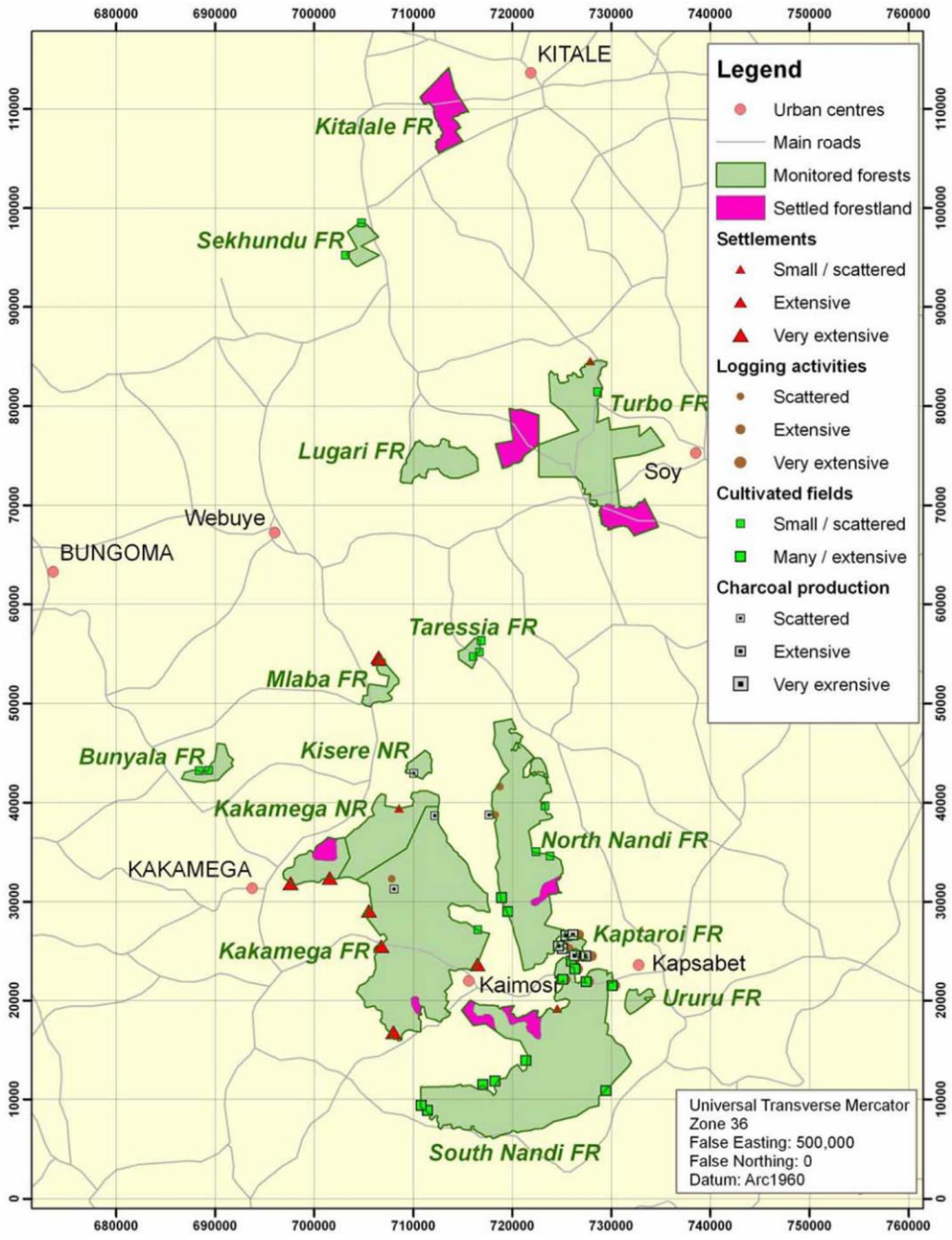

Figure 1. South Nandi Forest Location (Kenya Wildlife Service and UNEP, 2007) (Source: Klopp, 2012).

the forest adjacent households through use of FGD based on community perceptions. The household livelihood sources and assets were the basis of the categorization. The criteria by which the communities gauged socio-economic well-being of its member households included: the type of house in terms of building and roofing materials; land size; number of wives and children; hospitals attended for treatment; source of energy for cooking and lighting; schools and university attended by children; number of meals eaten per day; number of trees planted; contribution to social welfare of others and to community development projects; whether they own vehicles and type of clothing among others.

Four well-being categories were arrived at, each with clear differentiating characteristics generated at the FGDs in relation to the household richness (Tajiri A (very

Table 1. Well-being ranks for SNF adjacent households.

Conventional wellbeing rank label	Other rank labels
Wellbeing A	Tajiri (A) – Mutuji (Luhya) Mogoriot (Nandi) (Richest)
Wellbeing B	Tajiri (B), Mogoriot (B)(rich)
Wellbeing C	Tajiri (C), Mogoriot (C)(average)
Wellbeing D	Maskini; Mogoriot (D); Kibananiat (poor)

This was guided by a community based household wellness criteria.

rich), Tajiri B (rich), Tajiri C (poor) and Maskini (very poor). The households were ranked as guided by the characteristics developed by the community in Table 2.

The 1278 respondents selected randomly were accorded different wealth ranks (A, B, C and D) on the basis of the above criteria set by the community and as per field observation during the household interviews. Analysis of the wellbeing categories revealed that 81.5% of the respondents were poor, 18.4% were very poor, 11. 7% were rich and 5.1% were very rich. Therefore, majority of the community members living adjacent to South Nandi Forest are in poor wellbeing category.

As concerns interest in forest management, 93.7% of all the respondents were interested in PFM out of whom 5.2% were very rich, 11.7% were rich, 64.7% were poor and 18.4% were very poor. Therefore, due to the majority of community members being poor, majority of those interested in PFM were poor.

Analysis of interest in forest management based on each well-being category (Table 1) revealed that their interest was not determined by their well-being (Figure 2). Therefore, there was no significant association between wellbeing categories of the respondents and their interest in forest management ($\chi^2 = 1.050$, $p = 0.7$).

Land holdings

The average land holding for all respondents was 4.47 acres. Based on the well-being categories, the average land holdings were 13.74 acres for very rich, 7.56 acres for rich, 3.80 acres for poor and 2.29 acres for very poor hence a significant difference among the different categories was observed ($F = 38.370$, $p<0.001$).

Analysis of land holding among the 2 interest groups revealed that those interested in PFM had an average of 4.57 acres while those not interested had 3.04 acres hence no significant difference among them ($F = 2.170$, $p = 0.141$). This implies that the community members living adjacent to SNF may not necessarily be interested in PFM for the purpose of owning the land hence land size is not an important factor in determining interest in involvement in PFM

Distance from forest edge

The average distance from the forest edge for all households interviewed was 1.11 km. There was no significant difference in mean distance from the forest among the respondents in the different well-being categories (very rich- 1.16 km, rich- 1.06 km, poor- 1.15 km and very poor- 1) hence well-being was not a determinant factor in proximity to the forest.

All the respondents interviewed were within a distance range of 0.01 to 5 km from the forest where by 50.1% of them were within 0.01 to 0.50 km while 49.9% were at a distance beyond 0.50 and up to 5 km. About 17.5% of all the respondents were within 0.50 km distance from the forest. Considering the difference in mean distance from the forest among those interested in PFM and those not interested, it was noted that those interested were closer to the forest edge (1.04 km) than those not interested in PFM (2.19 km). The difference was highly significant ($F = 87.004$, $p<0.001$). This calls for the government to concentrate its efforts in encouraging PFM among the interested groups who are nearer the forest since distance from the forest is an important determinant for interest in PFM. The highest numbers of those using timber poles and posts (139), withies (134) and herbs (276) were within a distance range of 1.1 to 5 km from the forest while the highest number using grass was within 0.11 and 0.5 km from the forest. Timber users' location away from the forest is a strategy to avoid arrest.

Gender

There were more male headed households (79.2%) interviewed than female headed households (20.8%). From analysis of interest in PFM based on gender, it was observed that a higher percentage of the males were interested in PFM than the female hence a significant association between household head gender and interest in PFM ($\chi^2 = 12.463$, $p<0.001$) was deduced from this study. This could be associated with the fact that in African culture, men are the key decision makers and even where households are headed by women due widowhood or other reasons, and there are men who are consulted in making key decisions in the household whether as father figures, brothers or friends.

However analysis of mean consumption of firewood and forest contribution for the different gender revealed that the male headed households used 1.79 headloads while female headed households used 1.87 headloads per

Table 2. Community perceived well-being rank characteristics for households adjacent to South Nandi Forest.

Tajiri A (very rich)	Tajiri B (rich)
Permanent house roofed with gal sheet and brick walled	Owns a permanent house
Owns land between 20 and 50 acres	Owns 10-20 hectares of land
Uses river water	Uses river water
Have one or two wives	Have one wife and several concubines
Have 3-8 children	Have 4 - 8 children
Attends private hospital	Attend private hospital
Connected to national grid or uses generator and or solar	Level of education Diploma
Children attend private schools and universities locally and abroad	Children attend public and a few private schools
Eats four to five times a day including meat, bread, rice, blue band, spaghetti and chapatti	They are church goers
Have between 1000 - 3000 on farm trees	Use pressure lamp to light
Employed earning between 50,000 to over 100,000KES	Eats three times per day
Have income from other income generating activities	Attend both private and government hospitals
Contribute between 1000 and 2000KES during self-help functions	Have three meals a day
Have vehicles and tractor	Water source, well, bore holes, water tanks and rivers
Own exotic high grade dairy cows	Monthly income 20,000 to 40,000KES
Source energy: gas, charcoal and firewood	More than 2000 on farm trees
Owns five acres under tea crop	Have 3 cows Source energy: charcoal and firewood
Clothing imported and very expensive	Transport mode motorbike or vehicle
	Owns 2 acres of tea
	Clothing ordinary
Tajiri C (poor)	**Maskini (Kibananiat) (very poor)**
Have a semi-permanent house with mud wall roofed with iron sheets	Owns grass thatched house
Have one wife and several concubine	Have one wife
Owns 1-10 hectares	Uses river water
Have 8-12 children	Have more than 10 (12 to 14) children
Attends local dispensary and herbal clinics	Have few (0 to 100) on farm trees
Eats twice or three times per days	Use lantern for lighting
Have about 200 on farm trees	Use herbal medicine and attend local dispensary
Do casual jobs for 2,000 – 10,000 KES per month	Children rarely complete primary level of education attaining class five mainly
Water source river	Casual main source of livelihood, or house help or herds boy
Children attend polytechnic and public Schools	Owns 0.1 acre-0.3 acres of land
Have 1 – 2 cows	Attends local dispensary and also uses herbs
Source energy: firewood	Eats once or twice in a day
Owns ½ to 1 acre of tea crop	Children attend public schools
Mode of transport public	Have no cows
Clothing second hand	Means of transport walking
	Clothing second hand

Source: Survey FGD.

week. It was also noted that the forest contributed 1.06 and 1.11 headloads per week to male and female headed households respectively. In both cases, it was realized that there were no significant differences between the mean consumption and mean forest contribution for both male and female headed households.

Ethnic composition of the FAC

From the sampled population, Nandi (71.9%) were the majority followed by Luhyas (17.8%), Kipsigis (4.7%) and Maragoli and Tiriki tying (2.3%) other tribes (1.2%) including Banyore, Kikuyu, Basuba, Bashirima, Nyagori,

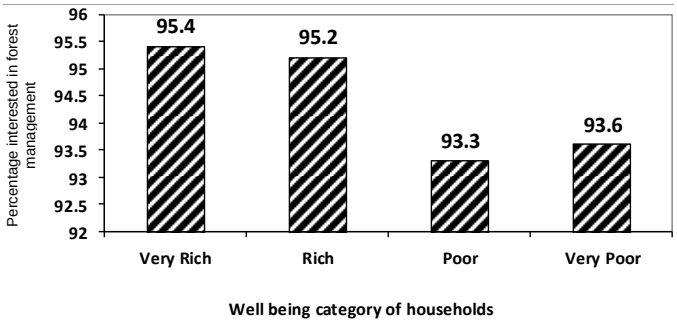

Figure 2. Interest in forest management based on well-being categories.

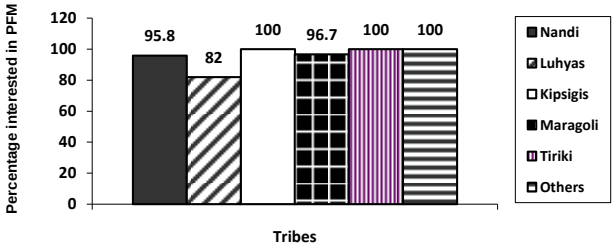

Figure 3. Interest in PFM among the ethnic groups in SNF.

Turkana and Idakho.

It was noted that all the tribes represented in this study were highly interested in PFM (Figure 3). The community will be practising good governance if the composition shown is reflected in its organizational structures like community forest association committees and benefit and costs sharing mechanisms taking cognizance of these factors. Further, the household well-being ranks, tribe composition, marital status and sex of household head should form the basis for any future community engagement in addition to:

1. A balance on equality and equity in representation
2. Equity in benefits and costs sharing
3. Resource access and tenure arrangement (*in-situ* and *ex-situ*).

There was a very high number of married household heads (89.2%) and very few widowed (6.6%), single (0.2%), separated 3.5%) and divorced (0.5%) household heads. The low social status accorded to single, divorced and widows categories in society may have their access to resources negatively affected as they are likely to be locked out of decision making organs. Female headed households remained low (18%) with male headed household comprising 88%. Deliberate affirmative action shall be necessary to ensure the minority and disadvantaged members of the community benefit through the forest management and livelihood activities. This includes single, divorced and widows considering that the community is patrilineal.

Forest adjacent community livelihood sources and resources

This was assessed to provide options to community members interested in forest management with a view of improving their benefits and participation in forest management.

The community indicated that mixed farming was their main source of livelihood as indicated by 71% of all the respondents interviewed. The other livelihood sources included; tea 20%; business 17%; salary 14%; casual work 25%; trees 4%; donations 2% and horticulture 1%. Though a lot of interest in forest management was indicated, only 4% of the respondents indicated to be entirely dependent on sale of trees as source of livelihood. The rest did not depend on trees for their entire livelihood.

The level of dependence on each source of livelihood varied within each of the source. For instance, among those depending on trees for their livelihood only 63% depended on them to a range of 50 to 100% level. More so, only 4% of those using trees as source of livelihood were entirely (100%) dependent on them while the rest had it with combination of other sources of livelihood.

The fact that forests/trees were not indicated as a major source of livelihood yet the community members were interested in their management could be due to the possibility that most of the forest goods and services were being used to meet domestic needs without evaluating their value in economic or financial terms. The forest supports dairy farming as it is a major source of fodder for dairy animals with grazing indicated as a major reason for community involvement in forest management.

River and streams were indicated as the major sources of water with 74.8% of the households relying on them. Springs as sources of water were relied upon by 12.4%, 5.6% using piped water, boreholes providing water for 3.6% and roof catchment for 1.6% of respondents. The streams and rivers have their source in the forest which also acts as reservoir which holds the water and releases it during the dry season. The forest contributes highly to the livelihood sources of the community calling for its better management.

Use of forest as source of fuel wood

The mean fuel wood consumption for interviewed households was 1.8 headloads per week. There was a significant difference in weekly consumption of fuel wood among the different wellbeing categories ($F=5.831$, $p=0.001$) as shown in Figure 4.

Considering interest in PFM and consumption of fuelwood, the mean consumption for interested group was

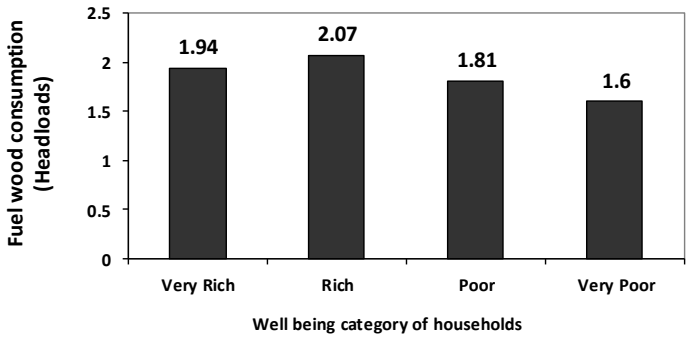

Figure 4. Consumption of fuelwood among different well-being categories.

1.79 headloads per week and for non-interested group it was 1.98 headloads per week. Hence there was no significant difference between the 2 groups (F=2.186, F=0.14) because fuelwood is a basic forest commodity needed by all the community members irrespective of whether interested in PFM or not.

Forest contribution to household fuel wood consumption

As indicated by the community members, there was a lot of interest in getting involved in forest management because of the forest provision of firewood. All members of the community were consuming fuel wood even if they were not obtaining it from the forest. About 45.8% of all the respondents indicated that each house hold was using at least one head load per week, 30.2% indicated 2 head loads per week and 16% indicated 3 head loads per household per week. The cost of headload at the local market ranged from Ksh 50 to 70. Therefore, for the sampled households this means that the forest was supplying fuel wood worth Ksh 4,329,000.0 to 6,060,600.0 respectively, per year. Therefore, firewood has an enormous value to the community.

It was also noted that the South Nandi forest contributed firewood to about 73% of the respondents interviewed. Considering an average weight of 30 kg per headload, the forest was therefore providing 2,164.500 tonnes of fuel wood to the community per year. Among these households obtaining their fuel wood from south Nandi forest, about 97.9% were among those who had indicated interest in forest management while 2.1% were among those who had indicated to have no interest in forest management. There was a 0.000 significant linear by linear association and correlation (at 95% confidence interval) between interest in forest management and consumption of fuel wood from the forest. Using actual figures of forest contribution to fuel wood consumption as indicated by the 925 respondents, it is clear that an average of 1.5 head loads of firewood per household were being obtained from the forest per week. This implies that the forest had a very important contribution in terms of fuel wood to the adjacent community members. Hence the aspect of maintaining a sustainable supply of firewood to the community members adjacent to the forest need to be looked into while developing the Participatory Management Plan for South Nandi forest.

Considering the distance from the forest for those obtaining firewood from the forest, it was noted that those accessing the forest for firewood were at a mean distance of 0.82 km and those not accessing were at a distance of 1.86 km from the forest giving a highly significant difference ($F = 272.275$, $p<0.001$). It is therefore clear that those closer to the forest are accessing it more for fuelwood.

For group interested in forest management and able to access the SNF, the forest contributed 1.47 headloads per week while the non-interested group accessing the forest were getting 1.33 headloads per week. There was a significant difference among the 2 group considering those accessing and those not accessing the forest ($F = 969.026$, $p<0.001$). The difference was still observed when analysis on forest contribution was undertaken without considering those accessing and those not accessing getting respective averages of 1.12 and 0.30 of headloads of firewood contributing to both interested and non-interested group ($F = 53.918$, $p<0.001$). Therefore, forest contribution to household fuel wood is an important determinant for interest in PFM.

Further analysis of interest in PFM based on access to the forest firewood revealed that there was a highly significant association between interest in getting involved in PFM for SNF community members and the capacity to access the forest for firewood ($\chi^2 = 108.392$, $p<0.001$). At the time of this study, firewood (73%) was indicated by 73% of the respondents as one of the most highly accessed forest product from South Nandi forest followed by herbs, (53%) poles and posts (31%), withies (28%), grass (26%) and timber (17%). However, considering the quantities though the units are different for different products, higher quantities of firewood and timber were obtained than for other products. It was also pointed out through FGDs that some of the forest products were also getting accessed from the forest both formally and informally with some like water from the forest appearing to be God given.

Majority of the respondents (73%) indicated getting firewood from the forest as the main reason for interest in getting involved in PFM. The communities did not emphasize on stopping forest extinction and farming as important reasons for interest in management though the forest was facing threats for extinction and PELIS had been stopped nationally. Other reasons for the high interest were also related to accessing different forest products and services from the forest (Table 3). This is a clear indication that South Nandi Forest (SNF) adjacent community relies heavily on the forest for different

Table 3. Products accessed by forest adjacent community from South Nandi forest.

Forest goods/services	No. of respondents	Respondents (%)
Firewood	934	73
Herbal medicine	455	36
Grazing	359	28
Rain	830	65
Fruits	34	3
Timber	65	5
Charcoal	99	8
Honey	55	4
Pleasant air	10	1
Strict law	11	1
Tourism	6	0.5
Windbreak	2	0.2
Soil conservation	6	0.5
Stop extinction	1	0.1
Farming	1	0.1

Source: Mbuvi et al., 2010.

products and services.

The high interest in PFM on the basis of forest product access needs to be harnessed well. According to Otsuka and Pokharel (2014), community management system is efficient in the sustainable management of forests and the provision of substantial benefits to forest users, to the extent that collective interests are accounted for in the decision making and the cost collective action is reasonably low. This is a reflection of the value of the forest to the community and that though they are not highly benefiting they anticipate to access more benefits once they start participating in forest management. However, there is need to guard against elite and political capture realizing that in Kenya the core elite have mastered the art of self-reinvention with changing times (Nyanjom, 2011).

This interest is required to be managed to guard against a possibility where democratic local government could choose to authorize deforestation to stimulate economic development and reduce poverty (Tacconi et al., 2006). Additionally, the interest conforms to what many environmentalists are advocating for; participatory and community-based natural resources management (CBNRM) as a means to increase environmental management efficiency and improve equity and justice for local people (Ribot, 2002). This is possible as the legislation support community participation in forest management. The Forest Act 2005 and The Kenya Constitution 2010 provides clear opportunities for devolution and clear provisions for rights and opportunities to hold the state responsible and accountable. Thus devolution is rooted in the supreme law of the land and the constitution further is clear on relative roles of the different levels of government(Nyanjom, 2011).

Use of forest as source of timber

A total of 211 (17%) indicated that they were using timber amounting to 66,608 feet per year hence giving an average of 316 feet of timber per household per year. It was also observed that 82.9% (175) of those getting timber from the forest (211) were those interested in getting involved in forest management. However, there were only 14.7% of all those interested in forest management. It was also noted that 42.4% (36) of those who had indicated to have no interest in being involved in forest management were getting forest products from the South Nandi forest. At 5% significance level, there was a significant correlation between interest in forest management and use of the forest as source of timber ($R = 0.186$, $p = 0$).

Use of forest as source of withies, poles and posts

About 31% (394) of the respondents were using an estimated amount of 56,499 poles and posts from the forest giving an estimated average of about 143 poles per household per year. It was also observed that 88.1% (347) of those using poles and posts were those interested in forest management while 11.9% (47) of them were those who had no interest. Chi-square tests at a 5% significance level indicated a significant (0.000) linear by linear association and correlation between interest in forest management and the use of forest as source of poles and posts. This implies that while developing the management plan for South Nandi forest in relation to its use as source of poles and posts, it is important to focus on those who are interested in being involved in forest management and propose measures to provide sustainable source of poles and posts. Withies were obtained from the forest by about 28% (359) of the respondents with each household obtaining an average of 291 withies per month.

Those interested in forest management formed 90% of those using withies from the forest while those not interested yet were using the forest as source of withies and formed only 10%. A significant (0.002) linear by linear association between interest in forest management and use of withies was observed.

Use of forest as source of grass

Grass was being obtained from the forest for thatching and for fodder by about 24.8% (317) of the respondents at an average of 18 bundles per household per month. Though animals were grazing in the forest, the respondents did not indicate (consciously as a way to avoid being found to be grazing for free in the forest) the forest as a source of grazing for their animals. It was therefore not easy to determine the number of animals grazing in the forest at any given time.

Use of forest as source of herbal medicine

About 53% (672) respondents obtained herbs from the forest. The frequency of obtaining herbs from the forest varied among the respondents with the frequency of once per month having the highest number of respondents (36.9%). A total of about 211 respondents forming 16.7% of those collecting herbs at a frequency of once per month were within the distance of 0.11- 0.5 km from the forest.

On-farm planted trees versus household use of forest resources

Most of the South Nandi Forest adjacent community members had planted trees in their farms as indicated by 87.5% (1118) of all the respondents interviewed. About 74.4% (157) of those using timber were those who had planted trees while 25.6% (54) were from among those who had not planted trees at all. However, 86% (961) of those who had planted trees were not using them as source of timber, an indication that the forest still serves as a major source of timber for the community.

For all the households to which the South Nandi forest was contributing fuel wood for consumption (925), 89.3% (826) of them were from among those who had planted trees. Therefore, we can deduce the fact that having planted trees in the farms did not imply that they were using them for fuel wood consumption. Only 26.1% (292) of those who had planted trees were not getting their fuel wood from South Nandi forest, the rest (73.9%) were wholly dependent on the forest for fuel wood. This is an indication that the trees were planted for sale and not for domestic consumption. This leads to the need to emphasize on managing the forest in a manner to enhance sustainable supply of fuel wood and also create awareness on the need to use own trees for fuel wood. This conforms to the view that while there are cases in which local people have conserved forests and other resources in their natural resources, conservation should not be presumed (Tacconi, 2000; Tacconi et al., 2006).

For poles and posts, 82.7% of those using them (326) were those who had planted trees while 17.3% were those who had not planted. The forest is a major source of poles and posts.

Only 26.9% (301) of those who had planted trees were using withies while 73.1% (817) were not using poles and posts. However, these respondents were 83.8% of all those using withies while 16.2% of those using withies were not planting trees.

Trends of forest and on-farm livelihood resources and Mitigation Measures by SNF stakeholders

The community provided a historical profile of livelihood sources availability status change for the valuable key forest resources for the last twenty years. According to their perception, the resources were getting scarce. This is a scenario that requires joint intervention measures from all stakeholders and the proposed mitigation measures could be the starting point.

The community perceived a decline in forestry resources both on-farm and in the forest and they proposed conservation, planting trees under agroforestry system and stopping of charcoal burning as the main mitigation measures. They also proposed use of alternative sources of energy to reduce pressure on the forests and introduction of IGAs such as bee keeping for improvement of community livelihoods.

The community perceived a decline in farm animals but proposed rearing few but high quality animals as a mitigation measure. For wildlife protection, the community proposed rearing of wild animals, establishment of small game parks and avoiding poaching.

Perceived interests and needs of stakeholders in SNF

The perception of SNF stakeholders' interest and needs was undertaken to get their perceptions and proposed means to attain the desired status. The participants also assessed how they felt their needs were being addressed by KFS. KFS did a self-assessment on how it felt it was satisfying its obligations (Table 4).

The community expected to get products from the forest under minimal restriction to maximise benefits with measures like reducing KFS and KWS strength being some of the mitigation measures. Their level of satisfaction is an indication that they have a fair access to forest resources. KFS had very positive mitigation measures like strengthening patrolling, involving communities and having a functional CFA and a management plan.

Conclusion and recommendations

Majority of the community members living adjacent to SNF were of poor well-being category. Therefore, PFM incorporate IGAs programs to enhance the livelihood of the community members. There are opportunities for improved community livelihoods in PFM activities such as Plantation Establishment Livelihood Improvement System, on-farm tree growing, fish farming and grazing in the forest. As concerns governance, CFAs should be representative of all the different ethnic groups living adjacent to SNF forest. Power and authority should always be well shared between all the community ethnic groups to avoid marginalization of the minority and other disadvantaged members of the community. This shall provide a foundation for sharing of costs and benefits.

Further as noted by Ribot (2002), the potential for decentralization to be efficient and equitable depends on the creation of democratic local institutions with significant

Table 4. Perceived interests and needs of key stakeholders in South Nandi forest.

Stakeholder	Responsibility	Community level of satisfaction with performance to address community needs[1]	Mitigation measures to attain the desired satisfaction
KWS	Conservation of wild animals	2	
	Conservation of indigenous vegetation for ecosystem sustainability	2	Increase strength (joint operations)
	Scientific research		Minimize charcoal burning
	Ecotourism development	2	
KFS	Increase biodiversity	4	Increase number of forest rangers Have functional CFA
	Increase volume of water and revenue	4.5	Planting indigenous trees
	High revenue	1	Tree planting
	Increase cover	4.5	Planting of trees
	High number of seedlings	1	Increase funding
	PFM	3	Develop management plan and agreements
	Well protected forest	2	Increase income, empowerment, awareness creation
	Well maintained forest boundaries	2	Erecting beacons planting of trees along forest boundaries, establishment of Nyayo tea zones
Community	High production of milk and meat	4	Reduce grazing fees
	Get enough firewood, income	2	Reduce the fees
	High production of honey, Increased income and food satisfaction	2	Allow apiaries in the forest
	Obtain medicinal plants in large quantities	3	Protection of medicinal plants
	Income	3	Reduce number of forest guards
	Obtain meat and skins	3	Reduce the strength of KWS
	Harvest enough timber, high income	2	Reduce restriction
	Income increment	2	Reduce restriction
	Large quantities to satisfy cultural sites	2	Reduce the fees No restriction
	Supply enough water	3	Free collection
	Know the forest more	4	No restriction
	Obtain large amounts for use	3	No restriction Protection of the plants

Source: Survey FGD discussion. [1]Level of satisfaction as perceived by the participants from a scale of 1 to 5. 1 being the lowest and 5 the highest satisfaction level.

discretionary powers.

The community members have a high interest in PFM hence the government should facilitate the process of initiating PFM in SNF while also taking care so that the forest condition is not compromised. High interest among the community members to manage forests should be considered to be an opportunity to introduce and implement PFM in new sites. However, this is likely to contribute to forest degradation considering that SNFR is a major resource contributing to the livelihoods of local communities through provision of firewood, fodder for grazing, poles, water among other forest products and services. Local communities living adjacent to forests are conscious about the decline of forest resources which can be mitigated through community involvement in forest management as noted in Nepal (Rajpoudel et al., 2014). This is possible in Kenya since the government is supporting community participation in forest management through PFM. Majority of those interested in PFM and those accessing the forest for firewood are nearer the forest hence the government should seek to encourage participation of community members that are closer to the forest.

Diversification and sustaining current and potential

income sources from forest resources is essential. In the case of South Nandi forest, the major in-direct sources of income at the community level were rather varied but tea and milk were the major livelihood sources with the forest still acting as a major resource which they access with minimal costs. Casual work as a source of income was a major source of income in several villages. The seasonality and unpredictability of this income needs to be considered when PFM implementation is started. Supporting uniform livelihood sources shall not lead to better community livelyhoods. Support should be geared towards intervene-tions that are location and or village specific as major sources of income are rather varied with some villages having tea or milk as the major while others have maize. Tea producing villages seemed to have more very poor households as per the well-being categorization. These villages may require livelihood interventions to mitigate this situation. PFM activities were not mentioned as a solution though some process aspects and outputs were mentioned. There is need for more awareness on PFM among the communities living adjacent to South Nandi Forest. The communities were reluctant to release information on the use of forest products like grazing hence the need for consensus and trust building among the stakeholders. There is need to do further work to determine the medicinal plants and other forest products collected from the forest and the actual quantities so as to determine the impact it has on the forest with a view to design mitigation programmes like domestication. Due to the high interest in PFM with the major reason being to access firewood from the forest, there is need for the government in partnership with the community to plant fast growing tree species that are suitable for fuel wood and timber provision.

The key stakeholders are aware that they are not optimally implementing what they are supposed to as per their formal and informal mandates. This calls for creating awareness on the policy opportunities, PFM guidelines provisions and providing opportunities to enhance this capacity. The design of decentralized forest management programs has to be grounded on the potential environmental and economic benefits of alternative land uses at the various geographical scales. Additionally, in SNF, it has to take into account the ethnic representation of the FAC. Conclusively, the South Nandi forest adjacent community are aware of the contribution of the forest to their household livelihood. From the results, it is also evident that SNF provides the community with several products and services an opportunity that could be harnessed to introduce community participation through PFM.

Better forest management and optimal contribution to community livelihoods would be attained through a joint management partnership that shall facilitate multiple stakeholders' participation in forest management. Additionally, this shall work; Tacconi et al. (2006) referred to it as “under the right circumstances” which include democratic decentralization that shall improve efficiency, equity, democracy and resource management. The stakeholders should be actively involved in the whole project cycle, particularly in defining what (activity) should be done, implementation process, (how it should be done), monitoring and evaluation (shaping the future). The local communities are being sensitized through training and adequate awareness on the importance of fully participating in the management of the forest. The existing direct and indirect community livelihood sources need to be formalized and enhanced to provide incentives for community participation in forest management.

Conflict of interests

Authors did not declare any conflict of interest.

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Medicinal plants use and conservation practices in Jimma Zone, South West Ethiopia

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Traditional medicine has continued to be the most affordable and easily accessible source of treatment in the primary healthcare system of Ethiopia. However, the medicinal plants used for such treatments are becoming increasingly rare and vulnerable to extinction because of improper utilization and conservation practices. Hence, this paper was initiated with the aim to assess the use, management and conservation practices of medicinal plants in some selected districts of Jimma Zone, south west Ethiopia. Ethnobotanical methods such as focus group discussions, key informant interview, semistructured interview and field walks were used to collect ethnobotanical data on use and management practices of medicinal plants in the study area. Data collected were classified into the use of the plants and management practice. Data of the semistructured interview was analyzed using SPSS version 16 software. The result revealed that a total of 69 plant species were identified in the study area, of which 30 are nutraceuticals, 30 are collected at wild habitat and 39 are cultivated. Source of medicinal plants include: cultivation in home gardens, live fences, crop fields and wild collection from the nearby environment. The cultivation practice include home gardens, mixed in field crops, live fences and agro-forestry. About 87% of respondents explained that they get medicinal plants easily in the study area and 10% explained that it is difficult. About 76% of respondents explained that medicinal plants are not sold in the market and 23% responded marketability of medicinal plants. About 33% of informants explained that medicinal plants are under threat and 67% explained that they are not threatened. Focus group discussion and key informant interview revealed that people conserve medicinal plant in live fences, home gardens, and they cultivate some species because of their nutraceutical value. They interpreted that there is no specific conservation activities targeted to medicinal planted by extension program. This indicates the necessary strategy and conservation of medicinal plants in the study area. Postharvest handling is not commonly known for many medicinal plants because they are collected and used immediately. Therefore, local people use their knowledge nowadays in this region. The resources require an urgent attention in research and policy which should include training on knowledge of medicinal plant use and management in cultivating, production, postharvest handling, promoting their use and sustainable utilization.

Key words: Conservation, medicinal plants, Jimma, Kersa.

INTRODUCTION

Traditional medicine has continued to be the most affordable and easily accessible source of treatment in the primary healthcare system of developing countries. The need is more pressing for resource poor communities and the local

therapy is the only means of medical treatment for such communities (Haile and Delenasaw, 2007). These medical systems are heavily dependent on various plant species and plant based products (Jansen, 1981). It is estimated that 70–80% of people worldwide rely chiefly on traditional, largely herbal; medicines need to meet their primary healthcare (Farnsworth and Soejarto, 1991; Pei, 2001).

The list of medicinal plants in Ethiopia, which is documented for National Biodiversity Strategy and Action Plan by Tesema et al. (2002) shows that about 887 plant species were reported to be utilized in traditional medicine. Among these, 26 species are endemic and they are becoming increasingly rare and are at the verge of extinction. It is believed that the greater concentrations of these plants are found in the southern and southwestern parts of the country following the concentration of biological and cultural diversity (Yineger, 2005; UNEP, 1995).

In Ethiopia, most of the medicinal plants used by herbalists are collected in the natural vegetation (Asfaw, 1999, 2001). Medicinal plants obtained at wild habitats are found in different natural ecosystems of the forests, grasslands, woodlands, wetlands, in field margins and garden fences, as weeds and in many other microhabitats where they are harvested when the need arises. These are free access resources. Many medicinal plants are also harvested for non-medicinal purposes such as for timber, implements, firewood and other purposes, and hence they are subjected to multiple depletion. Hence, sustainable utilization measures and conservation of plants should target the habitats of such vulnerable species.

Except in a few medicinal plant species where a few food crops are cultivated with medicinal value, there is no organized cultivation of plants for medicinal purposes in Ethiopia. The reason for this is that the quantities of medicinal plants traded are very small, and there is no organized large scale value addition and processing. However, there is a potential in the future for increased demand for some species, and therefore it is important to identify them and start the necessary research on the conservation and sustainable utilization techniques (Bekele, 2007).

Abera (2003) assessed the locally available medicinal plants in Jimma zone and found that 39 medicinal plants were used for treatment of various diseases. Haile and Delenasaw (2007) carried out also an assessment on traditional medicinal plant knowledge and their use by local healers in Jimma Zone on 27 medicinal plants. They found that the majority of the reported species grow in wild and they are rare. In addition, ethnobotanical study of medicinal plants was carried out by Awas and Demissew in southwestern Ethiopia (2009). However, there is no comprehensive systematic study on the use and conservation practices of medicinal plants in the current study districts. These demanded an urgent attention to conserve such vital resources. Therefore, this study was proposed to assess the use, management and conservation practices of medicinal plants in some selected districts of Jimma Zone, South West Ethiopia.

MATERIALS AND METHODS

Study site

The study was conducted in Jimma Zone (Manna, SeqaChekorsa and Kersa districts in Oromia National Regional State, Southwestern Ethiopia where 3 peasant associations were selected from each district.

Geographical location of the study area

Manna, SeqaChekorsa and Kersa districts are located in Jimma which is the largest city in southwestern Ethiopia. It is one zone of the Oromia National Regional State. It has a latitude and longitude of 7°40′N 36°50′E.

Population

Total population of the districts is: Kersa 165,331(83579 male and 82,812 female); Mana, 146, 67 (74,512 male and 71,878 female); Seka Chekorsa, 208,096 (104,758 male and 103,338 female).

Vegetation

The study area lies in moist evergreen montane forest of Jimma zone in south western Ethiopia and this specific study was conducted in Agro forestry, cultivated lands MPs. Emphasis was given more on utilization and conservation practices of medicinal plants than on ecosystem and forest type description or characterization.

Ethnic group

In Seka Chekorsa, Mana and Kersa districts the five major ethnic groups are Oromo the Yem, Amhara, Kafficho and Dawuro The majority of the inhabitants are Muslim, Ethiopian Orthodox Christianity, Protestant Christians and Waqefata .

The study area (Jimma Zone) has an agro-ecological setting of highlands (15%), midlands (67%) and lowlands (18%). The zone is one of the major coffee growing areas of Oromia National Regional State well endowed with natural resources contributing significantly to the national economy of the country (Lemessa, 2000).

The study area, Jimma zone is one of the major coffee growing areas of Oromia National Regional State well endowed with natural resources contributing significantly to the national economy of the

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Table 1. Source of medicinal plants in the study area.

Medicinal plant cultivation	Frequency	Percentage
Cultivated	112	48.91
Collect at wild habitat	85	37.12
Buy in market	17	7.42
From neighbors	14	6.11
others	1	0.44
Total	229	

Table 2. Cultivation status of medicinal plants in the study area.

Cultivation area	Frequency	Percentage
Home garden	114	59.69
Mixed with other crops	11	5.76
Live fences	42	21.99
Agro-forestry	24	12.57
others	0	0.00
Total	191	100

country. Major crops grown include are: coffee, maize, teff, of medicinal plants was carried out by Awas and sorghum, barley, pulses (beans and peas), root crops (enset,-false banana and potato) and fruits (Lemessa, 2000).

Climatically, Jimma Zone reliably receives good rains, ranging from 1,200–2,800 mm per annum. In normal years, the rainy season extends from February to October.

Study design

The districts were purposively selected based on their accessibility and because they are believed to be better biodiversity. Twenty informants were selected and interviewed in each district after having discussion with the inhabitants and authorities. Moreover, some discussions were held with concerned offices including agricultural development offices and development agents in each study site. Key informants are selected to get guidance in the field walk exercise.

Data collection

Both qualitative and quantitative approaches were used for this study. Ethnobotanical methods following Martin (1995) and Cotton (1996) were used for collecting data on the use and management practices and applied semistructured questionnaire, key informants' interview and focal group discussion. Data were collected from December 2012 to April 2014. Ethical clearance was sought from concerned departments of Jimma University and the district agricultural development offices, as well as from the informants who were involved in providing information in the study areas. The help of local administrators, local people and field assistants were taken care of before embarking on data collection.

Indigenous knowledge on local names of plants and their conservation practices was recorded. Plant species were also identified by field walk together with key informants. Related to the possible threats on plant species and traditional conservation, observation was made in the field on the general habitats of the medicinal plants. The medicinal plants were identified in the field spontaneously *in situ* by the help of taxonomic keys using Flora of Ethiopia and Eritrea such as Hedberg and Edwards (1995) and other volumes and for those which were not identified in *situ* voucher specimen were collected for further consultation of experts. There was no difficulty faced in identification as most of the plants mentioned have medicinal uses and there are sufficient information in the Flora books.

Data analysis

Questionnaires was coded, entered into excel sheet and analyzed using SPSS software version 16. The qualitative data was narrated and summarized into tables, figures and graphs for explanation following Martin (1995) and Cotton (1996).

RESULTS

Medicinal plants in the study area

The present study identified 67 plant species, of which 36 are used for medicinal purpose and 31 both for food and medicine, that is, nutraceuticals.

Source of medicinal plants in the study area

In the study area, 48.91, 37.12 and 7.42% of the respondents explained that medicinal plants are obtained in cultivation, wild and purchased form market respectively (Table 1).

Cultivation of medicinal plants

As a result, 48.91% of the respondents explained that people cultivate medical plants whereas, 37% collect at wild habitat and less than 20% in market and from their neighbours by social relations (Table 1). This indicated that medicinal plants need more attention in production, and accessibility to the community by minimizing unstructured production approach.

The analysis shows that 48.9% of the respondents cultivate medicinal plants for their day to day use. Among the commonly used method of cultivations, the followings can be mentioned: home gardens (59.69%), mixing with other crops (5.76%), maintaining in live fences (21.99%) and in agro-forestry (12.57%) (Table 2). These medicinal plants are not maintained or cultivated for medicinal use only; rather they have food value and other multiple uses for families. This is an issue for more research which need to promote nutraceutical plants for conservation and family use, marketing and extraction of crude drugs to contribute to health care system and conservation of biodiversity.

About 37 of the medicinal plants are cultivated and 30 species are collected at wild habitats (Appendix 1). This indicates the existence of diversity of medicinal plants both in farm and natural habitats in Jimma Zone.

Table 3. Availability of wild medicinal plants in the study area.

Availability of wild medicinal plants	Frequency	Percent
Easy to get	128	87.07
Difficult to get	15	10.20
Very difficult to get	1	0.68
No information	3	2.04
Total	147	

Table 4. Threats to medicinal plants in the study area.

Threat to medicinal plants	Frequency	Percentage
Yes	52	33.33
No	104	66.67
Total	156	100

Wild medicinal plants' availability

The result of the current study revealed that medicinal plants are easily available in forests, grasslands and woodlands. It was witnessed by 87% of the respondents. Whereas, < 20% of the responds explained that it is difficult to get medicinal plants even in wild state (Table 3). These responses focus on a debate in the light of the increasing agricultural land, selective harvesting of medicinal plants for medicine and other multiple uses.

Marketability of medicinal plants

Among respondents, 76% explained that medicinal plants are used locally for traditional treatments and not sold in the market. However, 23% explained that some medicinal plants are sold in the local markets seasonally depending on their availability in local harvest (Table 4). Concerning marketability of medicinal plants, 23.77% of the respondents explained that medicinal plants are marketed while 76.22% of them explained their not marketed state.

Threat to medicinal plants

Respondents were asked whether there are threats to medicinal plants in the study area or not. Hence, 66.67% of them explained that there is no threat to medicinal plants and 33% of them mentioned a critical threat due to deforestation, urbanization, agricultural land expansion and lack of awareness among the community and inadequate extension which support targeted to sustainable harvesting of plants (Table 4).

Conservation efforts of medicinal plants

The result of this study showed that 55% of the respondents explained no effort for conservation of medicinal plants. Whereas, 44% of them highlighted general conservation effort on natural resources which also include medicinal plants as a part of the conservations system. However, all respondents agreed that there is no particular attention given to medicinal plants conservation. The authors also observed the inadequate efforts made by the governmental and nongovernmental organization in conserving medicinal plants. The area has rich diversity of medicinal plant species; however, it is increasingly becoming degraded and lost at their natural habitat so that attentions must be given before time passes.

Postharvest management and conservation methods

The community has a living experience and knowledge on managing of medicinal plants for long term and short term benefits (Table 5). The applied conservation methods vary from species to species (Table 5). Some of postharvest managements include storing dried seeds for short and long times, dried leaves are stored for short time, crushed and pounded leaves kept in canned containers and sucks, and dried fruits in sucks and other containers for long time (Table 5). Even though the community has sufficient indigenous knowledge on conservation, postharvest storage and use, this unwritten knowledge should be supported with scientific studies and researches for the future as per the personal observations of the authors. In spite of variety of seasonal and temporary postharvest management of the medicinal plant parts, most users prefer the fresh material collected requiring more research in finding solutions for better postharvest management or identifying the alternative indigenous postharvest practices which will help the sustainable utilization of medicinal plants in the study area and elsewhere.

The commonly used conservation methods of medicinal plants include the following: seasonally cultivation, planting in home garden and live fence, planting as live fence and farm borders, seasonal cropping as field crop and home garden, planted in home and field top, as well as semi wild and grown as perennial field drop (Table 5). The key informants explained that these methods have helped to get medicinal plants year round.

DISCUSSION

Source of medicinal plants in the study area

The result revealed that people of the study are get medicinal plants from their agricultural land followed by wild collection. Similar studies have been reported from

Table 5. List of medicinal plants used in the area along their conservation and postharvest management practices.

S/N	Local name	Scientific name	Family	Postharvest management	Conservation method	Habit	Production type
1	Korarimaa	*Aframomum korarima* Pereia	Zingiberaceae	Dried fruits stored in sucks and other containers for long	Seasonal planting	H	Cult
2	Qulubi adi	*Allium sativum* L.	Liliaceae	Crushed, pounded and kept in covered container, mostly used in fresh form	Planted as field and home garden crop	H	Cult
3	Ariti	*Artemisia afra* Jacq. *ex* Willd.	Compositae	Dried leaves stored	Grown in home garden	H	Cult
4	Neemii	*Azadirachta indica* A. Juss	Meliaceae	Fresh leaves and sticks used	Planted as live fence	T	Cult
5	Xosinyi	*Calamintha paradoxa* (Vatke) Ryding	Labiatae	Dried leaves stored in sucks and also fresh leaves used as collected	Farm boarders in some homes, mostly collected at wild habitat	H	Cult
6	Ceeka	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Fresh leaves used	Collected at wild habitat	S	wild
7	Gora	*Capparis cartilaginea* Decne.		Fresh collected	Collected at wild habitat	S	wild
8	Arangama	*Capparis tomentosa* Lam.	Capparaceae	Not stored	Planted as live fence	S	wild
9	Miximixaa	*Capsicum minimum L.*	Solanaceae	Dried fruits stored for long	Grown as field crop and home garden	H	Cult
10	Papayaa	*Carica papaya* L.	Caricaceae	Fresh fruits used	Planted in home garden and field top	T	Cult
11	Hagmasa	*Carisa spinarum L.*	Apocynaceae	Fresh fruits used	Collected at wild habitat	S	wild
12	Azmudi adi	*Carum capticum* L.	Umbelliferae	Dried fruits stored for long	Grown as field crop and home garden	H	Cult
13	Shumburaa	*Cicer arietina* L.	Leguminosae	Dried seeds stored	Seasonal planting/cropping as field crop	H	Cult
14	Burtukana	*Citrus sinensis* (L.) Osbeck	Rutaceae	Fresh fruits used	Grown as field crop and in some cases in home garden	S	Cult
15	Buna	*Coffea arabica* L.	Rubiaceae	Dried beans collected and stored for long	Grown as perennial field drop	S	Cult
16	Wadesa	*Cordia abyssinica* R.Br	Boraginaceae	Fresh leaves and fruits are used	Collected at wild habitat	T	wild
17	Dimbilala	*Coriandrum sativum* L.	Apiacae	Seed stored	Seasonally cultivated	H	Cult
18	Makanisa	*Croton marostachyus* Hochst. ex Ferret et Galinier	Euphorbiaceae	Fresh from forest or farm borders	Collected at wild habitat	T	wild
19	Dabaqula	*Cucurbita peapo L.*	Cucurbitaceae	Fresh fruit used and seasonally stored	Grown as home garden plant	C	Cult
20	Irdii	*Curcuma* (L.) *domestica* Valeton	Zingiberaceae	Bulb kept for long	Grown as field crop and few as home garden	H	Cult
21	Astanagiri	*Datura stramonium* L.	Solanaceae	Fresh leaves and dried seeds used	Collected at farm borders	H	wild
22	Karootii	*Daucus carota* subsp. *sativus* (Hoffm.) Schübl. & G. Martens	Apiaceae	Tap root collected and used in fresh form/state	Grown as field crop and home garden	H	Cult
23	Akuku	*Dovyalis abyssinica* (A. Rich.) Warb.	Flacourtiaceae	Fresh part collected from the wild	Collected at wild habitat	T	wild
24	Barzafi adi	*Ecucalyptus gamadulensis* Labill	Myrtaceae	No data	Live fences	T	Cult
25	Ulaga	*Ehretia cymosa* Thon	Boraginaceae	Fresh leaves used	Collected at wild habitat	T	wild
26	Coqorsa	*Eleusine jaegeri* Pilg.	Poaceae	Fresh leaves	Collected at wild habitat	H	wild
27	Moqmoqo	*Embelia schimperi* Vatake	Myrsinaceae	Fresh buds collected and used	Grown as live fence	S	wild

Table 5. Contd

28	Hadamii	*Euphorbia abyssinica* J.F.Gmel.	Euphorbiaceae	Fresh exudates collected and used	Live fence	S	wild
29	Ano	*Euphorbia tirucalli* L	Euphorbiaceae	Fresh exudates	Live fences	S	wild
30	Insilal	*Foeniculum vulgare* Mill	Umbelliferae	Dried seeds stored	Seasonal cropping	H	Cult
31	Koso	*Hagenia abyssinica* J. F. Gmel.	Rosaceae	Dried flower is stored and fresh and dry flowers used	Collected at wild habitat	T	wild
32	Gatira	*Juniperus procera* Hochst. Ex Endl	Cupressaceae	Fresh leaves collected and used immediately	Planted as live fences	T	Cult
33	Dhumuga	*Justia schimperi* Jaub. & Spach	Acanthaceae	Fresh leaves used	Planted as live fence	S	wild
34	Dhumuga	*Justia Schimperi* Jaub. & Spach.	Acanthaceae	No data	Live fences	S	Cult
35	Kusaye	*Lantana trifolia* L	Verbenaceae	Dried leaves stored in sucks	Live fence and farm borders	S	Cult
36	Ras kimir (Amh)	*Leonotis* spp.	Labiatae			H	wild
37	Shimfi (Fexo)	*Lepidium sativum* L.	Cuicifarae/Brassicacae	Seed stored for long	Planting in home garden and live fence	H	Cult
38	Talba	*Linum ustitatissimum* L.	Linaceae	Dried seeds stored for long	Grown as field crop	H	Cult
39	Abbayi	*Maesa lanceolata* Forssk.	Myrsinaceae	Fresh seeds used	Collected at wild habitat	S	wild
40	Kombolcha (atat)	*Maytenus ovata* (Wall. ex Wight & Arn)	Celastraceae	Fresh parts collected from wild when needed	Collected from wild habitat	T	wild
41	Qoda	*Myrtus communis* (L) Myrtle	Myrtaceae	Fresh collected	Collected at wild habitat	T	Cult
42	Qoda	Myrtus communis L	Myrtaceae	Fresh leaves used	Collect at wild habitat	T	Cult
43	Timbo	*Nicotiana tabacum* L.	Solanaceae	Dried leaves stored in sucks or used in fresh form	Seasonal cropping as field crop and home garden	H	Cult
44	Abasuda guracha	*Nigella sativa* L.	Ranunculaceae	Dried seeds and leaves stored	Seasonal cropping as field crop	H	Cult
45	Damakasse	*Ocimum lamifolium* Wild	Lamiaceae	Fresh leaves collected and used	Planted in home garden	S	Cult
46	Basobila	*Ocimum sanctum* L.	Lamiaceae	Fresh leaves collected and used	Rarely in home garden and mostly collected at wild habitat	S	Cult
47	Ancabi	*Ocimum suave* Willd.	Lamiaceae	From wild forest, borders and grasslands	Collected at wild habitat	H	wild
48	Nole	*Olinia usambarensis* Gilg ex Engl.	Penaeaceae	Fresh fruits and leaves collected	Collected at wild habitat	T	wild
49	Hincini	*Pavonia patenis* (L.f.) Redouté	Malvaceae		Collected at wild habitat	S	wild
50	Avocadoo	*Persea americana* Mill	Lauraceae	Fresh fruits used	Planted in home garden and field top	T	Cult
51	Handodee	*Phytolacca dodocandara* L. Hert	Phytolaccaceae	Dried seeds stored in sucks	Planted as live fence and mostly collected at wild habitat	S	wild
52	Surumaa	*Pilea* spp.	Urticaceae	Dried leaves stored and mostly fresh leaves used	Grown in home garden	H	wild

Table 5. Contd

53	Zayituna	*Psidium guajava* L.	Myrtaceae	Fresh fruits used	Planted in home garden and field crop in a semi wild habitat	S	Cult
54	Geesho	*Rhamnus prinoides* L.	Rhamnaceae	Leaves dried & stored fir shirt time	Planting in home garden and live fence	S	Cult
55	Qobo	*Ricinus communis* L.	Euphorbiaceae	Dried seeds stored	Grown as a field crop	S	Cult
56	Tult(Amh)	*Rumex repalensis* Spreng	Polygonaceae	Fresh roots and leaves used	Collected at wild habitat	H	wild
57	Cilatama	*Ruta graveolens* L.	Rutaceae	Fresh leaves collected and used immediately	Planting in home garden	H	Cult
58	Alaltu	*Salix subserrata* Willd.	Salicaceae	Fresh young stems and leaves	Collected at wild habitat	T	wild
59	Chifrigi	*Sida ovate* Forssk.	Malvaceae	Fresh stem and root used	Collected at wild habitat	S	wild
60	Hiddi	*Solanum incanum* L.	Solanaceae	Fresh leaves used	Collected at wild habitat	S	wild
61	Hiddi holota	*Solanum* spp.	Solanaceae	Fresh leaves and fruits are used	Collected at wild habitat	S	wild
62	Dinicha	*Solanum tuberosum L.*	Solanaceae	Freshly and used	Grown as field crop	S	Cult
63	Baddessa	*Syzygium guineense* (Willd.) DC.	Myrtaceae	Fresh fruits used	Collected at wild habitat	T	wild
64	Abishi	*Trigonella foenumgraecum* L.	Fabaceae	Seed stored for long	Seasonal crop in home garden and mixed with crops	H	Cult
65	Dheebicha	*Vernonia amygdalina* Delile	Compositae	Fresh leaves collected and used	Planted as live fences and in some cases in home garden	S	Cult
66	Reejji	*Vernonia auriculifera* Hiern	Asteraceae	No data	Collected wild habitat	S	wild
67	Jinjibila	*Zingiber officinale* L.	Rosaceae	Collected and used	Perennial crop in home gardens and as field species	H	Cult

Cult= Cultivated, wild = collected at wild habitat, nutraceutical = medicinal and food value, medicinal = reported for medicinal use, T = tree, S = shrub, H = herb, most local names are in Afaan Oromo (Oromo language), Amh = Amharic language.

different parts of the country. Yirga (2010) reported 16 medicinal plant species utilized in Mekele town, Tigray National Regional State by the local people. The same author explained that most of plants are collected from wild habitat. The author also indicated that people have knowledge of indentifying the plant species which is believed to have medicinal value. Luizza et al. (2013) reported in their finding, women's local ecological knowledge is noted by many scholars to be unique and important for local conservation and development planning. This includes conservation in homegardens contributing to agrobiodiversity, thereby to food security of the family. Farnsworth and Soejarto (1991) stated that the conservation of biodiversity has uses. Kokwaro (1993) attested the sustainable utilization of Africa's medicinal plants which are wealth of people.

Luizza et al. (2013) stated that "with rapid population growth in the highlands and rural people's dependence on natural resources across Ethiopia, cataloguing and preserving local ethnobotanical knowledge is critical for future community based conservation efforts". This indicated that the diversity of nutraceutical plants need to be sustainably utilized and conserved for continuity of biodiversity in the study area at Jimma and elsewhere.

Wild medicinal plants availability

The farm ecosystem and natural vegetation are major sources of the medicinal plants in the present study districts of Jimma Zone. The same author stated that"contrary to previous thinking, it is becoming clear that women know more about these plants, because throughout history, women's daily work has required more of this

knowledge". Seventy one plant species were reported for use in the treatment of various diseases in the study area. These plant species belongs to 41 families in the Ngai and Otwal Sub Counties in Oyam district, Northern Uganda (Howard, 2003; Kamatenesi-Mugisha et al., 2011). The use of medicinal plants in primary healthcare is still a common practice in Ngai and Otwal Sub Counties. This is a practice similar to that the present study area, Jimma, Ethiopia. Kamatenesi-Mugisha and Oryem-Origa (2005) described, as a way to recognize the values and roles of traditional medical knowledge in health care provision, further research into the efficacy and safety of herbal remedies were emphasized in Uganda and beyond. As the research reports indicated availability of medicinal plants across contents and the present study area, it is essential to make efforts for the year round availability of these valuable resources. Hamilton and Alan (2004) stated that "billions of people in the world rely on herbal medicine, while millions gain income in their wild harvest or cultivation, or are involved in their trading or processing. Medicinal plants are symbolically significant in many cultures, often being seen as sources of power." Thus, indicate that local people are motivated by the use of nutraceutical species and conserve them in home gardens, live fences and nearby forests in Jimma Zone.

In the present study area, medicinal plants are collected from the wild. Kamatenesi-Mugisha et al. (2011) has concluded that "it should be noted that a high percentage of these plant species are harvested from the wild, but with no consideration for domestication hence threatening their existence. The plant species are being overexploited, and the rapid environmental degradation coupled with insurgency has put mounting pressure on the environment. This may lead to the disappearance of many species of medicinal plants of economic value."

Marketability of medicinal plants

From direct observation by researchers, there is no formal market scheme for medicinal plants in the present study area. It is an area which needs further investigation. According to Shahidullah and Emdad Haque (2010), the value chain for medicinal plants is produced by village-based marginal farmers and homestead growers whose livelihoods are significantly supported by the commercial scale production of several plant species. They suggested an improved value chain system through economic coordination that links production with the enhancement of the producers' livelihoods in Natore district of northwest Bangladesh.

In the study area, Jimma Zone, there is no clear and closer relationship between producers and processors through necessary integration in the value chain which can result in a diversified benefits to the producers and processors of medicinal plants in terms of price, quality and overall control of the supply chain. The authors believed that un-marketability and low return value of medicinal plants could be the reason for low production and area coverage of medicinal plants, so that marketing of medicinal plants should be promoted so as to encourage farmers who cultivate medicinal plants in the study area.

Conservation aspects

People in the study are conserving medicinal plants in Agroforestry, farm fields and live fences not to lose the valuable resources for its livelihood. The result indicated that 44.77% (30) medicinal plants in the study are collected from the wild. Wild collection has detrimental consequences unless the wild gene pool is sustainably handled. Mujawar (2012) reported that out of 235 species in 184 genera and 65 families, the herbaceous floristic composition is dominant and it shows that 120 species are recorded from this area. He also explained that floristic vegetation is affected by local activities and their natural regeneration prevented due to heavy cuttings, grazing, stone and soil mining activities. There is urgent need for whole area under conservation and protection as well to alert the peoples about the plant biodiversity. The recommendation of this author can be adapted to the present study area as there is increasing population pressure on natural vegetation, accompanied agricultural expansion and other development activities.

Conclusions

As sum, the study area involves diversified medicinal plants which have a potential role to contribute to healthcare system of the country. Currently, these medicinal and nutraceutical plants are serving for the majority of people as a source of medicine and food which narrow the gap in the shortage of medication and nutrition. The results show also the use, management and conservation of medicinal plants in agricultural fields, home gardens and live fences. These data have a positive contribution to the availability of medicinal plant in the study area and contributed generally to the conservation of biodiversity, and to the agricultural biodiversity, too. It also contributes to continued existence of the ingenious knowledge as a part and parcel of the use and management of medicinal plants.

There is no focused research in the region, conservation activity and postharvest management technology which can complement the indigenous postharvest management method which local people are using currently. People have their own value system in the production and utilization of medicinal plants.

However, there is no system which makes all stakeholders closely linked and benefit from the system.

From the present study, it is possible to state that medicinal plants are part and parcel of the livelihood of people in the study area. The fact that local people are owners of the knowledge of medicinal plants use and management needs integrating the traditional knowledge to conventional approach of medicinal plants production.

Local people's resources utilization needs attention in research and policy. This needs to include training, on knowledge of medicinal plant use and management including cultivating, production, postharvest handling, promoting their use and sustainable utilization. Appropriate market value chain need to be assessed and prompted for equitable utilization of the benefit arising from plants and also encourage the indigenous knowledge in this regard.

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Habitat use and preference by the African elephant outside of the protected area, and management implications in the Amboseli Landscape, Kenya

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Elephants in the borderland of Kenya and Tanzania landscape roam freely outside the protected areas. These areas are critical for long term elephant survival and viability. Understanding the ecological conditions in these landscapes and threats to elephants is critical in future elephant management. Using collared elephants, the habitat use and selection was studied. Elephants showed selection for habitats, but selection was independent on season, individual elephant and gender. Bushland and woodland habitats were most preferred by elephants because they represented better habitat patchiness and heterogeneity. This range was also shared by other elephants and wild large mammals particularly zebra, gazelles and giraffes. The presence of livestock in all habitats results in competition for forage and water and leads to conflicts over space and resource. Habitat (and its quality, quantity and risks) may be the most important factor in elephant viability and ranging in the landscape. Further, securing quality and sufficient space and controlling human-elephant conflicts are the most important aspects for elephant management. We therefore recommend focus on space needs and controlling conflicts outside protected areas, and negotiations with land owners for elephant space in this borderland landscape.

Key words: Amboseli ecosystem, African elephants, habitat selection, Kenya, landscape movements.

INTRODUCTION

Elephants interact strongly with the ecosystems they inhabit (Kerley et al., 2008). This is partly because the African elephant is the largest herbivore alive today, with females attaining a maximum body mass of over three tons and males over six tones (Estes, 2012). Coupled with this large size (and hence mega - herbivore status) is a fairly simple digestive system with most digestion taking place in the capacious hindgut, comprising the small intestine and colon. Throughput is relatively rapid, with mean retention time of about 24 h, independent of the daily food intake (Clauss et al., 2007; Davis, 2007). This fast passage (compared with other large herbivores) means that digestive efficiency is quite low, with less than half of the ingested food being assimilated and the

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remainder passed out as droppings (Estes, 2012).

Elephant are mega-herbivores, consuming vast quantities of food, and are known as 'wasteful feeders' (Kerley et al., 2008). They are a savanna keystone species (Western, 1989; Laws, 1970; Penzhorn et al., 1974; Pellew, 1983), meaning that their presence ecologically benefits other wildlife species and due to its ecological role in an ecosystem (Twine et al., 2008), they are important in nutrient cycling and seed dispersal, and elicit plant defense and growth responses (Kerley et al., 2008). Elephants and fire are regarded as drivers of alternate states in ecosystems (Kerley et al., 2008). It is sometimes difficult to disentangle the relative roles of elephant, fire, drought, disease, and other browsers in tree population patterns because they often affect the vegetation in combination (Kerley et al., 2008).

Grainger et al. (2005) investigated the influence of special heterogeneity on use of space and home range in elephants. They hypothesized that heterogeneity may influence ranging behavior of mammals. They related the home range size of elephants living in the Kruger National Park to the number of patches, proportion of each patch, spatial arrangement of patches, patch shape and contrast between neighboring patches. Home range sizes decreased exponentially with an increase in the number of patches per 100 km^2 and the home range sizes of bulls were in general more strongly related to measures of heterogeneity. This may reflect differences in perception of heterogeneity between the sexes.

Elephants roam the landscapes utilizing different habitats and its resources that meet their needs and enhance their survival. Within the landscape, habitat patches vary in their composition and spatial arrangement and this complexity represents landscape heterogeneity (O'Neill et al., 1986). So habitat characteristics and resources within them can determine level of preference and use of different habitats (Alldredge and Ratti, 1986, 1992; McClean et al., 1998).

Hierarchy theory predicts that resource selection at smaller scales (e.g. plant resources) will cause an aggregate selection response at larger habitat scale (O'Neill et al., 1986). As bulky feeders, elephants include low-quality plant matter in their diets (Owen-Smith, 1988). However, to maximize their energy intake there should be a trade-off between selection for scarce, high-quality resources and the utilization of lower quality resources that are presumably more abundant (Illius, 2006).

For elephants, nutritional constraints are pronounced as the dry season progresses. In theory, elephants are therefore expected to increase the size of their home ranges during the dry season to include the resources otherwise available during only the wet season. Most often, elephants tend to concentrate their foraging activities in areas close to water during the dry season (Chamaille´-Jammes et al., 2007; de Beer et al., 2006; Gaylard et al., 2003; Leggett, 2006; Osborn and Parker, 2003; Redfern et al., 2003) and they then conceivably depend on lower quality food (Owen-Smith, 1988). The restriction imposed by the distribution of water and possibly away from human infrastructure and presence may therefore coincide with selection for areas with higher food resource availability within the landscape, which may consequently determine the location of elephant home ranges (Damschen et al., 2006). In the Damschen et al. (2006) study, they hypothesized that landscape heterogeneity and water distribution are determinants of the location and size of elephant home ranges in arid savannas. The apparent selection for variables that are encapsulated by landscape heterogeneity metrics may explain the uneven distribution of elephants across landscapes as an outcome of their preferences for certain habitats. Moreover, by identifying how landscape heterogeneity and water distribution affects the spatial dynamics of elephants, we may be able to predict how elephants will respond to areas in which they do not occur at present. This may facilitate initiatives to improve conservation management plans that incorporate aspects of landscape ecology (Damschen et al., 2006; Potvin et al., 2001).

This study was undertaken to investigate the use of habitats by elephants and the elephant attributes that determine the use and choice of habitat types. The specific objectives of this paper are as follows:

1. To establish the proportion of various habitats found in the landscape used by collared elephants in the Amboseli Ecosystem.
2. To establish the frequency of habitat use by elephants in their home range in the landscape.
3. To establish elephant's selection of habitats by comparing the habitat proportion available and frequency of use for each habitats by the elephants.

Study area

The Amboseli Ecosystem is located in southern Kenya bordering Tanzania, in the Loitokitok Division of the Kajiado District. It consists of KGR which is 251 km^2 of land. Most of the Loitokitok Division is semi-arid and arid rangeland with a bimodal rainfall pattern (Katampoi et al., 1990). Mt. Kilimanjaro casts a rain shadow affect over the region where moisture in the clouds is lost as air masses move up the south side of the mountain and arrive on the north side of the mountain dry (Katampoi et al., 1990).

On the Kenya side, the landscape's key features include: Amboseli National Park and six (6) Maasai group ranches (Figure 1). On the Tanzanian side, key attributes include Mt. Kilimanjaro and Arusha National Parks, as well as Lake Natron, and the low-lying Savannas of Longido. Some of the main threats facing this landscape include: human-wildlife conflicts, land use changes especially proliferation of agriculture, sedentarization, unsustainable livestock grazing practices, and illegal poaching of wildlife (Ntiati, 2002; Okello and Kiringe, 2004; Okello, 2009).

The critical underlying drivers of these threats are: climate change and variability, human population growth, change subsistence to a commercial lifestyle and increase of poverty levels (Ntiati, 2002; Okello and Kiringe, 2004; Okello, 2009).

The Amboseli eco-system on the Kenyan includes Amboseli National Park and the adjacent six Maasai Group Ranches (GR) and community conservancies. Within the Kilimanjaro Landscape, the group ranches in the Amboseli Ecosystem include former (now subdivided) Kimana, Mbirikani, Kuku, Olgulului/Ololorashi, Eselenkei and Rombo (Figure 1). This is the general area where the elephant subjects in this work ranged on a landscape level. These group ranches comprise many ethnic groups, but are particularly dominated by the Maasai. A diverse ethnic community lives in markets, agricultural clusters and towards the Mt. Kilimanjaro slopes (Ntiati, 2002; Okello and Kiringe, 2004; Okello, 2009)

The long rain season begins from March to early June and the short rains occur in October and November. The average annual rainfall received in KGR is 210 mm with 30% being received during the short rains and 45% received during the long rains (Irigia 1995). The area has a variety of habitats including dense and open shrubland, bushland and woodland. The dominant vegetation in the riverine habitat is *Acacia xanthophloea* and the drier regions are dominated by *Acacia tortillis* and *Acacia mellifera* (Irigia, 1995). Soils in this region are classified as volcanic soils which are generally highly saline and alkaline. In addition, the soils in the KGR area are shallow due to the recent volcanic activity of the region. This volcanic soil is generally unproductive, but near water sources can be extremely fertile (Katampoi et al., 1990). Areas further away from water sources are suitable only for pastoralism and wildlife grazing.

Together, these group ranches create wildlife corridors and dispersal areas that connect the park islands, allowing the parks to support large populations of seasonally migratory mammals (Western, 1975). The group ranches also support large populations of wildlife. In support of this wildlife, Kimana Community Wildlife Sanctuary was established in 1996 (Lichtenfeld, 1998). It provides a concentration area in the group ranch for resident and migrating species between protected areas in the ecosystem.

This socio-economic changes are increasing demand for group ranch subdivision so that people individually feel secure in land ownership. Newer government polices aim to provide a framework for dismantling communal ownership of land and nomadic pastoralism into individual ownership in support for group ranch subdivision (Graham, 1989; Galaty, 1992, 1994; Seno and Shaw, 2002). Kimana is now fully subdivided, and all Maasai group ranches have already begun the process. As subdivision occurs, the Maasai will no longer be able to support their large herds of livestock without depletion of land resources. In response, many Maasai are becoming agro-pastoralists (Okello, 2005) despite the old belief that to till the land is a curse.

Also, land tenure policy promoting subdivision and private ownership increases the opportunity for migrant farmers to lease subdivided land, hence accelerating agriculture expansion in the area (Okello, 2005). This switch to agriculture causing serious problems since cultivation is considered one of the most serious threats to wildlife conservation in this region (Okello and Kiringe, 2004). Almost all agriculture that takes place in KGR requires the use of irrigation except in the areas near Kilimanjaro where rain fed agriculture is possible. The use of irrigation reduces water quantity available to other land uses such as pastoralism and wildlife (Campbell et al., 2000).

METHODOLOGY

This work was done between September 2013 and March 2014 in the landscape home range of 6 collared elephants. The dry season sampling points were taken from the satellite GPS locations of the elephants between September 2013 and December 2013. The wet season points were randomly sampled from landscape elephant locations in short rainy season (January 2013) and in early rainy season (month of February to March 2014).

A total of 260 landscape GPS elephant locations were selected randomly (rom computer random number generator of point identification numbers) from the 6 general elephant home ranges (determined from the cluster of locations) between September 2013 and March 2014. For the dry season, a total of 129 points were randomly sampled while for the wet season, a total of 131 points were sampled. The home ranges of most elephants overlapped, so an effort was made to restrict sampled points to be those exclusively used by each elephant to reduce compounding factors.

Total composition of habitats

Ten randomly located one kilometer long line transects were established in each elephant home range. The line transects run east to west in each of the general elephant home range. For each line transect, the length covered by each habitat type along the transect was recorded. The average length of each habitat coverage along all line transects was an index of the proportion of availability of that transect.

Total habitat use

For each random point selected from elephant actual locations obtained from the satellite data, the broad habitat type was recorded for both dry and wet season.

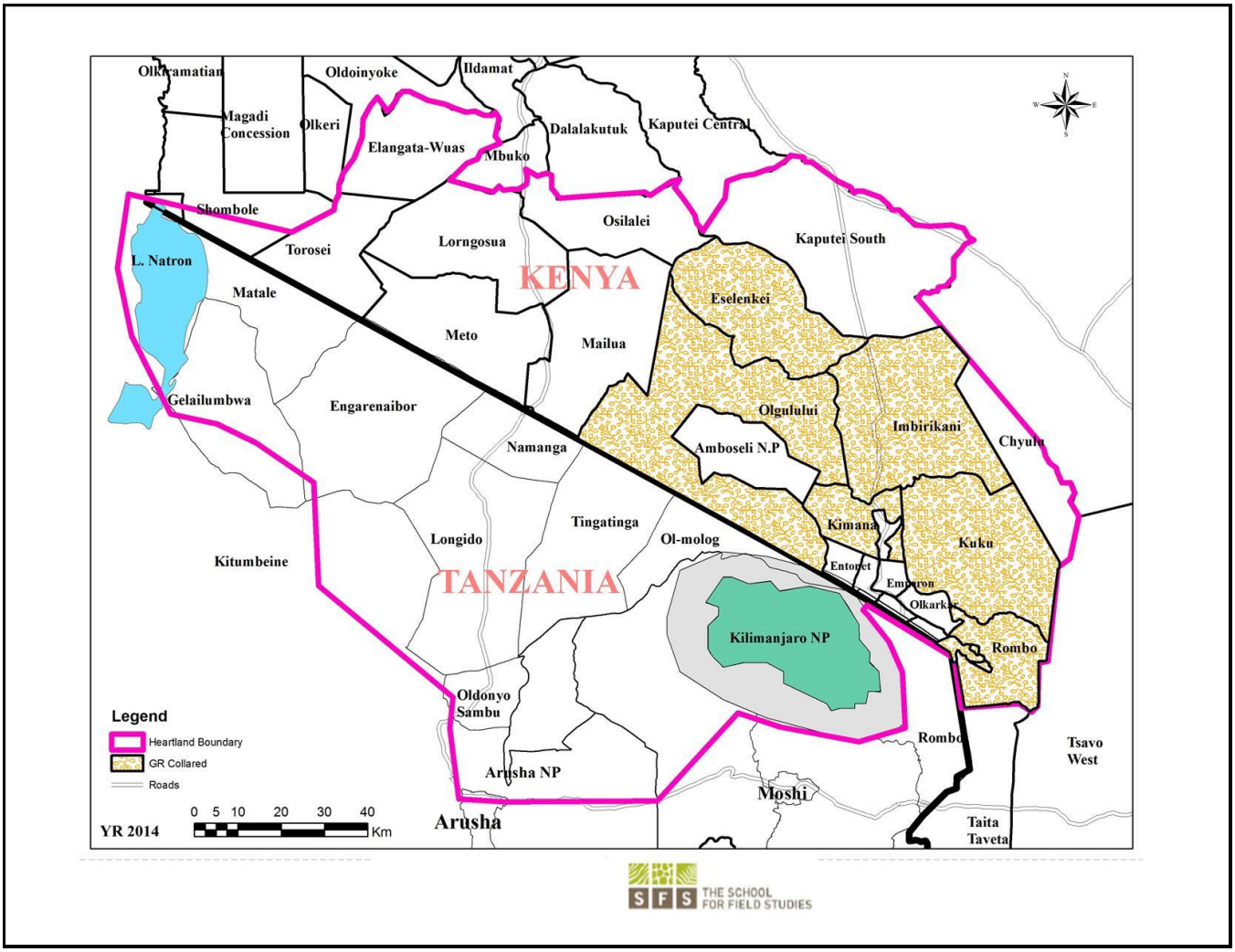

Figure 1. The Kilimanjaro Landscape which covers both the Northern Tanzania and Southern Kenya borderlands

The number of random points of elephant actual location selected from each habitat was the frequency of use of that habitat use by the elephants. The proportion of total random locations in each habitat from all the 260 random points sampled gave the proportion of habitat use for that habitat

Animal density

At each sampling point (considered a point transect), alllarge mammal (wildlife and livestock) numbers seen were recorded. Further, the distance from the sampling point to each of the species seen and its number were also recorded. The broad habitat type and season was also indicated. This data was used to summarize large mammals seen by signs, those seen live (wild and livestock) and the density (number of animals per observation point of same radius of one Kilometer, and the number of animals per area of circular sampling point) of each species at each sampling point. The data also gave information for the density per km^2 of live animals by dividing the number seen for each species over the circular area (using πr^2) from the distance of the live seen animals to the sampling point.

Data analysis

Normal mathematical calculations for area and means (with standard error) were applied. For establishing selection, *Strauss Linear Index of Food Selection* (Strauss 1979) which has which was compared to other complex statistical techniques of resource selection evaluated in the literature (Alldridge and Ratti 1986, 1992; McClean et al., 1998) but giving comparable inferences. Strauss linear index of food selection has advantages of being simple to use, symmetrical for selection and avoidance and being reliable for changes in items available for choice and non-parametric in approach. *The Strauss Index* was simply

calculated as the difference of the portion of use and availability of habitats by elephants based on the equation below:

Strauss Resource Selection, L = (ri – pi), Where L= Strauss measure selection / preference, ri = Proportion or percentage used , pi = Proportion availability of the same prey resource in the environment For the relationship between elephant selection and various elephant attributes (individual, sex) and other independent factors (season and habitat type used by elephants), a chi – square cross tabulations (Zar, 1999) was used to establish dependence of elephant habitat selection and these independent factors. Spatial analysis was done using GIS software to establish general elephant core use areas.

RESULTS

Habitat availability, use and selection by elephants

There were four main broad habitat types in elephant home ranges in the Amboseli Ecosystem: bushland, woodland, grassland and swamp (Table 1). In the Eselenkei (ESM) male whose core area is mainly in Eselenkei Group Ranch (Figure 3), the dominant habitat was bushland (70%) followed by woodland (20%). For Kimana (ESM), male elephant core area is in Kimana Group Ranch and Southern Amboseli (Figure 4), the dominant habitat was bushland (60%) followed by woodland (10%). Kuku (KUF) has its core area in Kuku Group Ranch (Figure 5) along the Chyulu Hills, and the dominant habitat in its home range was woodland (60%) followed by bushland (30%). The Osewan (OSM) male has its core use area in Olgulului and Eselenkei group ranches (Figure 6). The dominant habitat in its home range was bushland (60%) followed by woodland (30%). The Rombo (RF) female uses mainly Rombo group ranch and Tsavo West National Park (Figure 7). The dominant habitat in its home range was bushland (60%) followed by woodland (20%).

The proportion used for each habitat and for each elephant ranging varied (Table 1). The Eselenkei (ESM) male generally selected bushland and avoided woodland and grassland, often utilizing swamp in proportion to availability (Table 1).

There was no change in habitat choice across dry and wet season (Table 2). The Kimana (KM) male generally selected woodland and grassland, but avoided swamp, often utilizing woodland in proportion to availability (Table 1). There was no change in habitat choice dry and wet season (Table 3). For the Kuku (KUF) female, it generally selected the bushland habitat, but avoided woodland and grassland, only utilizing swamp in proportion to availability (Table 1). There was consistency in habitat choice in dry and wet season (Table 2). The Mbirikani (MBM) male generally selected Bushland and Swamp, but avoided woodland and grassland. It also avoided cultivated areas (Table 1). The elephant seemed to change its habitat choice based on season (Table 2). For the Osewan (OSM) male, it generally selected the bushland habitat, but avoided woodland and grassland, only utilizing swamp in proportion to availability (Table 1). There was consistency in habitat choice in dry and wet season (Table 2). The Rombo (RF) female generally selected bushland and grassland. This elephant also seemed to prefer using farmlands (Table 1). The elephant seemed to change its habitat choice based on season (Table 2). We established that habitat selection was independent on the individual elephant characteristics ($\chi^2 = 5.30$, df = 10, p = 0.87), implying that selection of habitat by elephants is consistent with any elephant (Table 4). In terms of gender, habitat selection was also independent on gender ($\chi^2 = 0.23$, df = 2, p = 0.88), implying that habitat selection is consistent irrespective of the elephant gender. Further, in terms of seasons, habitat selection by elephants was independent on the season ($\chi^2 = 5.90$, df = 2, p = 0.74), implying that habitat selection was consistent irrespective of season. However, despite habitat selection by elephants being independent of individual elephants, gender and season, selection was dependent on habitat type ($\chi^2 =$ 4652, df = 8, $p < 0.001$). Habitat type influenced habitat use and selection by the elephants (Table 3).

Animal density across habitats in elephant home range

Overall in terms of habitats, density of animals seen (per 1 km sampling radius point) was highest (Table 4) in the swamp (107.80 ± 76.36 animals per sampling point) followed by woodland (13.95 ± 4.71 animals per point), bushland (11.51 ± 2.13 animals per point) and grassland (11.39 ± 4.09 animals per point). In terms of livestock, the highest livestock density was found in swamp habitat (500.00 ± 100.00 per point) followed by bushland (129.95 ± 10.36 animals per point), grassland (113.18 ± 29.71 animals per point), farmland (101.75 ± 98.85 animals per point) and woodland (96.72 ± 16.98 animals per point).

In the Eselenkei (ESM) male home range, the highest density of wild large mammals occurred in bushland (4.48 ± 0.86 animals per point). Further, the highest density of livestock was also in the bushland habitat (77.00 ± 8.14 animals per point). In the Kimana (KM) male home range (Table 4), the highest density of wild large mammals occurred in bushland (26.63 ± 8.34 animals per point) followed by woodland (17.53 ± 7.93 animals per point). Further, the highest density of livestock was also in the bushland habitat (114.25 ± 27.33 animals per point) followed by woodland (100.30 ± 25.89 animals per point). In the Kuku (KUF) female home range, more common large mammal (wild and livestock) signs were in woodland (Table 4), but live wild large mammals occurred only in woodland (17.53 ± 7.93 animals per point) followed

Table 1. The habitat use and preference for habitats in the core use areas across the season for six collared elephants in the Amboseli Ecosystem.

Number	Elephant number and identification	Gender	Core area location in landscape	Season and its total	Habitat	Total points	Proportion used (PU)	Proportion available in landscape (PA)	Strauss Index (PU – PA)	Conclusion on habitat selection
1	Eselenkei ESM	Male	Eselenkei Group Ranch	Dry (17)	Bushland	16	0.94	0.70	0.24	Selected
					Woodland	0	0.00	0.20	-0.20	Avoided
					Grassland	1	0.06	0.10	-0.40	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
				Wet (21)	Bushland	20	0.95	0.70	0.25	Selected
					Woodland	0	0.00	0.20	-0.20	Avoided
					Grassland	1	0.05	0.10	-0.05	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
				Overall (38)	Bushland	36	0.95	0.70	0.25	Selected
					Woodland	0	0.00	0.20	-0.20	Avoided
					Grassland	1	0.03	0.10	-0.07	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
2	Kimana (KM)	Male	Kimana Sanctuary, Kimana Group Ranch in the private sanctuaries there, and Southern Amboseli Park	Dry (38)	Bushland	22	0.56	0.60	-0.04	Avoided
					Woodland	9	0.24	0.25	-0.01	Avoided
					Grassland	6	0.17	0.10	0.06	Selected
					Swamp	1	0.03	0.05	-0.02	Avoided
				Wet (25)	Bushland	16	0.64	0.60	0.04	Selected
					Woodland	8	0.32	0.25	0.07	Selected
					Grassland	1	0.04	0.10	-0.06	Avoided
					Swamp	0	0.00	0.05	-0.05	Avoided
				Overall (63)	Bushland	38	0.60	0.60	0.0	Neither
					Woodland	17	0.27	0.25	0.02	Selected
					Grassland	7	0.11	0.10	0.01	Selected
					Swamp	1	0.02	0.05	-0.03	Avoided
3	Kuku (KUF)	Female	Kuku A group ranch along the Chyulu Hills, and Tsavo National Park	Dry (14)	Bushland	9	0.64	0.30	0.34	Selected
					Woodland	3	0.21	0.60	-0.39	Avoided
					Grassland	2	0.14	0.10	0.04	Selected
					Swamp	0	0.00	0.00	0.00	Neither
				Wet (16)	Bushland	16	1.00	0.30	0.70	Selected
					Woodland	0	0.00	0.60	-0.60	Avoided
					Grassland	0	0.00	0.10	-0.10	Avoided
					Swamp	0	0.00	0.00	0.00	Neither

Table 1. Contd

				Overall (30)	Bushland	25	0.83	0.30	0.53	Selected
					Woodland	3	0.10	0.60	-0.50	Avoided
					Grassland	2	0.07	0.10	-0.03	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
4	Mbirikani (MBM)	Male	Mbirikani and Eselenkei group ranches, and towards Mombasa road in Kiboko area	Dry (22)	Bushland	13	0.59	0.55	0.04	Selected
					Woodland	0	0.00	0.10	-0.10	Avoided
					Grassland	7	0.32	0.30	0.02	selected
					Swamp	1	0.05	0.00	0.05	Selected
					Farmland	1	0.05	0.05	0.00	Neither
				Wet (21)	Bushland	17	0.81	0.55	0.26	Selected
					Woodland	3	0.14	0.10	0.04	Selected
					Grassland	1	0.05	0.30	-0.25	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
					Farmland	0	0.00	0.05	-0.05	Avoided
				Overall (43)	Bushland	30	0.70	0.55	0.25	Selected
					Woodland	3	0.07	0.10	-0.03	Avoided
					Grassland	8	0.19	0.30	-0.21	Avoided
					Swamp	1	0.02	0.00	0.02	Selected
					Farmland	1	0.02	0.05	-0.03	Avoided
5	Osewan (OSM)	Male	Eselenkei and Olgulului group Ranches, and Amboseli National Park	Dry (21)	Bushland	16	0.76	0.60	0.16	Selected
					Woodland	5	0.24	0.30	-0.06	Avoided
					Grassland	0	0.00	0.10	-0.10	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
				Wet (27)	Bushland	22	0.81	0.60	0.21	Selected
					Woodland	3	0.11	0.30	-0.19	Avoided
					Grassland	2	0.07	0.10	-0.03	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
				Overall (42)	Bushland	38	0.79	0.60	0.19	Selected
					Woodland	8	0.17	0.30	-0.13	Avoided
					Grassland	2	0.04	0.10	-0.06	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
					Bushland	6	0.35	0.60	-0.25	Avoided
					Woodland	6	0.35	0.20	0.15	Selected

Table 1. Contd

6	Rombo (RF)	Female	Tsavo West National Park on border in Taveta	Dry (17)	Grassland	4	0.24	0.10	0.14	Selected
					Swamp	0	0.00	0.00	0.00	Neither
					Farmland	1	0.06	0.01	0.05	Selected
					Bushland	21	1.00	0.60	0.40	Selected
				Wet (21)	Woodland	0	0.00	0.20	-0.20	Avoided
					Grassland	0	0.00	0.10	-0.10	Avoided
					Swamp	0	0.00	0.00	0.00	Neither
					Farmland	0	0.00	0.01	-0.01	Neither
					Bushland	27	0.71	0.60	0.11	Selected
				Overall (38)	Woodland	6	0.16	0.20	-0.04	Avoided
					Grassland	4	0.11	0.10	0.01	Selected
					Swamp	0	0.00	0.00	0.00	Neither
					Farmland	1	0.02	0.01	0.01	Selected

Ratios for proportion used (PU) were calculated from elephant frequency in each habitat, while proportion available (PA) was calculated from actual field habitat composition in the core areas of each elephant.

by bushland (1.33 ± 0.33 animals per point). However, the highest density of livestock was also in the grassland (500.00 ± 0.00 animals per point) followed by woodland (100.30 ± 25.89 animals per point).

In the Mbirikani (MBM) male home range, although it was more common to see large mammal (wild and livestock) signs in woodland and bush land habitats, (Table 4), the highest density of live wild large mammals occurred in bushland (4.48 ± 0.86 animals per point) followed by woodland habitat (26.63 ± 8.34 animals per point). Further, the highest density of livestock was also in the swamp habitat (500.00 ± 100.00 animals per point) followed by bushland habitat (114.25 ± 27.33 animals per point). In the Osewan (OSM) male home range, more common large mammal (wild and livestock) signs were in woodland and bushland (Table 4), but the highest density of live wild large mammals occurred in bushland (6.11 ± 1.70 animals per point) followed by woodland (5.00 ± 1.53 animals per point). However, the highest density of livestock was found in the bushland habitat (115.80 ± 19.57 animals per point) followed by woodland (57.00 ± 29.94 animals per point). In the Rombo (RF) female home range, more common large mammal (wild and livestock) signs were in bushland and grassland (Table 4), but live wild large mammals occurred in grassland habitat (80.00 ± 0.00 animals per point) followed by woodland (12.20 ± 6.80 animals per point).

However, the highest density of livestock was also in the bushland (155.75 ± 24.18 animals per point) followed by woodland (127.50 ± 47.77 animals per point).

In terms of species numbers across habitats, giraffe, Grants gazelle, Thomson's gazelle, elephants, Kirk's dik dik and impala were commonly seen in the bushland habitat, which had 20 large mammal species seen in the habitat (Table 5). In terms of density, the most abundant was Thomson gazelle followed by Kirk's dik dik, Olive baboons, impala, lesser kudu and Oryx (Table 5). Livestock was dominated by mixed herd of goats and sheep (acronym shoats) and cattle. In the woodland habitat, there were 6 large mammal wild species and ostrich. The most common were giraffe followed by Grant's gazelle, impala, zebra, Thomson's gazelle, common waterbuck and elephants. The most abundant in terms of density was Thomson's gazelle followed by zebra, waterbuck, giraffe, common eland and Kirk's dikdik. The shoats and cattle also dominated the habitat but were relatively fewer than the bushland.

The grassland had a total of 14 species with the most commonly seen being Grant's gazelle followed by ostrich, elephants, giraffes and zebra.

Table 2. Summary of elephant habitat preferences across seasons.

Number	Elephant	Season	Habitat preference status			Conclusion
			Preferred	avoided	Used in proportion	
1	Eselenkei ESM Male	Dry	Bushland	Woodland Grassland	Swamp	No change in habitat choice across seasons, with bushland selection while others were avoided
		Wet	Bushland	Woodland Grassland	Swamp	
		Overall	Bushland	Woodland Grassland	Swamp	
2	Kimana KM Male	Dry	Grassland	Bushland Woodland Swamp	-	Consistency in woodland selection and swamp avoidance
		Wet	Bushland Woodland	Grassland Swamp	-	
		Overall	Woodland Grassland	Swamp	Bushland	
3	Kuku KUF Female	Dry	Bushland Grassland	Woodland	Swamp	Mainly consistent selection across seasons, with grassland avoided in wet season
		Wet	Bushland	Woodland Grassland	Swamp	
		Overall	Bushland	Woodland Grassland	Swamp	
4	Mbirikani MBM Male	Dry	Bushland Grassland Swamp	Woodland	Farmland	Variable selection with swamps and farmland being avoided in wet season but bushland being selected consistently
		Wet	Bushland Woodland	Grassland	Swamp	
		Overall	Bushland Swamp	Woodland Grassland Farmland	-	
5	Osewan OSM Male	Dry	Bushland	Woodland Grassland	Swamp	Consistent selection across seasons and among habitats
		Wet	Bushland	Woodland Grassland	Swamp	
		Overall	Bushland	Woodland Grassland	Swamp	
6	Rombo RF Female	Dry	Woodland Grassland Farmland	Bushland	Swamp	Selection variable and not consistent among habitats and seasons, with farmland avoided during wet season
		Wet	Bushland	Woodland Grassland	Swamp Farmland	
		Overall	Bushland Woodland Farmland	Woodland	Swamp	

In terms of density, the most abundant was elephant followed by gerenuk, giraffe, zebra, Grant's gazelle and ostrich (Table 5). The shoats and cattle also dominated but they were less abundant as compared to the bushland and woodland. In the swamp habitat, there were 7 most commonly seen large mammals species and ostrich. The most abundant was elephant followed by Thomson's gazelle and wildebeest. This habitat has also

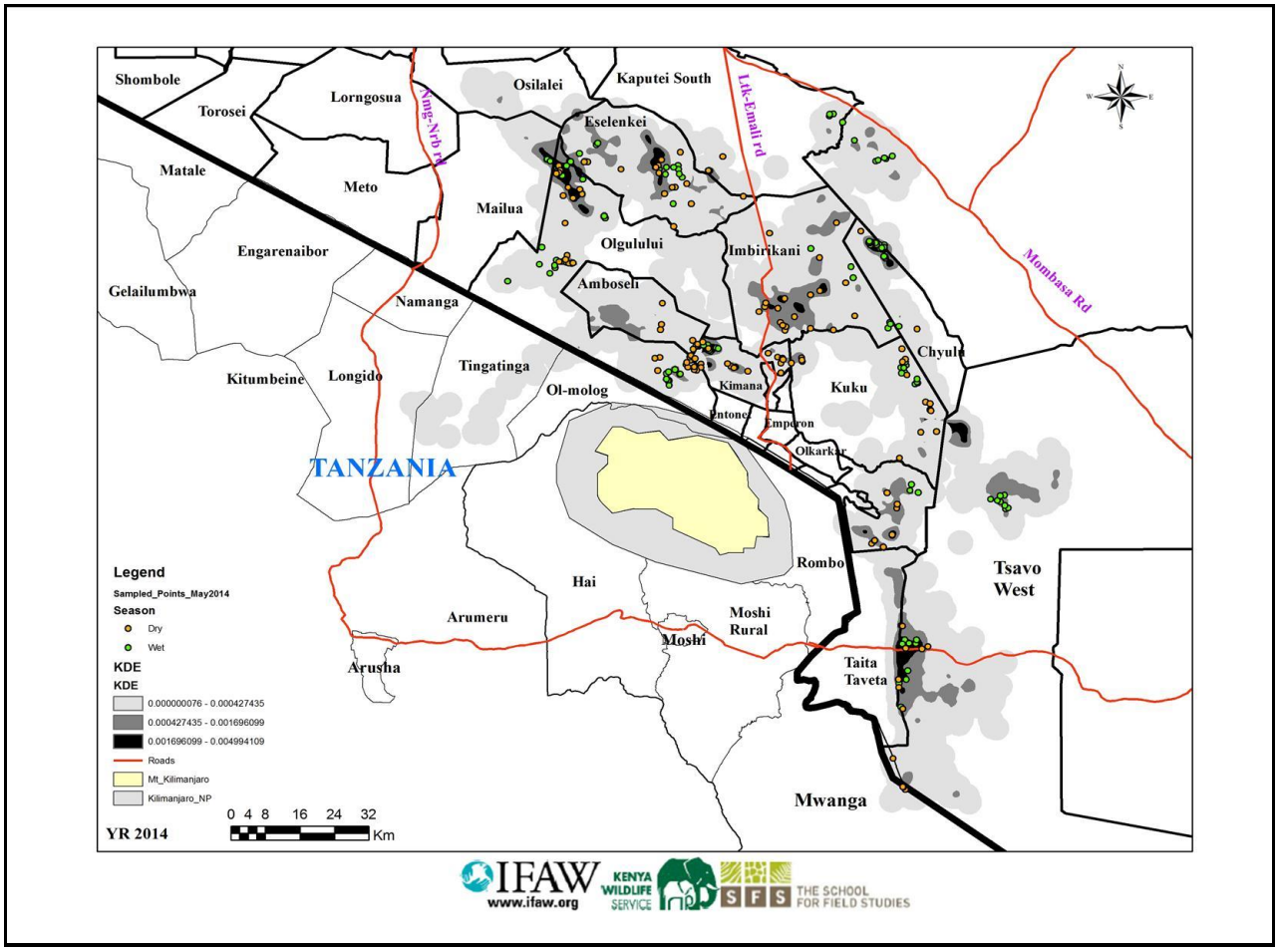

Figure 2. The home range of the six collared elephants and the sampled random points from their landscape movements between September 2013 and March 2014.

shoats and cattle, but the numbers being less than those in bushland, woodland and grassland (Table 5).

DISCUSSION

The home range of elephants in the Amboseli Ecosystem has a diversity of habitats, dominated mainly by bushland, woodland and grassland. Within these broad habitats is different vegetation structure with a varying amount of openness (with grassland) and density of woody plants. These vegetation structure and composition is critical for elephant use of the range because it provides heterogeneity which is a precursor for a diverse resource types needed for elephant survival. Elephants seem to prefer landscapes with vegetation and plant heterogeneity and such areas become their core use home ranges (De Beer and Van Arde, 2008). However, the habitats in all the elephant range in Amboseli are heavily shared with livestock from the Maasai pastoralists and also used by the local people for plant resources (for housing, fuel wood, fencing and medicinal purposes) and so the vegetation structure and composition is constantly being modified by people, livestock and wildlife. When there is over-utilization of plant resources by people, livestock and wildlife (especially elephants), habitat degradation will occur which may reduce the appeal of the range for elephant use.

Elephant use of habitats available to it varied because they actively select for it and also a combination of it will maximize vegetation heterogeneity. So, it was clear from the results that the most important aspect influencing elephant selection of habitat for use was the type of habitat. This implies that habitat composition in the landscape will influence the location and even size of elephant home range. Any factor that influences habitat quantity (plant harvesting and usage) and quality (range condition and risks to elephants through threats such as poaching and snaring) will determine elephant use. From the results, the bushland seemed the most common habitat, but also the most selected for across elephants

Table 3. The relationship between elephant selection decision and other elephant attributes as well as seasons.

Hypothesis number	Attributes that influence elephant selection	Attribute levels	Selection levels				Chi – square cross tabulations	Conclusion
			Selected	Neither (in proportion)	Avoided	Total		
1.	Individual elephants	ESM, Male	2	2	4	8	$X^2 = 5.30$, df = 10, p = 0.87	Selection of habitats was independent on individual elephant making the selection.
		KM, Male	3	0	5	8		
		KUF, Female	3	2	3	8		
		MBM, Male	5	2	2	9		
		OSM, Male	2	2	4	8		
		RF, Female	4	2	4	10		
	Total		19	10	22	51		
2.	Gender	Male	12	6	15	23	$X^2 = 0.23$, df = 2, p = 0.88	Selection of habitats was independent on elephant gender
		Female	7	4	7	18		
	Total		19	10	22	51		
3.	Season	Dry	11	5	10	26	$X^2 = 0.59$, df = 2, p = 0.74	Selection of habitats was independent onseason
		Wet	8	6	11	25		
	Total		19	11	21	51		
4.	Habitat type (broadly)	Bushland	10	0	2	12	$X^2 = 46.52$, df = 8, p < 0.001	Selection of habitats was dependent on habitat type.
		Woodland	3	0	9	11		
		Grassland	4	0	8	12		
		Swamp	1	9	2	12		
		Farmland	1	2	0	3		
	Total		19	11	21	51		

Tallies inside are counts based on the counts of the selection decision of Table 2 seen previously (without considering overall).

and across the seasons. This may be due to the preference of elephants on browsing on woody plants especially during the dry season when they switch from grass to branches and bark of trees. The bushland also provides different woody vegetation that may be providing different level of nutrients and palatability that elephants will specifically select for. Further, bushland may be more heterogeneous with varying amount of grass (open or dense) that provides the aspect of heterogeneity in the landscape that is critical for elephant use of the landscape.

In terms of factors influencing selection, it was noteworthy that neither season nor individual elephants influenced habitat selection as much as habitat type. This implies that selection pattern do not vary from an elephant to another and generalization to this effect is valid (Young et al., 2009). However, to be completely sure, more data duration as well as more elephant will provide more power of the test to make this inference. But going by the results, it then implies that any colored elephant will give information on habitat selection. Further, habitat selection was independent on gender. This implies that elephants sometimes generally will make decisions on habitat selection irrespective of gender. Again since only two female elephants collared gave data, more equal and or increased number of female elephants may improve the power of this test and inference. Results also indicated that season was not a factor in elephant habitat selection. This may be due to the fact that the area is mostly dry and many years can go by before rainy season occur or that rainy season is brief and patchy enough to influence habitat selection by elephants. So, the most prevailing circumstances are dry season circumstances. Since dry season is often hot and dry, it represents the limiting factor to elephant use of range and this is why selection of habitats and resources in the dry season will often represent the elephant survival strategy in the landscape. So given the results, the critical influence on habitat selection is habitat types (and their characteristics) and not individual elephant, gender or season. Therefore, to enhance elephant well-being and survival, focus should be on habitats (quantity, heterogeneity and quality) in the landscape.

Elephants shared their range with other wild large mammals and therefore securing of the elephant home ranges will also secure space for other large mammals that use the same space and possibly utilizing resources in same way and time with some species, and also in different ways and different times with other species ((Valeix et al., 2007). There were 16 species most of them using the bushland, woodland and grassland habitats. These

Table 4. The wild large mammals and livestock presence within a radius of one kilometer of a sampling point in elephant core use areas in the Amboseli Ecosystem.

Number	Elephant identification	Habitat type (broadly)	Number of random elephant use sampling points	Number of live large wildlife mammal seen per point (total, mean ± se)	Number of live livestock seen per point (total, mean ± se)	Number of live ostrich seen per point (total, mean ± se)
1	Eselenkei ESM, Male	Bushland	36	Total 103 (4.48±0.86)	Total 385 (77.00±8.14)	Total 7 (3.50±0.60)
		Woodland	0	-	-	-
		Grassland	2	Total 17 (4.35±0.86)	Total 0	Total 4 (4.00±0.00)
		Swamp	0	-	-	-
2	Kimana KM, Male	Bushland	38	Total 1,092 (26.63±8.34)	Total 1,371 (114.25±27.33)	Total 429 (143.00±35.68)
		Woodland	17	Total 754 (17.53±7.93)	Total 1,003 (100.30±25.89)	Total 53 (17.33±6.67)
		Grassland	7	Total 199 (16.58±9.07)	Total 283 (70.75±33.72)	Total 85 (28.33±16.91)
		Swamp	1	-	-	-
3	Kuku KUF, Female	Bushland	25	Total 4 (1.33±0.33)	-	-
		Woodland	4	Total 754 (17.53±7.93)	Total 1,003 (100.30±25.89)	Total 53 (17.33±6.67)
		Grassland	2	-	Total 500 (500.00±0.00)	-
		Swamp	0	-	-	-
4	Mbirikani MBM, Male	Bushland	30	Total 1,092 (26.63±8.34)	Total 1,371 (114.25±27.33)	Total 429 (143.00±35.68)
		Woodland	3	Total 10 (5.00±2.00)	-	-
		Grassland	8	Total 53 (4.42±1.41)	Total 412 (82.40±31.21)	Total 2 (28.33±16.91)
		Swamp	1	Total 539 (107.80±76.36)	Total 1,000 (500.00±100.00)	Total 6 (6.00±0.00)
		Farmland	1	-	Total 7 (3.50±3.30)	-
5	Osewan OSM, Male	Bushland	38	Total 110 (6.11±1.70)	Total 1,158 (115.80±19.57)	Total 5 (5.00±0.00)
		Woodland	8	Total 50 (5.00±1.53)	Total 228 (57.00±29.94)	-
		Grassland	2	Total 4 (2.00±0.00)	-	-
		Swamp	0	-	-	-
6	Rombo RF, Female	Bushland	27	Total 119 (6.61±1.36)	Total 623 (155.75±24.18)	Total 1 (1.00±0.0)
		Woodland	6	Total 61 (12.20±6.80)	Total 510 (127.50±47.77)	-
		Grassland	4	Total 80 (80.00±0.00)	Total 50 (50.00±0.00)	-
		Swamp	0	-	-	-
		Farmland	1	-	Total 400 (400.00±0.00)	-
Overall	All elephant use areas	Bushland	192	Total 1,681 (11.51±2.13)	Total 5,198 (129.95±10.36)	Total 443 (55.38±10.07)
		Woodland	37	Total 879 (13.95±4.71)	Total 1741 (96.72±16.98)	Total 52 (17.33±4.65)
		Grassland	25	Total 353 (11.39±4.09)	Total 1245 (113.18±29.71)	Total 91 (15.17±6.36)
		Swamp	2	Total 539 (107.80±76.36)	Total 1000 (500.00±100.00)	Total 6 (6.00±0.00)
		Farmland	2	-	Total 407 (101.75±98.85)	-

Included giraffes, Grants' gazelle, Thomson's gazelle, zebra, wildebeest, impala and other elephant herds. These large mammals are engaged in various activities, with feeding and drinking being the most critical for their survival. The highest frequency of sharing habitats with wild large mammals was in the bushland, woodland and

Table 5. Life large mammal species numbers and densities in various habitats in elephant core use areas.

Habitat	Species	Area (km^2) of point transect	Number of animals seen	Average density
Bushland	Baboon	0.015	1	1169.89 ±0.00
	Duiker	2.54	1	0.39±0.00
	Dikdik	0.18	16	24107.02±57.6
	Eland	0.20	9	1378.89±8.41
	Elephant	1.84	20	2.02±20.73
	G. kudu	1.39	3	18.33±14.73
	Gerenuk	0.21	7	14.31±10.83
	Giraffe	0.14	34	199.92±5.84
	Grant gazelle	0.52	23	281.51±10.37
	Hartebeest	0.20	1	30.57±0.00
	Impala	0.70	15	667.44±18.53
	Jackal	2.54	1	0.39±0.00
	L. kudu	0.56	4	650.56±17.42
	Oryx	0.50	5	540.40±16.15
	Ostrich	0.41	6	330.13±15.36
	Tommy	0.40	23	28353.96±149.15
	Velvet monkey	0.42	6	27223.65±146.06
	Warthog	0.45	2	36524.29±0.00
	Wildebeest	2.01	5	2.01±164.58
	Zebra	0.58	1	2589.57±16.49
	Shoats	0.43	17	30298.33±156.18
	Cattle	0.70	20	41548.76±70.18
	Donkey	0.13	2	31.85±57.67
Grassland	Elephant	0.42	3	18691.22±26.13
	Gerenuk	0.49	2	16616.32±25.39
	Giraffe	0.58	3	15948.44±23.98
	Grant gazelle	0.63	11	13545.01±16.26
	Hartebeest	0.15	1	0.00±0.00
	Hyena	0.28	1	3.54±0.00
	Impala	0.20	1	45.86±0.00
	L. kudu	0.01	1	127.39±0.00
	Oryx	1.54	1	0.65±0.00
	Ostrich	0.61	5	8683.69±4.38
	Tommy	0.08	1	679.41±0.00
	Warthog	0.58	2	7348.95±16.55
	Wildebeest	0.55	2	7078.78±16.52
	Zebra	0.50	3	1499.23±17.08
	Shoats	0.58	3	8016.08±17.17
	Cattle	0.53	2	2051.45±26.25
	Donkey	0.50	1	13.93±0.00
Swamp	Buffalo	0.50	1	83.60±0.00
	Eland	0.14	1	101.10±0.00
	Elephant	0.01	1	7515.92±0.00
	Hippopotamus	0.13	1	175.16±0.00
	Ostrich	0.08	1	84.93±0.00
	Reedbuck	0.13	2	23.89±20.53
	Tommy	0.03	1	1910.83±0.00
	Wildebeest	0.07	1	750.18±0.00
	Shoats	0.28	1	2123.14±0.00
	Cattle	0.07	1	5661.71±0.00

Habitat	Species	Area (km^2) of point transect	Number of animals seen	Average density
Woodland	Duicker	0.03	1	39.32±0.00
	Dikdik	0.29	2	4561.90±31.79
	Eland	0.25	2	56522.94±31.69
	Elephant	0.52	2	1.99±0.00
	Giraffe	0.29	12	10161.85±18.86
	Grant gazelle	0.37	11	2772.69±7.04
	Hartebeest	0.15	1	625.10±0.00
	Hippopotamus	0.28	1	38.92±0.00
	Impala	0.40	9	798.61±7.30
	Oryx	0.28	1	3.54±0.00
	Ostrich	0.42	2	724.67±7.04
	Tommy	0.40	6	102610.65±44.35
	Warthog	0.08	1	74.64±0.00
	Waterbuck	0.37	4	11382.80±45.88
	Wildebeest	0.20	1	5.10±0.00
	Zebra	0.32	8	12367.21±47.58
	Shoats	0.39	11	106163.22±45.58

grassland, but highest density of wild large mammals was in swamp and woodland. This means that potential competition between elephant and other wild large mammals' may occur often in bushland but the intensity of competition was more severe in the swampland. Elephants will compete with other large mammals for space, water and plant resources (Owen-Smith, 1988; Illius, 2006). The competition may not be that intense because elephants switch their diet to browsing on woody vegetation in dry season and therefore can easily associate with other wild species. But for water and grass, the swamps can be areas of intense competition. Since elephants are keystone species, they will often co-exist with other wild animals and it was not at all surprising that they share their home range with many other large mammals, especially in the bushland and woodland habitats. Given that bushland habitat is more common, and both bushland and woodland may have a varying degree of openness, that heterogeneity in patches will provide for more niches and feeding opportunities for more large herbivores and allow for more coexistence.

Scarcity of resources may result in high levels of animal aggregation; interference competition can occur in such a scenario and play a role in resource acquisition (Valeix et al., 2007). In Hwange National Park, Zimbabwe, waterholes were monitored in order to study agonistic interactions between elephants and other herbivore species. Results showed that in drier years, waterholes are crowded with elephants early in the afternoon. In general, the species most affected by interference competition with elephants shift their temporal niches at the waterholes, thus maintaining a constant temporal overlaps with elephants. The species less affected by interference competition with elephants showed no temporal niche shifts and increased their temporal overlap with elephants at waterholes, as predicted from a noncompetition hypothesis. This provided evidence that interference competition with a behaviorally dominant large species influences the temporal niches of smaller species, and suggests that the potential costs associated with interference between elephants and other herbivores at waterholes are linked to shifts in diurnal activities rather than interactions and water acquisition itself (Valeix et al., 2007).

Elephants also shared their home range with livestock. Most common type as well as in abundance was shoat (sheep and goats together) and cattle. The highest number of livestock was in the swamp and bushland in elephant home range. This means that competition for space, water and forage is most intense in swamps and woodlands. Water is a scarce and important determinant of elephant use of the landscape so potential conflicts and competition with other wild species and livestock may be around water resources as compared to either space or forage (Valeix et al., 2007). While elephants can co-exist with other wild large mammals, the same is not true for livestock. Frequent interaction and increased number of livestock in core elephant use and around critical resources such as water and salt licks can lead to conflicts (Valeix et al., 2007) in which elephants will attack if threatened by man or livestock (Ochola et al., 2013). This becomes a source of elephant-human conflicts and can elicit retaliation from Maasai herds and increase general negative attitude towards elephant presence in the Maasai pastoralists.

Livestock also have a more severe degradation effect on habitats (especially over grazing when the habitats are overgrazed or not given enough time to recover from grazing). This leads to general decline of habitat quality (due to overgrazing, decreased plant productivity and declining range condition). This will eventually affect elephant use of range. It is very important to balance the

grazing pressure of both wild and domestic large mammals' elephant home ranges to contain the conflicts and also safeguard habitat integrity. To do this, there is need for negotiations and awareness with local Maasai since most of the elephant ranges were on their land and outside the network of protected areas. Diversifying and properly locating more water sources and protecting existing ones will help alleviate conflicts especially around the water.

In conclusion, the diverse habitats were critical for elephant use of the landscape in Amboseli Ecosystem. The bushland and woodland habitats seemed most critical for elephants because they represented better habitat patchiness and heterogeneity (because of varying degree of openness) that promote elephant use of the landscape. This range was shared by other elephants and other large mammals particularly the zebra, gazelles and giraffes. These animals co-existed with elephant in the elephant range, with common activities being feeding and drinking especially in the swamps. Elephant habitat selection was not influenced by individual elephants, their gender and seasons. It was the habitat type (and may be its quality, quantity and risks to elephants) that was most critical in determining elephant selection of range. Human presence was common, mostly homesteads, roads and other infrastructure and this presence would increase competition for space and plant resources (Kiringe and Okello, 2005) and rate of encounter and therefore conflicts with elephants. The habitat destruction (through cutting of trees for firewood and other uses and for making charcoal) was the frequent habitat destruction activities of people. Further, clear risks directly to elephants occurred particularly in Kuku, Rombo and Tsavo West National Park as evidenced by presence of snares, elephant carcass and carcass of other large mammals.

The presence of livestock and competition for forage and water especially in bushland, woodlands and swamps may also likely lead to direct conflicts when elephant kill livestock, or increased habitat degradation due to overgrazing in critical elephant habitats. Since most elephants range outside the parks and the land belongs to the Maasai, unexpected encounter with elephants and competition for space and resources will likely increase. We recommend focus on the critical habitats needed by elephants outside of national parks, and negotiations with land owners so that the area can be made into wildlife sanctuaries and tourism investment brings direct benefits to the land owners, in addition to government support for such land owners in elephant management and appropriate compensation opportunity costs (Western, 1982). This should complement awareness and joint management of elephant forums between the government and local land owners who support elephants on their lands.

Conflict of interest

Authors did not declare any conflict of interest.

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