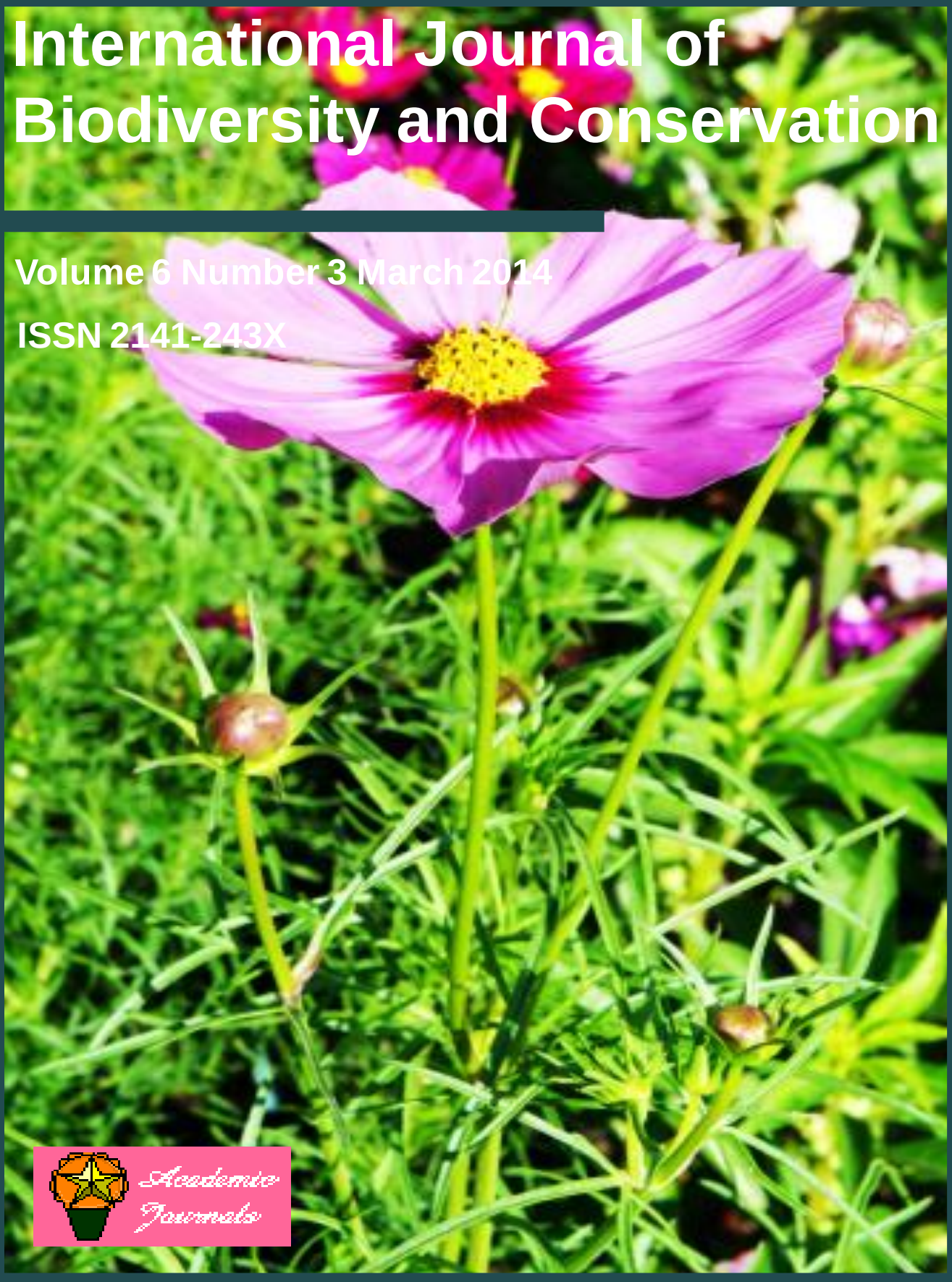
International Journal of Biodiversity and Conservation

Volume 6 Number 3 March 2014

ISSN 2141-243X



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International Journal of Biodiversity and Conservation

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Vol. 6(3), pp. 194-198, March 2014
DOI: 10.5897/IJBC2014.0689
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Artificial nest box for house sparrow: An apt method to save the dwindling species in an urban environment

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Accepted 13 January, 2014

House sparrow *Passer domesticus* belongs to Passeriformes order and Passeridae Family. It has a worldwide distribution living in all continents and many of oceanic Islands. Some of the ecologists believe that this bird is a symbiotic species with human, hence recognizing and identified as a bird species depended on human environments. A lack of holes suitable for nest sites on modern or renovated buildings has been proposed as a possible cause of the house sparrow population decline. There has been an increase in the use of plastic fascia boards and the use of contoured tiles or roofing sheets to prevent the entry of birds on modern housing. House sparrows predominantly nest in holes and gaps in soffit boards and under tiles, therefore this tendency may have an impact of the availability of nest sites. Hence the present study was undertaken to apt a suitable method to conserve the house sparrow population in urban areas of Sivakasi town by erecting artificial nest boxes in Sivakasi town from October 2012 - October 2013 and obtained a positive response by the house sparrow towards the artificial nest boxes.

Key words: Worldwide distribution, symbiotic species, renovated buildings, impact.

INTRODUCTION

House sparrows Passer domesticus are the commonest and widest distributed bird species in nature. The widespread and once abundant house sparrow which is universally familiar in appearance has become a rare bird at many localities in recent times. House sparrow num-bers have declined by about 60% in urban and suburban areas and the habitat composition and quality in urban-suburban landscapes is likely to have changed over this period (Dadam, 2009). In large cities, the number of house sparrows decreased significantly in recent decades. High reduction of sparrow population in London (60%), Glasgow (99%) and Hamburg (77%) have lead to the inclusion on the UK Conservation Red List (Crick et al., 2002; Prowse, 2002; Smith, 2005). The main reasons for the decline of this species in the urban-suburban landscape were the loss of suitable foraging habitat (Robinson et al., 2005) and the loss of suitable nesting sites. According to the survey at different places of India on the occurrences of house sparrow, it was reported that their population also has decreased considerably at present (Rajashekar and Venkatesha, 2008; Daniels, 2008; Khera et al., 2010; Bhattacharya et al., 2011; Ghosh et al., 2010).

The aim of this study was to determine the effect of artificial nest boxes for the house sparrows in urban areas in order to escalate the population of house sparrow in few selected study area of Sivakasi town in India.

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METHODOLOGY

Study species

The house sparrow is a member of the family Passeridae and it is one of the larger sparrows, with a length typically of 160-165 mm and a wingspan of 210-255 mm. It is rather a large headed, heavy billed and robust passerine. The sexes are dimorphic with the male being boldly patterned. The male is warm brown above, with a grey crown and nape. It has grey cheeks and grey under parts with black round the eyes. The mantle and scapulars are boldly streaked black, chestnut and buff and the tail is dark brown. The bib has black feathers with white tips that are gradually abraded so that by the beginning of the breeding season the bib becomes uniformly black. The female is rather featureless with a grey brown crown, a pale-buff super cilium, two wing bars and an unmarked throat and breast. The bill becomes darker during the breeding season and a few birds have a completely black bill (Lowther and Cink, 1992). The nest is built in holes of structures, under the tiles or around roof area of houses. It feeds on grain, insects, weed seeds, fruit buds, nectar *etc*. They usually form colonies having 10 to 20 pairs and do not spread far from the natal colony.

The study was conducted during the period of October 2012 to October 2013. Artificial nest boxes were placed on housing within ten study sites in Sivakasi town (Figure 1). The artificial boxes were made up of paper board because of its easy availability and economically cheap when compared with the wooden boxes. Sivakasi Taluk is located at 9.45°N 77.8167°E and has an average elevation of 101 m above mean sea level. Nest boxes were 29 cm in height, 13 cm in width and had an entrance hole 3.2 cm in diameter. Straw, fur, moss raked from the lawn were also supplied to the sparrow as nesting materials (modified from Chetan, 2012). Feeding stations were placed above the nest boxes for easy food access of sparrows, and a stick was inserted near the entrance hole for standing on it and feeding of young ones (Plate 1). Ten places were selected for the erecting of artificial nest boxes based on the disturbances from the environment and availability of natural nesting sites. The disturbed places selected were Market area, Muslim colony, Bus stand, N. R. K. R Road and Bye pass road. In each study site, five next boxes were erected in different houses 20 meters apart from each other. The boxes were erected at heights of approximately 4-5 metres on each house (Plate 2).

The nest boxes were watched at three days interval during the study period. Nest observations were done in the morning from 07:00 h to 11:00 h (IST) at regular interval. The entry and exit of sparrows are noted by visual observations while the nest activities are recorded by using camera.

Observations made on the response of House sparrows to the nest boxes were categorized into attempted, unattempted and productive. In the attempted category the house sparrows visit the box regularly but they didn't lay eggs. In the unattempted category the sparrows didn't approach the boxes, and in the productive category the house sparrows inhabited permanently in the nest box and started to lay eggs and nourish its young ones.

RESULTS AND DISCUSSION

Out of 50 boxes, 30 boxes are found to be attempted by the House sparrows.as the frequency of use of nest boxes are shown in the Table 1. The productivity in nest boxes was maximum in the Reserve line (3), Muslim colony (2), Bose colony (2) when compared to other places in which the artificial nest boxes were erected. In these nest boxes the House sparrow has stayed for a long time and laid eggs and nourishes the young ones with insects and plant materials (Plates 3 and 4).

Being a cavity nesting bird, use of artificial nest boxes may be an attempt to reduce the population decrease of House sparrow in the urban-suburban environment. This work highlights the response of house sparrow *Passer domesticus* to artificial nest boxes at different habitats of Sivakasi town during the breeding season of the sparrow. Loss of nest sites, especially in buildings, as a consequence of present construction and renovation style in building, may be one of the potential causes of house sparrow decline in Europe (Pineda et al., 2013). On the other hand, it is suggested that house sparrow is especially connected with urban areas of lower socioeconomic status, therefore with buildings in worse condition that offer more nesting sites. Additionally, being flexible in choice of nest sites, house sparrow is expected to build the nests in other available places (including nest-boxes), when those in buildings are lacking (Shaw et al., 2008).

The response of House sparrow to the artificial nest boxes were higher for boxes placed in the undisturbed areas of Coronation colony, Reserve line, Ayyanar colony, Bose colony and Velayutha Rastha. Loss of nest sites, especially in buildings, as a consequence of present construction and renovation style in building industry, may be one of the potential causes of House sparrow crisis in Europe. On the other hand, it is suggested that House sparrow is especially connected with urban areas of lower socioeconomic status, therefore with buildings in worse condition that offer more nest sites. Additionally, being flexible in choice of nest sites, house sparrow is expected to build the nests in other available places (including nest-boxes), when those in buildings are lacking (Shaw et al., 2008). Similar kinds of results were found by Anderson (2006) who reported that the availability of nest sites is one of the most important factors influencing sparrow abundance in urban places.

In India, a similar kind of response by house sparrows towards artificial placed nest boxes was reported by Balakrishnan et al. (2011) from Manjeri municipality, Kerala. They studied the nest site characteristics of House sparrow and found that majority of the nests (89.3%) were placed above the roller shutter boxes followed by the artificial boxes provided by the shop keepers (4.8%), shelter boards in front of the shops (3.57%) and the ventilators (2.4%).

House sparrow clearly prefers nesting in buildings, and uses other sites only when those in buildings are not available (Shaw et al., 2008). Where as in the Market area, Bye pass road and Bus stand, the response towards artificial nest boxes were too low which may be due to the presence of olden buildings and availability of food within their home range. A study by Wegrzynowicz (2012) in suburban housing estate of Wrzecion in Warsaw, Poland, reported that the number of house sparrows decreased in the years of the study from 53 pairs in 2005 to 20 in 2012. This decline was caused by the renovation of buildings (insulation) that was carried out gradually

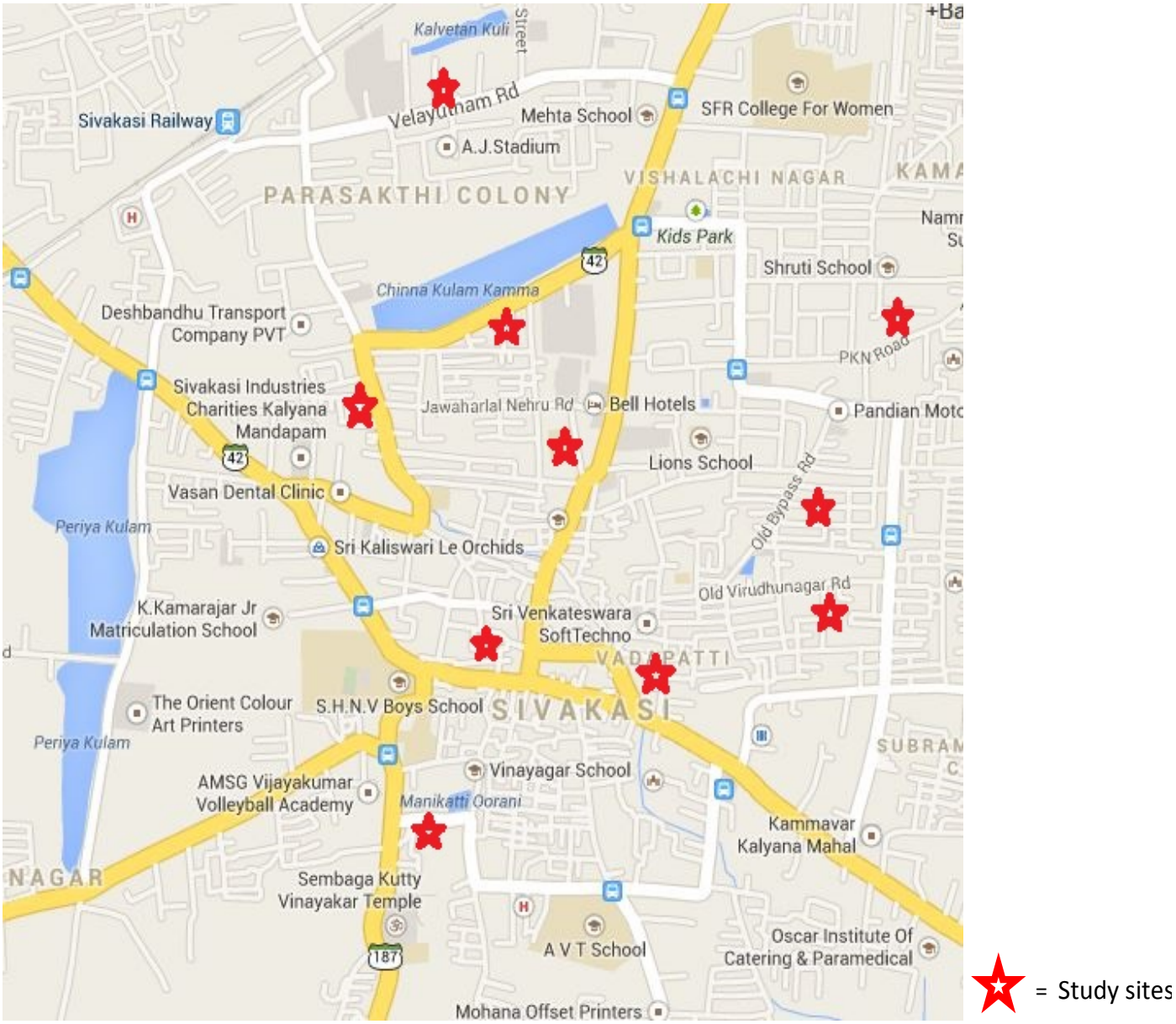

Figure 1. Map of Sivakasi town showing locations of artificial nest boxes erected Courtesy: www.GoogleEarth.com.

in the time of the study and resulted in loss of nest sites for house sparrows.

In some areas the competition and disturbances by Indian Myna (Acridotheres tristis) were recorded in the artificial nest boxes which were kept in the Reserve line and Muslim colony, and similar kinds of disturbances were reported from Bhattacharya et al. (2011) whom found that the artificial nest boxes was disturbed by woodpeckers at several sites and a pair of Pied cuckoo (Clamator jacobinus) is trying to enter the box but are defeated by a pair of house sparrow in competition.

Conclusion

This study highlights the response of House sparrow to artificial nest boxes erected at different places of Sivakasi town. From the study it was inferred that the response of house sparrow were maximum in urbanizing areas of Sivakasi town which was due to absence of nesting sites in the modern architecture of buildings. Hence artificial nest box was a suitable measure to increase the dwindling House sparrow population from the urban eco-system.

ACKNOWLEDGEMENT

The authors express the profound thanks to the Management of Ayya Nadar Janaki Ammal College for providing facilities to carry out this work and P. Rajasekarapandian, Assistant in Library for the designing of artificial nest boxes.

Plate 1. Design of the artificial nest box.

Plate 2. Erection of artificial nest box above 5 feet from ground level.

Table 1. Response of House sparrow, *Passer domesticus* to nest boxes in Sivakasi town, Virudhunagar District from October 2012 - October 2013.

Study site	Number of boxes	Attempted[a]	Un attempted	Productive
Market Area	5	1	4	1
Muslim colony	5	4	1	2
Coronation colony	5	4	1	1
Bye Pass Road	5	1	4	0
N.R.K.Road	5	3	2	0
Reserve line	5	4	1	3
Ayyanar colony	5	4	1	1
Bose colony	5	4	1	2
Bus stand	5	2	3	0
Velayutha Rastha	5	3	2	0
Total	50	30	20	10

[a] Number of attempted nest boxes was varied significantly (calculated *t value = 2.88, df = 9,* t_9 *(0.05) = 2.44*).

Plate 3. The chicks being nourished by the mother house sparrow.

Plate 4. Adult male sparrow feeding the older chicks with plant materials.

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Vol. 6(3), pp. 200-209, March 2014
DOI: 10.5897/IJBC2014.0690
ISSN 2141-243X © 2014 Academic Journals

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Abundance of hamadryas baboon (*Papio hamadryas hamadryas*) and conflict with humans in Awash National Park, Ethiopia

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Receive 04 February 2014; Accepted 20 February, 2014

A study on population size of hamadryas baboon (*Papio hamadryas hamadryas*) and its conflict with people was carried out from August 2011 to December 2013 in Awash National Park, Ethiopia. Abundance was estimated using total count method at five counting sites. To assess the species conflict with humans, questionnaires and structured interview methods were used. Data were analyzed using descriptive statistical methods SPSS version 15. The total number of individuals from August 2011 to November 2013 was 1581 and 1845, respectively. Abundance has no significant difference between wet and dry seasons ($P < 0.05$). There was no significant difference between the population of hamadryas baboon in 2011/2012 and 2013 ($P < 0.05$). There was no significant change in the rate of change in the population ($P < 0.05$). However, there was significant difference between male and female population of hamadryas baboon in 2011/2012 ($P < 0.05$). In 2012/2013 count, the number comprised of 26% adult male, 19% adult female, 9% sub-adult male, 14% sub-adult female, 11% juvenile male, 18% juvenile female and 3% infants. The proportion of female population was more in all age groups except for infants where sex identification was not possible. The species in the study area was highly influenced by forage resource distribution and hence, the high proportion of individual number was found in the northern part of the park, where more forage was available. The result of human survey showed that the overwhelming number (93%) of respondents felt that there was high conflict between people and hamadryas baboon. 92% of the respondents also noted that there was habitat encroachment including deforestation, overgrazing, charcoal production for fuel, and vegetation clearance for settlement in the park. Moreover, majority of the respondents witnessed frequent killing of baboons by farmers as a measure against alleged crop raiding by the species and also considerable number of species are killed by reckless vehicle and truck drivers on the high way crossing the park. About 64% of the respondents also felt that little was done by the park authority to create awareness on the local people about the economic and ecological benefits of wildlife species. Therefore, to minimize human-hamadryas baboon conflict, conservation measures that would ease human encroachment pressure on the habitat and increased local people's awareness should be practiced.

Key words: Abundance, conflict, conservation, hamadryas baboon, park.

INTRODUCTION

Hamadryas baboon (*Papio hamadryas hamadryas*) is distributed along mountainous areas of northeastern Africa and southwestern Arabia. However, in Ethiopia hamadryas baboon lives in semi-desert areas of Awash National Park, particularly in Filwoha area (Kummer, 1968; Swedell, 2002). Hamadryas baboon also lives at

higher altitudes during scarcity of resources (Kummer, 1968; Biquand et al., 1992b; Zinner et al., 2001a). Once the distribution of hamadryas baboon was widespread but gradually the distribution declined in the ranging countries and at present it is highly restricted to certain areas of the ranging countries in the northeastern Africa and southwestern Arabia. The current distribution of hamadryas baboon is in the eastern Ethiopia, Eritrea and Sudan, western Djibouti and Somalia, southwestern Saudi-Arabia and Yemen (Kummer, 1968; Kummer et al., 1981; Wolfheim, 1983; Schreier, 2010). Even though, the geographical distribution is limited to northeastern Africa and southwestern Arabia, hamadryas baboon is considered as a least concern (IUCN, 1996). Hamadryas baboon was abundantly found in Egypt in recent past, however at present it is locally extinct from Egypt (Winney et al., 2004). The restricted geographical distribution may be due to habitat loss through agricultural expansion, deforestation affecting the food resources, human settlement in and around the habitats of the baboons, hunting for meat and biomedical research, conflict between the baboons and farmers (Zinner et al., 2001a). The distribution of hamadryas baboon is highly influenced by the abundance, availability and distribution of resources like sleeping cliffs and water holes (Kummer, 1971; Schreier and Grove, 2010). The conflict among the farmers, pastoralists and hamadryas baboons may be due to crop raiding and killing young goats and lamb. The original habitats of the baboons have been taken by the farmers and pastoralists for agricultural activities resulting in the current conflict. The farmers highly curse the baboons for raiding their crops (Horrocks and Baulu, 1994; Hill, 1997, 2000, 2005; Chalise and Johnson, 2005). The farmers kill the baboons to protect their crop and young goats and lamb (Naughton-Treves, 1998). In Saudi-Arabia, hamadryas baboons are given food by people. However, the natural behaviour of these baboons may change through time because they can access food resources easily without travelling long distances to search, locate and forage (Biquand et al., 1992b; Al-Safadi, 1994).

In parts of Ethiopia, the distribution of hamadryas baboon includes agricultural areas as a result, the species move to agricultural fields, raid crops and considered as crop raiders (IUCN, 1996). Although, hamadryas baboons are least concern species, in Ethiopia there is hamadryas-human conflict because of habitat loss as well as deforestation for charcoal, over grazing, hunting and settlement in the park. The nomadic pastoralists living in the Park as well as in the proximal areas of the park kill and hunt the baboons because they raid commercial sugarcane plantations and other agricultural crops of the local farmers (IUCN, 2010). The conflict between hamadryas baboons and the local community is increasing because new farmers have been involved in sedentary agriculture from nomadic pastoralists to improve their livelihood. The population status of hamadryas baboon has never been well studied and there is insufficient demographic data except for social organization and structure (Yalden et al., 1977). Although, hamdryas baboons occur in different parts of Ethiopia, the population size has never been studied and determined (Mori and Gurja, 1990). Therefore, this study is aimed to 1. Assess population size of hamadryas baboon at Awash National Park (ANP). 2. Examine distribution of hamadryas baboon in relation to habitat suitability. 3. Survey people's view and attitudes towards their conflicts with hamadryas baboon.

Study area

ANP is located between latitudes 8°46' N and 9°16' N and longitudes 39°46' E and 40°6'E with its southern boundary along the Awash River. It is about 225 km east of the capital city, Addis Ababa, and covers 589 km^2 of *Acacia* woodland and grassland area in semi-desert area (EWCA, 2012). Its altitudinal elevation ranges from 1200 to 1829 m asl. Daily temperature ranges from 10to 22°C. Temperatures can reach as high as 40°C but nights are cooler. On average, December is the coldest month and May is the hottest month of the year. The main rainy season is from June to September, with a short rain from February to April. Most part of the park consists of open plains, short grass savanna and thorn scrub, dominated by Mount Fentale and a spectacular dormant volcano. Among the mammals, hamadryas and anubis baboons are among the commonest ones in the park. Hamadryas baboons are distributed along the northern part of the park particularly in Filwoha area where four of the study sites were located (Figure 1).

MATERIALS AND METHODS

Data collection

The study was conducted from August 2011 to November 2013 both during wet and dry seasons for ten days every month. To study and determine the abundance and structure of hamadryas baboon, a total count method was used (Beehner et al., 2007). Total direct count was carried out at five different counting sites, namely Wasero, Filoha, Urulie, Dahilebora and Fentale cliffs (small cliffs behind Dahilebora cliff) used by the baboons as sleeping sites (Figure 1). Habitat suitability was assessed through repeated observation of the baboons ranging and travel patterns in search of forage resources on daily basis. Population count was carried out four times during each wet and dry seasons in two years period. To

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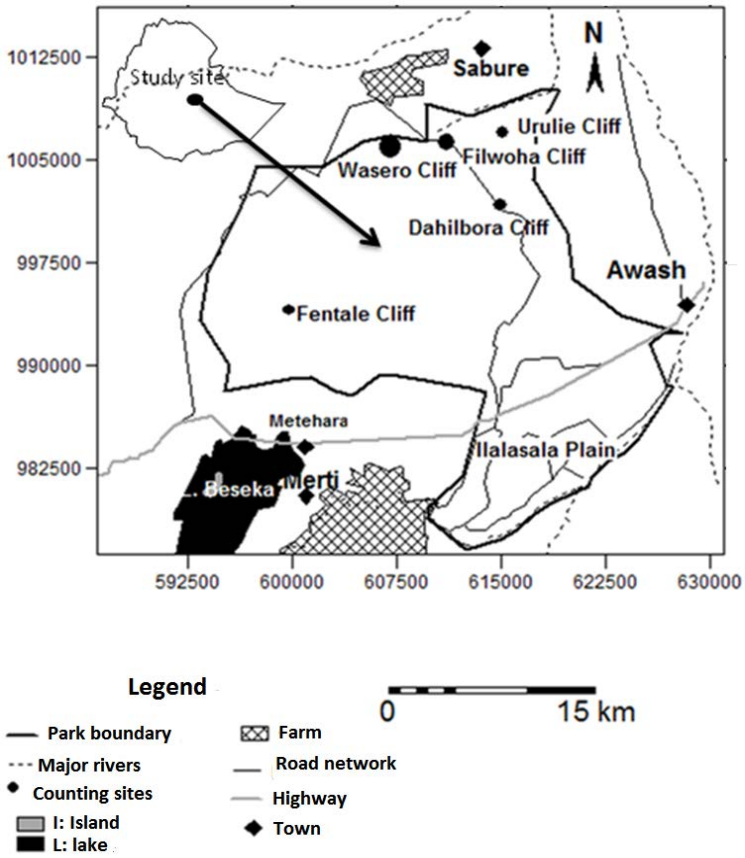

Figure 1. Map of Awash National Park with locations of counting sites of hamadryas baboon.

carry out direct count, ten individuals were employed, excluding the researcher. Hence, two individuals were assigned to count at each counting sites simultaneously early in the morning at 6: 00 a.m. and late afternoon from 5:00-6:30 p.m. when the baboons were at their sleeping sites (or resting sites). Usually hamadryas baboons stay at their sleeping cliffs late afternoon from 5:00-6:00 am and leave their cliff to forage early in the morning around 6:00 a.m. (Kummer, 1968; Schiere, 2010). Double counting is minimized following their behaviour of movement. Standardized check lists (that is used for recording the number of individuals) were used to collect data. For the baboon and human conflict assessment, interviews were carried out using questionnaires on randomly selected respondents. The questionnaires were then translated to local language. The structured questionnaire was developed to inquire on range of issues related to baboon and human conflicts. Accordingly, randomly selected respondents (males 188, females 49), local community members (4.2% of the total members), 8 scouts (3.4%), 3 park administrators (1.3%), 4 district administrators (1.7%), 10 students (4.2%), 120 pastoralists (50.6%), 80 farmers (33.8%), 2 visitors (0.84%) were interviewed by the help of enumerators. Sample size of respondents was 237 (Table 1). Structured interview was used to interview randomly selected interviewees in the park as well as in district administrator offices by the researcher alone. The sample size of the interviewees was 22 (Table 2).

Data analysis

The data were analyzed using descriptive statistical methods which were coded and entered into SPSS version 15 software to generate the required results.

RESULTS

Population size, sex and age structure of hamadryas baboon during 2011/2012 and 2012/2013 on each counting sites are given in Tables 3 and 4. Similar results were obtained during consecutive counts on each counting sites and statistically no significant difference was found between consecutive counts.

During the 2011/2012 count, there was significant difference in the population size between adult males and adult females ($df = 1$, $t = 3.428$, $P < 0.05$). There was also a significant difference in the population size between adult males and adult females during 2012/2013 count ($df = 1$, $t = 3.548$, $P < 0.05$). Sex and age structure of hamadryas baboon based on seasons during 2011/2012 and 2012/2013 is given in Tables 5 and 6.

There was no significance difference in the abundance of individuals between wet and dry seasons ($df = 1$, $P = 0.3173$ at $P < 0.05$). There was also no significant difference in the number of hamadryas baboon between 2011/2012 and 2012/2013 ($df = 1$, $P < 0.3173$ at $P < 0.05$).

Table 1. Randomly selected respondents to collect data on human-hamadryas baboon conflict in the surrounding areas of Awash National Park.

Respondent	Respondents' category		
	Sex		Age
	Male	Female	
Scouts	8	-	31-40
Crop farmers	65	15	31-50
Pastoralists	90	30	31-50
Community leaders	10	-	> 50
ANP authorities	3	-	31-40
District administration	4	-	31-40
Students	7	3	15-20
Others (visitors)	1	1	20-30

Table 2. Interviewees on human-hamadryas baboon conflict in Awash National Park.

Interviewees	Interviewees category		
	Sex		Age
	Male	Female	
Awash Fentale district head	1	-	31-40
Awash district Administrative head	1	-	40-50
Awash district staff	3	2	31-40
Awash Fentale district staff	3	2	31-40
Community leaders	4	-	> 50
ANP warden	1	-	31-40
ANP staff	5	-	31-40

At the same time there was no significant difference in the rate of change of variation in number (df = 1, P < 0.3173, P < 0.05).

There was no significant difference in the number of hamadryas baboon during the wet season of 2011/2012 (x^2 = 26.581, df = 1, P < 0.01). There was also no significant difference in the number of hamadryas baboon during the dry season of 2012/2013 (x^2 = 12.033, df = 1, P < 0.01).

During 2011/2012, the individual count at Awash National Park was 15% adult male, 27% adult female, 11% sub-adult male, 14% sub-adult female, 10% juvenile male, 16% juvenile female and 3% infant. During 2012/2013 count, it was 19% adult male, 26% adult female, 9% sub-adult male, 14% sub-adult female, 11% juvenile male, 18% juvenile female and 3% infant.

Male-female ratio of hamadryas baboon during the year 2011/2012 and 2012/2013 based on seasons are given in Tables 7 and 8. The proportion of male-female hamadryas baboon during 2011/2012 and 2012/2013 is given in Tables 9 and 10.

Habitat suitability is defined based on forage and water availability which determine the ranging and travel patterns of the baboons in search of resources on daily basis. Depending on the availability of resources, suitable, moderately suitable and unsuitable habitats of hamadryas baboons are given in Figure 2.

Respondents for questionnaires and structured interview are given in Tables 11 and 12. The respondents were scouts from local and federal governments, students, farmers, pastoralists, community leaders, park authorities, district administrators both from Afar and Oromia Regions. For questionnaires, 237 respondents and 22 interviewees were randomly selected. Responses of respondents on human-hamadryas baboon are given in Table 11.

Most of the respondents responded that hamadryas baboons in ANP were killed by farmers and their response was significantly different (X^2= 173, df = 1, P < 0.01). The majority of the respondents also responded that hamadryas baboons in ANP raid crops and their response was significantly different (x^2 = 44.764, df = 1, P < 0.01). Almost all the respondents commented that palm forest was deforested by the local people and their response was significantly different from those who responded against (x^2 = 163.751, df = 1, P < 0.01). The majority responded that there was deforestation of Acacia trees for charcoal production in ANP and their response was significantly different (x^2 = 170.468, P < 0.01). The majority responded that hamadryas baboons kill young goats and lamb, and their response was significantly different (x^2 = 150.722, df = 1, P < 0.05). Most of the respondents responded that there was settlement in the park and their response was significantly different (x^2 = 157.169, df = 1, P < 0.01). The majority responded that there was illegal settlement in the park and their response was significantly different (x^2 = 53.878, df = 1, P < 0.01). Structured interview responses on the relationship between park authorities and local community leaders for managing ANP are given in Table 12.

Majority of the interviewees responded that hamadryas baboons in ANP were threatened due to habitat loss and killing by farmers, and their response was significantly different (x^2 = 14.727, df = 1, P < 0.01). Most of the interviewees responded that awareness creation on the local people was lacking and their response was significantly different (x^2 = 4.545, df = 1, P < 0.05). Almost all the interviewees responded that ethnic disputes disturb hamadryas baboons in ANP and their response was significantly different (x^2 = 11.636, df = 1, P < 0.01). The majority of the interviewees responded that ANP authorities and local community leaders do not work together to safeguard the species in the park and their response was significantly different (x^2 = 14.727, df = 1, P < 0.01).

There was no significant difference between their response on the presence of deforestation and overgrazing in ANP (x^2 = 0.182, df = 1, P > 0.05).

DISCUSSION

The current study showed that hamadryas baboons in ANP have been using five sleeping cliffs. Besides,

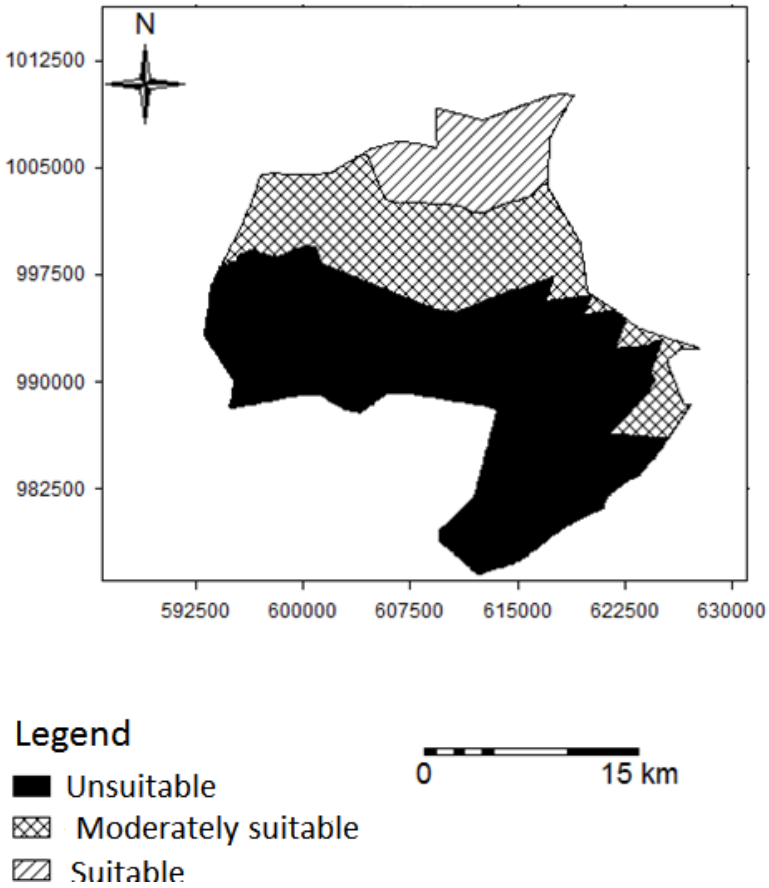

Figure 2. The distribution of hamadryas baboon based on habitat suitability.

Table 3. Population size, sex and age structure of hamdryas baboon during 2011/2012 in ANP (M = male, F = female, SUI = sex unidentified).

Counting site	Adult		Sub-adult		Juvenile		Infants	
	M	F	M	F	M	F	SUI	Total
Wasero cliff	105	175	94	145	80	119	22	740
Filwoha cliff	64	100	54	84	42	64	12	420
Urulie cliff	6	14	6	8	4	6	2	46
Dahilebora cliff	28	62	22	34	18	38	8	210
Fentale cliff	22	51	12	22	16	36	6	165
Total	225	402	188	293	160	263	50	1581

Table 4. Population size, sex and age structure of hamadryas baboon during 2012/2013 in ANP (M = male, F = female, SUI = sex unidentified).

Counting site	Adult		Sub-adult		Juvenile		Infant	
	M	F	M	F	M	F	SUI	Total
Wasero cliff	190	210	60	94	102	146	18	820
Filwoha cliff	60	98	36	48	24	38	12	316
Urulie cliff	12	18	10	14	8	11	5	78
Dahilebora cliff	64	116	38	70	44	88	11	431
Fentale cliff	24	56	22	34	18	38	8	200
Total	350	498	166	260	196	321	54	1845

Table 5. Size and age structure of hamadryas baboon based on seasons during 2011/2012 count (M = male, F = female, SUI = sex unidentified, S. adult = sub- adult).

Season	Adult		Sub-adult		Juvenile		Infant	
	M	F	M	F	M	F	SUI	Total
Wet	130	240	100	160	90	145	28	893
Dry	95	162	88	133	70	118	22	688
Total	225	402	188	293	160	263	50	1581

Table 6. Size and age structure of hamadryas baboon based on seasons during 2012/2013 count.

Season	Adult		Sub-adult		Juvenile		Infant	
	M	F	M	F	M	F	SUI	Total
Wet	190	264	87	140	105	180	31	997
Dry	160	234	79	120	91	141	23	848
Total	350	498	166	260	196	321	54	1845

Table 7. Male-female ratio of hamdryas baboon during 2011/20 12 based on season (M = male, F = female).

Season	Adult	Sub-adult	Juvenile
	M:F	M:F	M:F
Wet	1: 1.85	1: 1.6	1: 1.61
Dry	1: 1.71	1: 1.51	1: 1.69
Total	**1: 1.79**	**1: 1.56**	**1: 1.64**

Table 10. Male-female ratio of hamadryas baboon on each counting sites during 2012/2013.

Season	Adult	Sub-adult	Juvenile
	M:F	M:F	M:F
Wet	1: 1.39	1: 1.69	1: 1.71
Dry	1: 1.46	1: 1.52	1: 1.55
Total	**1: 1.42**	**1: 1.57**	**1: 1.64**

Table 8. Male-female ratio of hamadryas baboon during 2012/2013 based on season

Counting site	Adult	Sub-adult	Juvenile
	M:F	M:F	M:F
Wasero cliff	1: 1.7	1: 1.5	1: 1.5
Filwoha cliff	1: 1.6	1: 1.6	1: 1.5
Urulie cliff	1: 1.2	1: 1.3	1: 1.5
Dahilebora cliff	1: 2.2	1: 1.5	1: 1.2
Fentale cliff	1: 2.1	1: 1.5	1: 2.1
Total	**1: 1.8**	**1: 1.6**	**1: 1.6**

Table 9. Male-female ratio of hamadryas baboon on each counting sites during 2011/2012.

Counting sites	Adult	Sub-adult	Juvenile
	M:F	M:F	M:F
Wasero cliff	1: 1.1	1: 1.6	1: 1.4
Filwoha cliff	1: 1.63	1: 1.3	1: 1.6
Urulie cliff	1: 1.5	1: 1.4	1: 1.4
Dahilebora cliff	1: 1.8	1: 1.8	1: 1.2
Fentale cliff	1: 2.3	1: 1.5	1:2.1
Total	**1: 1.4**	**1: 1.6**	**1: 1.6**

sometimes the baboons may use palm trees as a sleeping site. Similarly, Schreier and Swedell (2008) reported that hamadryas baboons living around Filoha at ANP use *Hyphaene thebiaca* trees as sleeping sites. It is not common to observe hamadryas baboons and other species of baboons using trees as a sleeping site. According to Schreier and Swedell (2008), baboons sometimes sleep on trees because Wasero and Filoha cliffs have been highly disturbed by nomadic pastoralists. Baboons do not permanently use trees as a sleeping site especially during the wet season, so the palm tree areas were not used as a counting site for hamadryas baboons.

In the year 2011/2012, the number of hamadryas baboon in ANP was counted. In 2012/2013 the number of hamadryas baboon was similarly estimated. In the estimates of 2011/2012 and 2012/2013, the number of female hamadryas baboon was higher than the males. In both estimates, the largest individuals of hamdryas baboon sleep on Wasero and Filoha sleeping cliffs and a few individuals in Urulie cliff both during wet and dry seasons across the study period. In ANP, the female individual number of hamdryas baboons was larger than the males. However, in terms of social organization, the male is highly dominant. Similarly, Zinner et al. (2006) reported that dominant male leader prevents females from interacting with other males and females and keep them for him-

Table 11. Responses of respondents' on human-hamadryas conflict in Awash National Park.

Reason	Respondents' response			
	Strongly Agree	Agree	Strongly Disagree	Disagree
Hamadryas baboon raid crops	130	90	8	9
People settle in the Park	145	30	43	19
Local people kill hamadryas baboon	100	80	27	30
There is overgrazing in ANP	198	10	10	10
Local people kill hamadryas baboon to exercise shooting targets	80	90	60	7
Crop raiding is controlled by shooting	133	45	40	19
Hamadryas baboon is a threat for farmers and pastoralists	143	30	40	24
Caracas of hamadryas baboon was observed around agricultural areas	30	38	100	69
Palm forest in ANP is deforested by local people	200	17	10	10
Acacia trees are deforested for charcoal	188	31	9	9
ANP and hamadryas baboon are not important	18	40	178	1
Gunmen are common in ANP	200	30	3	4
It is right to get into the park and cut trees for fire fuel and other reasons	194	24	10	9
Hamadryas baboon are not important for economic benefits of local people	200	20	9	2
Hamadryas baboon killed lamb and goats	196	17	18	6
Only central government must conserve hamadryas baboon in ANP	143	58	27	9
Community leaders and ANP leaders must conserve the baboons	61	27	122	27
Everybody is responsible for conservation	30	40	145	22
Training was given to local people	10	12	173	42
Hunting is common in ANP	130	64	33	10

Table 12. Interviewees' responses on conflict between the local people and hamadryas baboon in ANP.

Question	Number of interviewees			
	Strongly Agree	Agree	Strongly Disagree	Disagree
Hamadryas baboon is threatened	14	6	1	1
Community leaders and ANP authorities work together on conservation	1	1	16	4
Awareness is lacking about economic benefits of wildlife by local people	14	2	4	2
Deforestation and overgrazing are common in ANP	8	2	8	6
Scouts and drivers are killed by pastoralists	18	1	2	1
Ethnic disputes disturb hamadryas baboon in ANP	19	1	1	1
Training was not given to the local people about hamadryas baboon importance	2	3	15	3
ANP may not continue as a park	16	1	4	1
Hunting, Overgrazing and charcoal production may affect the number of hamadryas baboon	19	1	1	1
ANP authorities and community leaders work together to safeguard the hamadryas baboon	1	1	18	2

self. In hamadryas baboons, high ranking dominant leader males had access to females. Where there are large numbers of females, the prospect of size would be good, unless resources become scarce and human interferences affect the population trend. Abundance has no significant difference between wet and dry seasons. The ratio of adult male-female, sub-adult male-female, and juvenile male-female showed the number of female individuals were higher than male individuals. The increase in number of females can be good because in social organization of hamadryas baboons, the dominant males can form one male unit, by having more than two females, their young and sub-adult males. The current study also showed that the density of hamadryas baboons was also estimated during both seasons.

The current study showed that hamadryas baboons were distributed largely along the northern part of ANP. The reason may be due to the availability of sufficient resources like forage, water holes, sleeping cliffs and trees that are also used as sleeping sites. Kummer (1968a) re-

ported that hamadryas baboons live in semi-desert and savanna habitats but their distribution in semi-deserts is affected when resource availability decreases and hence, move to live in higher altitudes about 3000 m. This shows that the distribution of hamadryas baboon is limited by the availability of food and water resources in their habitat. Although, hamadryas baboons were largely distributed in the northern part of ANP, it was confirmed that hamdryas baboons also travel towards the south in search of resources during drought. The concentration of individuals along the northern part was due to the presence of major food plants. However, some of the plant species consumed by hamadryas baboons were also found in the south central and southern part of the park. *Balanites aegyptiaca* and *Dobera glabra* were abundantly found in the northern as well as in the southern part of ANP. Usually, the baboons move to the south central and far southern part of the park during the dry season. Therefore, the northern part of the park is a highly suitable habitat to the baboons. Habitat conditions such as forage, water holes, sleeping cliffs and trees can limit the distribution of hamadryas baboons in ANP. Similarly, Shefferly (2004) reported that the distribution of hamadryas baboons is highly influenced by the distribution and availability of resources, specifically food, water and sleeping cliffs. Besides, hamadryas baboons require water holes and forage not far from their sleeping cliffs to minimize the distance travelled in obtaining water as well as forage resources.

The current study confirmed that there is conflict between the local people and hamadryas baboon in ANP. 93% responded that there has been conflict between the local people and hamadryas baboon. Chapman and Peres (2001) reported that when baboons and humans live together around protected areas, conflict is inevitable because the natural habitats of baboons have been taken and disturbed by people. 89.9% responded that hamadryas baboons kill lamb and young goats which can increase the level of conflict between the local people and hamadryas baboons. The local farmers and nomadic pastoralists kill hamadryas baboons to revenge their raided crop and killed lambs and goats. Strum (2010) reported that recently baboons are highly threatened due to anthropogenic impacts on the habitat of baboons.

Similarly, Mesele et al. (2011) reported that large mammals cause crop raiding if agricultural fields are proximal to wildlife habitats. This may be due to competition between wildlife species and people living near protected areas. Similarly, Hockings et al. (2009) reported that when agricultural plantations, orchards, sugarcane plantations and other larger irrigation projects border the habitats of baboons, it will result in direct contact and competition between people and baboons. In the surrounding areas of ANP, there are agricultural activities such as orchards, sugarcane plantations, small scale farming and large number of nomadic pastoralists. Since, these agricultural activities are near ANP, hamadryas baboons cause conflict both with farmers and nomadic pastoralists by crop raiding and killing of lamb and young goats.

According to the current study, competition between livestock and wildlife in ANP such as grazers and browsers has been serious and hence, needs an immediate solution to minimize the level of competition. Unless immediate solution is taken, it will go beyond the control of the Park authorities and result in localized species extinction. In the current study, 73.8% of the respondents confirmed that the local people settled in the park, disturbed and intimidated wildlife species living in the park. Similarly, Pimbert and Pretty (1995) reported that local people who settle in the protected areas cause great damage to wildlife species and forests. Hence, the conflict between hamadryas baboon and the local people in the surrounding areas of ANP demands an immediate conservation management solution. The current study showed that the local people have deforested the palm forest which is very vital to the local people themselves and to the hamadryas baboons. Doum palm fruit is one of the major food sources for hamadryas baboons in ANP, particularly at Filwoha area, especially during the dry season when other resources become scarce. In ANP, deforestation is the major threat to wildlife species, especially to hamadryas baboons because the diet includes *Acacia* tree species that are being deforested for charcoal production.

Acacia forest in ANP is being deforested for charcoal production on a regular business by the local people who did not have awareness about the ecological importance of *Acacia* trees. The majority of the local people deforest *Acacia* trees for charcoal production. Similarly, Abbiw (1990) reported that when forests are deforested for any human interest, wildlife species in the forest will be homeless and threatened. Baboons of ANP are facing similar problems.

In the current study, it was confirmed that hamadryas baboon is considered as a crop raider by most local people in the surrounding areas of ANP affecting their agricultural fields. The major reason for the conflict between the local people and hamadryas baboon is that, the original habitats of the baboon was taken by people for sugar industry project and small scale farming in the area. Similarly, IUCN (1996) reported that in Ethiopia, hamadryas baboons live proximal to agricultural areas, raid crops and hence, considered as crop pests. According to the current study, enough training was not given to the local people in the surrounding areas of ANP about economic and ecological benefits of wildlife and plant species in ANP. Hence, the ANP authorities and non-governmental organizations should take part in giving training to create awareness about wildlife and plant species to safeguard these species from becoming extinct.

The majority of the respondents confirmed that scouts and drivers of ANP have been killed by nomadic pastoralists, while trying to secure law and order in the park. Hence, the nomadic pastoralists are beyond the control

of the ANP management and need the interference of the head quarter as well as the Regional and Federal Governments to minimize the impact of the nomadic pastoralists on ANP. In addition to disputes between Afar and Oromo ethnic groups, overgrazing, illegal settlement in the park, hunting, deforestation for charcoal production, killing hamadryas baboon to exercise target shooting, ignorance of the local people about the economic and ecological benefits of wildlife species particularly hamadryas baboon, lack of coordination between the local community leaders and ANP management are the major threats. Unless an immediate conservation management action is taken most species in ANP will disappear. If the current trend of ANP management continues the, park may not be able to sustain and continue as a protected area.

Conclusion

This study revealed that hamadryas baboons that dwell in the Awash National Park are threatened due to human created problems. Human-hamadryas baboon conflict has been aggravated because of crop raiding and killing of lamb and goats by hamadryas baboons in the surrounding areas. Besides, agricultural activities have been carried out near the park and the original habitats of the baboon were taken by people for sugarcane plantation, orchards and for small scale farming. This is confirmed by interviews and direct observation while the baboons raid crops. The count of individuals in ANP showed that number was almost constant during the two years of population study. However, if the current condition continues, the number of hamadryas baboon would be at risk and even become locally extinct. Therefore, conservation measure should be in place to safeguard the threatened hamadryas baboon in ANP. The park management should be able to plan new strategies for conservation and safeguard the species of wildlife including hamadryas baboon in the park.

Conflict of Interests

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

ACKNOWLEDGEMENTS

Addis Ababa University and Animal Diversity Thematic Research are acknowledged for financial assistance. We are grateful to Adama Science and Technology University for providing transport facilities during data collection. We thank the Ethiopian Wildlife Conservation Authority for providing permit.

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Vol. 6(3), pp. 210-216, March 2014
DOI: 10.5897/IJBC2011.144
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Impacts of climate change on Yerramalais forest of Eastern Ghats of Kurnool District, Andhra Pradesh, India and options for adaptation

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Accepted 16 January, 2014

Biodiversity is an element of the natural resource base, which is one of the main components of eco-environment system. It would be noted that the biodiversity in the system of natural resources brings the sustainability in the production and utilization of the eco-environment system on the earth. Biodiversity changes caused by anthropogenic activities through over mining, over grazing, deforestation, and forest-fires etc. are studied in Yerramalais forest of Eastern Ghats. Other important factors of global change interacting synergistically with climatic factors are also mentioned, human greed is also one major reason for its degradation as they only think for today and not for their future. The forest vegetation is declining tremendously for the past 50 decades due to climatic changes, resulting in thee disappearance of flora at an alarming rate leading to the loss of biodiversity. Climate change poses major new challenges to biodiversity conservation. Increased population and uncontrolled human activities have misused the natural resources which led to the disturbance in the ecosystem and scarcity of natural resources.

Key words: Nallamalais, yerramalais, soil erosion, firewood, tribal communities, deforestation.

INTRODUCTION

India is not only gifted with cultural diversity, geographical diversity, social diversity and climatic diversity but also adorned with biodiversity which broadly include plant biodiversity. Forests play a key role in maintaining a wide range of delicate relationships with nature and its eco-systems. Yerramalais forest is home to many endemic, endangered and threatened species, as well as to the indigenous people, who are dependent on its biological resources. Most of the world's forests especially the temperate and boreal forests, are already being utilized by humansocieties(LindenmayerandFranklin,2002;Kanowski et al., 2005). Effect of anthropogenic activities not only threatens the biodiversity, but also affects the socio-economic condition of the indige-nous people of the forest. Various activities like habitat loss, deforestation, clear felling and overexploitation amplify the impact of climate change on biodiversity. In recent years, attention has focused on the possible impact of atmospheric and climatic changes on plants and vegetation. Much uncer-tainty still exists as to the possible effects of such change on ecosystems and soils in the Yerramalais forest, which could have severe biological and economic consequences

Therefore, some management initiatives should be taken for mitigating climate change. Also, more research work needs to be carried out in Yerramalais forest to monitor the susceptibility of biodiversity. We studied the location

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in the forest and suggest the adoption of prescribed system of forest utilization systems as a management policy. Such a policy has two advantages; on one hand, it contributes to sustainable livelihood of the tribal people depending on local forest resources, and on the other hand, it contributes to conservation of plant species diversity.

Excessive mining, loss of forest area due to human activity, loss of agricultural lands increased deforestation for fuel and commercial purposes, encroachment of forest land for agriculture, construction, industrial purpose and mining are some of the activities of humans which led to scarcity and misuse of resources. Climate change poses major new challenges to biodiversity conservation. Today most grasslands and forests have been converted to agricultural land or urban center. It has become the centre of human activity, of mans dominance over the environment. Many plant and animal species are under threat due to habitat loss, over exploitation, intensive agriculture, introduction of exotic species, genetic modification, urbanization, pollution caused by Industrialization and tourism industry. Natural calamities like floods, droughts, famine, landslides, earthquake, tsunamis, cyclones, avalanches etc. also help anthropogenic factors in doing irreversible damage to the ecosystem. Biodiversity is the multitude forms of life within each ecosystem. These ecosystems are now at risk as a result of human developmental activities. There is growing concern among the scientific community regarding climate change and scientists have proved its occurrence through ample evidence and tested models (Pounds et al., 1999; Woodward, 2002; Klanderud and Birks, 2003; Chaudhari and Kamal, 2009; Crimmins et al., 2011). Biodiversity is essential for human survival and economic well being, as it regulates ecosystem function and stability (Singh, 2002; Sagar et al., 2003).

Due to anthropogenic activities habitat loss, climate change is now being recognized as one of the greatest threats to future biodiversity. Climate is one of the most important factors controlling the growth, abundance, survival and distribution of species as well as regulating natural ecosystems in a variety of ways (Faisal, 2008). The effect of climate change on the natural system may be diverse, such as change in the timing of phenological events of plants, changes in species abundance and range, shifts in habitat, etc. Today climate change is happening at an increasingly rapid rate. According to the prevailing extinction theory, the larger and more specialized species are likely to be lost due to habitat destruction (Sodhi et al., 2004). Under continuing climate change, tree species will be affected in different ways and ranges will adjust at different rates and by different process (Subedi, 2009). Levin and Levin (2002) have predicted that around the world, a species becomes extinct every 20 min. Although the extinction of various species is a natural phenomenon, the rate of extinction occurring in today's world is exceptional, 100 to 1000 times greater than normal. The exploitation of natural resources has been degraded at a very rapid speed causing serious threat to the environment. After two centuries of technological progress, we still fail to manage well our natural resources.

Climate is probably the most important determinant of vegetation patterns globally and has significant influence on the distribution, structure and ecology of forests (Kirschbaum et al., 1995). Several research articles have shown that climate changes bring down the changes in ecosystems and biodiversity. Climate change impact is resulted in changing the species composition, productivity and biodiversity. These changes ultimately affect the livelihood of tribal people who are dependent on the forest resources for their livelihood (Gitay et al., 2002). India is a mega-biodiversity country where forests account for about 20% (64 million ha) of the geographical area. (12 State of Forest Report 2001, Forest Survey of India, Ministry of Environment and Forests, Dehra Dun). It is a fact that natural forests are progressively shrinking due to overexploitation and makes it obligatory to investigate scientifically. Over-mining, grazing and forest fires have damaged our environment. They have degraded our surrounding to the extent of driving many flora and fauna species to extinction and threatening, the survival of thousands of others. Deforestation, mainly conversion of forests to agricultural land, continues at an alarmingly high rate. Yet currently, we are losing an estimated 200 km of forests a day. The rates of deforestation and of forest degradation are therefore crucial to better understanding and address recent trends in the status of forest biological diversity. No comparable information is currently available on the rate of forest degradation or the area of degraded forest. However, information does exist on some elements of forest degradation notably the area of forest adversely affected by mining, over grazing and forest fire.

Yerramalais forest consists of 75% weathered rocks and remaining 25% forest is green and are scattered, not in continuous range. Yerramalais forest covers over 1 lakh of the 4 laks hectares of forest in Kurnool district. Yerramalais receives very low rainfall and they come under the Sothern thorn forest. The vegetation is varied depending upon the climate and edaphic factors. Apparently there are signs of forest becoming degraded from moist deciduous and to scrub type dominated by thorny succulent and xerophytic bushes. Some parts of the forest shows valleys with streams. In Owk, Maddilete, Racherla, North Dhone, Gani and Lanjabanda forest shows slightly degraded deciduous type of vegetation. Deciduous trees met within this region are showing gradual degradation towards disappearance. Factors and underlying causes of the processes deforestation and forest degradation are over mining in PanyamRF, N. Dhone for Bethamcherla slabs, slab kankar. Iron ore mines at Ramallkota RF, Cement factory at Cement nagar RF divisions are some the causes for the degradation of the forest.

Figure 1. Yerramalais forest.

MATERIALS AND METHODS

Study area

The present study was carried out on a different parts of the Yerramalais forest of Kurnool district. Exploration trips were carried out at various places in the forest and recoded the distribution of flora of PanyamRF, BethamchrlaRF and VeldurthyRF; Kurnool district is present in Andhra Pradesh, situated between eastern longitudes of 76 58' - 78 56' and northern latitudes of 14 54; -16 14'. Yerramalais scarcely exceed at any point 606 min height. Yerramalais composed of archaean rocks. The oldest rocks exposed in the study area are metamorphic rocks and comprise of minerals such as auartzites, phylites, schists and amphibiolites. These rocks have been highly folded and intruded into granites and are found exposed in Adoni, Aalur and Pattikonda taluks and western parts of Kurnool and Done taluks. The Cemetnagar RF area possesses deposits of limestones suitable for cement manufacture. It has extensive deposits of constructive material such as granites, dolomites, slates, quartzites etc. Kurnool system is predominantly calcarius with limestone and clacarious shells which are exposed mostly in Banganaplli, Dhone and Koilakuntal taluks. These forests are inhabited by nomadic tribal group called Sugali tribes (Krishna Reddy, 2003).

The climate is characterized by hot summer. The year is divided into four seasons. The period from December to February is dry and comparatively cool season. The summer season is from March to May and it is followed by South West monsoons from June to September, while October and November form the post monsoon season. Generally, mean daily average temperatures are 0 above 73.5°C. Mean daily maximum temperatures are highest in May (48.4°C) and lowest in December 3°C. Like wise, the mean daily minimum temperatures are lowest in December and highest in May. Similarly humidity varies and it is lower in the months from December and January, but seldom drops below 50%. The forest area receives rainfall of 591.6 mm during the South West monsoon and the remaining rainfall was received mostly during the North East monsoon. The monsoon is also erratic apart from being mostly below normal during the South West monsoon, the area is considered drought prone. The relative humidity varies between 27 and 55%. The major disturbances to these forests were from human activities.

Forest - vegetation

Almost all plain near villages are brought under plough, leaving only hill slopes and forests. The local populations depend on these forests for their needs of fuel, timber, fodder etc. The forests are degraded and even reserve forests are generally devoid of any trees of great height and Qirth. The forests in the study area are classified into 5 types on the basis of their regulation: (a) superior dry mixed deciduous type (b) inferior dry mixed deciduous (c) Hardwickia binate type (d) thorny scrub and (e) bamboo type (Venkataraju and Pullaiah, 1995).

RESULTS

The transitions are forecast to be a collection of different types of changes; the most common being transitions from forest ecosystems to more shrub-dominated vegetation. Due to drastic climate changes most of the Yerramalais forest (Figure 1) shows scrub type of forest dominated by thorny succulent and xerophytic bushes. Plants like *Alangium salvifolium.Albizia amara*, *Atalantia monophylla Balanities aegyptiaca, Chloroxylon swietenia* and *Zizyphus mauritiana* occupy scrub forest. Plants like *Acacia leucopholea, Cadaba fruticosa, Corchorus olitorius*. *Capparis sepiaria* and *Zizyphus xlopyrus* occupy middle storey. The undergrowth consists of *Alysicarpus scariosus, Caralluma adecendens, Corchorus olitorius* and *Hibiscus ovalifolius* (Gamble, 1956).

In some parts, it shows dry deciduous forest with plants like *Cassia fistula* (6), *Dalbergia lanceolaria, Diospyros chlroroxylon, Grewia damine* and *Anisomeles malabarica.*

Main causes

1. Biotic interference and forest fires, grazing, and firewood are some of the factors, responsible for the degradation of flora of Yerramalais forest of Kurnool district.
2. Indian farmer's poverty and illiteracy obliges them to clear more heritable lands in order to enable them to buy the inputs that would allow them to produce more or less land.
3. Over mining for minerals and metals from earth is another cause for climate change affecting the forest. Mining is a money making business. Not only do mining companies prosper, but governments also make money from revenues. Workers also receive income and benefits; mining at Dhone RF for minerals, mining at Bethamcherla RF for natural stones such as sandstone slabs, limestone tiles, marble, granite, flooring slate stone, cobbles, landscaping pebbles, mosaic patterns, and stone garden decorative items flooring slabs. Manganese, tantalum, cassiterite, copper, tin, nickel, bauxite (aluminum ore), iron ore cleared. As a result, after few years the entire land becomes barren and not fit for growing any trees nor food crops. Large scale mining operations are done by using huge bull-dozers and excavators to extract the metals and minerals from the soil. In order to amalgamate (cluster) the extractions, they use chemicals such as cyanide, mercury, or methyl mercury. These chemicals go through tailings (pipes) and are often discharged into streams. This pollution contaminates all living organisms within the body of water and ultimately the people who depend on the fish for their main.
4. **Excessive use of firewood:** As a primary source of energy for domestic purposes, is leading to severe deforestation. Firewood consumption is a pattern of the tribal communities of Yerramalais forest. The fuel wood is burnt for various activities such as cooking, water heating, lighting and livestock rearing, etc. Among various activeties, cooking required maximum energy. Commercial fuel is beyond the reach of the tribal com-munities due to their poor socio-economic conditions.
5. Cement factories: Due establishment of Cement factories like Panayam Cement factory in PanyamRF, Priya cement factory in DhoneRF (Figure 2).
6. Soil erosion: The replacement of a forest cover for red soil area for cash is a direct and visible factor, as for example the opening of a road (public or for forest logging) in a forest zone, which, in addition to being a direct factor of relatively small significance (eliminating a strip of forest along the road) attracts farmers in search of land who will clear the forest for cultivation. With regard to the area cleared by these farmers, should one attribute deforestation to the direct factor, to the indirect factor, or to both? In our view, we must always consider the direct factor either as the only one or as one of the two factors, but under no circumstances can we consider the indirect factor as the only one.
7. D**eforestation**: This involves a decrease in the area covered by forest. However, it cannot be so defined without adding a reference to its use (or allocation). In point of fact, there exist certain forms of forest utilization - and priority objectives of forest management - that clear temporarily the forest cover while guaranteeing its maintenance.
8. Tribal people: The semi-nomadic tribal people Sugalis who live in the forest area are called Thandas have slightly affected the vegetation due to shifting cultivation. Usually the tribals cut trees adjacent to their existing agricultural lands in order to increase the extent of cultivable land. Encourage by some political members tribals keep on encroaching the nearby forest in the hope that they will be given rights on the land eventually.
9. Temperature and Rainfall: Yerramalais forest receives lowest rainfall and the temperature goes up to 46°C it the main reason for degradation of forest.

Main impacts

The main impact focuses on:

1. Water resources: Perhaps the most significant impact of a mining is its effects on water quality and availability of water resources within the project area. Surface and groundwater supplies will remain unfit for human consumption. Mining operations mobilize large amounts of material, and waste piles containing small size particles are easily dispersed by the wind. Particulate matter transported by the wind as a result of excavations, blasting, transportation of materials, wind erosion and nearby fertile lands becoming sterile and barren.

Mining can contaminate soils over a large area. Agricultural activities near a mining project may be particularly affected. Mobile sources of air pollutants include heavy vehicles used in excavation operations, cars that transport personnel at the mining site, and trucks that transport mining materials. Noise pollution associated with mining may include noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, power generation, and other sources. When mining activities are not adequately managed, the result is degraded soils, water, biodiversity, and forest resources, which are critical to the subsistence of local people. When contamination is not controlled, the cost of the contamination is transferred to other economic activities, such as agriculture and fishing.
2. Loss of biodiversity: The forests that are cleared for mining purpose are home to a large number of micro and macro flora and fauna. Indiscriminate and unplanned clearing of the forest leads to loss of home for thousands of animals this make the survival of large number of plant species to be at stake. The cutting down of trees in itself

Figure 2. Cement factoy.

is a big threat to a number of plants, trees, birds and animals that dwell in the forests. Various studies have noted that a number of bird, tree, scrub and herb species have migrated. Deciduous trees met in this region are showing gradual degradation towards disappearance. The undergrowth consists of grass of good fodder value. The thorny scrub types of forests are generally found in the bordering villages. These forests have become so depleted of their stock due to over grazing and illicit felling of trees that they consists of an open type of thorn forest.

DISCUSSION

The degradation of forest lands caused by deforestation or overexploitation that voluntary national policies aiming at the regeneration of forest lands were implemented in a generally authoritative manner, following a more or less rapid phase of decline. The industrialized and emerging countries are presently in a phase of forest restoration, unlike the developing world, which is generally in a deforestation phase. In all countries, the decisions to be taken with regard to the occupation of forest lands and the utilization and management of forests require a good knowledge of the situation and the changes involved at all times and at the appropriate levels. This presupposes the development of human resources and the strengthening of the units responsible for forest inventory in each country, as well as at the international level. This activity should be perceived as a whole with all of its disciplines, including the most modern and appealing, such as remote sensing and geographic information systems, as well as the more classical and frequently neglected ones of forest measure and taxonomy. Cultural degradation also occurs in mining villages. Awareness has to be created in the students, the next generation of scientists, who will undoubtedly face new environmental challenges and have to fully understand that these challenges cannot be delt with alone.

The future of our environment lies in cooperation-cooperation between scientists, between disciplines and between countries; focusing on strengthening natural resources management such as aforestation, vehicle for regeneration of the depleted forest. School children should be given compulsory primary education so that they will not go into the forest for collection of fodder and fuel

wood. Gramasabha must play important role in the implementation and monitoring of schemes like Vana samrakhsana samithi. Serious efforts of the forest department, local bodies, may protect this diminishing forest; starting awareness campaign among youth in the forest so that they accept forest protection as a moral duty. Over grazing of animals should be avoided, stopping of uncontrolled fire setting. Apparently, there are signs of becoming degraded from moist deciduous to deciduous and to scrub jungles.

Preventive measures have to be taken like establishing a forum for the exchange of information on forest vegetation management techniques, methodology, and research through periodic meetings and other appropriate means. Cooperate with local, state, regional, and national agencies, both public and private, in the identification and solution of forest vegetation management needs. Promoting awareness by the public and concerned agencies on the need for forest vegetation management encourages research on forest vegetation management methods by both government and private agencies. Promoting uniformity and coordination of activities among agencies concerned with the regulatory aspects of forest vegetation management and symposiums have to be conducted where ecologist, social scientists, physicist, economist, community representatives should share their views and thoughts about conservation of forests. Successful implementation of environmental polices has to be legislated. We have to analyze the failures and success of polices implemented in the forest development and conservation throughout the developed countries. Strict planning and monitoring of our conservation efforts use satellite technology for conservation.

People biodiversity centers are established at rural level and grazing by animals may be prevented by providing subsidy from government to cultivate forage crops as an alternative. Tribals appointed by government on temporary basis as forest protection force will be made permanent for better protection. Vana Samrakshna Samithies (VSS) are to be constituted involving tribals and other villagers. In order to stop exploitation of timber yielding plants permission given by government to tribals and others for procuring honey, gum bamboo etc is an indirect conservational measure. Exploitation of medicinal plants by tribals and pharmaceutical companies through them should be stopped. Forest fires which destroy both flora and fauna should be prevented. It may damage temple property and hamper tourists also. To stop deforestation, gobar gas plants should be established by using agriculture and animal waste, and social forestry may be developed for domestic and agriculture purpose. Keeping in mind the threatened category of plants, entry should be prevented in protected areas of identified medicinal plants to avoid exploitation. Only the students and researchers may be allowed for study purpose. Hence, Yerramalis forest which is rich in floristic diversity, a treasure trove of rare, medicinal and economically potential plants can be maintained for the welfare of local farmers, villagers and for rural development by its conservation.

Conclusion

Conservation of biodiversity requires the foremost importance from the government at the centre as well as the state. Thus political will in terms of formulation of proper policies with specific focus on critical physio-graphic areas, adequate budgetary grants, formation of regulating, implementing and appetelate authority is necessary. Crime control Board, Forest guards and tough laws towards poachers and piracy need to be looked at. The recent initiatives of the government towards adopting a National Action Plan for Climate Change are a welcome step. Environmental Impact Assessement, use of public forums, setting up of new parks and sanctuary and creating a complete database are other The most impor-tant link to the role in conservation is to be played by our scientific intelligentsia areas which is being focused at by the central government. Environment and climatic implications of man developmental activities are posing an unsustainable pressure on the biodiversity of the region. Timely maneuvered step requires the proper estimation and compilation of the diversity database and moreover coordination on various fronts.

ACKNOWLEDGEMENTS

Authors are thankful to the Madam Azra Javeed saheba Secretary and Correspondent of Osmania College for her encouragement and permitting us to carry on this exploration work. I am also expressing my sincere thanks to the Forest Department who helped us in tracing out the tribal villages and accompanying in the forest. Author (K.B) grateful to the University Grants Commission (UGC) New Delhi for providing the financial assistance in the form of Minor research Project.2011.

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Vol. 6(3), pp. 217-221, March 2014
DOI: 10.5897/IJBC2011.146
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Birds of Srinagar City, Jammu and Kashmir, India

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Accepted 20 January, 2014

An avifaunal survey was carried out in Srinagar city of Jammu and Kashmir from November 2007 to December 2009 to assess the migratory status and local abundance of the birds. Line and point transect methods were used for sampling. A total of 54 species of birds were recorded. Of these 54 species, 25 species were residents, 17 species were summer visitors (summer migrants) and 12 species were winter visitors (winter migrants).

Key words: Srinagar, abundance, avifauna, migratory status, point transect.

INTRODUCTION

Birds form an important component of the ecosystem. They play useful role in the control of insect pests of agricultural crops, as predators of rodents, as scavengers and pollinating agents. But, this wildlife resource, like other resources, is being exploited at a greater pace. This overexploitation has endangered many species, various species have already become extinct and many more are losing their number at an alarming rate. Wildlife conservation takes precedence in world natural resource agenda; for conservation measures to be implemented, it becomes necessary to know the species diversity, type of the habitat they live in and local abundance of fauna of an ecosystem.

State level faunistic surveys have been carried out by Choudhary (2002), Sharma (2003), Ahmed (2004), Wani and Sahi (2005), Kumar and Sahi (2005, 2006), Kumar (2006) and Kotwal and Sahi (2007). These studies were carried in Jammu division of Jammu and Kashmir State. The workers who have contributed to database of aves of Kashmir division are Shah et al. (2000) and Dar and Dar (2009). The present study was carried out in Kashmir division of the Jammu and Kashmir state to know species diversity, habitat choice and abundance of the birds in the city, so that the conservation strategies may be devised for the area.

Study area

The study area lies between 34° 05' 24'' north latitude and 74° 47' 24'' east longitudes and at an altitude of 1730 m above sea level. Temperature of study area ranges between 37°C in June-July and -14°C in December-January.

Srinagar is the summer capital of Jammu and Kashmir State of India. Situated in the centre of Kashmir Valley, the city is known for its beauty all over the world. It has world famous Dal and Nageen lakes, and the Mughal gardens like Nishat Bagh, Shalimar Bagh, Cheshmashahi and Harwan. These gardens not only give picturesque look to Srinagar but also provide important habitat to the avifauna. Besides, the beautiful hills of Shankaracharya and Hari Parbat are situated on the eastern and western sides of Dal Lake, respectively.

The vegetation around Dal includes trees of *Populus nigra, Platenus orientatis*, *Salix babylonica*, *Salix wallichiana*, *Salix alba, Morus alba*, *Morus nigra*, *Cedrus deodara*, *Pinus wallichiana*, *Aesculus indica*, etc. There are almost no bushes or tall grasses like *Phragmetes* sp.

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Table 1. List of avifauna of Srinagar city together with their migratory status and abundance.

Zoological name	Common name	Migratory status	Abundance	Preferred habitat
Pycnonotus leucotes	White cheeked bulbul	Rst.	F	TH
Acredotheries tristis	Common myna	Rst.	C	TH
Columba livia	Rock pigeon	Rst.	C	TH
Curvus splendense	House crow	Rst.	C	TH
Corvus monedula	Eurasian jackdaw	Rst.	O	TH
Milvus migrans	Black kite	Rst.	C	TH
Myophonus caeruleus	Blue whistling thrush	Rst.	O	TH
Dicrurus macrocercus	Black drango	Rst.	O	TH
Parus major	Great tit	Rst.	F	TH
Passer domesticus	House sparrow	Rst.	F	TH
Tachybaptus ruficollis	Little grebe (Dabchick)	Rst.	F	AqH
Alcedo atthis	Common kingfisher	Rst.	O	SH
Halcyon smyrenensis	White throated kingfisher	Rst.	O	SH
Megaceryle lugubris	Crested kingfisher	Rst.	O	SH
Turdoides subrufus	Rufouse babbler	Rst.	F	TH
Dendrocopos himalayensis	Himalayan woodpecker	Rst.	F	TH
Dendrocopos atratus	Stripe breasted woodpecker	Rst.	O	TH
Dendrocopos macei	Fulvous breasted woodpecker	Rst.	O	TH
Actitis hypoleucos	Common sand piper	Rst.	O	SH
Ardea cinerea	Eastern grey heron	Rst.	O	SH
Ardeola grayii	Indian pond heron	Rst.	F	SH
Egretta garzetta	Little egret	Rst.	O	SH/ TH
Bubuicus ibus	Cattle egret	Rst.	O	SH/TH
Tyto alba	Indian barn owl	Rst.	R	TH
Gallinula chloropus	Common moorhen	Rst.	O	SH/AqH
Turdus unicolor	Tickell's thrush	SM.	R	TH
Ixobrychus minutes	Little bittern	SM	O	SH
Pericrocotus brevirostris	Indian short billed minivet	SM	R	TH
Lanius schah	Long tailed shrike	SM	R	TH
Cuculus canorus	Eurasian cuckoo	SM	O	TH
Eudynamus scolopacea	Asian koel	SM	O	TH
Apus apus	Common swift	SM	F	TH/SH
Delichon dasypus	Asian house martin	SM	F	TH/SH
Upupa epops	Eurasian hoopee	SM	O	TH
Psittacula krameri	Rose ringed paraket	SM	O	TH

for the nesting of birds in the lake in the city.

MATERIALS AND METHODS

The study area was surveyed for recording avifaunal diversity by applying line transect (Sales and Berkmuller, 1988) and point transect methods (Verner, 1985). The surveys were carried out from November, 2007 to December, 2009, daily during the morning (1-2 h) and evening (1-2 h) hours when the birds are more active. Besides, several irregular visits were also made during different hours of the day. Binoculars (12 x 50 Super Zenith) were used to record the observations in order to avoid any disturbance to the birds.

For the identification of bird species, coloured plates of Ali and Ripley (1974), Ali (1996), Grimmett et al. (1998) and Grewal et al. (2002) were used.

The birds reported were seperated into winter migrants/winter visitors, summer migrants/summer visitors and residents.

RESULTS AND DISCUSSION

A total of 54 species of birds were reported from the study area (Table 1). The migratory status of avifauna revealed that 25 species were residents, 17 species were summer migrants and 12 species were winter migrants. Thus, avifauna comprised of 46.3% residents, 31.5% summer visitors and 22.2% winter visitors. Similar studies carried

Table 1. Contd.

Psittacula himalayana	Slaty headed parakeet	SM	O	TH
Megalaima zeylanica	Brown headed barbet	SM	O	TH
Megalaima virens	Great barbet	SM	O	TH
Streptopelia chinensis	Spotted dove	SM	O	TH
Streptopelia senegalensis	Little brown dove	SM	O	TH
Oriolus oriolus	Golden oriole	SM	R	TH
Sturnus vulgaris	Common starling	SM	O	TH
Anas penelope	Eurasian wigeon	WM	O	AqH/SH
Marmaronetta angustirostris	Marbled duck	WM	O	AqH/SH
Anas strepera	Gadwall	WM	F	AqH/SH
Anas platyrhynchos	Mallard	WM	O	AqH/SH
Anas crecea	Common teal	WM	O	AqH/SH
Fulica atra	Coot	WM	C	AqH/SH
Anas clypeata	Northern shoveler	WM	O	AqH/SH
Rhodonessa rufina	Red crested pochard	WM	O	AqH/SH
Aythya farina	Common pochard	WM	O	AqH/SH
Aythya nyroca	Ferruginous pochard	WM	O	AqH/SH
Mergus merganser	Common merganser	WM	O	AqH/SH
Grus grus	Common crane	WM	R	SH/TH

C = Common, F = Frequent, O = Occasional, R = Rare, AqH = Aquatic habitat, SH = Shore habitat, TH = Terrestrial, Rst = Resident, WM = Winter migrant, SM = Summer migrant: Terminology after Khan (2002). C = Common means it can invariably be seen in the habitat where it occurs with the provision that the season is also appropriate. F = Frequent means that even visiting appropriate habitat, it will not be seen or heard invariably, perhaps only in one visit out of three. O = Occasional means seen or heard only in one visit out of six. R = Rare means even less likelihood of occurrence. Besides this, depending upon whether the species of birds are sighted during all the months/seasons of the year or only during particular season/some months of year and absent during others from the study area, it was referred to as residents (Rst) or migrants (M), respectively. Migrant category was further differentiated into: SM = summer migrants, those which visit the study area during summers. WM = winter migrants, those that visit the study area during winters.

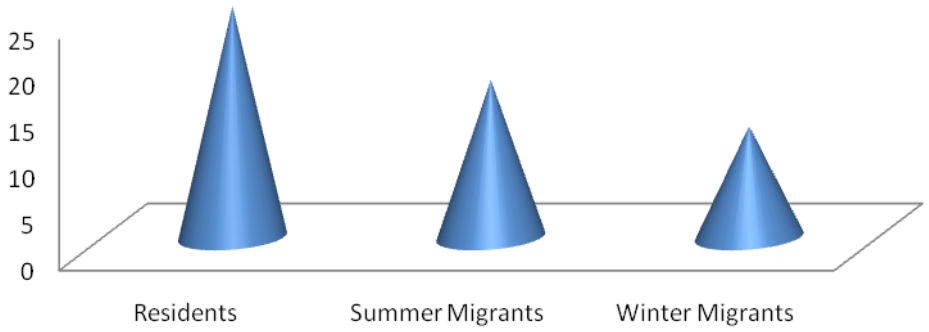

Figure 1. Migrant-resident status of avifauna of Srinagar city.

out by Sharma (2003) in Ramnagar wildlife sanctuary reported 70 species, Ahmed (2004) in Tehsil Doda recorded 45 species and Kotwal and Sahi (2007) reported 63 species of birds from Lake Manser. Out of total 63 species reported from Lake Manser (J & K), 50 species were residents, 11 species were winter migrants and two species were summer migrants (Figure 1).

Comparison with the works of Kumar (2005) and Kotwal and Sahi (2007), shows that number of summer migrants (17 species) in Srinagar is higher as compared to those in Jammu region (two species), but the number of winter migrants (12 species) is more or less the same at both places, however some of the species were different. This shows that the summer visitors are more in temperate regions.

Record of the preferred habitats was also made, and showed that the number of bird species living in terrestrial habitat was 29, in aquatic habitat was one and in shore

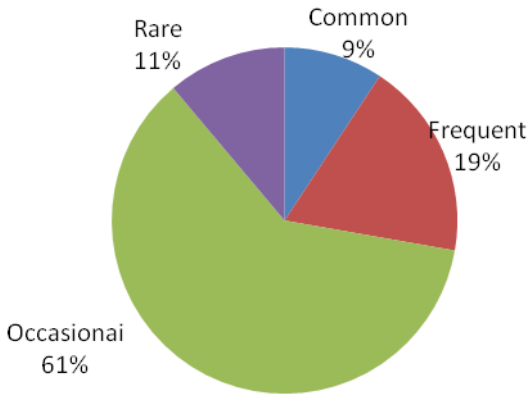

Figure 2. Pie chart showing abundance of bird species of Srinagar city.

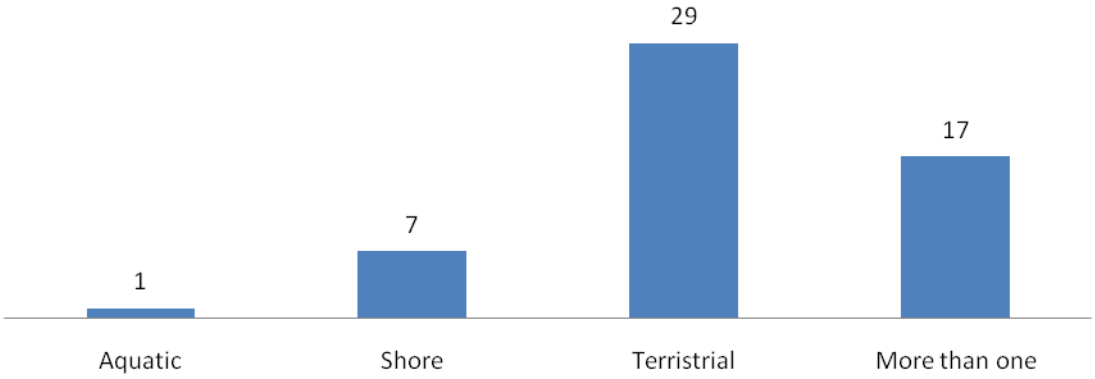

Figure 3. Number of species living in different habitats in Srinagar city.

habitat was seven species, whereas 17 species occupied more than one habitat. Thus, the number of species living in terrestrial habitat was more, which is in accordance with Kotwal and Sahi (2007) Figure 2 and Figure 3.

The study on abundance of bird species shows that five species were common, 10 species were frequent, 33 species were occasional and six species were rare. 72% of the avifauna was rare and occasional.

Thus, it is evident that most of the species are residents, terrestrial and occasional. The reasons for more numerous species in terrestrial habitat is that the terrestrial area of the city is larger than the aquatic habitat, the food items are abundant as compared to aquatic and shore habitats, and moreover, the human activities have degraded the aquatic habitat to a great extent. The study also shows that the Srinagar has good number of the species of birds, but most of the species are represented by very few individuals and the habitat needs proper care to raise the abundance of birds.

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academicJournals

Vol. 6(3), pp. 222-229, March 2014
DOI: 10.5897/IJBC2013.0670
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Farmers' dependency on forests for nutrients transfer to farmlands in mid-hills and high mountain regions in Nepal (case studies in Hemja, Kaski, Lete and Kunjo, Mustang district)

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Accepted February 12, 2014

The study assessed NPK (Nitrogen, Phosphorus, Potassium) transferred through litter from forest to farmlands, forest product extraction systems and farmers' perceptions on forest dependency for maintaining farm fertility in Lete and Kunjo, Mustang (high mountain) and Tibrekot, Kaski (mid-hill region), Nepal. NPK in composite samples of forest litter were determined by standard methods. Questionnaire survey of randomly selected households (HH) (25% of 138 in Mustang and 14.15% of 212 HHs in Kaski), key informant survey and field observations were conducted to solicit socio-economic and resource use information. In Lete, each HH collected 582 kg *Pinus wallichiana* needles, made compost and transferred 3.84, 0.54 and 2.99 kg N, P and K to 0.7965 ha whereas in Kunjo, each HH collected higher (2162 kg) which transferred 19.66, 1.84 and 10.39 kg respectively to 0.55 ha farmlands per year, indicating higher dependency of Kunjo farmers for maintaining soil fertility. Forest product extraction was regulated by a local Conservation Area Management Committee consisting of ward representatives and Mukhiyas. All HHs depended on forest for maintaining soil fertility with 85.29% totally depending on forest while 14.71% also used some chemical fertilizers. In Hemja, each HH collected 250 kg leaf litter of mainly Schima-Castonopsis and transferred 11.08, 1.26 and 5.86 kg of N, P and K respectively, and 612 kg grass, transferred 16.27, 2.22 and 11.42 kg respectively per year to farmlands (0.1538 ha upland- Bari and 0.2383 lowland- Khet per HH). The litter and grass collection was regulated by operational plan and constitution of Tibrekot Community Forest. In both regions, peoples' dependency on forest resources was decreasing (according to 73.5% HHs in Mustang and 60% in Kaski) because of change in lifestyle and decrease in dependency on agriculture and livestock. Detailed study regarding effects of removal of leaf litter/grass on the functional aspect of forest ecosystem in the Nepalese context is recommended.

Key words: Soil fertility, leaf litter, community forest, compost, forest resources, Bari land, Khet land.

INTRODUCTION

In the mid-hills of Nepal where the majority of the population (about 85%) is still dependent on agriculture (CBS, 2005), maintenance and improvement of soil fertility is a prime concern. Mountain farming is heavily

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dependent on forest resources, such as leaf litter, green manure, poles, fuelwood, fodder, and non-timber forest products (Mahat, 1987; Thapa and Weber, 1995; Kadaria, 1992). According to Denholm (1991), between 3.5 and 6 ha of forestland are required to support each ha of crop land whereas the relations of agricultural to forest land are quantified by area as 1:2.8 (Wyatt-Smith, 1982). For hill farming systems to be sustainable, it primarily requires a net transfer of fertility from the forest through fodder and leaf-litter to stall-fed animals. The forest and crop biomass flow into cropland in the forms of organic residues/manure, mulch, animal feed and bedding materials via livestock (Griffin et al., 1988; Gilmour, 1989; Yadav, 1992). About 50% of leaf litter is removed from the mid-hill forests annually for composting purposes. Forests contribute more than 50% of the total fodder supply (Kadaria, 1994). The litter used as bedding material for livestock, along with fodder fed to livestock, is a major pathway for the nutrient flow from forest to agricultural land (Pilbeam et al., 2000; Aase et al., 2009, 2013). Rural farmers collect these materials from nearby forests to prepare the farmyard manure, which is the only source of soil organic carbon (SOC) and nutrient replenishment for sustainable farm productivity. Changes in the forest conditions have effects on nutrient transfer to farms and these can have major implications on change in livelihood of the farmers living near the forests.

The declining availability of forest-produced fodder and leaf-litter means that nutrient levels and soil structure cannot be maintained. Given the present rate of soil and nutrient loss from the hills, the productivity of hilly agricultural land will continue to decline even if forests are restored (Upadhya, 1994). The soil fertility decline and resulting impact on production has been a major concern for sustaining agricultural production in the hills of Nepal (Schreier et al., 1995). Thus, in the high-pressure hill/mountain areas sustainable soil management is a critical issue because of deteriorating soil fertility and the consequent decline in crop productivity (Tulachan and Neupane, 1999). The forest resources are important to local livelihoods and therefore, a decrease in the supply of livestock feed and litter would decrease the production of farm yard manure (FYM), which might affect the fertility and productivity of agricultural land (Giri and Katzensteiner, 2013). Soil fertility decline is not well documented in Nepal, because it is attributed to a variety of other causes such as climatic variations, changing farming practices and soil erosion. This is a complex process and it occurs when the organic content and nutrient availability decline in the soil by nutrient leaching, oxidation during humification and over use of chemical fertilizer and pesticides.

In this respect, evaluation of soil fertility and productivity and management of available resources is required. Following the works initiated by Stoorvogel and Smaling (1990), many studies indicated that nutrient balances were negative in sub-Saharan Africa (Smaling et al., 1993; Brand and Pfund, 1998; Elias et al., 1998; Van den Bosch et al., 1998; Wortmann and Kaizzi, 1998). Truelsen and Lundsby (2001) found farm balance negative indicating a depletion of the farm nutrient stock in mid hills of Nepal.

Investigation on the contribution of forest types to sustainable livelihood of farmers is needed because the challenge lies in increasing the productivity of farms adjacent or closer to the forests, streamlining the benefits from forests towards livelihood promotion, particularly poverty alleviation (Kanel, 2004). The extraction of nutrients from the forests for farmlands is acknowledged by all but researches regarding the system of extraction, amount of nutrient being extracted, the type of products being extracted and the effect of nutrient extraction in forest are scanty. While there are attempts to document soil fertility decline, the amount of nutrient being extracted from forest for farmland is not well documented in Nepal; especially in high mountains and quantification of amount of nutrient being extracted by farmers for farm lands is rarely given much interest. Very few researches have been conducted on the amount of nutrient being extracted from the forest for the agricultural lands in mid hills and it is scarce to find documents regarding this in high mountains. Therefore, the study investigated and evaluated the contribution of forests in sustaining farm productivity through nutrient transfer in nearby farmers' fields and assessed farmers' perception on their dependence on forest litter at Lete and Kunjo, Mustang and Hemja, Kaski. This study is an effort to fill in the knowledge gap with regards to quantification of nutrients being extracted by farmers for farm lands and the system that they follow to do so.

MATERIALS AND METHODS

Study area

The study was carried out in Lete (Lete and Kalopani) and Kunjo (Chhyo, Kunjo and Taglung villge) village development committees (VDCs) of Mustang district, high mountain region and Tibrikot community forest, Hemja VDC in Kaski district, mid hills of western development region, Nepal. The study sites are shown in Figure 1.

The Mustang sites are quite representative in the context of the Himalayan and Trans-Himalayan region depicting similar natural resources and modes of subsistence (Rayamajhi, 2009). The latitude and longitude of Lete and Kalopani villages of Lete VDC are 28°38'09.1" N and 83°36'18.1" E and lie at 2513 m from mean sea level (msl). Kunjo VDC (Chhoyo, Kunjo and Taglung villages) is located east of Lete VDC between 28°38'01.5" N and 28°39'08.9" N latitude and longitude between 83°37'11.0" and 83°38 00.2" E at an altitude above 2400 m from msl.

The terrain is highly variable with grasslands in rugged steep mountain slopes, forests in mid-slopes and plateau, and cultivated river valleys. Being in a plateau and valley there is strong wind, frost and occasional snow cover. The climate is temperate to subalpine with yearly average temperature of 11.7°C (1976-1986) and monthly average temperature ranging between maximum 20°C in July and minimum -4°C in February; the average annual precipitation is 1267 mm (1970 -2006) and the rainfall peaks in June to September.

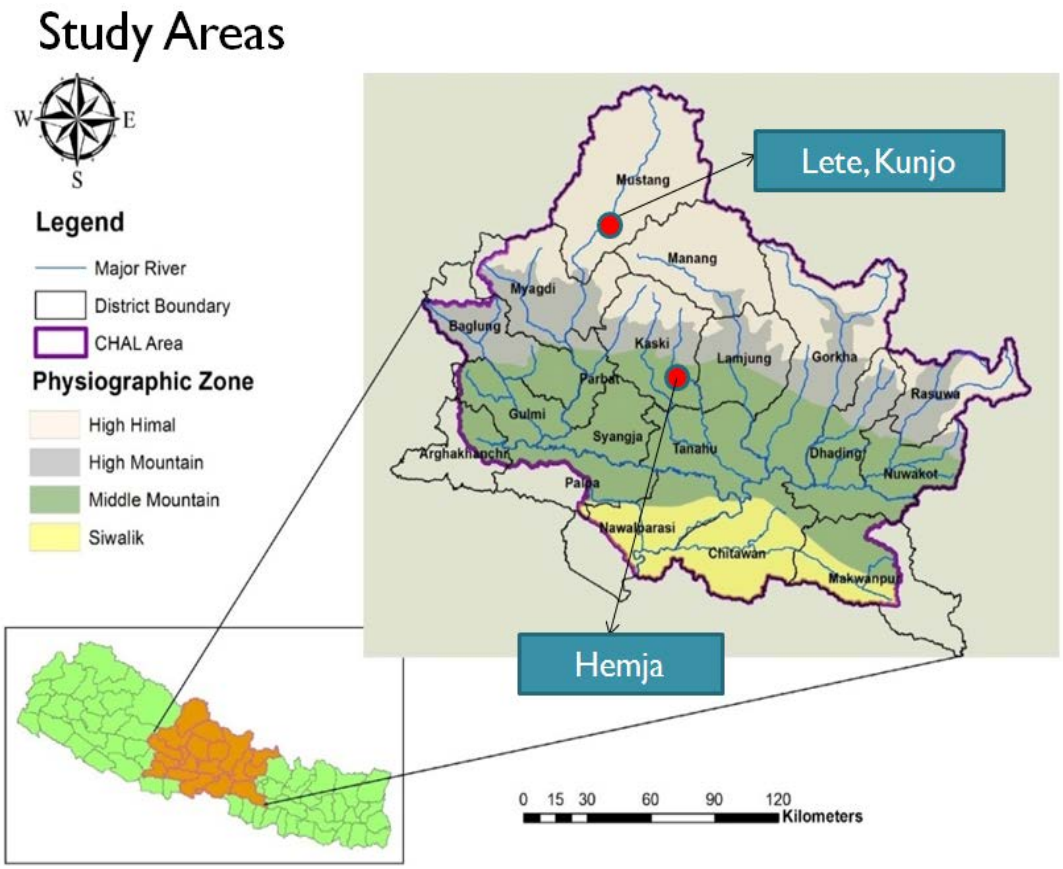

Figure 1. Location map of region showing study sites in Mustang and Kaski Districts (Modified after Gautam et al., 2012). Inset: Map of Nepal showing Narayani Basin (in brown color).

The forest is mostly temperate conifers with *Pinus wallichiana* as a dominant species and other genus like *Rhodendron, Cupressus, Juglans, Alnus, Taxus, Hippophae, Salix, Betula, Populus, Ougenia*, etc. Natural forest is the dominant land use covering about one third of the total area. Area suitable for agriculture is about 5% of the total area of which more than half is cropped and the rest is permanent fallow. Cropping and major crops grown are buckwheat, potato, naked wheat, etc. for a subsistence livelihood.

Lete covers an area of 50.8 km^2 consisting of 163 households (HHs). The total population of this VDC is 899 of which 481 are male and 418 are female. Kunjo covers an area of 75.7 km^2 consisting of 153 HHs. The total population of this VDC is 772 of which 421 are male and 351 are female. Rural but tourism based economy exists in Lete while rural subsistence economy exists in Kunjo.

Tibrekot community forest is situated in Hemja VDC 7, 8 and 9 in Kaski district. It is 13 km away from Milanchok (highway route) and is located at 28°16'53"N latitude and 83°55'50"E longitude. The average elevation of the site is 1000 m from msl. This forest was approved as a community forest on 17 August 2007. The total area of the forest is 119.75 ha located on the North-South aspect. The soil type is silty loam and silty clay loam. The forest is of mixed type consisting of Schima-Castonopsis with dominant tree species of *Schima wallichii* and *Castonopsis indica.* Other species found in the forest are *Myrica esculenta, Myrsie capitellata, Holarrhena pubescens, Engelhardia spicata, Rhododendron arboretum*, etc. The regeneration of forest is natural and its age is 40 years. The number of total households of the community forest is 212 with a population of 1139. Cropping and major crops grown are paddy, potato, maize, fruits, vegetables, millet, etc. as part of semi urban: commercial production livelihood. Grazing of livestock is controlled in the community forest.

Methods

Twenty percent of the households (n=70) were randomly selected from Kalopani and Lete villages of Lete whereas 30% of HHs (n=68) from Chhyo, Kunjo and Taglung villages of Kunjo for questionnaire survey.

In Hemja, 30 HHs out of 212 households constituting sampling intensity of 14.15% were randomly selected for the household survey. Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) tools like structured and semi-structured questionnaire, interviews, key informant survey, field observations, focused group discussion and small group meetings were also held. Key informants were selected from the people knowledgeable about the forest resources and the farm management activities. Direct observation was conducted for cross checking the information collected from household interview and other sources.

From the heap of pine leaf litter stored near the farmers' houses /livestock sheds, part of litter heap from top, bottom and middle were obtained and mixed to make a sample for analysis of nutrient content. Six of such samples of litter were collected; three from Lete and three from Kunjo. Since the litter was only of a single species (*P. wallichiana*) and the collection sites were similar in nature (climate, soil, altitude), six samples were enough for tissue analysis which is also supported by a research conducted by Mladenoff

et al. (2010) in which they took three samples from each individual species for tissue analysis. Similarly, six trays were used for litter and rainfall collection for *Pinus radiate* by Will (1959). For comparison of nutrient content (nitrogen- N, phosphorus- P and potassium- K) two samples of grasses (composite sample consisting of grasses commonly used, one from Lete and one from Kunjo) as well as one sample of fern (composite sample from both Lete and Kunjo) were also collected as it was also used as bedding material for animals and ultimately used as manure as well.

In Hemja, since the forest type was Schima-Castonopsis (*Schima walichii* and *Castonopsis indica*), the litter constituted of Schima-Castonopsis of which only three composite samples were taken. Likewise, three composite samples of grass were taken for determination of NPK. Leaf litter and grass samples were analyzed to determine the nutrients (NPK) by following standard methods (AOAC, 1990). Nitrogen was determined by semi-micro Kjeldahl method (Block Digestion). Phosphorus was determined by Modified Olson (%) direct observation taken by spectrophotometer CECIL CE7200. The potassium was determined by the flame photometer Sytronic 128.

The numbers of Bhari (head load) of litter collected by farmers were recorded while conducting questionnaire survey. The extraction of forest litter and associated nutrients for the replenishment of nutrients in farmlands were estimated from household use data collected through the questionnaire survey and average nutrient content in leaf litter samples for all sites and multiplied by percenttage dry matter to obtain the approximate amount of nutrient extracted from the forest per HH. This method was similar to that followed by Fiegl (1989) and Schmidt (1992).

RESULTS AND DISCUSSION

Socio-economic condition

In Lete and Kunjo, most of the respondents were Thakalis (44%) followed by Dalits (38%) and Magars (18%). Thakalis and Magars are ethnic communities whereas Dalits are disadvantaged community considered untouchables. The average HH size is 5.68 with minimum 3 and maximum 9 members. Respondents' ownership of bari-land is on an average 13.03 ropani with a minimum of 2 ropani and maximum 60 ropani area (20 ropani = 1 ha). The crops grown include beans, potato, maize, barley, millet, buckwheat, seasonal vegetables and some farmers also grow tomatoes and carrots in plastic green houses. Some people also planted rye grass, white clover, etc. Most people (28, 82.4%) reported some problems in crop production due to diseases and pests in crops, wild animals, lack of sufficient manure, etc. Almost all respondents (32, 94.1%) have livestock that included buffaloes (8), cattle (80), pigs (7), goats (138) and poultry (255). Problems in livestock farming included diseases, lack of proper feed, wild animals' attack, lack of medicine, veterinary service, etc. 61.8% respondents had their farm production sufficient for annual consumption.

Insufficiency of farm production for consumption throughout the year indicates subsistence living and poverty of people in that area. However, in recent times, there have been some changes in the occupations of the people. Rayamajhi (2009) and CAMOP (2010) state that more than 90% people follow agriculture as their main occupation. But only 58.8% respondents were found to still continue agriculture as their main and only occupa-tion. Hence, the agricultural lands are being left fallow.

In Hemja, the average family size was 5.21 with a minimum of three and maximum 11. The majority of the people were Brahmins/Chhetri (83%), followed by indigenous (14%) and Dalits (3%). Most of the people are dependent on agriculture (73%) followed by shops/business (10%), teaching (10%) and governmental service (7%) for their livelihood. 44% of HHs had food subsistence for 9 to 12 months, followed by 23% (3-6 months), 13% (6-9 months) and 13% (up to 3 months). The average land holding were 0.1538 ha upland-Bari and 0.2383 lowland-Khet per HH and the average number of livestock included 1.11 buffaloes, 1.32 cow/ox and goats 2.92.

Dependency on forests

Since most people had livestock with them and followed agriculture in Lete and Kunjo, farmers were dependent on forest in one way or the other. Most respondents (85.29%) did not use chemical fertilizers and used only compost or FYM as the main source of manure. The main reasons for using compost instead of chemical fertilizers were its easy availability, cost and negative impacts on soil qualities (such as hardening of soil, continuous requirement, etc). However, majority of respondents (73.5%) agreed that their dependency on forest and forest resources has decreased, had no change (17.6%) and increased (8.8%) as shown in Figure 2. People are mainly dependent on forest for fuelwood, litter (for manure) and grass (for livestock). However, dependency on fuelwood has decreased due to using alternative sources of energy (such as LP gas, solar, electricity). As a result of adopting other occupations, number of livestock has decreased thus, decreasing their dependency on forest for manure and grass.

In Hemja, the majority of the respondents (60%) as compared to 73.5% in Lete and Kunjo said that their dependency on the community forest resources has decreesed, followed by 20% constant, 13.33% increasing and 6.66% no response (Figure 2). Respondents perceived that the dependency decreased due to increasing population, decrease in livestock and agricultural land, and changing lifestyle of people.

Most of the respondents (40%) perceived that crop production has increased because farmers have adopted new technique of farming, application of chemical fertilizers, irrigation facility, modern seed and practices. However, 26.7% respondents perceived that due to the increasing occurrences of different diseases, lack of farming skills, irrigation problem and agricultural problem, the crop production decreases.

Forest products extraction system

The secondary information and information collected through key informant survey, focused group discussion

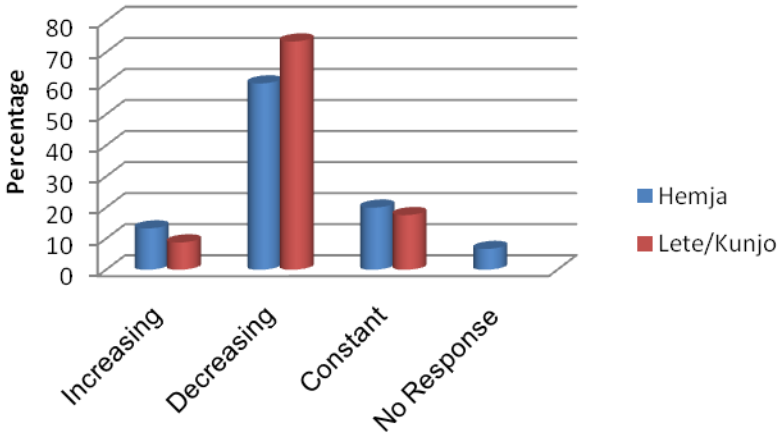

Figure 2. Peoples' perception on their dependency on forests in the study sites.

and small group meetings were used to know the details of forest products extraction systems. The management of the area is the responsibility of a non-political VDC Conservation Area Management Committees (CAMCs) in Lete and Kunjo. Each VDC level local government chairperson (sometimes secretary) is represented in the CAMC as a member for ensuring coordination. Each CAMC has a written constitution and operational plan for regulating the use of the forest and other natural resources. There are three subcommittees under CAMC main committee consisting of the village Mukhiyas (chief) as members. Both CAMC and Mukhiyas play important role in regulating and controlling extraction of forest products mainly leaf litter and seabuckthorn fruit. The Mukhiya system has been legally abolished in 1956 (2013 BS) after the dawn of democracy. But it is still largely accepted and practiced in the study area.

Period for collecting the *sanpat* (pine litter) from the forest is fixed for about a week during the winter generally after the first flush of snow. Leaf litter collection is allowed from mid-December (1st of Paush) during which a maximum of three persons from each HH are allowed to collect pine litter for only 5 days in Lete. In Kunjo, pine litter collection starts in late autumn or early winter but there is no time limitation. The forests are difficult to access and heavy snowfall starts shortly after the winter begins. Hence, the time for extraction is regulated naturally. Violators of collection period get strong punishment that is decided by the Mukhiya. The pine litter collected is stored in heaps near the houses and animal sheds.

In Hemja, the studied forest- Tibrikot community forest is controlled and regulated following its operational plan and constitution. Every user must obey the rules and regulations as prescribed in the operational plan and constitution. The condition of forest was good and it was revealed that the users strictly followed operational plan and constitution of the community forest. People were dependent on forest for fuelwood, grass, fodder and leaf litter collection. The forest is opened for 10 days in April-May during which users are allowed to collect leaf-litter; while grass collection is allowed twice a year for about 10 days, during May-June and July-August.

Nutrient content and transfer

In Lete, the amount of litter extracted was 23.28 bhari per HH (1 bhari = 25 kg), which was almost same (25 bhari) as mentioned in CAM operational plan (OP). In Kunjo, the average litter collected was 86.5 bhari per HH, which was comparatively lower than mentioned in CAMOP of 200 bhari. This might be due to the decreasing number of people involved in agriculture in Lete and Kunjo and increasing involvement of people from other villages in extracting more litter. Only 8.82% people collected small amount of fodder and grass from the forest to stall-feed their cattle during winter. Most of the respondents let their cattle in the forest during the monsoon season. Farmers collected on an average 85.29 mutha of grass from farmlands and wastelands per year (1 mutha = 5 kg).

The nutrient content of the pine leaf litter was in the range of 0.70 to 1.53% N, 0.086 to 0.138% P and 0.603 to 0.807% K. The nutrient content of grass samples and fern samples were higher than that of litter samples. However, grass and fern could not be stored for long and not found abundantly in all seasons. Fern was found to be used as bedding material. Grass was primarily used for feeding purposes rather than as bedding material. Hence, pine litter was the most suitable for making compost by mixing with animal dung and urine.

The average amounts of N, P and K extracted by each HH were 3.84, 2.99 and 0.54 kg corresponding to the transfer of 4.82, 0.62 and 3.75 kg per ha, respectively, through pine litter only in Lete. If all 70 HHs collected same quantity of litter, then about 268.8 N, 209.3 P and 37.8 kg K would be extracted per year in Lete (Figure 3).

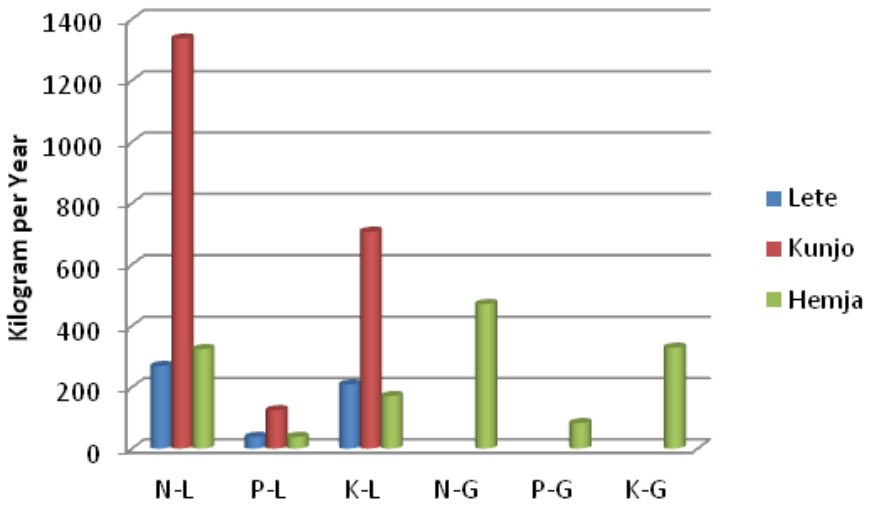

Figure 3. total npk extracted per year in the study sites. Note: N (nitrogen), P (phosphorus), K (potasium), L (leaf litter) and G (grass).

Table 1. Average forest litter and grass collection per household (Bhari/Year) in two eco-regions.

	Study Site	N	Mean	Std. deviation	Std. error mean	p- Value
Litter collected from forest in bhari per year	High mountain	34	54.9**	41.979	7.199	0.001
	Mid mountain	30	8.27	5.246	.958	
Grass collected from forest in bhari per year	High mountain	34	7.71	28.040	4.809	0.299
	Mid mountain	30	14.93	10.761	1.965	

Independent T- test; 1 bhari = 25 kg fresh biomass.

However, the average amount of N, P and K extracted by each HH were 19.66, 1.84 and 10.39 kg, respectively (35.75 N, 3.35 P and 18.89 kg K per ha) in Kunjo, which would translate to total quantity of about 1336.88 N, 125.12g P and 706.52 kg K extracted per year. The nutrient extracted per year in both study sites are shown in Figure 3.

In Hemja, the total amount of leaf-litter of Schima-Castonopsis and grass collected were 250 and 612 kg per HH per year, respectively. The average nutrient- N, P and K content in the leaf litter of Schima-Castonopsis species were 1.5, 0.177 and 0.797%, and in grass were 0.94, 0.167 and 0.66%, respectively. The average nutrients transferred from the forest to farmlands by each households through leaf litter were 1.53 N, 0.18 P and 0.81 kg K (28.26 N, 3.21 P and 14.95 kg K per ha and through grass were 2.22 N, O.39 P and 1.55 kg K (16.22 N, 2.22 P and 11.42 kg K per ha) which would translate to total quantity of about 324.4 N, 38.2 P and 171.7 kg K extracted per year through leaf litter and 470.6 N, 82.7 P and 328.6 kg K through grass (Figure 3).

Data collected from the HHs (Table 1) showed that the main source of plant nutrients in Lete and Kunjo (high mountain) was pine litter collected from the forest. The farmers in high mountain collected significantly higher amount of forest litter as a nutrient source (54.9 Bhari/yr/HH) as compared to Hemja (mid mountain). It means high mountain farmers are more dependent on forest for nutrients supply for crop production. However, there was no significant difference in collection of grasses between two regions. It is due to the dominant pine forest in the high mountain where grass does not grow well for collection to feed livestock.

The analysis of the pine litter collection in Lete and Kunjo in the high mountain region (Table 2) showed that Kunjo farmers collected significantly higher amount of pine litter as compared to the farmers in Lete. The lower amount of litter collected by the farmers in Lete is due to its location as the tourist trek area and local people depending on hotel business rather than farming as compared to Kunjo.

The nutrient content determined in pine litter samples was similar to the nutrient content mentioned by different researchers. Singh (2011) reported 1.14 N, 0.25 P and 0.22%

Table 2. Average pine litter collection per household (Bhari/year) in Lete and Kunjo.

	Studied VDCs	N	Mean	Standard deviation	Standard error mean	p-Value
Litter collected from forest in bhari per year	Lete	14	23.29	8.033	2.147	0.001
	Kunjo	20	86.50**	35.840	8.014	

Independent samples t- Test.

K content in pine litter in mid hills of Nepal. Roder (1990) reported 0.81 N, 0.05 P and 0.27% K content in *Pinus wallichiana* litter above 2500 m in Bhutan. Similarly, Siddiqui et al. (2000) found that nutrient contents in *Pinus* leaf litter above 2500 m were 1.585 ± 0.715% N, 0.785 ± 0.035% P and 0.57±0.23% K.

Large amounts of compost are produced from a mixture of livestock manure, forest leaf-litter and farm waste. Animal manure combined with large quantities of forest products collected for animal bedding and fodder accounts for a considerable proportion of nutrient supply to crops (Yadav, 1992). Khadka et al. (1984) reported that 50% of the litter is removed from the forests of the mid-hills annually for manuring purposes. Soil fertility under the traditional farming system has been maintained by repeated addition of various amounts of organic compost/ manure, ranging from 3 to 21 mt per ha per annum (Heuch, 1986). Animal fodder and leaf litter for compost production are in high demand and account for 31 kg N/ha and 53 kg bases/ha removed annually (Brown, 1997). Giri and Katzensteiner (2013) found that 39-40 kg N per ha was applied to arable land as FYM. The study findings show that N applications in Kunjo and Hemja through leaf litter are almost similar whereas in Lete, it is much lower. Farming activities, such as collection of forest fodder and litter for livestock feed, bedding, and the making of compost, which was eventually applied to Bari and Khet land as a nutrient source, are likely to have led to low soil organic carbon accumulation in the forest and the enrichment of Bari land (Tiwari et al., 2010). However, chemical fertilizer uses have increased by about 11.5 kg per ha annually in Nepal but, purchase of high priced chemical fertilizer is very difficult for marginal farmers of hills and mountains (NARMA, 2011). Therefore, it is suggested to use both organic and inorganic sources of plant nutrients for sustaining the productivity for a wide range of cropping patterns (Sherchan et al., 1999; Tripathi, 2001).

Conclusion

The farmers of Lete and Kunjo extracted on an average 582 and 2162.5 kg leaf litter (of *Pinus wallichiana*) as main source of composting material in their farm land after mixing with animal dung and urine. The amount of fodder and grass extracted in the study area was negligible. The amount of N, P and K extracted per HH per year was estimated at 3.84, 2.99 and 0.54 kg in Lete VDC (Lete and Kalopani) and 19.66, 1.84 and 10.39 kg in Kunjo VDC (Chhyo, Kunjo and Taglung). People of Kunjo depended more on agriculture and hence extracted more N, P and K from the forest. The extraction of forest products was regulated by the CAMC and Mukhyas of the study area. The farmers of the study area relied heavily upon forest resources for maintaining soil fertility of their farmlands. Due to difficult access, expensive price and observed negative impacts of chemical fertilizers, most respondents (85.29%) refrained from using chemical fertilizers and used compost or FYM only. 14.71% of the respondents only used chemical fertilizers in small quantities in addition to forest leaf litter to maintain the fertility of their land.

In Hemja, the total amount of leaf-litter of mainly Schima-Castonopsis and grass collected by each household were 250 and 612 kg per year, respectively. The leaf litter transferred the total amount of 1.53 N, 0.18 P and 0.81 kg K to farmland by each household and in the form of grass, 2.22 N, 0.39 P and 1.55 kg K. Peoples' dependency on forest was found to be in decreasing trend due to the changing lifestyle of people.

Realizing the importance of fodder, grass and leaf-litter in nutrients transformations, the information on flow of nutrients and their balance in farm-forest interface can be used for future management of forests and farming systems for their sustainable production. To what extent the amount of nutrients is being extracted, the removal of litter and wood/forest products on forest site productivity, nutrient balances, and other site characteristics affect the functional aspect of forest ecosystem which is still ambiguous and need a detail study in the Nepalese context. Significant improvement in soil fertility and thereby increasing the crop productivity can be achieved as the benefits of integrated nutrient management with the use of some amount of inorganic fertilizers to supplement part of plant nutrients required by various cropping systems and thereby fulfilling the nutrient gap.

ACKNOWLEDGEMENTS

The authors are thankful to all the farmers of Lete/Kunjo and Hemja for sparing their time and knowledge during questionnaire survey and discussions, ComForM Project IOF for the financial support to conduct the study and LIBIRD for analyzing the litter and grass samples.

Acknowledgement is also due to ComForM Project and Dean, IOF for providing travel support to the first author

for paper presentation in the 8th Himalayan Policy Research Conference, Madison, Wisconsin under the international conference participation.

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Vol. 6(3), pp. 230-237, March 2014
DOI: 10.5897/IJBC2013.0671
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Woodlands degradation in the Southern Highlands, Miombo of Tanzania: Implications on conservation and carbon stocks

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Accepted 5 February, 2014

Miombo woodlands is one of the major forest vegetation types covering about two thirds of the country forest land and form an integral part of the rural landscape in Tanzania, also they play crucial role in providing wide range of ecosystem services including carbon sequestration. This study aimed at assessing the effects of degradation on the structure and carbon stocks of miombo woodlands. Data were collected from 50 rectangular plots measuring 40×20 m. Stump diameter, diameter at breast height, tree height and species local and botanical names were recorded. Analysis was done by using R software and excel spread sheet. Results showed total harvesting of 10.53 m^3ha^{-1} as compared to standing volume of 32.6 ± 2.3 m^3ha^{-1} with basal area of 4.73 ± 0.5 m^2ha^{-1}. Estimated annual harvesting was found to be 6.63 ± 3.0 m^3 ha^{-1} which exceeds mean miombo annual increment of 4.35 m^3 ha^{-1} $year^{-1}$, this is indicator for unsustainable utilization which could results into woodland change. Harvesting resulted into total loss of 4.1±0.9 $tCha^{-1}$ equivalent to 15.05 ± 3.3 $tCO_2eha,^{-1}$ new harvesting presenting 9.91 tCO_2e ha^{-1} and old 5.14 tCO_2eha^{-1}. Managing the miombo woodlands carbon stocks for emissions and climate change mitigation in Tanzania and elsewhere requires rigorous effort to reduce anthropogenic degradation.

Key words: Carbon emissions, climate change, Miombo woodlands, degradation.

INTRODUCTION

Deforestation[1] and forest degradation[2] are estimated to account for about 20% of global anthropogenic CO_2 emissions through combustion of forest biomass and decomposition of remaining plant material and soil carbon (Van der Werf et al., 2009). Rate of deforestation and degradation has been significantly compounded by the need for land to be used for settlement, agriculture and energy (wood-fuel and charcoal), the development of infrastructure, particularly roads and the provision of water, are major contributing factors (Bond et al., 2010)

Tanzania has a total area of about 94.5 million ha out of which 88.6 million ha is covered by landmass and the rest is inland water. Forests in Tanzania cover about 34 million hectares making about 40% of total land. The total forest area can be divided into a number of different ecological forest types. According to the WWF ecoregion

[1] Deforestation involves the conversion of forested areas to non-forest land use such as arable land, rural settlements, urban use, logged area or wasteland.
[2] Degradation is considered as changes that take place in the forests or woodland which negatively affects its structure, function or both and thereby lower the capacity to supply products and or services.

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classification of Burgess and Clarke (2000), miombo woodlands is the dominant vegetation type covering about 95% of total forest area (MNRT, 2006). Rate of deforestation and degradation in Tanzania is estimated to be 403,000 ha/year equivalent to 1.13% (FAO, 2010). It is therefore logical to link the high rate of deforestation and degradation to be impacted on the miombo woodlands because of its wide distribution in the country.

Degraded forest, woodlands and secondary[3] forests cover significant areas in the tropics. In fact in most countries they now exceed areas covered by primary[4] forests (FAO, 2005). It is estimated that, during the 1990s, 16.1 million ha of forests was lost globally each year due to deforestation, of which 15.2 million ha was lost in the tropics (Achard et al., 2004; FAO, 2005). This corresponds to annual forest losses of 0.4% globally and 0.8% in the tropics. The root causes underlying these changes are complex combination of the interrelated factors that include population growth (Peacrce and Brown, 1994; Bawa and Dayanandan, 1997), economic growth and household resource consumption (Lui et al., 2003), poverty (Naughton et al., 2011) and land tenure insecurity (Gardner-Outlaw and Engelman, 1997). These trends of deforestation signify that a greater proportion of the world's primary forest will be replaced by secondary and degraded forests.

Miombo is a vernacular word that has been adopted by ecologists to describe those woodlands dominated by trees in the genera *Brachystegia, Julbernadia* and *Isoberlinia* (Leguminosae, sub-family Caeasalpinioideae) (Abdallah and Monela, 2007). They cover between 2.7 and 3.6 million km^2 in 11 countries in Africa although it is the dominant vegetation in the region it is by no means the only ecosystem, nor is it equally distributed across the 11 countries. To the rural poor, miombo woodlands are a valuable resource (Chidumayo, 1993). They provide an effective safety net in times of distress and stress. However, many urban residents also use a range of goods from the woodlands, such as fuel wood, charcoal, fruits and fungi and there is a steady flow of goods and services between rural and urban areas (Bond et al., 2010).

Despite the miombo woodlands wide coverage, focus on deforestation and degradation has tended to be on those major tropical forest and less substantial attention paid to the miombo woodlands where the per unit area of carbon stocks are lower than tropical forests (Bond et al., 2010). Climate change mitigation initiatives resulting from the United Nations Framework Convention on Climate change are now managing tropical woodlands to sequester carbon (Silver et al., 2004). Miombo are likely to have high potential for carbon storage and mitigation of carbon dioxide emissions due to its dominance (Grace et al., 2006, Williams et al., 2008) however they have been undergoing severe degradation due to various uses which results in carbon dioxide emissions. Tanzania being one of the nine pilot countries undertaking Reduced Emissions from Degradation and Deforestation (REDD+) initiatives is supposed to calculate its forest and woodlands area, rates of deforestation and degradation, which will act as baseline information of emission levels. This study was conducted in Chunya district, whereby about 4% of the total land is dominated by miombo woodlands which are major source of woodfuel in Mbeya region (URT, 1997). Increasingly need for woodfuel especially in township and agricultural expansion activities due to population increase has resulted in unsustainable utilization of dominating miombo ecosystems and carbon dioxide (Co_2) emission. Therefore, this paper aims at investigating extent of Co_2 emission resulting from extensive utilization of miombo woodlands by quantifying harvesting intensity from the stumps.

MATERIALS AND METHODS

Study sites

Chunya District is located in the North - Western part of Mbeya Region. The district is among seven (7) districts of Mbeya region and it is located at 8° 32' 07" S 33° 27' 37" E. The District is bordered by Singida and Tabora regions to the north; Iringa region and Mbarali districts to the East; Mbozi and Mbeya districts to the South; Rukwa region and Lake Rukwa to the West. It is the biggest district as compared to others in the region occupying a total area of 29,219,000 ha (46% area of Mbeya region). The land area is classified into different uses including arable land occupying 3,005,000 ha (78.73%), game reserves 2,000,000 ha (6.85%), forest reserves 396,400 ha (1.36%), water bodies 1,505,000 ha (3.78%) and the other uses 2,712,600 ha (9.28%) (URT, 1997). Predominant natural vegetation is miombo woodlands, with vast areas in Kwimba and Kipembawe Divisions. Data were collected in Manga reserve, in Chokaa Division (Figure 1), the reserve is domi-nated by miombo species *Brachystegi, Julbernadia* and *Isoberhinia* species (MFMP, 2008). It covers a total area of 9830 ha under community forest management (CBFM). According to Manga Forest Management Plan (2008), the forest is divided into utilization zone which is South of Mwashiwangu River with controlled utilization through the issuing of licences and conservation zone to the north of Mwashiwangu River. However, utilization pattern do not conform to agreed conditions (Chunya Socio Economic Profile, 1997).

Data collection

Forest inventory with systematic sampling design was used. The Number of plots were calculated after determination of study area variations whereby 50 plots were laid out. Rectangular plots of 40 × 20 m were used as they are more efficient in heterogeneous area as compared to circular plots (Goslee, 2006; Stohlgren, 1995). Within plots all trees with diameter at breast height (DBH) > = 5 cm, basal diameter of the stumps were measured. The minimum diameter was selected because smaller trees are not resistant to annual fires in miombo woodlands Kielland-Lund (1990b) as cited by Luoga et al. (2001). Other data collected include species name

[3] Primary forest refers to those forest occurring in areas which has never been invaded by human activities such as agriculture

[4] Secondary forests occurs in areas which has been under disturbance e.g. cleared for shifting cultivation

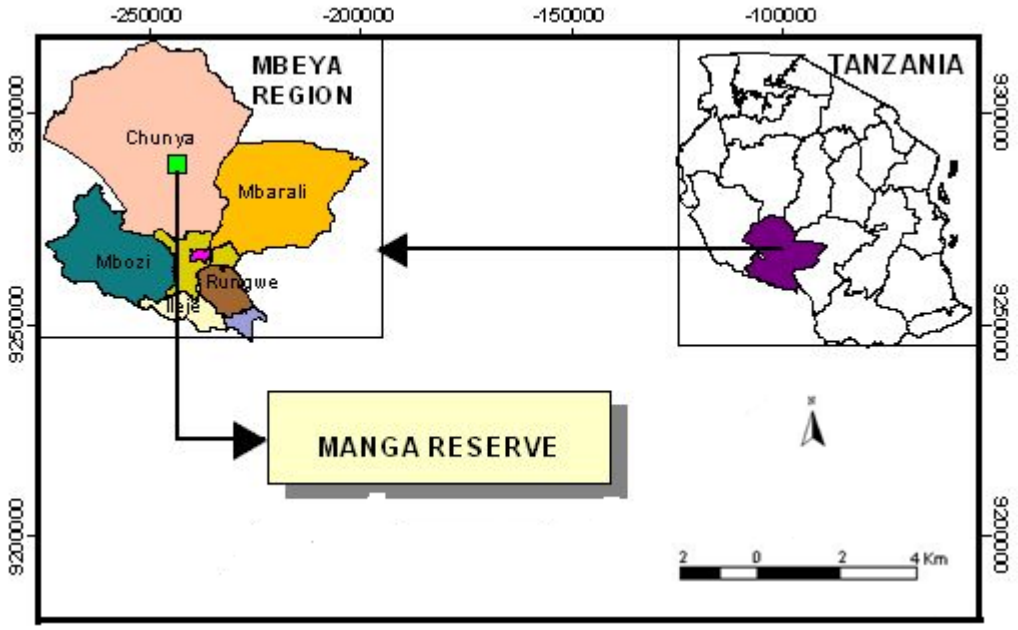

Figure 1. Map showing study site within Tanzania.

for all trees, shrubs and age of stumps since harvesting, which was decided to be either new or old. The distinction between old[5] and new[6] stumps was established by the colour and freshness of the exposed wood, the size of the sprouts/coppices and the presence of fire scorch on exposed wood. Identification of stumps age and naming was done with the aid of local elders well acquainted with ethnobotany and aspect of wood utilization. The criteria used for identification of the harvested species were coppice growth, wood and bark characteristics of the stump. Tree and shrub species were locally named by local botanist; botanical identification was made by matching local names with botanical names available in the literature. Three sample trees were measured from each plot (large, medium and small) which made a total of 150 trees from all plots. These trees were measured for stump diameter (bd), diameter at breast height (dbh) and total height (ht).

Data analysis

Tree volume for both removed and standing trees were calculated by multiplying tree basal area (g), height (h) and form factor (f) (Philips, 1994). The form factor of 0.5 for natural forest was used (Malimbwi and Mugasha, 2002). Biomass of the standing and removed trees were computed by multiplying tree volume with average wood basic density of 0.58 g/cm^3 (Malimbwi et al., 2000). Then tree carbon was obtained by multiplying biomass by 49% as a conversion factor for biomass to carbon (MacDicken, 1997). A factor of 3.67 tCo_2 per unit of C was used to convert obtained carbon to emissions (Zahabu, 2008). Diameter at breast height:

dbh = -1.77+0.924(bd), R^2 = 0.9628, p<0.0001

Height of removed trees was obtained by regressing height to basal diameter of sample trees, and the following equation was obtained:

ht=4.325+0.257(bd), R^2=0.64, p<0.0001

RESULTS

Structure of Manga Miombo woodland

The average stem density (N; d ≥ 5 cm) was 232 stems ha^{-1} with big variation between plots. The basal area (G) ranged from 2.4 to 7.9 m^2 ha^{-1} with average of 4.73 m^2 ha^{-1}. Stand volume averaged 32.6 m^3 ha^{-1}. Diameter distribution of the stand resemble those of uneven aged stand with a constant reduction towards larger classes (Table 1 and Figure 2). The following general were dominant, *Brachystegia spiciformis, Pericopsis angolensis, Pterocarpus angolensis, Rhus natalensis* and *Lapotea ovalifolia.* On the other hand, it was noted that middle class diameter estimates more volume and basal area.

Carbon storage and degradation in Miombo woodlands

Total above ground was estimated to be 10.6 t C ha^{-1} which was contributed by different species found in Manga reserve, however *Brachystegia spiciformis*, *Pterocarpus angolensis* and *Pericopsis angolensis* were found to contribute 60.3% of total above ground carbon and 39.7% contributed by remaining 24 species (Table

Old[5] Harvested before 2010
New[6] Harvested within 2010
(dbh) for removed trees was obtained by regressing dbh and stump diameter (bd) of sample trees, and the following equation was obtained:

Table 1. Stand characteristics of Miombo woodlands in Manga Reserve.

Parameter	
Basal Area (m^2/ha)	4.73 ±0.5
Stem density (stems ha^{-1})	232±13
Standing V (m^3 ha^{-1})	32.6±2.3
Above Ground Biomass (tha^{-1})	21.7±1.6
Above Ground Carbon (tha^{-1})	10.6±1.3

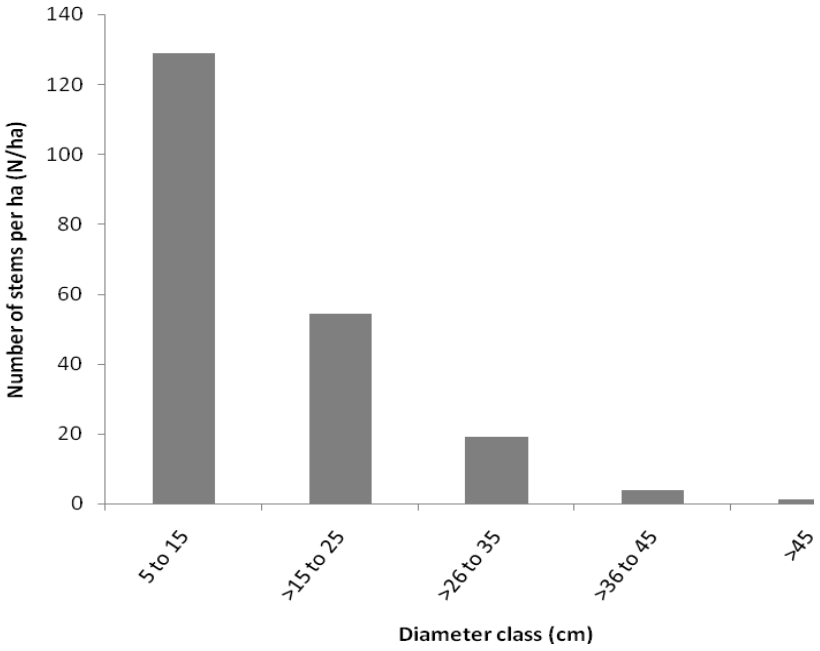

Figure 2. Number of stems distribution by diameter class in Manga reserve.

2). We estimated a total carbon loss of 4.1 $tCha^{-1}$ from 187 stumps of which majority were *B. spiciformis, Brachystegia boehmii* and *P. angolensis* contributing to 89.3% of total removal. The major activities contributing to wood removal were charcoal making (88.3%), timber harvesting (9.3%), poles, explosives and ropes (2.4%) (Tables 3 and 5).

DISCUSSION

Harvesting intensity

Tree removal represented a basal area of 1.53 ± 5.06 m^2 ha^{-1} and an average volume of 10.53 ± 3.1 m^3 ha^{-1}. Similar study conducted by Luoga et al. (2001) in Kitulangalo forest reserve, reported harvested volume of 7.1 ± 1.2m^3 ha^{-1} which is less as compared to results from this study; however he used bigger plot as compared to this study (Table 4). Majority of stumps were found to be new however it was noted that villagers uproot old stumps due to the easiness of uprooting as compared to new for agricultural land (shifting cultivation), this case is contrary to other studies whereby more stumps were recorded to be old (Luoga et al., 2001; Zahabu, 2008). On the other hand, it was observed that charcoal and timber were the major activities conducted in the forest contributing to 88.3 and 9.2% of total harvest respectively, other activities that were found to be practiced by villagers includes pole extraction, making explosives and ropes which fill the remaining percent. Luoga et al. (2001) reported from his study in Kitulangalo that only 0.5 and 54% of total harvesting was contributed by timber harvesting and charcoal, respectively. This shows that there is high demand for charcoal and timber in Mbeya town

Table 2. Biomass and carbon contribution by different species in Manga Forest Reserve, Tanzania.

Scientific name	Biomass (tha^{-1})	Carbon (tha^{-1})	Percentage (%)
Brachystegia spiciformis	7.786	3.893	36.3
Pterocarpus angolensis	3.846	1.923	17.9
Pericopsis angolensis	1.308	0.654	6.1
Rhus natalensis	1.184	0.592	5.5
Laportea ovalifolia	1.168	0.584	5.4
Crotularia grandibracteata	0.876	0.438	4.1
Pourtelia maprouneifolia	0.868	0.434	4
Ozoroa insignis	0.864	0.432	4
Brachystegia boehmii	0.824	0.412	3.8
Combretum molle	0.71	0.355	3.3
Pourtea adolfi	0.696	0.348	3.2
Vitex doniana	0.46	0.23	2.1

Only species contributed more than 2% biomass; carbon are shown.

Table 3. Uses of harvested wood and their proportional contributions (%) to overall harvesting intensity in Manga Reserve.

Purpose	Number of sampled stumps (Nha^{-1})	All Stumps (%)
Charcoal	165	88.3
Timber	17	9.2
Poles	3	1.6
Explosives	1	0.1
Ropes	1	0.4
Total	187	100

Table 4. Harvesting intensity (wood and carbon removals) in Manga Reserve, Chunya District Tanzania.

Stump age	Stems (Nha^{-1})	G (m^2ha^{-1})	V (m^3ha^{-1})	Biomass (tha^{-1})	Carbon (tha^{-1})
New Stumps	107 ± 8	0.98 ± 5.1	6.63 ± 3.0	5.55 ± 0.2	2.7 ± 0.2
Old Stumps	80 ± 6	0.55 ± 3.4	3.90 ± 2.0	2.85 ± 0.2	1.4 ± 0.1
Total	187 ± 9	1.53 ± 5.06	10.53 ± 3.1	8.4 ± 0.4	4.1± 0.90

Table 5. Major harvested species and their contribution to total carbon loss in Manga forest reserve.

Species name	Biomass (tha^{-1})	Carbon (tha^{-1})	Carbon (%)
Brachystegia spiciformis	4.76	2.38	70
Brachystegia boehmii	0.42	0.21	6.3
Pterocarpus angolensis	0.88	0.44	13
Other species	0.74	0.37	11

which poses pressure in nearby woodlands and forest. Estimated annual harvesting from this study exceeds reported mean annual increment (MAI) of miombo woodlands which is estimated to be 1.88-4.35 $m^3ha^{-1}year^{-1}$ (Ek, 1994; Malimbwi et al., 2005). Thus, the patterns of harvesting are definitely changing the structure and com-

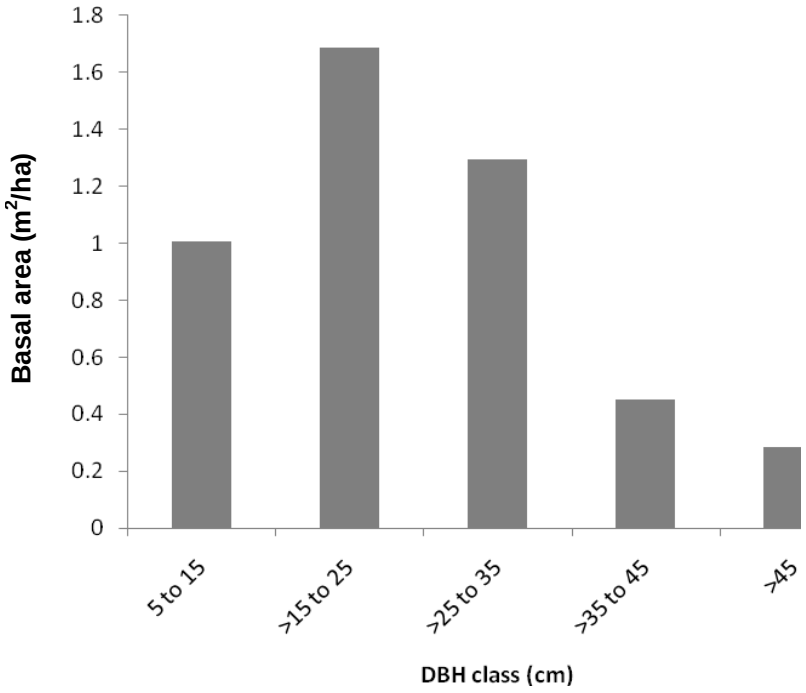

Figure 3. Basal area distribution by diameter classes in Manga forest reserve.

position of the vegetation substantially.

Woodland structure

Despite the miombo of Manga showing decrease in number of stems with increase in diameter (Figure 2) class which is normally expected in well stocked natural forest, this study recorded an average of 232 ± 13 stemsha^{-1} which is less as compared to reports from other study in miombo woodland. It has been reported that, stem density in miombo woodlands varies widely; however, it ranges from 380 to 1400 stems per hectare (Nduwamungu and Malimbwi, 1997; Mafupa, 2006; Mohamed, 2006). Malimbwi and Mugasha (2002) and Mohamed (2006) reported average number of stems per hector of 355 and 817, respectively in miombo woodlands of Handeni Hill forest reserve. Furthermore, this study reported mean basal area of 4.73 ± 0.5 m^2 ha^{-1} and mean volume of 32.6 ± 2.3 m^{3}ha^{-1} and their plotting against diameter class did not follow normal J shape which is expected in healthy natural forest (Figures 3 and 4). The values of total volume and basal area reported in this study are lower as compared by what has been reported by other studies in miombo which reports a range of 7 to 25 m^2 ha^{-1} (Nduwamungu and Malimbwi, 1997; Zahabu, 2001; Mafupa, 2006; Mohamed, 2006; Maliondo et al., 2005). The lower basal area in relation to miombo ecoregion reported in this study can be explained by variation in methodologies, however wood exploitation rate reported might have considerable impacts on standing parameters. It was also noted from this study that southern miombo have high potential for carbon storage and wood material supply if utilization would be sustainable, this is indicated by standing volume of 32.6 ± 2.3 m^{3}ha^{-1} despite heavy utilization for charcoal and timber which led to annual harvesting of 6.63 m^{3}ha^{-1}yr^{-1}.

Carbon stock and emissions

Study estimate average carbon density of 10.6 ± 1.3 tCha^{-1} which is relatively lower than carbon reported in similar studies by Munishi et al. (2010) and Zahabu (2008) who reported carbon density of 19.12 tCha^{-1} for un degraded miombo of southern Tanzania, 21.1 and 19.89 tCha^{-1} for miombo of Kitulangalo and Kimunyu Reserves in Eastern Tanzania, respectively. These differences in carbon densities might be due to varying degrees of exposure to human degradation, difference in age of the tree species and the type of miombo woodland involved (Shirima et al., 2011).

Woodland degradation emanating from human disturbances searching for their livelihoods in Manga reserve has resulted in a loss of 4.1 ± 0.9 t Cha^{-1} (equivalent to 15.05±3.3 tCO$_2$e ha^{-1}) new harvests presenting more loss of 9.91 tCO$_2$e ha^{-1} as compared to old harvesting 5.14 tCo$_2$ e ha^{-1}. Presence of many new stumps as compared to old stumps which were found to be uprooted by the locals in some areas for shifting cultivation, explains the estimated higher values of annual carbon loss and hence emissions. These removals are higher as compared to reports from other scholars in miombo woodlands of Tanzania. Zahabu (2008) recorded a biomass loss of 1

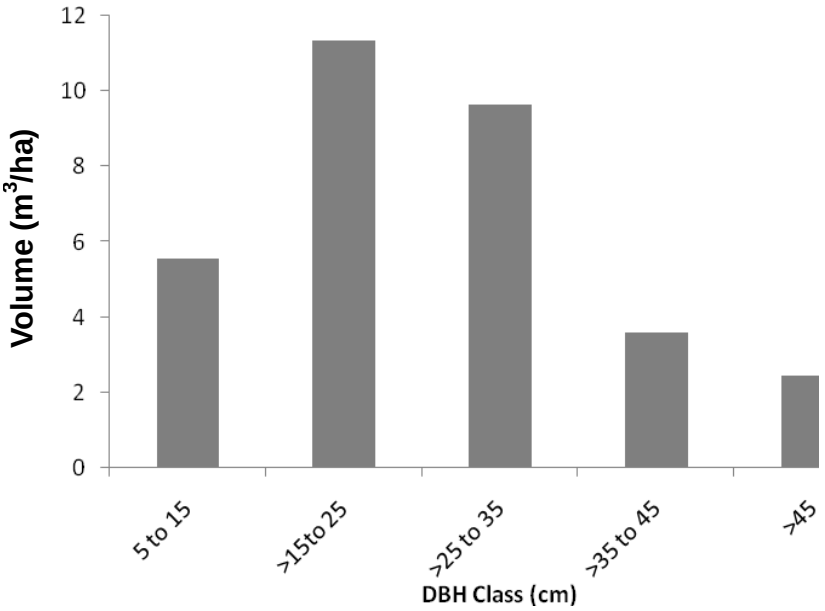

Figure 4. Volume distributions by diameter classes in Manga forest reserve.

and 3.5 t $ha^{-1}yr^{-1}$ equivalent to Co_2 emissions of 1.8 and 6.5t $ha^{-1}yr^{-1}$ for the woodland forests at Kitulangalo and the lowland and montane forests of Handei in Tanzania. Elsewhere in Miombo woodlands of Sofala province Central Mozambique, William et al. (2008) reported higher carbon take-off 0.26 $MtCha^{-1}year^{-1}$ estimated by inventory and remote sensing data. Godoy et al. (2011) estimated a carbon dioxide loss of 0.2 $MtCo_2yr^{-1}$ resulting from deforestation of Tanzania coastal forest for seven years period (2000-2007). Full potential of terrestrial ecosystems in carbon sequestration can only be realized through conservation. *B. spiciformis, P. angolensis* and *B. bohemii* (Table 5) which were found to be key species contributing to total carbon, however were also the most exploited for timber and charcoal, thus low above ground carbon.

Conclusion

This study has reported large levels of harvesting which not only results into high rates of carbon dioxide emissions, but also they are not parallel to what is recruited which suggest that the woodlands is exploited than its producing capacity, as the annual wood removal of 6.63 ± 3.0 m^3ha^{-1} exceeds the MAI of 4.35 $m^3ha^{-1}yr^{-1}$. Although, there is considerable volume in forests reserve, there is substantial utilization of key species which are potential for carbon sequestration as they constitute large part of the ecosystems, indicating that the reserve is not being effectively managed. This paper calls for appropriate management strategies to ensure sustainability of this ecosystem.

Apparently, there is tremendous capacity for the miombo ecosystem to store carbon and act as carbon sink if properly managed. Efforts to ensure proper mana-gement of the miombo ecosystem putting emphasis on important species e.g. *B. spiciformis*, *B. bohemii, P. angolensis* can contribute to creation of considerable car-bon sink as well as ensure persistent potential for the miombo woodland to store carbon as sinks rather than emissions sources thus contributing to the REDD+ pro-cess in Tanzania and global initiatives at large. Moreover, there is a need for further studies which will incorporate satellite images to estimate changes in forest canopy due to fire and agricultural farming observed in the study area.

ACKNOWLEDGEMENT

This study was funded by CCIAM programme in Tanzania jointly implemented by Norwegian government and Tanzania government.

Thanks to Mr Mwangoka from TFCG for his taxonomic expertise and assistance with plant identification in the field. We are also thankful to Mr Luguta for field assistance in Mapogoro Chunya.

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Vol. 6(3), pp. 238-246, March 2014
DOI: 10.5897/IJBC2012.134
ISSN 2141-243X © 2014 Academic Journals
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http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Regeneration potential and stand structure of a proposed plantation site in the transition zone of Ghana

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Receive 11 September, 2012; Accepted 20 February, 2014

A proposed timber plantation site (approximately 1,900 hectares) located in the forest-savanna transition zone of the Ashanti Region, Ghana was surveyed. The objectives of the study were (1) to analyze the present stand structure (2) and to assess the tree regeneration potential on the plantation site. The forest assessment used systematic sampling design which revealed an open and fire disturbed stand structure with an estimated average basal area per hectare (α = 0.05) of 9.89±1.94 m^2. The forest vegetation comprises of a single layer and features an average top height (α = 0.05) of 17.7 ± 0.8 m. The assessment of the tree species composition indicated a relatively homogeneous floristic composition with an average tree species number per sample plot of 10.0±1.0. A total of 65 tree species belonging to 48 genera and 25 families was recorded. Tree regeneration from seeds and resprouts recorded an average number per hectare (α = 0.05) of 3.884 ± 746 with a total of 38 species regenerating. The remnant forest vegetation is assumed to be in a regressive succession stage towards savanna vegetation. A conversion of the remnant forest vegetation to production forest seems to be possible, if the existing socio-economic pressure on the forest resources can be reduced and wildfires can be prevented.

Key words: Savanna, fire, forest regeneration, stand structure, Ghana.

INTRODUCTION

The sustainable management and conservation of remnant forest resources deserves ample attention at the local, regional and international level. Though the tropical forests are estimated to be the host of more than four-fifth of the world's biodiversity (FAO, 2001), the rate of deforestation in the tropics is alarmingly high with West Africa being the hardest hit by this trend (Schroeder et al., 2010). It is estimated that natural forests of the tropics will not be able to sustain increasing domestic and international demands for wood and its products (Tiarks et al., 1998). The establishment of timber plantations is inevitable to meet increasing demand of wood and its products including fire wood, pulpwood and saw logs (Brown et al., 1997). In addition, the establishment of timber plantations can reduce deforestation by decreasing pressures on natural forests, restore degraded soils and enhance biodiversity (Parrotta, 1992, 1995).

Practical and scientific work has been concentrated on sustainable management of mostly temperate and rather

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recently tropical forests. Some scientists have even identified the apparent failure to manage forests sustainably as one of the main concerns with regard to tropical forests destruction (Leslie, 1994). If this is true it can be anticipated that timber which originates from tropical forests will be harvested and marketed to a lower extent in future. Sustainable forest management is an approach that balances economic, social and ecological objectives. Essentially, the difficult task of achieving this goal lies in combining conservation with a potentially destructive use such as timber harvesting. The fact that tropical forests are ecologically the most complex terrestrial ecosystems is a major factor that accounts for the limited success in sustainable forest management. In addition, the socio-economic problems arising from the use of tropical forests for wood production is a contributing factor (Leslie, 1994). Lastly, the dependence of developing countries' economies on wood production greatly hampers the objectives of sustainable forest management.

In terms of protective functions, a requirement for the implementation of sustainable forest management is that existing forest resources, that is, forest area, growing stock, biodiversity of forest ecosystems- are not further degraded by human activities. This can only be accomplished if the pressure on forests of the user groups (forest dwellers, exploration firms, logging concessions) can be reduced. One option is the establishment of timber plantations. Sustainable plantation forestry can ensure the conservation of biodiversity, increase wood production and can produce further benefits. Timber plantations in the tropics consist almost always of one or very few tree species. Such stands are biologically not diverse and have a low ecological value. Experiences with the establishment and management of mixed tree species plantations are widely missing. A new approach towards ecological sound plantation forestry is the integration of existing natural tree vegetation into the plantation concept. This leads to the conservation of remnant forest areas which would have diminished otherwise (Brockerhoff et al., 2008). Such concepts for the implementation of sustainable plantation forestry are needed in the West African Region for the enhancement of economic development, conservation of biodiversity and improvement of rural livelihoods.

Since forests play a key role in the conservation of plant species and ecosystem management (Tilman, 1988; Ssegawa and Nkuutu, 2006) surveys of the floristic composition and stand structure studies are essential for addressing the diversity in forest ecosystems (WCMC, 1992; Addo-Fordjour et al., 2009). Ecological data obtained in this context are not only important for the introduction and application of sound management practices but, among others, are also useful in identifying important elements of tree diversity, protecting threatened and economic species and monitoring the state of forests (Tilman, 1988; Ssegawa and Nkuutu, 2006; Addo-Fordjour et al., 2009). The main objective of this study was to determine the stand structure of the proposed plantation site for the elaboration of a biological diverse forest plantation concept. The specific objectives were (1) Analysis of the present stand structure and (2) determination of the regeneration potential of present tree species on the plantation site.

Figure 1. Location of the Ejura plantation site and ecological zones in Ghana (Ackermann, 2007).

MATERIALS AND METHODS

Study area

The study was carried out on a privately owned proposed site for a Teak plantation 100 km north of Kumasi, in Ejura - Sekyedumase district of the Ashanti region. The area is located in the forest-savanna transition zone which is characterized by the co-existence of the two distinct ecosystems forest and savanna. The district is marked by two rainfall patterns; the bimodal pattern in the south and the unimodal in the north. The main rainy season is between April and November with annual rainfall varying between 1,200 and 1,500 mm. The plantation site (Figure 1) is approximately 17 km from the Ejura Township and is bordered to the north by two villages Nkrama and Bisiu, Boami to the south, while to the west it is fringed by the Awura forest reserve and to the east by the Afram River (Knoell, 2004). The soil types were classified according to WRB/USDA Soil Taxonomy as Albic Plinthosols/Typic Plinthustalf. The soil-texture consists predominantly of sandy loams. The soils are relatively shallow, encountering a hard ironstone pan at the petroferric contact at an average depth of 42 cm (Werner, 2008).

Sampling design

Long term research is intended for this plantation site, therefore

Table 1. Stem-form classes according to Synnott (1979).

Class	Description
A	Stem is straight in length, no apparent defects or major branches (diameter ≥5 cm) over the top length or the lower 7 m of the stem, suitable for high quality sawn timber and veneer
B	Stem is relatively straight in length, few apparent defects or major branches (diameter ≥5 cm) over the top length or the lower 7 m of the stem, suitable for sawn timber
C	Stem is formed irregularly with limitations of length and/or numerous or major apparent defects, commercially useless, recorded for botanical purposes

the systematic sampling method was used because the systematic distribution of sample plots is more efficient at detecting phenolmena such as variations in species composition and stand structure (Synnot, 1979). A total of 47 circular sample plots were laid on the plantation site. Each plot of 15 m radius (706.5 m^2) was set up on the field with the use of the ultra sonic measure device Vertex IV. Smaller circular sub-sample plots of 5 m radius (78.5 m^2) were established using the same centre point for the assessment of regenerating trees with a height < 1.30 m (seedlings and small saplings).

Tree species inventory and measurements

The sample plot measurements followed standard procedures as described by Synnot (1979). All trees (≥ 5.0cm diameter at breast height (1.3 m), DBH) were counted, tagged and identified to the species level by a botanist from the herbarium in Kumasi. Tree heights were assessed to the nearest decimeter by using a Suunto hypsometer. The DBH were measured with a diameter measure tape to the first decimal place. In case of stem-form anomalies at 1.3 m height, the diameter was determined by the mean of measurements above and below the irregularity. The botanical nomenclature in this paper follows Irvine (1961), Arbonnier (2004) and Hawthorne and Jongkind (2006). All tree regeneration with a height <1.30 m which occurred in the inner sub-sample plot were identified, counted and assigned to the three height classes; seedlings < 30 cm, small saplings 30 - 50 cm and big saplings 50 - 130 cm.

The stem-form of all trees with a height ≥ 1.30 m was assessed. A 3 point system relates the straightness of a stem to its utilization potential. For multi-stemmed trees the stem-form of the stem closest to the average DBH was recorded (Table 1).

For the assessment of reoccurring fires, every tree with a height ≥ 1.30 m was assessed for fire signs. A binary system was implemented consisting of two categories; visible fire signs on stem and/or lower branches and no visible fire signs on stem and/or lower branches.

Data analysis

The data on the abundance of tree species, number of trees and number of stems were scaled to number per hectare and represented graphically by the species/area curve. The top height which is the average height of the 100 tallest trees of the survey was calculated by dividing the sum of the maximum height per sample plot with the number of sample plots (Kramer and Akca, 1982). The basal area which is the cross-sectional area of all stems in a stand at 1.3 m height was calculated per hectare. The number of regenerating tree species was also scaled to the number per hectare. All data analysis was carried out with Microsoft Excel software.

RESULTS AND DISCUSSION

General findings

A total of 1,171 trees (with a height ≥ 1.30 m) were assessed in 47 sample plots of 3.3 hectares size. All recorded trees belong to 65 species, 48 genera and 23 families. The species/area curve is a measure for the floristic representativeness of a botanical survey. It indicates how many new species are found when a survey plots becomes enlarged. In our case, the curve performs a strong progression until 0.8 hectares, indicating that 50% of all tree species are represented in this size of the surveyed area (Figure 2). Later, the curve becomes flatter and is almost reaching an asymptote at 3.3 hectares. From this point onwards a further enlargement of the survey area would not increase the tree species spectrum. The trend of the species/area curve follows a natural logarithmic function ($R^2 = 0.95$). Lamprecht (1989) proposed that the minimum representing area has been reached, when the increase in the number of species per unit area remains below 10% while the sample plot is enlarged in size by 10%. In our case, this point was reached at 1.5 ha sampling area. Thus, the species/area curve proofs that an almost complete tree species survey was carried out.

Stand structure

The assessment of the surveyed forest vegetation revealed an average stem number per hectare ($\alpha = 0.05$) of 518 ± 88 trees and an average basal area per hectare ($\alpha = 0.05$) of 9.89 ± 1.94 m^2. Swaine and Whitmore (1988) stated a wide range of tree numbers (395–734 / ha ≥ 10 cm DBH) for natural tropical forests from three continents while for semi-deciduous forests in Venezuela Lamprecht (1989) recorded a range of 284-333 trees/ha. Hall and Swaine (1981) give reference to various forest types of Ghana. According to their findings tree numbers vary from 474 to 514 / ha (Table 2).

On a first view, our results seem to be comparable to the average stand parameters of Hall and Swaine. But their standard error was lower and their minimum diameter threshold was ≥ 10.0 cm whereas our tree numbers

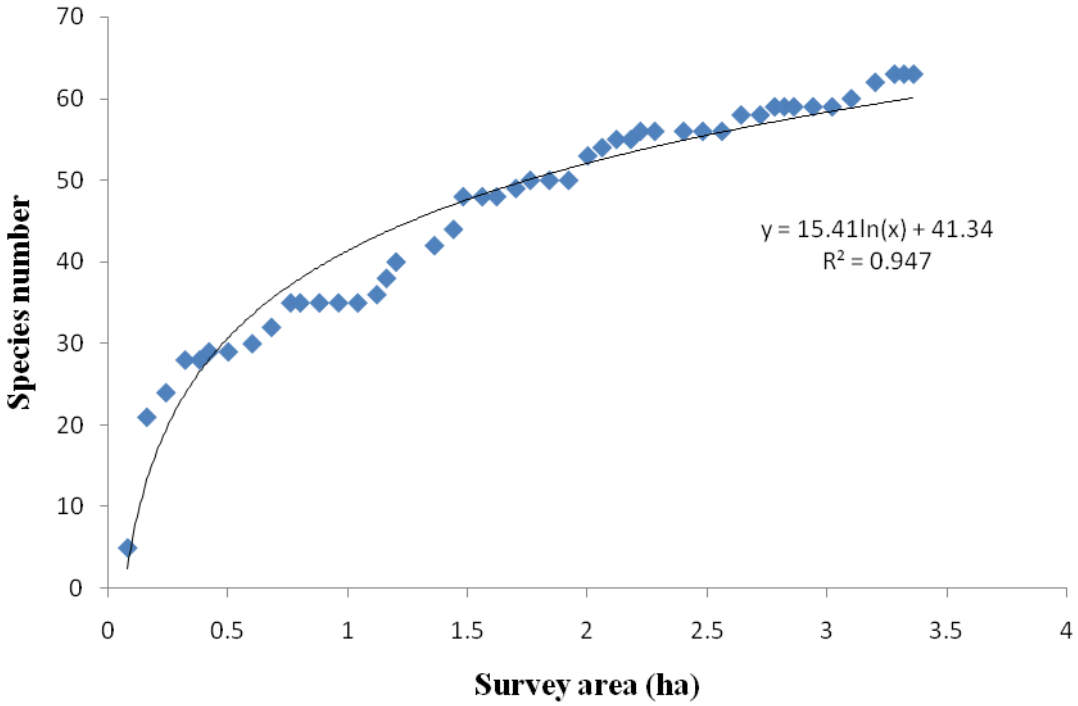

Figure 2. Species/area curve proofs that the surveyed area is representative of the floristic assessment of the tree species composition.

Table 2. Average stand parameters of Ghanaian forest types (Hall and Swaine, 1981).

Forest Type	Stem number (trees/ha)	Basal area (m^2/ha)
Moist semi-deciduous	514 ±29	24.3 ± 1.1
Dry semi-deciduous (inner zone subtype)	504 ± 32	24.2 ±1.1
Dry semi-deciduous (fire zone subtype)	474 ± 32	22.3± 1.2

refer to a diameter threshold of ≥ 5.0 cm. If we would have applied a ≥ 10.0 cm diameter threshold, the average tree number would have been reduced to only 168 ± 38 per hectare (α= 0.05) which accounts just for 35% of the category “Fire Zone Subtype” from Hall and Swaine. The tree numbers ranged from a minimum of 28 to a maximum of 481 trees/ha.

The average top height of the forest vegetation (α= 0.05) of this research site was determined as 17.7±0.8 m. The maximum height of 27.6 m was recorded for a specimen of *Daniellia oliveri*. Hall and Swaine (1981) mention an average top height of 49 m for moist semi-deciduous forest and 36 m for dry semi-deciduous forest. From this point of view, the top height of the assessed forest is very low as compared to the given literature values, which indicates that the forest vegetation might be severely degraded or belong to a different forest type.

The mean height of the forest vegetation (α= 0.05) is low with 6.8 ±1.4 m and differs widely from the average top height. The mean heights of the various sample plots range from 4.6 to 10.2 m. The large difference between the average top height and the mean height is due to the relatively high number of tree saplings (trees of DBH <10.0 cm), which contribute to the development of the single layer canopy structure of the forest vegetation. The low average values of the aforementioned stand parameters in combination with large differences between the maximum stand height (height of the tallest tree per sample plot) and the mean height per sample plot indicate disturbances of the stand structure of the forest vegetation. “Shifting cultivation” and fire are estimated to be among the major causes. During the field survey, large trees were observed to be often left standing, that is, due to their missing utilization potential or for cultural reasons (Lovett and Haq, 2000) or simply for lack of technical equipment to fell the trees while other parts of the vegetation were cleared. When the cultivated areas are abandoned, secondary forest vegetation develops, which consists of an early succession stage of numerous small trees (saplings) and a small number of “old”/large trees. In a later succession phase the secondary forest vegetation grows higher which results in a closer gap between

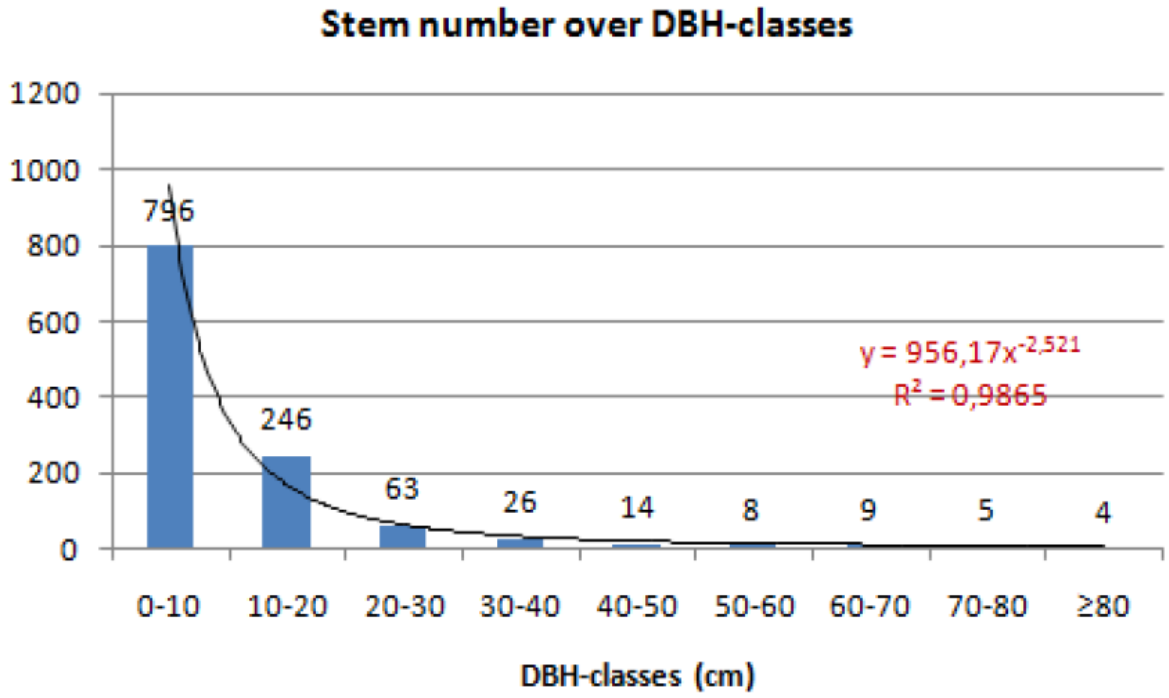

Figure 3. Distribution of stem number over DBH-classes illustrating the absence of thick diameter classes.

maximum height and mean height.

The diameter distribution shows a hyperboloid function (Figure 3) with the lower diameter classes containing more trees. The distribution of stem number over DBH-classes features an exponentially decreasing curve (R^2= 0.99) towards the larger DBH-classes. The trend is characteristic for natural forests regenerating from seeds (Lamprecht, 1989). Only 381 trees of the survey area (32.5% of surveyed trees) recorded a DBH ≥ 10.0 cm, while 796 trees (77.5% of surveyed trees) featured a DBH < 10.0 cm with an average DBH of 5.1 ±0.5 cm. Moist and dry semi-deciduous forests regenerating from seeds demonstrate exponentially decreasing distribution trends, but feature higher stem numbers in all DBH-classes (Lamprecht, 1989). Especially trees of the medium DBH-classes (30–60 cm) and higher DBH-classes (≥ 60 cm) are represented with extremely low stem numbers. Thus, the trend of the exponentially decreasing curve resembles a natural stand structure only in the lower diameter classes.

A further proof for severe disturbances of the forest vegetation is revealed when the distribution of the relative basal area - percentage of the total basal area – over DBH-classes is analyzed (Figure 4). The bimodal distribution shows a dominant peak for the DBH-classes, 10–30 cm and a minor peak for the DBH-class, 60–70 cm. Illegal wood harvest for charcoal production which has been reported from the site is assumed to have a drastic impact on the disappearance of trees of the medium DBH-classes (30–60 cm) since they are targeted for such operations and thereby severely reduce the average basal area per hectare. As a result the forest vegetation develops to an “over thinned” stand structure, that is, in terms of stem number and basal area per hectare. According to Pancel (1993) this phenomenon is also typical for “fire degenerated” forest vegetation. The open stand structure of the forest vegetation (Figure 5) in combination with the single layer canopy structure suggests that the majority of trees are pioneer species or tree species that are adapted to habitats of the savanna vegetation.

Wildfires belong to the natural site condition in the transition zone of West Africa. But today their frequency is by far higher than under natural conditions. Gautier and Spichiger (2004) even assume that “almost all fires are currently of anthropogenic origin” in West Africa. On our research site, 83% of all trees were visibly affected by fire. Beyond wildfires shortened fallow cycles under shifting cultivation and increased population pressure have further reduced the vitality of the forest vegetation and have a determining influence on the structure and the current tree species composition (Bongers et al., 2004). The majority of the trees show a crooked and/or low branching habitus, typical for fire disturbed forest vegetation (Lamprecht, 1989). Only 1% of the surveyed trees are classified as potential crop trees and can potentially be utilized for sawn timber production (feature a relatively straight stem form with minor defects) (Table 2), while 99% of the surveyed trees are classified as non-potential crop trees for sawn timber. Thus, the surveyed forest vegetation features characteristic traits of fire climax vegetation.

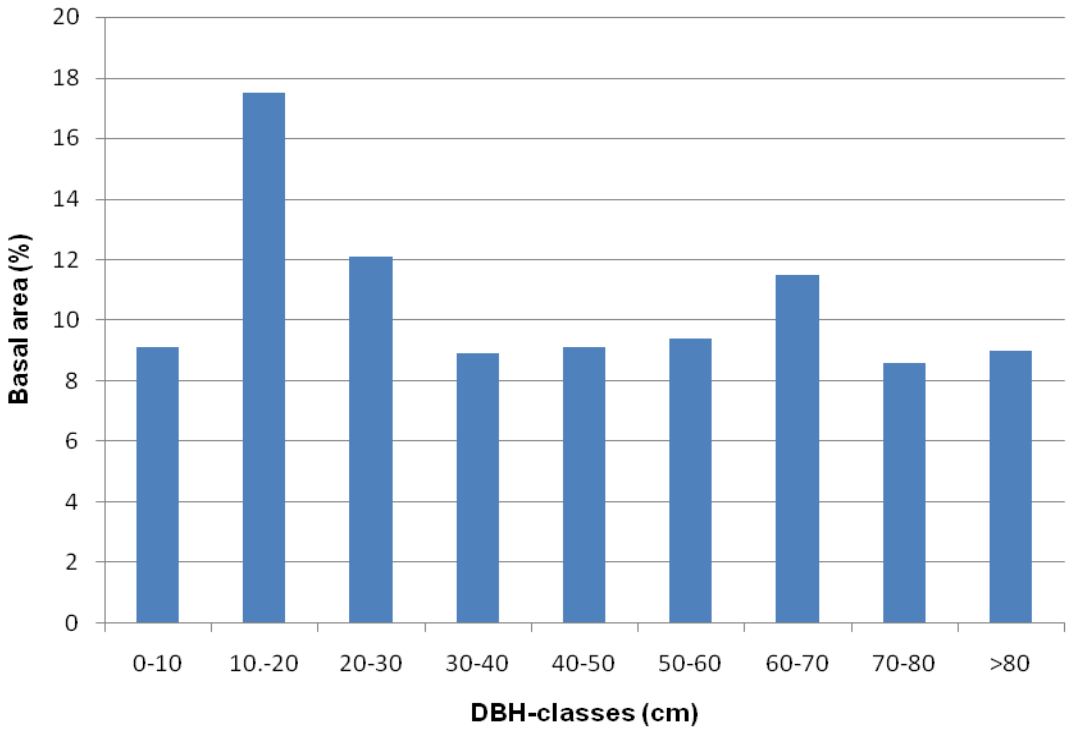

Figure 4. The irregular distribution of relative basal area over DBH-classes indicating that the forest is severely disturbed.

Figure 5. The indigenous vegetation on the proposed plantation site displaying the open stand structure

Table 3. List of regenerated tree species encountered, their plant families and abundance.

Specie	Family	Number of trees/hectare
Afzelia africana Sm.	Leguminosae	3
Albizia adianthifolia W.Wight	Leguminosae	18
Albizia zygia J.F.Macbr.	Leguminosae	26
Anogeissus leiocarpus Guill.&Perr.	Combretaceae	56
Baphia pubescens Hook.f.	Leguminosae	15
Borassus aethiopium Mart.	Arecaceae	3
Bridelia ferruginea Benth.	Euphorbiaceae	126
Cola chlamydantha K.Schum.	Sterculiaceae	100
Crossopteryx febrifuga Afzel. (ex Guill.&Perr.)	Rubiaceae	21
Cussonia barteri Seem.	Araliaceae	3
Daniellia oliveri (Rolfe.) Hutch.&Dalziel	Leguminosae	462
Elaeis guineensis Jacq.	Arecaceae	3
*Ficus kamerunensis*Warb. (ex.Mildbr.&Burret)	Moraceae	3
Ficus sur Forssk.	Moraceae	179
Ficus vogeliana Miq.	Moraceae	3
Grewia mollis Juss.	Tiliaceae	47
Holarrhena floribunda T.Durand.&Schinz	Apocynaceae	62
Lannea acida A.Rich.	Anacardiaceae	26
Lonchocarpus sericeus (Poir.)DC	Leguminosae	6
Lophira lanceolata Tiegh.	Ochnaceae	21
Lychnodiscus spp.	Sapindaceae	138
Manilkara obovata (Sabine&G.Don)J.H. Hemsl	Sapotaceae	9
Margaritaria discoidea (Baill.)G.L.Webster	Euphorbiaceae	276
Maytenus buchananii (Loes) Wilczek	Celastraceae	24
Nauclea latifolia Sm.	Rubiaceae	512
Parkia biglobosa (Jacq.)R.Br. (exG.Don)	Leguminosae	6
Pileostigma thonningii (Schumach.) Milne-Redh	Leguminosae	109
Pseudospondias spp.	Anacardiaceae	21
Pterocarpus erinaceus Fern. Vill.	Anacardiaceae	18
Spathodea campanulata P. Beauv.	Polygalaceae	3
Sterculia tragacantha Lindl.	Sterculiaceae	65
Stereospermum acuminatissimum K.Schum.	Sterculiaceae	123
Terminalia glaucescens Planch.exBenth.	Bignoniaceae	100
Trichilia roka (Forssk)Chiov.	Meliaceae	509
Trichilia monadelpha (Thonn.)J.J. de Wilde	Meliaceae	12
Vitellaria paradoxa C.F.Gaertn	Meliaceae	670 (IUCN listed “vulnerable”)
Vitex doniana Sweet.	Sapotaceae	9
Vitex micrantha Guerke	Lamiaceae	71
Total		**3854**

Regeneration potential

A total number of 38 regenerating tree species were encountered (Table 3). The average number of regenerating trees per hectare (α=0.05) was 3,854 ± 746. It ranges from a minimum of 127 individuals per hectare to a maximum of 9,555. In this survey, the number of regenerating tree species is high as compared to the literature values given by Swaine (1992) who recorded 2,133 seedlings and 18 resprouts per hectare in the “Inner zone” of the Ghanaian semi-deciduous forest subtype while the “Fire zone” subtype featured 156 seedlings and 2,032 resprouts per hectare. In comparison, Addo-Fordjour et al. (2009) reported only 29 regenerating tree species from 12 families for the Tinte Bepo Forest Reserve in Ghana, while Tom-Dery and Schroeder (2011) recorded 46 tree species which also contained double the number of big trees (≥ 40 cm DBH) from a site located about 70 km west of the proposed plantation.

This suggests that the remnant forest surveyed in this

study still has a vigorous regeneration potential and that seed dispersal vectors are active. The high tree regeneration might be due to a variety of reasons. The open stand structure of the remnant tree vegetation allows a strong solar radiation of the forest floor and soil layer, which can lead to high germination rates. While the majority of the surveyed tree species must be regarded as pioneer species and non-pioneer light demanders, they are well adapted to full overhead light conditions. The high tree regeneration number might also be a result of good resprouting capability of many of the tree species. The above ground parts of small saplings (height 50–130 cm) and tree saplings (trees of DBH < 10cm) are probably frequently damaged or killed by the occurrence of bush fires. If the root parts survive, the trees can resprout under favorable conditions. Due to a high fire frequency tree regeneration is probably not given enough time to grow to a tall tree. Therefore a permanent resprouting phase is prevailing which over time, results in an accumulation of saplings and trees of small diameter. Despite the relatively high regeneration rate, it can be assumed that under the present fire regime, the forest is in a regressive phase and develops towards a savanna of secondary origin as described by Gautier and Spichiger (2004).

Conclusions and recommendations

The assessment of the stand structure and tree regeneration of the remnant forest vegetation has revealed severe disturbances of anthropogenic origin. Hence, integrated forest management strategies are needed, which should consider the demands of adjacent communities. The medium to high diversity of the remnant forest vegetation gives credence to the conservation of part of the remnant natural forest. The occurrence of commercial timber species and the open stand structure of the remnant forest vegetation open a long-term perspective for their integration into production forest. Although, it will be a challenge for silviculturists to develop a forest plantation scheme consisting of an uneven aged mixture of exotic and indigenous tree species, it can be a rewarding contribution to the conservation of forests and biodiversity in a sparsely wooded landscape. Furthermore, the constant endangerment of forests through wildfires must be managed. For that purpose, fire preventing measures for example, fire breaks, buffer zones, prescribed burning techniques and awareness creation should be taken into consideration as an essential precondition for a successful forest management in the Ashanti region.

Conflict of Interests

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

ACKNOWLEDGEMENTS

We wish to sincerely thank DuPaul Wood Treatment Ltd. for the logistic support throughout this research. We are also thankful to Mr. Thomas Agyekum of the Forestry Commission in Kumasi, Ghana for aiding in species identification. Furthermore, we are very grateful to the Foundation for Forest Conservation in Africa (Stiftung Walderhaltung in Afrika), Hamburg, Germany for funding the field research.

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Vol. 6(3), pp. 247-255, March 2014
DOI: 10.5897/IJBC2014.0684
ISSN 2141-243X © 2014 Academic Journals
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International Journal of Biodiversity and Conservation

Full Length Research Paper

In vitro study of effects of growth hormones on sporophyte development of *Cyathea spinulosa*

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Accepted 20 February, 2014

***Cyathea spinulosa* Wall. ex Hook. is a type genus of Cyatheaceae family. It is listed in endangered category of IUCN Red Data Book and also placed in Convention on International Trade of Endangered Species of Flora and Fauna (CITES) Appendix II. The spore germination, gametophyte morphogenesis and sporophyte rooting of *Cyathea* in response to 2.0% sucrose and three major growth hormones: Indole–3 acetic acid (IAA), indole–3 butyric acid (IBA) and naphthalene acetic acid (NAA) was studied. The study was carried out at the tissue culture laboratory of Central Department of Botany, Tribhuvan University, Nepal. The spore of *Cyathea* was reared on Knop's Basal Medium (KBM) with 2.0% sucrose after surface sterilization. The sporophyte was sub-cultured on medium with growth hormones IAA, IBA and NAA, each containing 1, 2 and 3 ppm concentrations. The study suggested that *Cyathea* exhibited bipolar germination and the gametophyte development was Adiantum type. The mature gametophyte was observed as heart shaped. Sex organs were not observed up to 24 weeks which indicates the development of apogamous sporophyte. The growth hormones affect the development of leaves and roots. The sporophyte containing three leaves and two roots was the best result obtained in KBM containing 1 ppm IAA.**

Key words: Cyatheaceae, *Cyathea spinulosa*, morphogenesis, Knop's medium, growth hormones, apogamous sporogophyte.

INTRODUCTION

Cyathea spinulosa Wall. ex Hook. is a genus of Cyatheaceae family (Leptosporangiate of Pteridophyta), and well known for its excellent beauty for outdoor decoration. This plant prefers warm and humid atmosphere for its luxuriant growth along the streams side at 335 to 2000 m altitudes in East and Central Nepal (Gurung, 1991). It has great afforestation value due to well adoptability to push the rhizome into barren soil, act as colonal of disturbed soil especially in water logged areas, shade beneath the fronds help in the establishment of other grass, the root system efficiently binds top soil, can be easily propagated by rhizome cutting and splitting (Gurung, 1992). It is economically important and the wood log is much in demand in orchid cultivation and for starch extraction (Khare et al., 2005). It was listed in endangered category of IUCN Red Data Book in 1998.

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It is also included in the appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2013).

It has been possible to induce apogamous sporophytes and aposporous gametophyte without the intervention of fertilization and sporogenesis by suitably manipulating the cultural condition *in vitro*. Nutritional studies on fern have highlighted their response to cultural condition (Bir et al., 1982). Some of the studies carried out on tree fern were variation in performance across a successional mosaic (Arens, 2001), effect of sterilization and storage conditions on the viability of spores (Simabukuro et al., 1998), relationships of Papuasian Cyatheaceae (Raubeson et al., 1995), spore germination and gametophyte development (Rechenmacher et al., 2010), evidence for Gondwanan vicariance and limited transoceanic dispersal (Korall and Pryer, 2014), effects of light, temperature and pH on spore germination and early gametophytic development (Du et al., 2009), morphology of the gametophytes and young sporephytes (Huang et al., 2001). Some of the studies in which fern gametophytes have been used include investigation of growth correlations, regeneration and hormonal effects (Albaum, 1938a, b), the induction of sex organ formation (Naf, 1956, 1958), the effect of the inhibition of protein synthesis on growth (Hotta and Osawa, 1958), induction of apogamous sporophyte development (Whittier and Steeves, 1960, 1962; Mehra and Sulklyan, 1969; Kato, 1970), effect of sucrose on heteroblastic leaf development (Sussex and Cluttter, 1960; Caponetti, 1970), effect of storage temperature (Ballesteros et al., 2011) and many more.

The objectives of this research were to observe the effect of 2% sugar concentration on the gametophyte morphogenesis in the spore germination and to investigate the effect of different growth hormones on *in vitro* rooting, and micropropagation of *C. spinulosa*. *In vitro* studies of threathened species- *C. spinulosa*, so far has not been done in Nepal. Realzing the importance, it is very necessary to study *Cyathea in vitro*.

MATERIALS AND METHODS

Spores of *C. spinulosa* were collected from Godavari Botanical Gardens, Kathmandu, Nepal for micropropagation. Fresh spores were taken from May to October and dry spores were taken on remaining months.

Surface sterilization, spore culutre and preparation of explants

The mature fronds of *C. spinulosa* with spores on their ventral surface were washed serially with diluted detergent in running tap water for 30 to 45 min, and with distilled water for 3 to 4 times. The pinna was cut into small pieces and surface sterilized with 1% sodium hypochlorite solution for 12 min and finally rinsed with sterile distilled water for 5 to 6 times inside the laminar airflow chamber. Spores were taken in the sterilized Petri dish with the help of surgical blade pressing one side of the frond with the forceps. Then, spores were inoculated on 10 different cultrue tube containing slanting Knob's basal medium (KBM, 1884) containing 2% sucrose. Joshi et al. (2002) studied the effect of sucrose on spore germination of *C. spinulosa*. They found 91% as the highest percentage of spore germination in KBM with 2% sucrose. Similar protocol had been adopted in the study.

For the sub-culture of sporophytes, sporophytes were cut down into small pieces in Petri dish and inoculated in KBM containing different concentration (1, 2 and 3 ppm) of growth hormones–Indole–3 acetic acid (IAA), indole–3 butyric acid (IBA) and naphthalene acetic acid (NAA) by the help of forceps (Table 1). All the cultures were maintained at 25°C (±2) and eight-hour light daily. The responses were observed after one week of culture. Various stages of germinating spores and prothalli were observed under microscope. The slides were prepared by mounting in glycerine. Each culture was subcultured after three months on fresh media. The observations were taken in one week interval.

Acclimatization

The sporophytes were observed after 24 weeks of spore inoculation. After several sub-culture, sporophytes having developed roots were grown in soil containing soil, compost and sand in 2:1:1 ratio and high humidity was maintained covering by plastics. After few weeks the plastic cover were removed and the plants were planted in pots.

RESULTS

Spore germination and gametophytic morphogenesis

A spore, consisting of a single haploid cell, has simple requirements for differentiation. It is significant that no nutritional or hormonal gradients are imposed on the spore by the adjoining cell (Rasid, 1999). The spores did not germinate as soon as they were shed. They remained dormant for a period of time ranging from 3 to 4 weeks to 10 to 12 weeks. The rate of spore generation with respect to different period of year when spore collected is represented in Figure 1. The dormancy was found to be dependent on temperature of spore collection, maturity of spores and degree of hydration. At the lower temperature during winter, the spore took up to 12 weeks to germinate while during summer spore germinated within 3 to 4 weeks.

Swelling, expansion and greening of a spore (Figure 2) and rupture of exine were the basic pre-germination changes. That change was followed by the appearance of small protuberance like structure almost all over the spore surface. With the opening of the exine, the protoplasmic mass of the spores with intine appeared in the form of small protuberance, that is, protonemal filament. The germination of spore was bipolar resulting in the formation of small rhizoidal cell and a larger protonemal initial cell. A rhizoid was seen to be given off from the rhizoidal initial cell. The protonemal filament ultimately developed into prothalli after 8 weeks of spore inoculation (Figure 3) which contained few numbers of rhizoids.

Table 1. Culture of sporophyte on KBM containing various concentration of IAA, IBA and NAA.

Weeks of observation	IAA concentration			IBA concentration			NAA concentration		
	1 ppm	2 ppm	3 ppm	1 ppm	2 ppm	3 ppm	1 ppm	2 ppm	3 ppm
6 weeks	2 leaves + 2 roots	1 leaf + no root	2 leaves + no root	2 leaves + no root	1 leaf + no root	4 leaves + no root	2 leaves + no root	1 leaves + no root	2 leaves + 1 root
12 weeks	3 leaves + 2 roots	2 leaves + no root	3 leaves +1 root	Yellower and dead	2 leaves + no root	4 leaves + no root	3 leaves + no root	2 leaves + no root	3 leaves + 1 root
18 weeks	3 leaves + 2 roots	2 leaves + no root	3 leaves + 1 root	-	4 leaves + no root	6 leaves + no root	4 leaves + no root	3 leaves + no root	4 leaves + 1 root

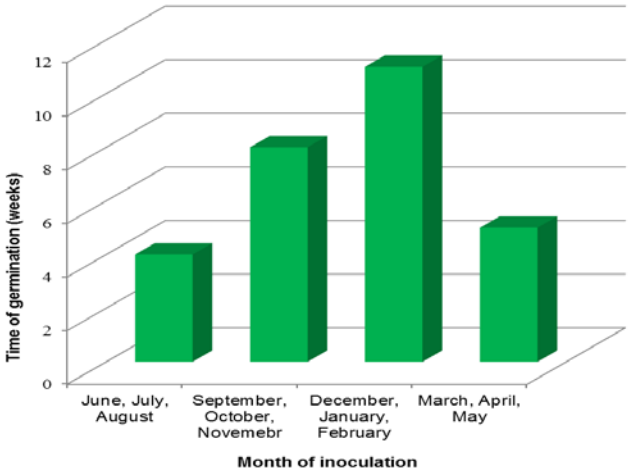

Figure 1. Effect of spore collection date on spore germination.

Figure 2. Sweeling, expansion and greening of spore.

Figure 3. 8-Celled prathallus after 8 weeks (400x).

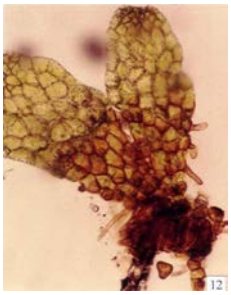

Figure 4. Gametophyte showing meristematic region at apical end and non-germinated spores below gametophye after 12 weeks (100x).

Structure of prothallus/gametophyte

Spatulate gametophytes with clearly visible meristematic cells at the apical end were observed after 12 weeks (Figure 4). At that stage, rhizoids were shorter than the length of the gametophyte. Numbers of rhizoids were more towards the distal end while no rhizoids were observed towards apical end. After 14 weeks, apical notch began to form at the anterior end below that laid the growing apex, consisting of meristematic cells. After 16 weeks, mature heart-shaped gametophytes were found. The growing apex was present in a deep notch at its anterior end, consisting of meristematic cells (Figure 5). The gametophytes were dorsoventrally flattened and numerous delicate rhizoids ascended from under surface. The rhizoids were unicellular, hyaline in colour, and double-layered wall. There were a single nucleus and a large number of chloroplasts in each cell and there were no intercellular spaces between the cells. Gametophytes of different age (20 and 22 weeks) grown on KBM + 2% sucrose are shown respectively in Figures 6 and 7. During entire developmental stages, the sex organs, that is, both antheridia and archegonia were not observed. This clearly indicated the development of apogamous sporophyte.

After three successive subcultures on KBM with 2% sucrose, the sporophytes initiation was observed only after 24 weeks of spore inoculation (Figure 8). After 26 weeks of culture, both gametophyte and apogamous sporophyte were observed in same medium (Figure 9).

Figure 5. Mature heart-shaped gametophyte clearly showing notched meristematic region and chloroplast affter 16 weeks (100x).

Figure 6. Gametophytes inside culture tube after 20 weeks.

Figure 7. Gametophytes inside culture tube after 22 weeks.

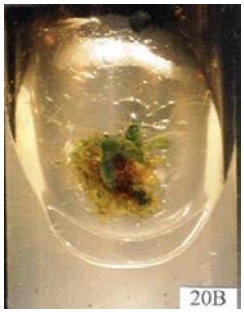

Figure 8. Development of sporophytes start after 24 weeks.

Figure 9. 26 weeks old culture showing both gametophyte and apogamous sporophyte.

Figure 10. 30 weeks old apogamous sporophyte.

After 30 weeks, the well-developed sporophyte was obtained (Figure 10). At that stage, roots were very few in number, unbranched and feebly developed. Rhizome were small, leaves were small and bipinnate or bifid.

Figure 11. Sporophyte on KBM + 1 ppm IAA after 12 weeks.

Figure 12. Sporophyte on KBM + 1 ppm IAA after 18 weeks.

Figure 13. Sporophyte on KBM + 2 ppm IAA after 6 weeks.

Figure 14. Sporophyte on KBM + 3 ppm IAA after 12 weeks.

Culture of sporophyte

The sporophyte explants were obtained from the *in vitro* grown spore on KBM with 2% sucrose. They were sub-cultured on KBM containing various concentrations of IAA, IBA and NAA.

On KBM with 1 ppm IAA, there was small protuberance like gametophyte on lower part of sporophyte with two roots observed after four weeks of culture. After six weeks, there was sporophyte with two leaves and two roots. One leaf was added and altogether formed three leaves and two roots after 12 weeks (Figure 11). This was sub-cultured on new media with same concentration of hormone. After 18 weeks of subculture, sporophyte with 3 leaves and 2 roots was observed (Figure 12). On KBM with 2 ppm IAA, there was only one leaf, root failed to form after six weeks (Figure 13). After 12 weeks, one leaf was added and two-leaved sporophyte was formed. After 18 weeks, still there was only two-leaved sporophyte, roots were not developed. On KBM with 3 ppm IAA, sporophyte only with three leaves was observed after six weeks. After 12 weeks, the sporophyte with three leaves and one root was developed (Figure 14). After 18 weeks the leaf and root number were same as 12 weeks and no further development was observed.

The sporophyte cultured on KBM supplemented with 1 ppm IBA showed two new leaves and no root after six weeks of culture (Figure 15). This remained as such for 10 weeks and after that ultimately became yellower and died. On KBM with 2 ppm IBA, after six weeks there was sporophyte with one leaf only and one gametophyte like body, but root was absent (Figure 16). After 12 weeks there was sporophyte with two leaves and no root (Figure 17). The gametophyte like body became brown and dead. After 18 weeks, sporophyte with four leaves and no root was observed (Figure 18). The sporophyte cultured on KBM supplemented with IBA 3 ppm showed four new leaves and no root after six weeks (Figure 19). Up to 12 weeks, the sporophyte remained as above. While after 18 weeks, two leaves were added and finally sporophyte with

Figure 15. Sporophyte on KBM + 1 ppm IBA after 6 weeks.

Figure 16. Sporophyte on KBM + 2 ppm IBA after 6 weeks.

Figure 17. Sporophyte on KBM + 2 ppm IBA after 12 weeks.

Figure 18. Sporophyte on KBM + 2 ppm IBA after 18 week.

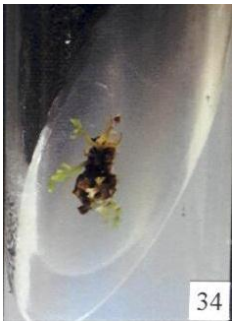

Figure 19. Sporophyte on KBM + 3 ppm IBA after 6 weeks.

Figure 20. Sporophyte on KBM + 3 ppm IBA after 18 weeks.

with six leaves and no root was observed (Figure 20).

On KBM with 1 ppm NAA, the sporophyte with two leaves and no root was observed after six weeks (Figure 21). There was appearance of three leaves and no root after 12 weeks. After 18 weeks, there was sporophyte with four leaves and no root (Figure 22). When sporophyte was cultured on KBM with 2 ppm NAA, there was sporophyte with one leaf and no root after six weeks. After 12 weeks, two leaves sporophyte appeared where roots were to develop (Figure 23). After 18 weeks, sporophyte with three leaves were observed, root was not developed. On KBM supplemented with 3 ppm NAA, the sporophyte having two leaves and one root was observed after six weeks (Figure 24). After 12 weeks, three leaved and one-rooted sporophyte was found (Figure 25). The sporophyte with four leaves and one root was observed after 18 weeks (Figure 26).

When sporophytes were cultured on KBM with 2% sucrose, there were significant number of leaves but roots failed to develop. Roots were not observed up to 18 weeks (Figure 27).

Figure 21. Sporophyte on KBM + 1ppm NAA after 6 weeks

Figure 22. Sporophyte on KBM + 1 ppm NAA after 18 weeks.

Figure 23. Sporophyte on KBM + 2 ppm NAA after 12 weeks.

Figure 24. Sporophyte on KBM + 3 ppm NAA after 6 weeks.

Figure 25. Sporophyte on KBM + 3 ppm NAA after 12 weeks.

Figure 26. Sporophyte on KBM + 3 ppm NAA after 18 weeks.

Acclimatization

The rooted sporophytes were then transferred to soil and were kept at high humidity to avoid desiccation of the delicate fern fronds by covering with plastic from the upper side. The sporophyte with green leaves remained up to one week (Figure 28).

DISCUSSION

Sugar is an important factor for the spore germination. Kato (1973) observed that carbon compounds have a potent influence on protonema growth and secondary rhizoid formation. Parajuli and Joshi (2013) found 86% of spore germination of *Colysis latiloba* in 1% sucrocse. Similarly, in *Microsorium alternifolium* and *Microsorium scolopendria,* maximum germination was reported on media containing 1.0% sucrose and glucose while in *Melanophidium punctatum* and *Anisocampium cumingianum,* highest percentage of spore germination was reported in 0.25 and 1.5% sucrose respectively (Joshi, 1977). The findings of Miller and Miller (1961) showed that 1% sucrose for spore culture of *Onoclea sensibilis* growing under low intensities of light increased the growth rate of gametophyte. Whittier (1964, 1965) also found that vegetative growth of prothallus was accelerated by sucrose in *Cryptomium falcatum*, *Cheilanthes tomentosa* and *Cheilanthes farinose*.

Figure 27. Sporophyte on KBM after 12 weeks.

Figure 28. Acclimatization of rooted sporophyte.

The spore of ferns shows various germination pattern viz. bipolar, tripolar and amorphous germination (Rashid, 1999). Nayar and Kaur (1968) have considered bipolar pattern as most advanced where first division results in a small rhizoidal cell and large prothallial cell. *C. spinulosa* also exhibited bipolar germination in the study. The gametophyte of *C. spinulosa* was heart-shaped. Prothalli of homosporous fern follow a definite pattern of development and attain a characteristic adult form. Seven different patterns recognized (Nayar and Kaur, 1969) are: Osmuda-type, Marattia-type, Adiantum type, Drynaria-type, Kaulinia-type, Ceratopteris-type and Aspidum-type. The *C. spinulosa* gametophyte development was Adiantum-type.

Presence of sugar, carbon source for vegetative growth under sterile condition in the medium has been reported as one of the causal agents in the induction of apogamy (Kato, 1970; Mehra and Sulkalyan, 1969; Whittier 1964a, b). In the present work, sucrose at the concentration of 2% induced apogamous sporophytes in *C. spinulosa*. Similarly, Whittier and Steeves (1960, 1962) induced apogamy in *Pteridium aquilinum* by using 4.0% sucrose. They obtained greater response of apogamy at 5.0% sucrose. In *Ampelopteris* also 4.0% sucrose or 5.0% sucrose with 1 to 2 mg/l 2, 4-D was found optional for apogamous soprophyte initiation (Sulkalyan and Mehra, 1971). Earlier investigation of induced apogamy was done on soil grown gametophyte. Sulklyan and Mehra (1977) induced apogamy in the haploid and diploid gametophyte of *Nephrolepsis cordifolia* on Kundson's medium supplemented with 0.5 to 2% sucrose. Chopra and Loyal (1979) induced apogamy in four-months old culture of *Ceratopteris pteroides* containing 3-5% sucrose whereas the perennial gametophytes of *A. lepotophylla* exhibited apogamy in half year old cultures raised on sucrose free medium. Kawakami et al. (1995) has in-duced apogamous sporophyte in *Pteris multifida* asepti-cally in the dark but dark grown culture did not form apo-gamous sporophyte even when supplied with sugar (Whittier and Steeves, 1962). While, Elmore and Whittier (1974) has demonstrated the involvement of ethylene, a natural product of gametophyte metabolism as a true cause of apogamous bud induction.

In the present study, when the sporophytes of *C. spinulosa* were cultured on the KBM with different concentration of auxin, that is, IAA, IBA and NAA, best rooting was observed in KBM + IAA (1 ppm), KBM + IAA (3 ppm) and KMB + NAA (3 ppm), while no root was observed in IBA. Arockiasany et al. (2000) also found the regenerated shoots of *Pterocarpus santalinus* L. rooted on quarter strength of MS medium with IAA (1 mg/l). But IBA at 10 mg l^{-1} had a significant effect, both on rooting percentage and rooting system morphology of *Acacia tortilis raddiana* microcuttings, at NAA (1 to 5 mg l^{-1}) number of roots were low but strong (Sune et al., 2001). Copes and Madal (2000) has found 1 μM NAA treatment induced significantly greater rooting than the control in Douglas- fir cuttings. He also found 24.6 mM IBA produced greater rooting percentage. He further concluded that rooting decreased with both too little and too much auxin. Asami et al. (2000) found the rate of rooting from the adventitious shoots cultured in MS medium containing 0.1 mg l^{-1} NAA was higher than cultured in MS medium without NAA in the Japanese butterbur. Bonomo et al. (2013) noted that supplementing media with BAP affected the longiitudinal growth of the filamentous gametophytes, and the proliferation of ramification from early stage.

Conclusion

The result of the study suggested that *C. spinulosa* exhibited bipolar germination and the gametophyte development was Adiantum type. The mature gametophyte of *C. spinulosa* was observed as heart shaped. Sex organs were not observed up to 24 weeks which indicates the development of apogamous sporophyte. The sporophyte containing three leaves and two roots was the best result obtained in KBM containing 1 ppm IAA.

The knowledge on germination, morphogenesis and sporophyte development are very important to undersand the entire life cycle of *C. spinulosa* and to analyse the effect of sugar and various growth hormones. Moreover, these findings provide information to support the cultivation, management of conservation of this endangered species.

Conflict of Interests

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

ACKNOWLEDGEMENT

The authors gratefully acknowledge Central Department of Botany, Tribhuvan University (TU), Nepal for the lab facility for the study. Thanks are due to Dr. Bijaya Pant for valuable suggestion and Mr. Santosh Mani Nepal for encouragement. They are grateful to Dr. Maan Rokaya for review of this paper. They are also indebted to Dr. Sangeeta Rajbhandari, Mr. Sanjeev Rai, Mr. Sajan Subedi and Mr. Samik Mishra for their cooperation in photography.

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Vol. 6(3), pp. 256-270, March 2014
DOI: 10.5897/IJBC2013.0635
ISSN 2141-243X © 2014 Academic Journals
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International Journal of Biodiversity and Conservation

Full Length Research Paper

Land use, land cover and climate change impacts on the bird community in and around Lake Zeway, Ethiopia

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Accepted 16 December, 2013

This study aimed to show impacts of land use and land cover change (LULCC) and climate on waterbird community structure of Lake Zeway and the surrounding areas. Purposive sampling techniques were used to collect primary data. Based on the purposive sampling techniques, 12 key informants and 12 focus group discussants were selected. A semi-structured questionnaire prepared in English and translated into Afan Oromo was used to interview the focus groups. The key informants participated in the interview under close inspection of the researcher. Field observations and literatures searches were also carried out on the impacts of LULCC, climate changes, lake hydrodynamics and biodiversity. Most (92%) of the discussants indicated decreases in the level and width of Lake Zeway during the last 3-4 decades. The lake water withdrawal for irrigated agricultural activities in the surrounding areas was the main reason for decreases. Eleven groups (92%) reported temperature increases and lower and unpredictable rainfall patterns as cause for the decreases. These changes reportedly resulted in decreased waterbird species diversity and abundance and changed distribution patterns across the lake and the surrounding areas. The FGD identified fish production and irrigated farm and bird habitat as the three most important values of the lake. The discussants also reported the combination of land-use and climate, or climate changes, as important drivers that altered the lake water level, wetland habitats and bird community structure. Urgent conservation measures that could reduce the impacts are needed to conserve the bird species at the lake.

Key words: Bird community, climate, changes, impacts, irrigated agriculture, land use.

INTRODUCTION

Although human-induced changes in Earth's terrestrial surface is not a recent phenomenon, the present rate, extent and intensity of land use and subsequent changes to land cover are unprecedented (Ellis and Pontius, 2011). Land use and land cover changes (LULCC) are linked to climate change, biodiversity loss and pollution of water, soil and air (Waltert et al., 2004; Ellis and Pontius, 2011).

The LULCC affect the climate of an area which in turn affects natural resources such as water, wetlands and biodiversity (IPCC, 2001; Gibbard et al., 2005). Though wetlands are important in the global cycling of water and chemicals, including greenhouse gases and stabilize climate changes, wetlands and their biota are at risk from the combined effects of the changes (Sanz, 2002; Finlayson et al., 2006). Thus, degradation of the environment, which negatively impact ecosystem processes and function, especially conversion of wetlands to irrigated lands, represent significant challenges to biodiversity (Sharsm et al., 2007). Changes to wetlands threaten bird

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species conservation although the impacts vary with specific land use type (Brambilla et al., 2011). Lukkarinen et al. (2011) showed variations in the structure of waterfowl communities with changes in land use around 15 lakes in Brazil. Land fragmentation at the local scale can also negatively impact the richness and composition of waterbird species (Guadagnin et al., 2005) and land cover changes alter bird distributions locally and regionally (Jetz et al., 2007).

Impacts of land cover change on African climate include reduction in surface water transpiration and increases in surface temperature (Maynard and Royer, 2004), which have impacted hydrological systems, particularly in East Africa. The East African Rift Valley Lakes, such as Lake Zeway in Ethiopia, have experienced fluctuations in lake level of tens to hundreds of meters in the past 200 years (Olaka et al., 2010). Climate changes coupled with water for domestic use, fisheries, small and large scale agriculture, floriculture and horticulture have altered the lake hydrodynamics (Abebe and Geheb, 2003; Zeray et al., 2006; Hengsdijk and Jansen, 2006; Olaka et al., 2010). Furthermore, Olaka et al. (2010) revealed that the water balance of the lake is dominated by rainfall and surface inflow, which are sensitive to climate change. The change in the lake water balance has negative consequences on the water inflow into lake and the lake size. Zeray et al. (2006) showed up to a 19.5% decline in total average annual inflow into the lake owing to woodland vegetation degradation and reduction in the amount of rainfall in its watersheds. Legesse et al. (2004) showed that a 4% rainfall decrease in the lake's catchment that was associated with woodland conversation to agriculture and increased temperature led to a 14% decrease in runoff and a 20-cm decrease in the level of Lake Zeway.

Lake Zeway supports considerable aquatic and terrestrial biodiversity including birds and fishes. Its ecosystem serves as breeding and wintering ground and as a migration stopover habitat for several resident and migratory waterbird species (EWNHS, 1996). The pressures on the lake, specifically the irrigation-based agriculture that alters the lake water dynamics, could result in reduced fish and waterbird species compositions (Birdlife International, 2012). The changes in hydrodynamics have reduced the lake size and width which may subsequently reduce the lacustrine habitats for waterbird species (Birdlife International, 2012). Therefore, the waterbird species diversity, abundance and distribution might have changed in Lake Zeway and the surrounding environs. Moreover, fruit, vegetable, and cut flower producers released chemicals (fertilizers, pesticides) and Ethiopian government introduced exotic species into the lake ecosystem. This might have also reduced fish, waterbirds, and other life forms (Birdlife International, 2012). Nevertheless, no scientific study has been conducted to determine whether there is any evidence for such effects.

Birds have been used to indicate changing environmental conditions including climate changes (Oster, 1978; Reed et al., 2011). Further, local peoples' knowledge on their environment plays a vital role in natural resource research (Wurburton and Martin, 1999). Local or indigenous knowledge is acquired by the people through the accumulation of experiences, informal experiments and intimate understanding of the environment (Warren and Rajasekaran, 1993). These people also hold knowledge on previous variation in climate and weather (FAO, 2009)

This paper aimed to collect information from local people around Lake Zeway and examine the impacts of LULCC and climate changes on diversity, distribution and abundance of waterbirds of the area.

MATERIALS AND METHODS

Study area

Lake Zeway (07°51'-08° 07'N latitude -38°43'-38°50'E longitude) has an open water area of 434 km^2, the third biggest of the Rift Valley lakes in Ethiopia (Figure 1) (Syvertsen, 1995; Abebe and Geheb, 2003). There are two big and three small islands located in the lake (Tulu Guduo, is the largest at 4.8 km^2, while Tsedach is 2.1 km^2). Lake Zeway is in the same drainage system as lakes Abijata, Shalla and Langano. The agro-climatic zone is classified as 'Weinadega' (Legesse et al., 2003). The wettest months are July and August.

Approximately a total of 460,000 humans live in the Woredas, an area of 403,000 ha, that surrounds Lake Zeway. According to Jansen et al. (2007) the socio-economic activities of the rural people of the Woredas involve a conventional mixed farming (growing of crops and rearing animals).

Lake Zeway is one of the Ethiopian Important Bird Areas that may support over 20,000 waterbirds on a seasonal basis (EWNHS, 1996; Birdlife International, 2012). The lake water, its shoreline and wetland habitats also serve as roosting and stop-over sites for a diverse and abundant assemblage of resident and Palearctic migratory bird species (EWNHS, 1996). For migratory birds in particular, the lake ecosystems have served as a wintering ground and stopover sites during unfavorable climatic conditions in other places (EWNHS, 1996; personal observation). The most common bird species that use the lake and its wetlands include White Pelican (*Pelecanus onocrotalus,* Linnaeus 1758*)*, Marabou Stork (*Leptoptilos crumeniferus* Lesson, 1831) and Fulvous Whistling-Duck (*Dendrocygna bicolor,* Viellot, 1816) which roost in large numbers, Reed Cormorant (*Phalacrocorax africanus,* Gmelin, 1789*),* European Swallow (*Hirundo rustica,* Linnaeus, 1758*)* and Yellow Wagtail (*Motacilla flava,* Linnaeus, 1758) (Birdlife International, 2012). Although, the lake and its associated habitats are known to harbor various species of birds in large numbers, a combination of socio-economic and climatic factors has resulted in the loss of biodiversity in the lake (Abebe and Geheb, 2003; Legesse et al., 2003). Both the garage highland that drains to Zeway through the Meki River, and the Arsi highland that drains through the Kater River, have been seriously degraded, which has accelerated the local loss of biodiversity (Sisay, 2003; Zeray et al., 2006). Lake degradation is linked to deforestation, mainly for agriculture, industry, human encroachment and settlements (Ayenew, 2002; Jansen et al., 2007; Ayenew, 2009). The increased land use is also linked to increases in human and livestock populations leading to overgrazing, soil erosion and decreased water level and quality.

Methods

For the primary data collection and informant selection, we used purposive sampling techniques (judgment sampling) as described by Devers and Frankel (2000), Tongco (2007) and Teddlie and Yu (2007). To reduce biases that arises due to purposive sampling

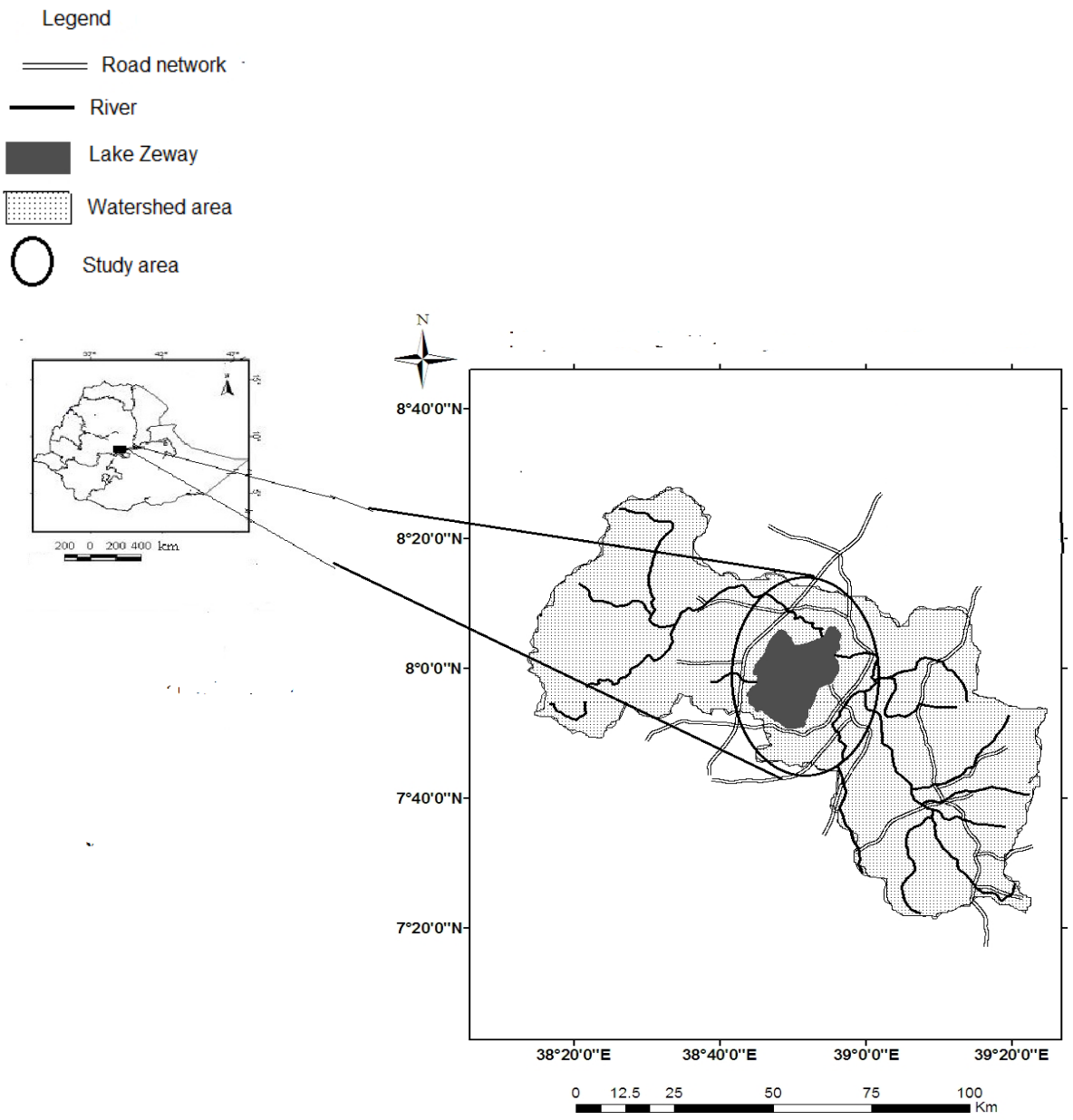

Figure 1. Map showing the location of Lake Zeway, study area in Ethiopia, and watershed area.

techniques, key interviewees were first selected from three districts (2 in each) and 'Kebeles' (divisions within a district) in the study area. The interviewees were selected with the help of districts or Woreda and Keble officers. In addition, the officers of agriculture and land administration of the districts in the study area assisted in the selection of the key interviewees, the key informants were those who are native and agricultural development worker in the study area.

After the key interviewees (N = 12) were introduced to the subject matter, each of them selected five to six additional individuals to participate in the focus group discussions (Teddlie and Yu, 2007). Thus, twelve focus groups of discussants were formed for interviews on the impacts of LULCC and climate change on the water and waterbirds of Lake Zeway and the surrounding environs. The focus group participants were purposively comprised of adults and old aged (≥60 years) individuals who have lived for a long time in the area. The individuals were selected since they have in-depth knowledge and experience of conditions of their environs (Warren and Rajasekaran, 1993), and could provide long-term information about LULCC and climate change impacts on the lake water, its surrounding areas and its bird species. The key interviewees were used as the interviewer to the discussants and the researcher closely monitored the interview. A comparison was also made between similar literature on the impacts of LULCC and climate changes in biodiversity in the area.

Human populations that live in the 'Kebeles' adjacent to Lake Zeway (1-1.5 km) were selected for the study. Most of the population inhabiting these areas is from Oromo tribes whose language is Afan Oromo, and most members of other tribes in the area also speak and write in Afan Oromo, which is the official language of the region. Thus, a semi-structured questionnaire was delivered in Afan Oromo. The questionnaires were used to assess information on

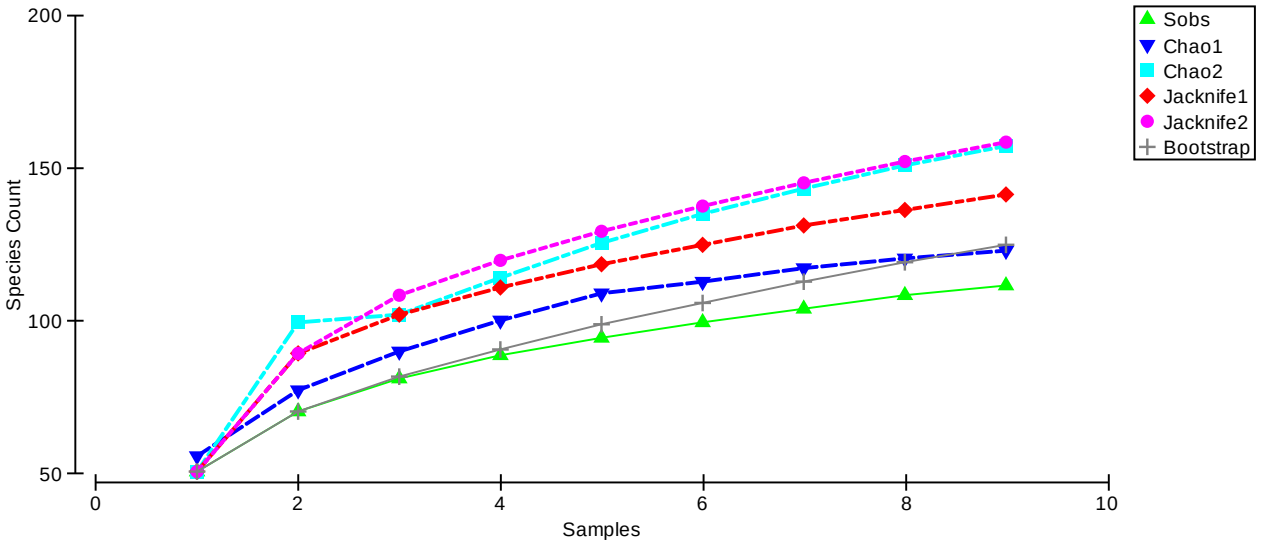

Figure 2. Bootstrap of the 1999-2008 waterbird species data.

Table 1. Temporal waterbird species richness and diversity between 1999 and 2008.

Year	N	S	Chao1	Chao2	Jacknife1	Jacknife2	H'	J'
1999	1599	56	56.42	51.42	51.42	51.42	3.36	0.83
2000	1854	48	77.69	98.76	89.45	89.45	3.11	0.81
2001	1888	52	90.46	102.59	102.49	108.90	3.11	0.79
2002	883	50	101.44	114.23	111.36	120.09	3.23	0.83
2003	2223	51	09.38	124.68	118.47	129.17	2.78	0.71
2004	2070	52	113.93	34.8635	125.08	137.89	2.94	0.7
2005	4396	52	117.71	143.67	131.03	145.56	1.65	0.42
2007	204	40	120.51	150.29	136.21	152.13	3.19	0.87
2008	1619	62	123.25	157.38	141.33	158.83	3.39	0.82

the previous and present status of Lake Zeway and its waterbirds in relation to LULCC and climate changes impacts (Appendix 1).

Data analysis

The collected data were analyzed using SPSS 15 and Microsoft Excel statistical software packages as in Asefa (2008) for assessing local people's economic and conservation perspective of biodiversity in Harrena Forest, Ethiopia. Finally x^2 was computed to test associations of discussants ranking values of Lake Zeway (Table 6). Statistics are given as the mean ± standard deviation (SD).

RESULTS

A total of 131 bird species were compiled using data between 1999 and 2008 obtained from Ethiopian Wildlife and Natural History Society that was collected by African wildlife census. Some of these bird species such as Wattled Carne and Black Crowned Crane are threatened bird species of conservation concern. The species count and sample test for the species richness indicators revealed good relationship (Figure 2). The Chao 1, Chao 2, Jacknife 1 and Jacknife 2 computed for the birds indicated lower species richness in 1999 and 2000 and almost increasing trends thereafter (Table 1). However, the bird species diversity and evenness is high during 1999 and showed decline in the year 2005 which was the lowest and increase in 2007 and 2008 (Table 1). From the data, there was no clear trend except fluctuation of decrease in some years and increase in others. The highest species abundance similarity was obtained between 1999 and 2008 but the abundance data for 2007 showed no similarity with almost all years (Table 2).

According to Vuik (2008) there were various land use types in the surrounding areas of Lake Zeway including its watershed systems where some of the areas were intensively cultivated and others used for irrigation (Figure 3). Based on Vuik (2008) and researchers, the crosschecked irrigated land around the lake was once covered by wood and wet grassland. Furthermore, researchers observed further increase in irrigated land that drastically reduced the riverine and wet grassland habitats close to the lake.

Table 2. Temporal similarity of the waterbird species of Lake Zeway between 1999 and 2008.

	1999	2000	2001	2002	2003	2004	2005	2007	2008
1999									
2000	38.34197								
2001	55.94512	48.56512							
2002	64.7482	50.17026	58.30619						
2003	49.11661	41.94842	59.36902	40.02478					
2004	43.63895	59.83494	57.19045	47.92139	52.1262				
2005	11.08765	15.01956	16.9297	13.22894	17.51313	23.56792			
2007	0	0	0	0	0	0	0		1
2008	66.19718	38.80884	43.22767	59.34066	44.98309	53.00067	12.99172	1.73913	

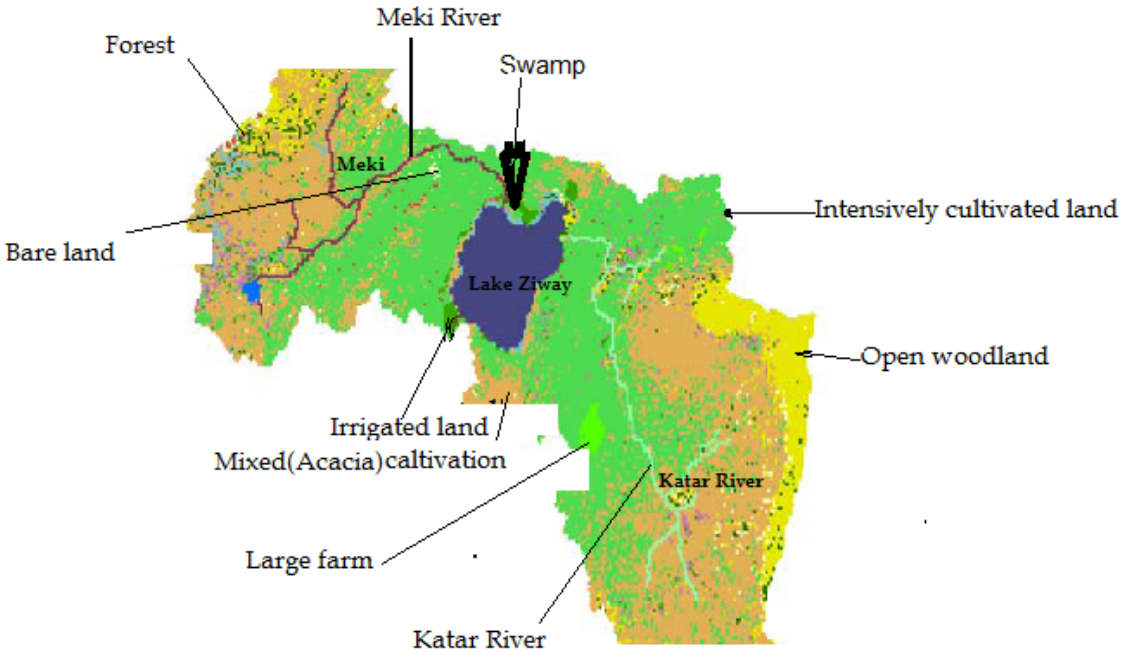

Figure 3. Land use in the surrounding area and the catchment in Lake Zeway (adopted from Vuik 2006).

Ol'ka et al. (2010) showed that the Lake Zeway was located in the range 0.23-3.00 aridity index (AI) and hypsometric integral (HI) 1 and it is one of the most sensitive lake to local and regional climate change. Moreover, Degnenovsky and Getahun (2008) revealed fluctuations and decreasing trends of the Lake Zeway's water level in response to local and East African climate change impacts (Figure 4). Such studies show the preva-lence of climate change and its impacts on the area. In addition, other studies on water resources, land use and climate changes in the Ethiopian Rift Valley areas that include the Lake Zeway indicated existence of change in land use and climate and their impacts (Table 3).

The researchers crosschecked the current situation by observations and this proved changes in land use such as increased irrigated land, where they observed local farmers papering intact riverine wood and grassland for cultivation. In addition, researchers estimated 100-150 m lake width reduction based on platform of landmark at the previous water point (2-3 decades) and non-sampled local elders. Researchers also observed silt accumulation, high temperature, erratic rain fall, overgrazing with estimates between 60 and 10,000 individuals of livestock. Overfishing using various sized fish traps by the locals and commercial co-operatives were also noted. Few number of birds species that were once abundant in the area such as

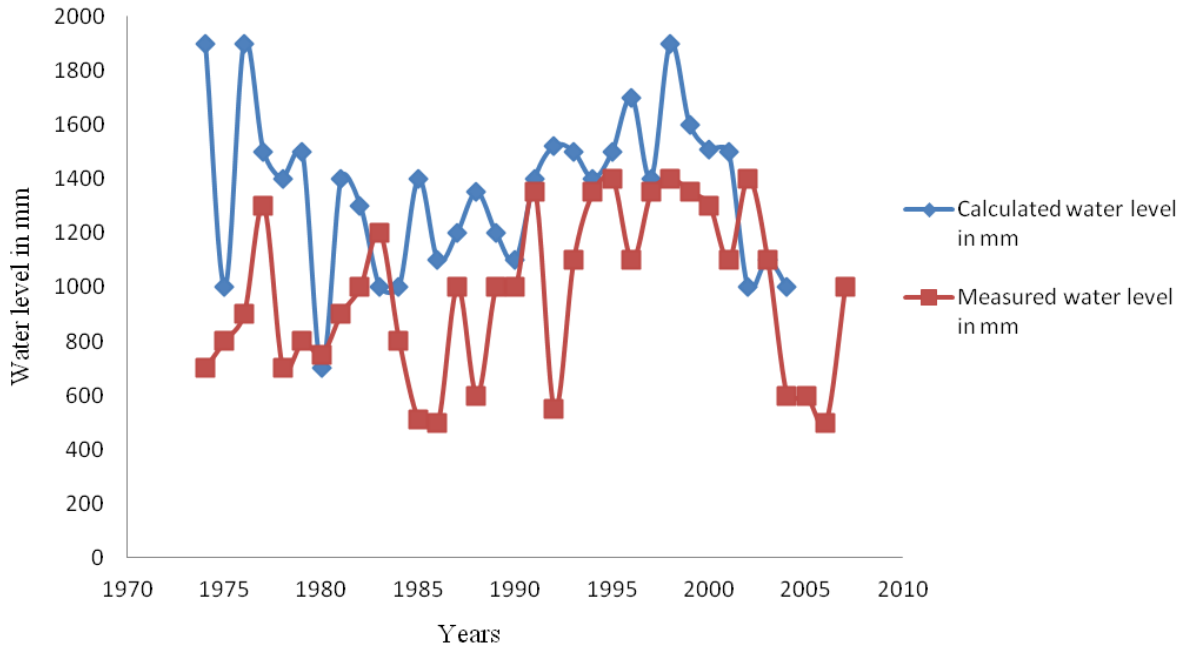

Figure 4. Lake Zeway water level oscillation (as a result of regional climate change impact) calculated amd measured (adopted from Denanovisky and Getahun, 2008).

Table 3. Impact of Land-use, land cover and climate changes on the Lake Zeway and the surrounding environs.

Change	Trend	Impact on the lake	Remarks (literatures or researchers)	Source
Land use	Increased Irrigated agricultures (large and small scale farms)	Decrease in the level by 0.5 m since 2002	The literature assumed that this negatively affect fishery and aquatic birdlife	Jansen et al., 2007
	Increased cultivation of the catchment areas to the lake (around Katar and Make rivers)	Contributed to the decrease in the lake level as above increased salinity and increased evapo-transpiration	The literature assumed that they negatively affected fishery and aquatic birdlife	Jansen et al., 2007
	Increased in cultivated land from approximately 10,000 ha in 1973 to above 100,000 in 2002	Degradation to the lake's catchment areas	The literature assumed that this negatively affected fishery and aquatic birdlife and other biodiversity	Jansen et al., 2007
Climate	Temperature increase	Increased average temperature by 1.5^{0}C since 1951 and evapo-trnaspiration by 3-4%	The literature assumed that these negatively affected fishery and aquatic birdlife	National Metrological Agency (NMA,2007)
	Rainfall(no obvious trends)		Researchers observed erratic and lower rainfall	National Metrological Agency (NMA, 2007)

Table 4. Characteristics of the focus group participants.

Parameter	N	Minimum	Maximum	Mean ±SD	Proportion by age, occupation, education and longevity in years in the area (%)	
Age	65	28.00	80.00	50.8±13.3	80%.≥ 40 years old	20% < 40 years old
Occupation	65	-	-	-	91.7% farmers	6.3% others
Education	65	Basic,1-3	10+1	2.4±4.4	84.6% (basic education)	13.4% from grade 4-10+1 (diploma level)s
Longevity	65	28.00	80.00	49.8±13.3	77.8% ≥40 years	32.8% < 40 years old

N= Number of individuals that participated in the FGD, basic education = informal or formal, grade 1-3, 10+1 = after completing grade 10 and getting 1 year professional training or learning to 1 year next education level, Longevity = the number of years the individual lives in the area.

Table 5. Some of the reasons given for the decrease in the depth and width of Lake Zeway as caused by land use and climate change impacts.

Reasons for decrease in lake depth and width	N (frequency of responses)	Frequency of the responses (%)
Land conversion to agriculture	11	92
Wetland conversion to small scale irrigated agriculture	12	100
Land conversion to floriculture	10	83
Land conversion to horticulture	9	75
Wetland conversion to large scale agriculture	7	58
Temperature increase contributed to change in lake size	11	92
Decrease in the amount of rain fall	12	100
Woody and other vegetation cover loss to agriculture by local people	11	92
Change of wetland to farmland	10	83
Change of wetland to grazing land	6	50

Marabou Stork, White Pelicans, Pink Backed Pelicans, Long-tailed Cormorant, African Darter and absence of Lesser Jacna, Lesser and Greater Flamingos were observed. Moreover, presence of large number of international tourists watching birds on the accessible western side of the lake where large number of pelicans and other bird species gather was seen. On this side of the lake, several investors who were constructing lodges destroying riverine vegetation were also noted. The turning up of more and more water withdrawal using large and small motor boats, new ditches that were dug as passage of water tubes were also noted during the survey period.

Furthermore, those interviewed provided their views on the impact of land use and climate changes. Most (80%) of the individuals who participated in the focus group discussions were ≥40 years old and 78% lived in the area between 1-1.5 km throughout their life time (Table 2). Most discussants (92%) depended on mixed farming activities (growing crops and rearing domestic animals) that are directly or indirectly based on the water of Lake Zeway and its surrounding areas (Table 4). Eighty-five percent of the participants had only basic education (up to grade 3), while a few (13%) had grade 4-diploma levels (10+1, that is completed grade 10 plus one year professional training) (Table 2). All (100%) discussants identified LULCC and climate changes as the major environmental drivers that altered the hydrodynamics of Lake Zeway. According to 11 (92%) of the discussants, the depth (level) of Lake Zeway has decreased because the lake is filled with silt, inflow from feeder rivers has decreased, and rainfall has become scarce and unpredictable in the area. One (8%) of the discussants reported no change in the lake size. All 12 of the focus groups described lake water withdrawal for irrigated agriculture as contributing to the decrease. Estimates of irrigation water use are from 11 (92%) discussants, which on average estimated that 14.8 ± 10 m^3/day/ha of water, is pumped for irrigated agriculture. The remaining group did not estimate the amount of water pumped. Discussants who did make estimates stated that water was used for the production of cut flowers, grapes by closed irrigation, and other food crops (onion, tomatoes, cabbages and maize) by both small- and large-scale open irrigation. The lowest rates of water use (4.8 m^3/day/ha) were said to be used by small-scale farming and the largest (24.8 m^3/day/ha) by the Share Ethiopia Floriculture Enterprise (SEFE) that produces flowers for export. SEFE were estimated by the discussants to hold about 100 ha of land, suggesting that an estimated 2,480 m^3 of water was diverted from Lake Zeway each day by the SEFE alone. All (100%) the discussants also indicated a decrease in the width of Lake Zeway (Table 5). Woodland deforestation in the lake catchments and wetland fragmentation for expansion of agriculture were among the impacts the focus group discussants indicated for the lake width decrease. Twelve (100%) of the groups suggested that long dry seasons and evapo-transpiration have led to the decline in the level and width of the lake.

At least half of the focus groups suggested that specific reasons for lake depth/width changes included: land conversion to irrigated agriculture (92% of the groups), floriculture (83%), horticulture (75%), woodland conversion to agriculture (50%), wetland conversion to agriculture (50%), increased local temperatures (92%) and decreased local rainfall (100%).

Nine (75%) of the focus groups indicated that the diversity (number of bird species) within and in the areas surrounding, Lake Zeway was decreasing, and that LULCC and climate changes are the major reasons. One group (8%) indicated an increasing trend and two (17%) did not make an assessment. Most focus groups (92%) also thought that the abundances of bird species were decreasing. Most of the respondants (10 groups, 83%) thought that Lake Zeway's waterbird distributions have changed.

A majority (83%) of the discussants proposed lake water withdrawal by small- and large-scale irrigated agriculture as the most likely reason for decline in food and habitats of waterbird species and their diversity and abundance. Eight of the discussants (66%) thought that waterbird species diversity and abundance decreases

Table 6. Values for Lake Zeway ranked by focus group discussant.

Values of Lake Zeway	N	Rank value Total		Mean Rank ± STD	Rank
	7	5	35		
Fish	3	4	12		1st
	2	3	6		
Total	12		53	4.4±.79	
	4	5	20		
Farming activities	4	4	16		
	1	3	3		
	2	2	4		2nd
Total	1	5	5		
	12		48	4.0±1.0	
	2	4	8		
Bird habitat	7	3	21		3rd
	3	4	12		
Total	12		35	3±.67	
	1	5	5		
Grazing	3	4	12		
	1	3	3		
	5	2	10		
	2	1	2		
Total	12		32	2.67±1.30	4th
	2	3	6		
Tourist attraction	9	1	9		
	1	2	2		
Total			17	1.4±.79	5th

5 = highest value, 4 = very high value, 3 = high value, 2 = low value, 1 = very low value, STD = standard deviation.

were linked to woodland deforestation and wetland fragmentaion or conversion to irrigated agriculture. According to the focus group discussants, the decreases were caused by losses of food, cover, nest sites, stopover habitat and maintenance stations for resident and migrant birds. Five (42% of the discussants) suggested that chemicals, fertilizers and pestcides drain into the lake as a result of floriculture killing fish and reducing other biodiversity that waterbirds consume. The discussants stated that this could have caused the species diversity and abundance decline. Ten (83%) of the discussants proposed that overfishing by local and commercial cooperatives at the lake has depleted the composition of fish fauna and fish-eating birds. Half (50%) of the groups said that reductions in the worm and fish species that waterbirds consume, caused by the introduced African Catfish (*Clarias gariepinus*, Burchell, 1982), were rea-sons for waterbird diversity and abundance decreases. Ten (83%) of the discussants thought that pesticides sprayed in the 1970s by the Ethiopian government to destroy birds that are pests on cereal crops have contributed to the reduction in bird species composition in the Lake Zeway area. Five groups (42%) suggested that overgrazing by local and seasonal nomads in wood and wetland habitats at the lake has reduced roosting, breeding and feeding habitats as well as species diversity and abundance of waterbirds.

The majority (83%) of the discussants thought insufficient and unpredictable rainfall, destruction of aquatic vegetation, and associated food shortages contributed to changes in waterbird species distributions. One focus group discussants thought there was no change in species distributions and another did not know whether there was change or not.

All (100%) groups suggested that an increase in temperature and long dry seasons in the past 3-4 decades have contributed to the decline in waterbird species composition and changed their distribution. Twelve (100%) discussants stated that impacts of the long dry seasons in the area have affected plant species phenology, altered bird species spatial and temporal migration patterns, and reduced bird species richness and abundance.

The focus groups were divided into in what they thought were the most important drivers of changes in local biodiversity. Five (42%) indicated climate change as the more important environmental variable that negatively impacted biodiversity and the productivity of the natural resources of the area. Another five (42%) groups indicated equal impacts of climate and land use changes. One group thought climate change and deforestation were the most important drivers, while the remaining group did not identify any driver.

Five (42%) focus goup discussants indicated positive views towards the occurrence of bird species in the Lake Zeway area. The discussants loved birds because birds' plumage and songs are attractive and their presence in the area is interesting to them. Four (33%) groups thought the occurrence of birds was good because they are the creation of God and have the right to exist in the environment and two (17%) groups thought their occurrence was bad, because they destroy crops they grow. One group (8%) was indifferent.

According to the respondents, the primary value of Lake Zeway is its use for fish production. Farming activeties were ranked next most highly, breeding bird habitat was third and tourist attraction was ranked lowest (Table 4). Congruence in rankings among groups was significantly higher than expected by chance (x^2_4 = 25.88, p< 0.01).

DISCUSSION

Land conversion and climate changes can have significant impacts on biodiversity and associated ecosystem services (Finlayson et al., 2006; Jetz et al., 2007; Ayenew, 2009; Gudina, 2011). Based on the perceptions of experienced local people, this study also revealed signs of reduced waterbird species diversity as related to increased conversion of wood and wetlands to irrigated agriculture around Lake Zeway.

Comparisons of small lagoons and large fragmented wetland habitats in Brazil indicated lower waterbird species richness, diversity, and abundance in the fragmented wetlands (Guadagnin et al., 2005). Congruent to this, the present study showed that apparent declines might be caused by fragmentation of Lake Zeway wetland habitats by small scaled irrigated agricultures has contributed to its waterbird species diversity and abundance decline.

Among the threats to Ethiopian wetlands and their biodiversity are deforestation, overfishing and overgrazing, the consequences of high human population pres-sure (Sisay, 2003). These changes coincide with the cur-rent study, which identified deforestation in the lake's catchments as a perceived cause of decline in bird species composition and abundance, and distribution change. The study further indicated that overgrazing by livestock in the areas surrounding the lake has reduced vegetation cover, nest sites, birds' food, habitats, and as a result the birds. Other studies have also revealed impacts of habitat destruction and overgrazing on cover, nest sites, and food availability to birds in the area (Hegsdijsk and Jansen, 2006; Jansen et al., 2007; Melesse et al., 2009; Mengesha et al., 2011). The inter-views in this study revealed that terrestrial habitat destruction, siltation, and water diversions may have caused a contraction in the birds' habitat, reduced their population sizes and changed their distribution. Other studies have also indicated a contraction of wetland habitats and decreased lake volume due to woodland destruction and the water diversion for irrigated agriculture (EWNHS, 1996; Legesse et al., 2003; Ayenew et al., 2009).

The present study suggested chemical release into the lake, from the floriculture and horticulture enterprises, was perceived to have killed fishes and contributed to the decline of piscivorous bird populations. Jansen et al. (2007) and Birdlife International, (2012) have also suggested that increased pollution may impact the fisheries and aquatic birdlife of Lake Zeway. Reduced bird species diversity and abundance at the lake may also be caused by direct kill by pesticides. During the past 30 years, the Ethiopian government used helicopters to spray pesticides that kill bird species that are considered crop pests in the vicinity of Lake Zeway (Bruggers and Jaeger, 1982; Cheke, 2003). The imapct of chemicals and pesticides on birds, their habitats and reproduction have been found in many studies to be an indirect impact of land use changes (Jaeger and Erickson, 1980; Sisay, 2003; Ellott, 2006; Sharma et al., 2007; Brambilla et al., 2011; Kolecˇek et al., 2010).

The present study revealed that fisheries were the most important value of Lake Zeway to the local people, and that there were both local and commercial fishing. These fisheries were thought to have contributed to fish scarcity through overfishing (Sisay, 2003), which in turn, the discassants percived as contributed to a decline in the diversity and abundance of waterbirds. Members of the focal groups also persumed that the abundance of worms in the lake may have declined due to the introduced African catfish which could have altered the prey base for some waterbirds.

Increased temperature and decreased rainfall, via their effects on lake depth and width, were also thought to have contributed to the decline in waterbird species diversity. Increased evapo-transpiration due to higher temperature has previously been reported in the same area (Misganaw, 2007).

Migration can enable mobile animals such as bird species to escape harsh environmental conditions (Rivalan et al., 2007). Nevertheless, climate change alters timing of migration, breeding performance, population size and distribution of birds (Crick, 2004; Levinsky, 2007). Observations by the local people suggest that waterbirds movements away from the area of the Lake Zeway, to escape the long drought and high temperatures, contributed to reduced diversity and abundance of birds. Overall, the observations of local people suggest that, climate chan-

ges combined with LULCC or in isolation have put great stress on Lake Zeway's hydrodynamics, reduced its waterbird diversity and abundance, and changed the birds' distributions. The lake is highly valued by local people for fish production, farming and breeding birds, but not for tourist attraction at present. Conservation measures that reduce the impacts of LULCC and climate changes on Lake Zeway's water and biodiversity resources need be in place to conserve its resources and prevent the lake from drying

ACKNOWLEDGEMENTS

We are grateful to the districts and Kebeles offices, in particular, the offices of agriculture, land administration and environment of Admin Tulu Jedo Komolcha, Dugda Bora and Zeway Dugda for their invaluable assistance and help in making the focus group discussants available. Moreover, we thank the key informants and the focus group discussants. Our gratitude also goes to individuals who assisted us during data collection. We are especially indebted to Fekadu Teferra who gave his unreserved guidance in the social survey design. We also greatly thank our driver Alemahyeu Abiso both for his driving services and his assistance in organizing the FGD. We are greatly indebted to Chris Elphick who helped in editing the manuscript. Finally, we thank Addis Ababa University for the financial support provided.

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Appendix 1. Questions posed to the local people during the interview.

Personal information (Wa'eeEngnyumaaoffii)	**Sex (Sala): Male (Dhira) - Female (dubartii), Age (Umurii)**
Occupation (Hojii) (milikitaa X qodhii).	Farmer (QoteBulaa), Merchant (Daldalaa), Government Employee (Hojettamotumma), Other (Kabirra)
Educational background (HalaaBarnotaa)	Below grade 6 (kutaajaa'agaddi), 10th grade complete (Kutaa 10 xumeree), 12 grade complete (KuttakudhIamaxumuree), Diploma graduate (diplomaanEbefamee), BSc/BA (barumsaDgriijalbaanebifamme), MSc. /MA (Degriilamatatiinebifamee)
Longevity in this area in Years (Baraaturtiinanno kana wagaadhan)	
Knowledge of the Lake Zeway (bekuumisaharaaillalichisee)	**1.** Lake water level/depth in size is **a.** increasing from the previous (Hariikun fagenyiisalafaakesaadaballamoxinnataajiraduraerra); **b.** decreasing from the previous. If decreasing why do you think it decreases/ (Yooxenateemalifii) **2.** What amount of water could be pumped out for the purpose of consumption/industries/agriculture per day from the lake Zeway? M^3 (Bishanakattatilimamananottinharraakeesaguyyatiiammaamitubh'a?) **3.** Is the lake width decreasing or increasing in size(Bal'niiHaraaZewayiidaballamodhiphtaajira) **a.** increasing (bala'taa) **b**. decreasing (dhibatta) **4.** If your answer to question 3 above is decreasing, why do you think it is decreasing? You debbinkee lak.3 dhiphattajirata'eemaliffi? i. Because of land use change (Jijiramittifyadammalafaa); Because of climate change (jijiramaaQilensaa); Because of land cover/vegetation changes (jijiramabosonnashafnni); Because of both land use and climate changes (jijirammaFaydammaLafaat'fiQilensa) • If your answer is land use change, what type of change is it? (Yoodebiinjijrmaalafata'eJijramilafamaliimaliitijejiramee) a. to agriculture from grazing land above the lake(Qonatiimargadhedchisuu) b. the wetland around the lake to small-scale agriculture(jidhaanharabirragaraqonatii) c. from agriculture to floriculture around the lake (Qonaairradarrarahomoshuutii) d. from agriculture horticulture around the lake (Qonaairra -tii) e. the wetland around the lake to large scale agriculture (lafijidhaanharrabirraendastriigugdaatiijijramuu) • If your answer to question 3 is Climate change is temperature (Yoodebbiinkeelak. 3 jijiramaaqelinsaata'e, qelinisii) a. increasing (hoi'eniidaballeera) b. decreasing (qoerera) c. the rainfall is increasing (Robiindabaleaa) d. the rainfall is decreasing (Robiinhirateera) • If your answer to question 3 is land cover change (Yoodebbeinkee lak.3 badiinaabosonaata'e) a. vegetation cover to agriculture by local people (Bossniiqotebullniqonaatijijirmmu) b. Loss of wetland habitat to farmland (Badinnalafaajidhaaharabirragaraqonatti) c. Loss of wetland to grazing land (Baddinnajidhaalafaharraabiragaradhedootamargattii) d. Others (kabirrayoojiratee) **5.** What is the importance of the Lake Zeway other than providing drinking water? (FaddyanHarraZewayii, bishaandhugatiihalamalii) Put in order of importance (Tarreesiiakattaafydaatiin)(5=highest value, 4=very high value, 3=high value,2=low=1=very low) Akaataaitiifyadamaacaliimaatiintartibaanka'ee, 5=fiddabayeesagudda, 4= fiddabayeegudda, fiddagudda, 3=fiddaguudda),2=fiddaxiqqa,fiddabyeexiqqaa) i. For fish production (Misommaqurxummi) ii. For tourist attraction(Tiristiihawachuu) iii. For farming activities(Qonaafii) iv. For grazing land (Lafamargaatifii) v. Breeding and supporting waterbird species (lafaSinbiroonitiihortuu)

Appendix 1. Contd.

	6. Describe if there is any problem that arises as a result of the value of the lake to birds species? (Rakkineefyddaaharratiikabtteesinbirooragauujira?, ibissaa) **7.** What are the trends of bird species diversity/variety in the lake Zeway and its surrounding area? (Wa'eensinbiriigaraagaraharaarafinanooharaajirachuu fi jirataaturuanmalfakataa?)**a.**Increasing (dhablaajiru); **b**. Decreasing(Xiqataajiruu) • If your answer to question 7 above is decreasing, why do you think the cause of decrease in variety? (Yoodebiinkeelak. 8 XiqattajiruutaemalifiiXiataan?) i. Land use/cover change(Jijiramaitiifyadamalafaa) ii. Climate change(JijiramaQelinsaa) iii. Both land use and climate change (JijiramalafafiQilensa) **8.** Is the abundance of the bird species in the lake Zeway and the surrounding increasing or decreasing? (BayeenisinbirottaharraZewayifinannosaDaballamoqinataajiru?) a. Increasing(Dhaballajiruu)----------why(Maliif) b. Decreasing (xinnatajiruu)----------why(Maliif) • If your answer to question 7 above decreasing, why decreasing? (Yoodebbinlak. Xinattajiruta'emallifi). **9.** Do you think the bird species change their distribution in response to changes in the environment? (Sinbroonasi eddo addatibakatannirujijramaanannoo) **a**. Yes (eyee); **b**. No (hinbaqannee) • If yes how do they change or from where to where? Yooeyyeeta'eisaaisaatiibaqataan/ demaan) **10.** What is your attitude towards birds in general?**a**. Excellent **b**. good **c**. bad **d**. worse **e**. worst **11.** How do people in this area overcome the impact of climate change (Ummattinanoo kana akamitiinjejiramaqilensaajalaba'a). **12.** In your opinion, is land use change or Climate change has great impact on the wetland, lake water and birds in the area? Akaa at yaduutijijiramalafatiifyadamummo,jijiramqilensatuucallmatiijijidhaalafa,harryknsinbraairranmiidhaajabaga'aa?
Personal information (Wa'eeEngnyumaaoffii)	**Sex (Sala): Male (Dhira) ---Female (dubartii), age (Umurii)**
Occupation (Hojii) (milikitaa X qodhii).	Farmer (QoteBulaa), Merchant (Daldalaa), Government Employee (Hojettamotumma), Other (Kabirra)
Educational background (HalaaBarnotaa)	Below grade 6 (kutaajaa'agaddi), 10th grade complete (Kutaa 10 xumeree), 12 grade complete (KuttakudhlamaxumureeDiploma graduate (diplomaanEbefamee), BSc/BA (barumsaDgriijalbaanebifamme), MSc. /MA (Degriilamatatiinebifamee)
Longevity in this area in Years (Baraaturtiinanno kana wagaadhan)	
Knowledge of the Lake Zeway (bekuumisaharaaillalichisee)	**1.** Lake water level/depth in size is **a.** increasing from the previous (Hariikun fagenyiisalafaakesaadaballamoxinnataajiraduraerra); **b.** decreasing from the previous. If decreasing why do you think it decreases/ (Yooxenateemalifii) **2.** What amount of water could be pumped out for the purpose of consumption/industries/agriculture per day from the lake Zeway? M^3 (Bishanakattatilimamananottinharraakeesaguyyatiiammaamitubh'a?) **3.** Is the lake width decreasing or increasing in size(Bal'niiHaraaZewayiidaballamodhiphtaajira) **a.** increasing (bala'taa) **b**. decreasing (dhibatta) **4.** If your answer to question 3 above is decreasing, why do you think it is decreasing? You debbinkee lak.3 dhiphattajirata'eemaliffi? i. Because of land use change (Jijiramittifyadammalafaa); Because of climate change (jijiramaaQilensaa); Because of land cover/vegetation changes (jijiramabosonnashafnni); Because of both land use and climate changes (jijirammaFaydammaLafaat'fiQilensa) • If your answer is land use change, what type of change is it?

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	(Yoodebiinjijrmaalafata'eJijramilafamaliimaliitijejiramee) a. to agriculture from grazing land above the lake(Qonatiimargadhedchisuu) b. the wetland around the lake to small-scale agriculture(jidhaanharabirragaraqonatii) c. from agriculture to floriculture around the lake (Qonaairradarrarahomoshuutii) d. from agriculture horticulture around the lake (Qonaairra -tii) e. the wetland around the lake to large scale agriculture (lafijidhaanharrabirraendastriigugdaatiijijramuu) • If your answer to question 3 is Climate change is temperature (Yoodebbiinkeelak. 3 jijiramaaqelinsaata'e, qelinisii) a. increasing (hoi'eniidaballeera) b. decreasing (qoerera) c. the rainfall is increasing (Robiindabaleaa) d. the rainfall is decreasing (Robiinhirateera) • If your answer to question 3 is land cover change (Yoodebbeinkee lak.3 badiinaabosonaata'e) a. vegetation cover to agriculture by local people (Bossniiqotebullniqonaatijijirmmu) b. Loss of wetland habitat to farmland (Badinnalafaajidhaaharabirragaraqonatti) c. Loss of wetland to grazing land (Baddinnajidhaalafaharraabiragaradhedootamargattii) d. Others (kabirrayoojiratee) **5.** What is the importance of the Lake Zeway other than providing drinking water? (FaddyanHarraZewayii, bishaandhugatiihalamalii) Put in order of importance (Tarreesiiakattaafydaatiin)(5=highest value, 4=very high value, 3=high value,2=low=1=very low) Akaataaitiifyadamaacaliimaatiintartibaanka'ee, 5=fiddabayeesagudda, 4= fiddabayeegudda, fiddagudda, 3=fiddaguudda),2=fiddaxiqqa,fiddabyeexiqqaa) i. For fish production (Misommaqurxummi) ii. For tourist attraction(Tiristiihawachuu) iii. For farming activities(Qonaafii) iv. For grazing land (Lafamargaatifii) v. Breeding and supporting waterbird species (lafaSinbiroonitiihortuu) **6.** Describe if there is any problem that arises as a result of the value of the lake to birds species? (Rakkineefyddaaharratiikabtteesinbirooragauujira?, ibissaa) **7.** What are the trends of bird species diversity/variety in the lake Zeway and its surrounding area? (Wa'eensinbiriigaraagaraharaarafinanooharaajirachuu fi jirataaturuanmalfakataa?)**a.**Increasing (dhablaajiru); **b**. Decreasing(Xiqataajiruu) • If your answer to question 7 above is decreasing, why do you think the cause of decrease in variety? (Yoodebiinkeelak. 8 XiqattajiruutaemalifiiXiataan?) i. Land use/cover change(Jijiramaitiifyadamalafaa) ii. Climate change(JijiramaQelinsaa) iii. Both land use and climate change (JijiramalafafiQilensa) **8.** Is the abundance of the bird species in the lake Zeway and the surrounding increasing or decreasing? (BayeenisinbirottaharraZewayifinannosaDaballamoqinataajiru?) a. Increasing(Dhaballajiruu)----------why(Maliif) b. Decreasing (xinnatajiruu)----------why(Maliif) • If your answer to question 7 above decreasing, why decreasing? (Yoodebbinlak. Xinattajiruta'emallifi). **9.** Do you think the bird species change their distribution in response to changes in the environment? (Sinbroonasi eddo addatibakatannirujijramaanannoo) **a**. Yes (eyee); **b**. No (hinbaqannee) • If yes how do they change or from where to where? Yooeyyeeta'eisaaisaatiibaqataan/ demaan)

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Vol. 6(3), pp. 271-279, March 2014
DOI: 10.5897/IJBC2013.0627
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Diversity and seasonality of some of the ground dwelling invertebrates in the Eastern Region of Abu Dhabi, United Arab Emirates

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Accepted 27 January, 2014

A study was conducted to understand the diversity, distribution, abundance and seasonality of ground dwelling invertebrate species in the eastern region of Abu Dhabi Emirate, from March 2010 to February 2011. Pitfall traps were used for this study in two sites with distinct micro - habitats in the Eastern Region of the Emirate. The site includes a wadi habitat at Jebel Hafit, Al Ain and another one is a gravel plain habitat at Mezyad, Al Ain. Beetles (Coleoptera) of the family Tenebrionidae (darkling beetles) are a conspicuous element of these arid and semi-arid environments. Variable stalker beetle (*Adesmia cancellata cothurnata*) was the most abundant Tenebrionid among twenty species collected using pitfall traps in the wadi of Jebel Hafit whereas opossum beetle (*Mesostena puncticollis*) was the most abundant Tenebrionid among twenty in the sandy gravel plain habitat of Um Ghafa, Mezyad.

Key words: Diversity, seasonality, Abu Dhabi Emirate, Jebel Hafit, Mezyad, darkling beetles, pitfall trapping, ground dwelling invertebrates.

INTRODUCTION

A definitive goal for invertebrate conservation would be the wide use of a set of relatively standardized sampling methods, to collect and study a relatively limited number of taxa (focal taxa) from many different habitats and ecosystems, with electronic access to a large amount of taxonomic and ecological data. Standardized and comparable data would be collected on species presence /absence, distribution patterns, habitat associations, diversity, rarity and abundance. These data are needed for effective conservation and monitoring of invertebrate species and their habitats (Kermen et.al, 1993). Although insect fauna of Jebel Hafit as a whole has been worked and previous studies were restricted to qualitative data collection and analysis and publication of checklists (Howarth and Gillett, 2004). The eastern region is characterized by numerous wadis which offer a combination of climate, soil and water suitable for vegetation. The main objective is to evaluate the importance of these different habitats for biodiversity conservation in terms of invertebrates and also to provide knowledge on invertebrates that can be used for biodiversity conservation programmes of the Emirate.

In this study, we examined the abundance, diversity, seasonality, dominance and percentage of distribution of ground dwelling invertebrate species within the wadi habitat and gravel habitats in Eastern Region. Invertebrates were captured mainly by setting pitfall traps and the capture rate showed difference between sites and seasons. *Mesostena puncticollis* was the most abundant ground dwelling invertebrate species among the forty species

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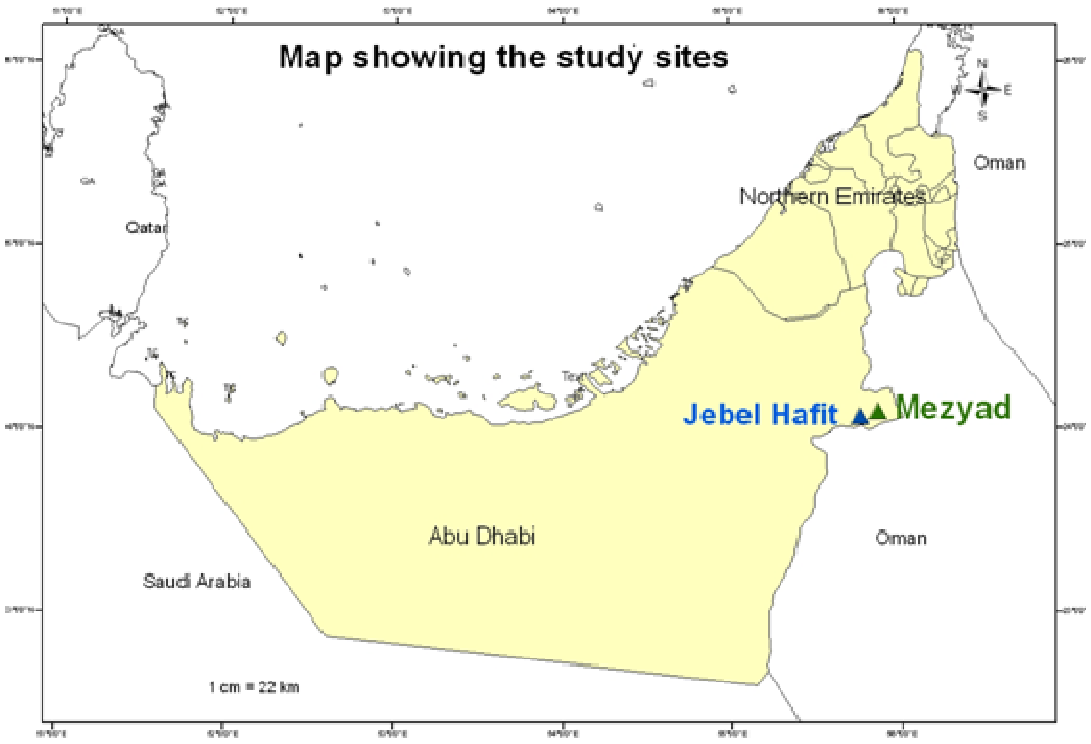

Figure 1. Satellite image of the study sites.

collected from Jebel Hafit and Mezyad.

Beetles (Coleoptera) play a significant role in most ecosystems (Ehrenfeld, 1988). Prominent epigeic examples are the Tenebrionidae that play a relatively major role in tropical and subtropical dry lands, more so with increasing aridity.

The study area

This study was carried out at two different sites of Al Ain, Eastern Region of Abu Dhabi Emirate which is located approximately 160 km east of the capital city of Abu Dhabi and about 120 km South of Dubai. The Eastern region covers an area of approximately 13,100 km^2. Two distinct sites with two distinct microhabitat sites were selected in Jebel Hafit and Mezyad-Um Ghafa in Al Ain. The satellite image of study sites are shown in Figure 1 and the photographs of study sites are given (Figures 2 to 5).

Jebel Hafit is the only mountain, and certainly the most prominent landscape feature, within the Emirate of Abu Dhabi. It is an isolated massif or inselberg (an isolated hill or mountain), lying just to the south of the city of Al Ain. It is aligned in a north to south direction and is approximately seventeen kilometers long, with its greatest altitude at about 1300 m above-sea-level. Jebel Hafit is the south most, and by far the largest series of mountain ridges which run north-south in the vicinity of Al Ain (Richard, 2004). The microhabitat identified as a wadi

Figure 2. Wadi-Jebel Hafit, Al Ain.

habitat is in close association with mountains and alluvial plains with distinct tree vegetation. The soil substrate consists of alluvial plains, gravel, pebbles and rocky material (Brown G, Sakkir, S (2004a).

The site chosen for pitfall trapping is unique in the wadi on account of the abundance of medium sized Acacia trees (*Acacia tortilis*) and other vegetation types include *Acridocarpus orentalis*, *Aerva javanica*, Foxtail grass

Figure 3. Acacia trees in Jebel Hafit pitfall site.

Figure 4. Um Ghafa, Mezyad.

Figure 5. Camel Camp in Um Ghafa, Mezyad.

(*Cenchrus ciliaris)*, Incense grass (*Cymbopogon commutatus)*, *Convolvulus virgatus*, *Dodonaea viscose*, *Euphorpbialarica*,*Morettiaparviflora*,*Ochradenusarabicus*, *Iphiona aucheri*, *Indigofera colutea*, *Physorrhynchus chamaerapistrum*, *Tephrosia apollinea* and Christ's torn (*Ziziphus spina-christi*) (Brown and Böer, 2004). There is a considerable variation in the occurrence of plant species from one year to another and it was observed as the rainfall has influence on plant population. Majority of the above species were observed in winter months of 2010 and were absent in the same periods of 2011.

MATERIALS AND METHODS

Pitfall trap

Pitfall trapping is a sampling technique which is widely used in studies of seasonal occurrence, to examine spatial distribution patterns, to compare relative abundance in different micro-habitats, to study daily activity rhythms, and in community surveys. Pitfall trapping using small containers with preservatives is a standard invertebrate sampling method. Most ecological studies of beetles use approximately 10-20 pitfall traps per sample site (Driscoll, 2005; Baker et al., 2006; Martikainen et al., 2006). There are many variations of pitfall traps, but in its most basic form, a pitfall trap consists of some types of cup or other container (gallon bucket, for example) that is submerged in the soil and partially filled with a preservative. Insects and other organisms crawling about on the ground simply walk into the container and then cannot get out. In the current study, beetles were collected mainly by setting pitfall traps on two distinct sites of Abu Dhabi's Eastern Region over a period of 12 months, from March 2010 to February 2011. Twenty pitfall traps were placed randomly in an area of 40/40 m at each site. They were constructed using small plastic buckets (17 cm in length and 17 cm in diameter).

Pitfall traps were emptied on monthly basis and the data collected was recorded in the data sheets.

Species identification

Collected specimens were preserved; dry pinned or preserved in 70% ethanol. Voucher specimens (insect specimens collected from study sites and preserved for future reference) were identified to species level by comparing with identified specimens in the Environment Agency-Abu Dhabi (EAD)'s invertebrate reference collection. Majority of the beetle specimens are identified to species level. All the identified specimens were deposited in the Invertebrate Collection of EAD.

RESULTS

Average monthly air temperature, atmospheric humidity and rainfall data was noted (data recorded at weather stations, Water Resources Department, EAD) and the maximum temperatures observed are 37.5°C in the month of August and minimum temperatures observed is 19.5°C during February. Atmospheric humidity observed high during the month of December (73.01 %) and low during the month of May (32.61%). Rainfall occurred maximum during January (0.0131 mm) and rest of month it was 00 mm (Figure 6).

In the present study, pitfall trap data were used to study the invertebrate diversity, abundance, percentage of distribution and peak appearance of ground dwelling inverte-

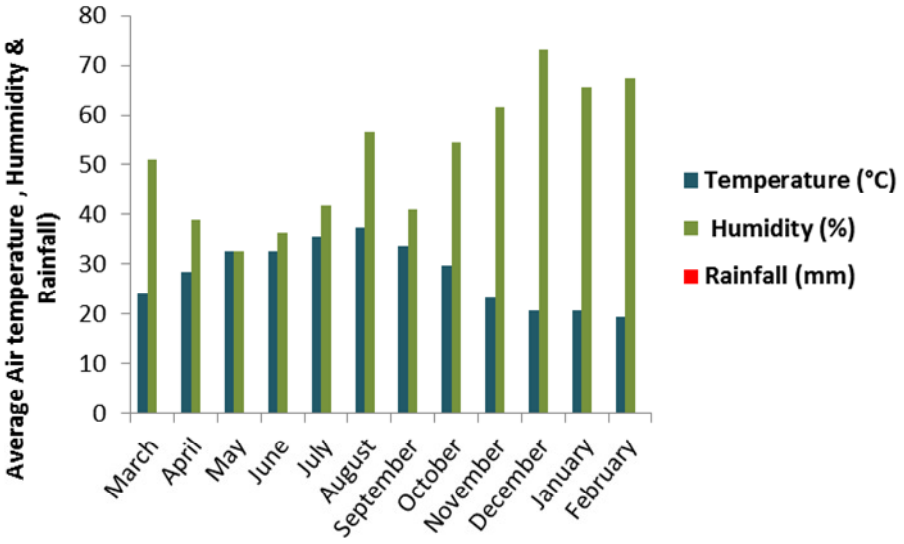

Figure 6. Monthly recorded average air temperatures, humidity and rainfall in the Eastern region.

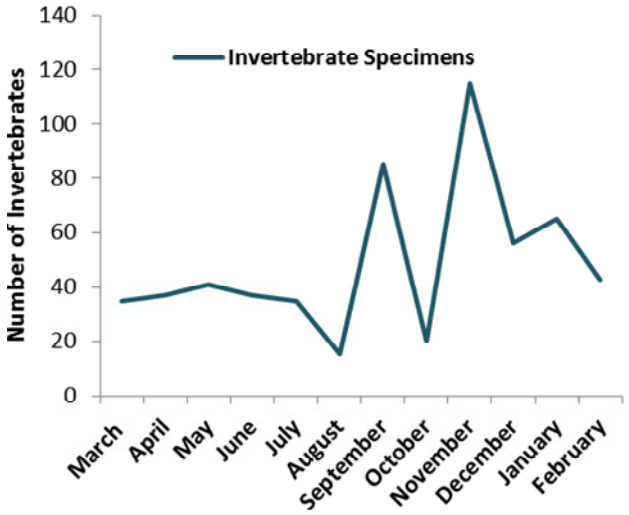

Figure 7. Seasonal abundance of invertebrates in Wadi Habitat - Jebel Hafit.

brates in two different habitats of Eastern Region of Abu Dhabi Emirate. A total of 3,502 specimens were captured in pitfall traps representing approximately 40 species. The majority of the species collected are beetles (Coleoptera) and ants (Hymenoptera). The total number of invertebrates, dominant species and seasonal patterns in the number of beetles at the two sites are presented in Figures (7 to 14 and in the Table 1.).

Invertebrates of Wadi Habitat – Jebel Hafit

A total of 584 specimens species were collected from the wadi habitat at Jebel Hafit site in pitfall traps. The most of the pitfall trap capture species were beetles of the family Tenebrionidae, Scarabaeidae, ants (Formicidae), grasshoppers (Acrididae), ground mantis and praying mantis (Eremiaphilidae and Mantidae). The diversity and population dynamics of the invertebrate species in seasons of the site is shown in the Figure (7, 8 and 9).

There was a variation in the capture of invertebrates throughout seasons and their population densities throughout the season were gradual and two peak periods observed in wadi site. The number of collected invertebrates in March, April, May, June, and July were low and it showed a peak in the months of August and September and a drop in the month of October.

Four beetle species of *Adesmia cancellata cothuranata*, *Thiraptera kraatzi*, *Trachyderma philistina*, *Adesmia stoeckleini rasalkhymana* and two ant species *Monomorium wahibiensis* and *Monomorium tumairi* were trapped frequently among the twenty invertebrate species from this site. *A. cancellata cothuranata, A. stoeckleini raslkhymana* and *M. wahibiensis* showed long period of activity and the changes in their population densities throughout the season were gradual.

In Jebel Hafit two species of beetles *A. cancellata cothurnata* and *A. stoeckleini rasalkhymana* trapped from March to February. *A. cancellata cothurnata* had relatively long period of activity and changes in their population densities throughout the season were gradual. *A. cancellata cothurnata* were the dominant species, characterized by a high rate of mobility and also were very active during the day. The first one showed peak in December and February and the later one reached a gradual increase in July and began to decline in August to October and increased in January and February. The ant species *M. tumairi* appeared in August and showed peaks in September and November. *T. philistina* and *T.*

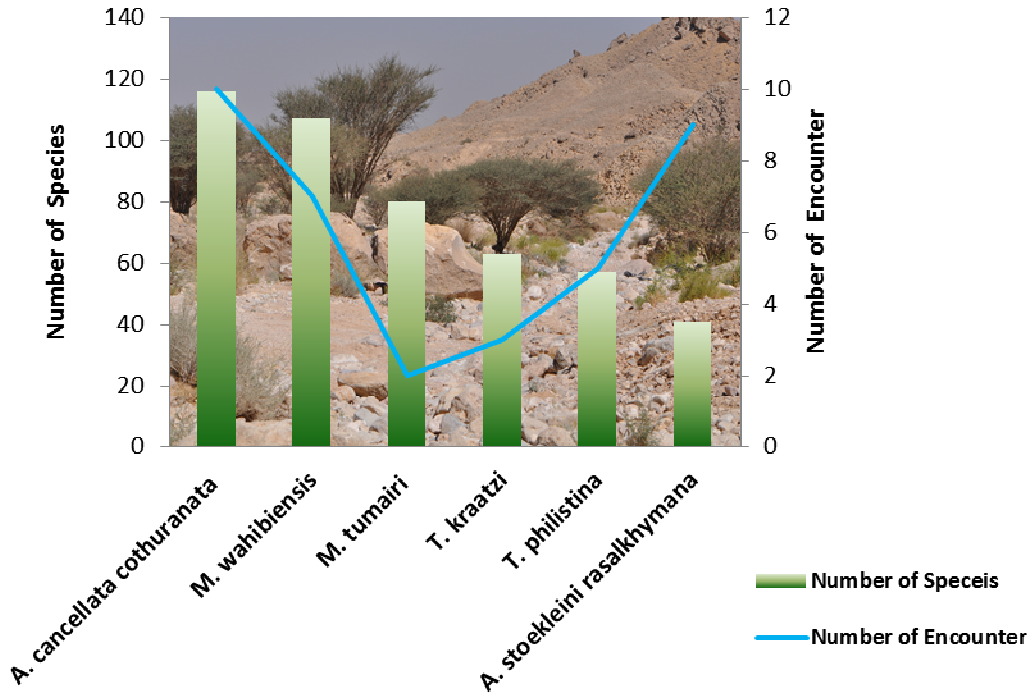

Figure 8. Capture frequencies of most abundant species in Jebel Hafit.

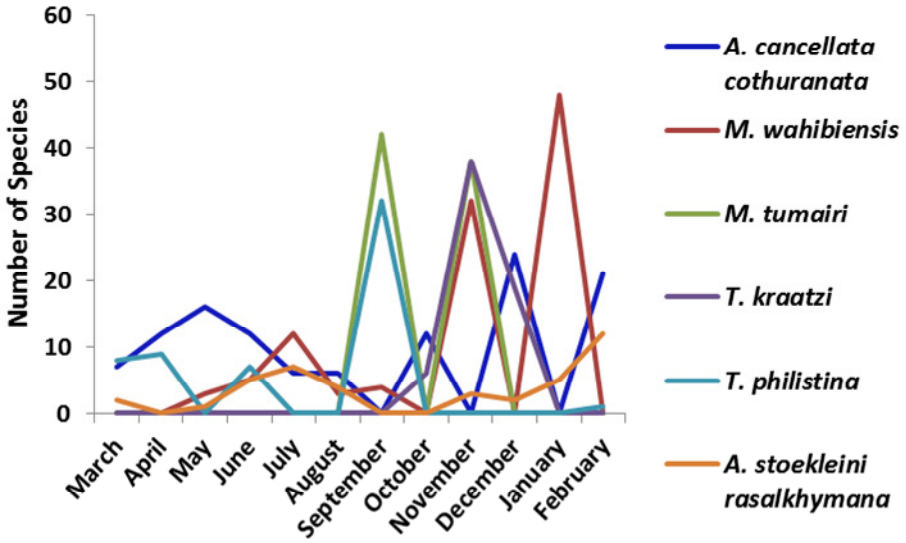

Figure 9. Seasonal abundance of abundant insect species in Jebel Hafit.

kraatzi had relatively short period of activity and population density of the species were peak in September and November Figure 9.

In addition to the six major recorded species, a beetle family named Hydraenidae was identified which is a new record from the Jebel Hafit wadi. They are very minute beetles with body length approximately 1.4 mm. The ant species *Cataglyphis falvobrnneaus* and *Camponotus xerxes*, beetle species *Apentanodes arabica*, *Mesostena puncticollis, Adesmia arabica wittmeri* and Scarabid beetle *Scarabaeus baunensis* were found very infrequently.

Invertebrates of Mezyad – Al Ain

A total of 2918 specimens were collected from Mezyad Site in pitfall traps during the study period from March 2010 to February 2011 (Figure 10). Twenty species of invertebrates collected includes insect species (*A. arabica,*

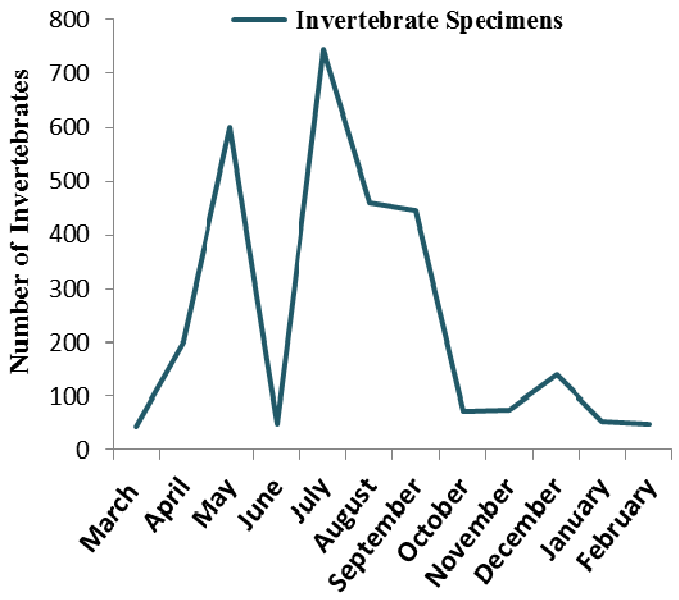

Figure 10. Seasonal abundance of Invertebrates in Mezyad.

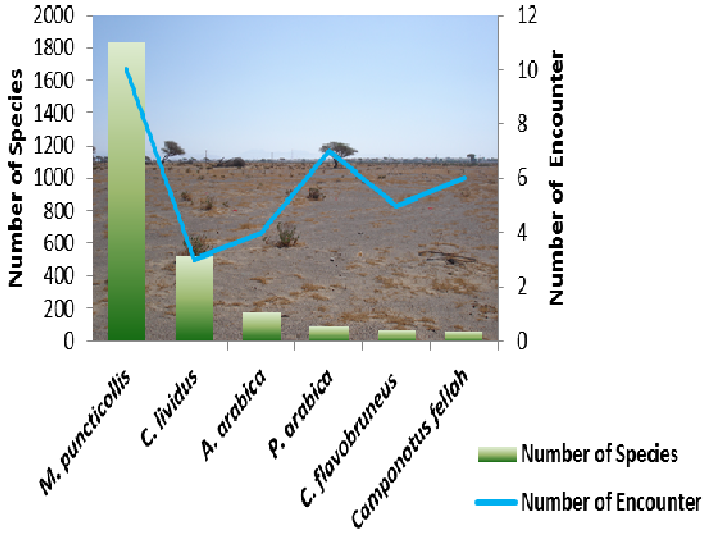

Figure 11. Capture frequencies of most abundant species in Mezyad.

Blaps kollari kollari, Pimelia arabica, M. puncticollis, Trachyderma philistina, Zophosis pharaonis simplex, Zophosis complanata, Phaeotribon sp, Crosscherichia richteri, Capricephalinus bazmanicus, Camponotus fellah, Cataglyphis flavobrunneus Cataglyphis lividus, Monomorium tumairi, Monomorium wahibiensis, Thermobia domestica, Eremiaphila gene and Arachnids include black fat tailed scorpion (*Androctonus crassicauda*) and camel spider species (*Rhagodes* sp).

There was a variation in the capture of invertebrates throughout seasons and their population densities throughout the season were sharp and two peak periods observed in Mezyad site. The numbers of pitfall trapped invertebrates were low in the month of March and showed a peak in the month of April. The number of invertebrates trapped was low in the month of May and it increased sharply in the month of July and in later months it showed a decreasing trend until the month of February.

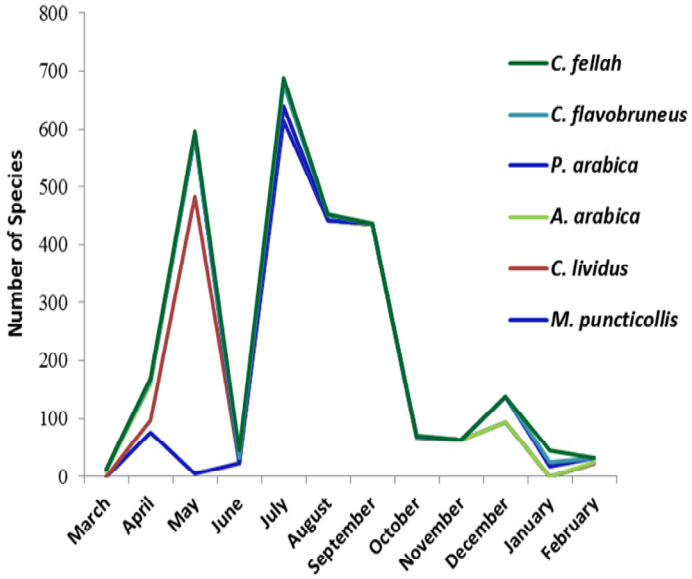

Figure 12. Seasonal abundance of dominant species at Mezyad from March 2010 to February 2011.

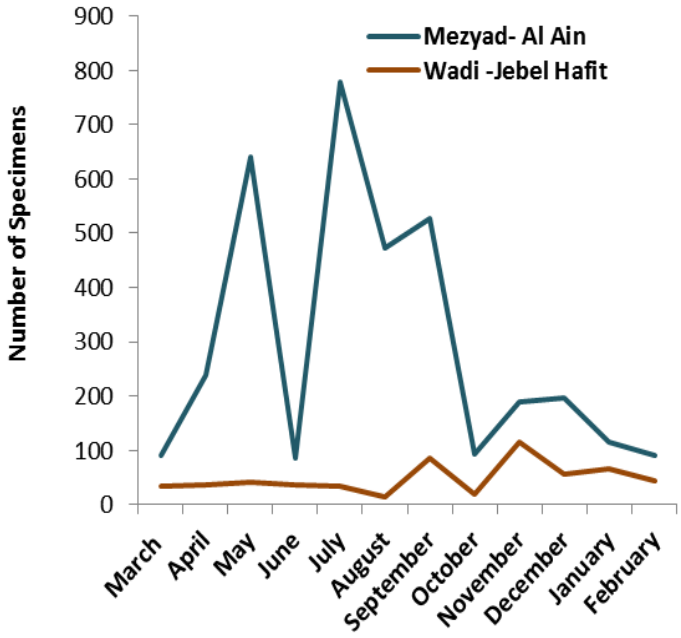

Figure 13. Number of invertebrates trapped in Wadi-Jebel Hafit and Mezyad from March 2010 to February 2011.

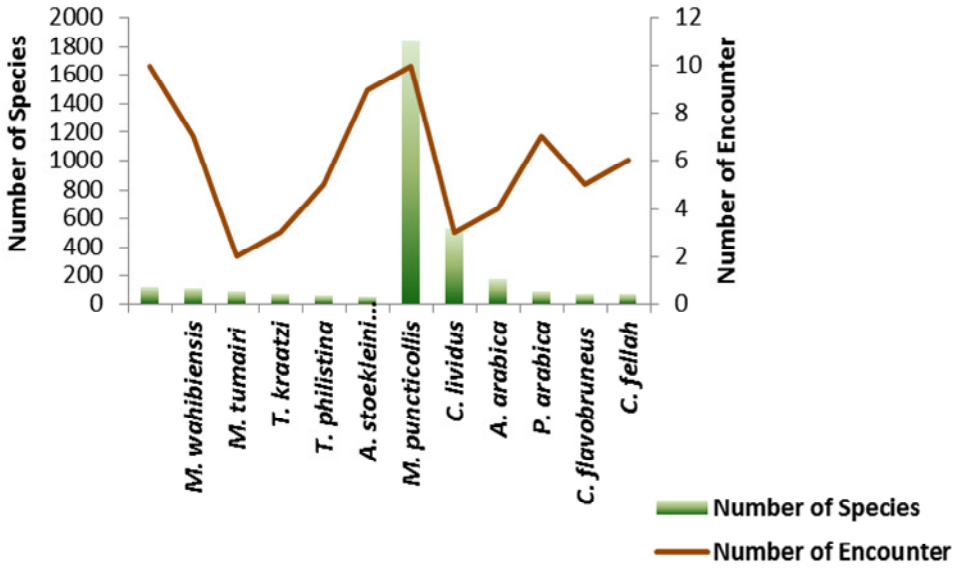

Figure 14. Dominant species recorded from two sites of Eastern Region.

Three beetle species. *M. puncticollis*, *A. arabica*, *Pimelia arabica* and three ant species *Cataglyphis lividus*, *Cataglyphis falvobrunneus* and *Camponotus fellah* were trapped frequently among the twenty invertebrate species from this site. *M. puncticollis* had a relatively long period of activity and in their population densities and were trapped from April to December and it declined in January. In contrast, *C. lividus*, *A. arabica* and *P. arabica* had relatively short periods of activity and their population fluctuations throughout the season were sharp. Species *C. lividus* and *A. arabica* showed peak densities in the month of May and almost disappeared in rest of the months. The seasonal pattern showing the number of major species in the site is presented in Figure 11.

The population of ant species *C. falvobrunneus* fluctuated considerably, forming peak in July and the other two species of ants *C. lividus* and *C. fellah* also showed comparatively medium capture rate in the same period. The ant species recorded from this site showed a decreesing trend from August to December. *M. puncticollis* is the most abundant species recorded from Mezyad site in terms of the number and number of encounter. Peak density of *M. puncticollis* was in July. *C. lividus* was noted to be the second abundant species in terms of number but this species appeared for a short period from April to July. The seasonal abundance of dominant species in the site is showed in Figure 12.

The other two abundant beetle species observed from the site are *A. arabica* and *P. arabica* of which first one showed peak appearance in April and the latter one in May. To summarize the results, we were able to show relationships between the physical parameters (temperature, humidity and rainfall) and the invertebrate occurrence. In Jebel Hafit, there is no correlation between invertebrate species occurrence and the physical parameters considered. But in Mezyad, no parameters except temperature have correlation between Invertebrate species' occurrence. The seasonal abundance of species trapped in two sites was different in the two sites. The number trapped in Wadi site was high in the month of November whereas in Mezyad site the numbers were high during the months of May, July, August and September (Figure 13). The seasonal abundance of Invertebrate species in the two sites of eastern region is shown in (Figure 13).

DISCUSSION

Invertebrates are now recognized as important components of biodiversity (Oliver and Beattie, 1996; Yen and Butcher, 1997). Invertebrate diversity and abundance were found to be relatively similar in Mezyad and Jebel Hafit with pitfall sampling method. The seasonal abundance of species trapped in two sites were different in the two sites. The number trapped in Wadi site was high in the month of November whereas in Mezyad site the numbers were high during the month of May, July, August and September.

In the current study, the distribution of ground dwelling invertebrate species varied in the different sites. Only five species were found in all sites but few species were strictly confined to particular habitats. The two beetle species *M. puncticollis, A. arabica,* and the ant species *M. tumairi, M. wahibiensis*, *C. falvobrunneus* were found in all sites. This indicates that these species are capable of existing in a wide range of habitats but the percentage of their distribution in each site shows that they have marked preferences to certain habitats. *A. cancellata cothurnata* were confined to Wadi site and they were scarce at Mezyad site. The Tenebrionid beetle species *M. puncticollis* were the dominant species, characterized by a high rate

Table 1. Total number, dominance and percent of distribution of Invertebrates in Eastern Region of Abu Dhabi Emirate.

Site wise species list	Distribution (%)		Dominance (%)	Abundance
	Jebel Hafit	Mezyad		
Mesostena puncticollis	1.1	62.9	52.6	1843
Cataglyphis lividus	0	17.9	14.9	525
Apentanodes Arabica	1.3	6.1	5.3	186
Monomorium tumairi	13.6	1.6	3.6	127
Adesmia cancellata cothurnata	19.8	0	3.3	116
Monomorium wahibiense	18.3	0.2	3.2	114
Trachyderma philistina	9.7	1.2	1.6	93
Pimelia Arabica	0	2.8	2.3	83
Cataglyphis flavobrunneus	2.7	2.1	2.2	80
Thiraptrea kraatzi	10.7	0	1.7	63
Camponotus fellah	0	2.0	1.6	59
Crosscherichia richteri	0	1.5	1.2	45
Adesmia stoekleini rasalkhymana	7.0	0	1.1	41
Wadicosa fidelis	2.7	0	0.4	16
Zophosis pharaonis simplex	0	0.5	0.4	15
Camponotus xerxes	2.3	0	0.3	14
Adesmia cothurnata omanica	2.2	0	0.3	13
Adesmia arabica wittmeri	1.8	0	0.3	11
Sphingonotus rubescens	1.3	0	0.2	8
Dieuches mucronatus	1.1	0	0.1	7
Eremiaphila braueri	1.0	0	0.1	6
Paranysius fallaciosus	1.0	0	0.1	6
Phaeotribon sp.	0	0.1	0.1	4
Rhagodes sp	0	0.1	0.1	4
Scarabaeus baunuensis	0.6	0	0.1	4
Zophosis Complanata	0	0.1	0.1	4
Thermobia domestica	0	0.1	0.0	3
Androctonus crassicauda	0	0.0	0.0	2
Capricephalinus bazmanicus	0	0.0	0.0	2
Microthespis dimitriewi	0.3	0	0.0	2
Ochthebius (s.str) patergazellae	0.3	0	0.0	2
Prionotheca coronata	0	0.0	0.0	2
Blaps kollari kollari	0	0.0	0.0	1
Eremiaphila gene	0	0.0	0.0	1

of mobility. The least abundant beetle species such as *Prionotheca coronata*, *Z. complanata*, *B. kollari kollari* and *S. baunuensis* were least active and, therefore, their capture rate was low. The number of pitfall trapped species of invertebrates in any habitat is well correlated not only with species abundance but also with activity (Aldryhim, et al., 1992; Saji and Al Dhaheri, 2011). However, the standarised and comparable data collected on species presence/absence, distribution patterns, habitat associations, diversity and abundance would be needed for effective conservation and monitoring of invertebrate species and their habitats.

Conclusions

The pitfall traps have been considered as a reliable method for beetles (Ericson et al., 1985) and long-term trapping is required to understand the biodiversity, community composition and activity of different species in

different climatic conditions (Henschel et al., 2003). Our results indicate that there is an abundant, diverse assemblage of arthropod species, principally darkling beetles, associated with ant species in the Mezyad site at Eastern Region. It is important that most of the individuals associated with the ant-nest in Mezyad were Tenebrionid. This might be due to darkling beetles which are principally detritivorous (Crawford, 1979, 1991) and the darkling beetles and ants are the principal ground dwelling arthropods in the arid areas of eastern region in Abu Dhabi Emirate.

ACKNOWLEDGEMENT

We would like to thank Dr. Majid Al Qassimi (Director, Terrestrial Biodiversity Sector, Environment Agency- Abu Dhabi, UAE.) for his support and encouragement. Thanks to Ms Swapna Rajesh for the statistical analysis of the study.

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academicJournals

Vol. 6(3), pp. 280-289, March 2014
DOI: 10.5897/IJBC2013.0673
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Genetic erosion of barley in North Shewa Zone of Oromiya Region, Ethiopia

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Accepted 12 February, 2014

This study was conducted during the cropping season of 2010 at Degem wereda. The objectives were to assess the extent of genetic erosion of barley and justify reasons for its conservation at community and household levels. Formal and informal surveys were made aimed at assessing causes for genetic erosion and quantify the level of genetic erosion. Collected data were subjected to descriptive statistics; Chi-square test and relative regression analysis and analyzed with SPSS software version 15. Accordingly, 17 farmers' variety (FV's) were grown before 1994 and during 2010 only 5 FV's (35%) were grown. The estimated loss accounts for 65%. The major causes for genetic erosion were introduction of improved varieties, replacement of other crops, weather variability, and change in land use pattern and lack of policy support (76, 14, 14, 8, 13 and 90%, respectively). Moreover, socio-economic factors affected genetic erosion and statistically and highly significant at $p<0.001$ for Chi-square and at $p<0.05$ for regression analysis. Wealth of traditional sayings, poems and songs gave a picture of the importance of barley in society's daily life. Therefore, attention should be given to conservation of farmers' varieties. Involving farmers' participation is very important in order to use their indigenous knowledge for conservation of FVs', varieties end-use and share their socio-cultural preferences. On farm conservation strategies should be practiced for FVs' sustainable use and attain food security.

Key words: Genetic erosion, barley, conservation, varieties.

INTRODUCTION

Barley was domesticated in Southwest Asia from two-rowed wild barley, *Hordeum vulgare* ssp. *spontaneoum* (Harlan, 1976). However, recent researches attributed two origins for barley, that is, mountainous areas of Ethiopia and Southeast Asia. The earliest cultivation of barley was believed to have begun some 8,000 to 10,000 years ago in the area of the Middle East known as the Fertile Crescent (Giles and Von–Bothmer, 1985; Von-Bothmer and Jacobsen, 1985).

Barley is the predominant cereal crop in the high altitudes (>1800 m.a.s.l.) and it can be cropped twice a year. The main season, locally known as *meher*, relies on June-September rainfall, while the March-April rainfall provides moisture for a second season, known as *belg* (Lakew et al., 1997; Bekele et al., 2005; Shewayrga and Sopade, 2011).

The greatest diversity of barley in terms of morphological types, genetic races, disease-resistant lines, and endemic morphotypes exists in Ethiopia (Orlov, 1929; Huffnagel, 1961). In Ethiopia it was cultivated by the ancient Agews as early as 3000 before Christ (Gamst, 1969) and since then the crop is grown as farmers' variety (FV's) by subsistence farmers and provide a more dependable and sustainable production for the farming community than the other cereals in the highlands of Ethiopia. In parts of southern and central Ethiopia, the

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history of barley cultivation is reported to have coincided with the history of the plough culture (Haberland, 1963).

As one of the oldest cereal crops cultivated since ancient times in Ethiopia, barley has passed through the processes of farming which in turn have been affected by the complex socio-cultural attitudes of communities and the prevailing environmental changes. Information concerning the impacts of socio-cultural conditions of farmers on the maintenance of crop genetic resources is rare in Ethiopia (Eticha et al., 2010). Indigenous knowledge and socio-cultural preferences of FVs' have not been assessed. Very few studies have examined the significance of traditional farming system (Hunduma, 2006).

In most cases, the conservation and maintenance of FV's as part of cultural heritage of a region or country has received too little attention (Zeven, 1998). Farmers' varieties are in many ways comparable with monuments, traditional costumes and folk songs as examples of cultural heritage.

At present, increasing crop yield through improved technology led to the loss of genetic diversity. On-farm genetic resource conservation receives less attention. Agricultural extension in the zone has focused on the improved varieties. Even though FV's has far greater importance to the livelihood of millions of farmers in developing countries, substantial information is lacking. In North Shewa, improved varieties of barley have been disseminated to the farmers as of 1990s. Some of the FV's have been replaced while others remained. However, the level of genetic erosion and conservation and the reasons are not known and quantified. In Ethiopia, native barley varieties are suffering serious genetic erosion (Mekonen et al., 2000).

Genetic erosion is defined as the loss of variability from crop populations in diversity centers, that is, areas of domestication and secondary diversification (Brush, 1999). Hammer et al. (1996) defined it broadly as the loss of particular local landraces expressed as the ratio of the number of landraces currently available to their former number. The term "genetic erosion" is sometimes used in a narrow sense, that is, the loss of genes or alleles, as well as more broadly, referring to the loss of varieties (FAO, 1998). It is a process acting both on wild and domesticated species. It is also both natural and man-made process. Naturally, it occurs when there is inbreeding between members of small population that will reveal deleterious recessive alleles. It causes a population "bottleneck" by shrinking gene pool or narrowing the genetic diversity available. This natural process could be the causes for the losses of heterozygosity that reduces the adaptive potential of every population (Caro and Laurenson, 1999). In cultivated plants, genetic erosion is the loss of variability from the population, that is, the loss of heterogeneity of alleles and genotypes with their attendant morphotypes and phenotypes. The American plant explorers are credited for first recognizing the problem of genetic erosion in crops (Harlan and Martini, 1936).

The causes and effects of the genetic erosion of plant genetic resources are poorly understood. Agricultural modernization is the major cause of the erosion of plant genetic resources. At present, increasing crop yield through improved technology led to the loss of genetic diversity. On-farm genetic resource conservation receives less attention. Agricultural extension in the zone has focused on the improved varieties. In Ethiopia, traditional barley and durum wheat varieties are suffering serious genetic erosion due to displacement by introduced varieties (Friis-Hansen, 1999). For many years government agricultural policy did not adequately address the role and contribution that farmers' varieties could play. This is partly due to lack of information regarding the traditional ways of life using farmers' varieties and partly because of the ambition to fill gaps in food security. On the other hand, information on traditional farming system is scanty. Genetic erosion of crops and their wild relatives is accelerating at a high rate because of human activities in Ethiopia (Mekonen, 1997). The recurrent drought in the past decades has eroded considerable amount of biodiversity in the country. Furthermore, less is known about the causes and the degree of genetic erosion on local varieties of crop plant species or list of varieties/species lost in various parts of the country. Knowing the causes of genetic erosion is equally important for devising conservation measures. Likewise, identifying local crop varieties and associated wild relatives that are lost or are on the verge of extinction, play crucial role in designing and implementation of conservation policies.

Research on crop genetic resource management is indispensable for wise use of crop varieties by research and seed producers for further improvement and conservation in particular, research on traditional management of crop genetic resource in a marginal areas help to develop sustainable on-farm conservation strategy.

Therefore, the objective of this study was: to assess the extent of genetic erosion and justify reasons for its conservation at community and household levels.

MATERIALS AND METHODS

North Shewa Zone, Oromiya (Figure 1) was selected for the following reasons: (I) barley was the dominant crop in the area, (II) improved varieties have been disseminated for over fifteen years that influence on-farm diversity of the barley FV's, (III) it had less government attention with regard to conservation of FV's of barley and (IV) there was no known similar study of any kind that was done before in the study area that could be used as a baseline reference. This assumption emanates from the fact that the prevailing networks in the farmers' seed system had been highly influenced by the formal seed system. In order to assess farm GE, survey research was undertaken. These were, formal and informal survey to explore the level of on-farm genetic erosion in depth by interviewing carefully selected group, homogenous in social composition with 105 farmers; key informant interviews (interviews with special barley knowledge holders in farming community) with 3 to 5 farmers (farmers seconded by the farming community for their rich indigenous technical knowledge on barley production, management

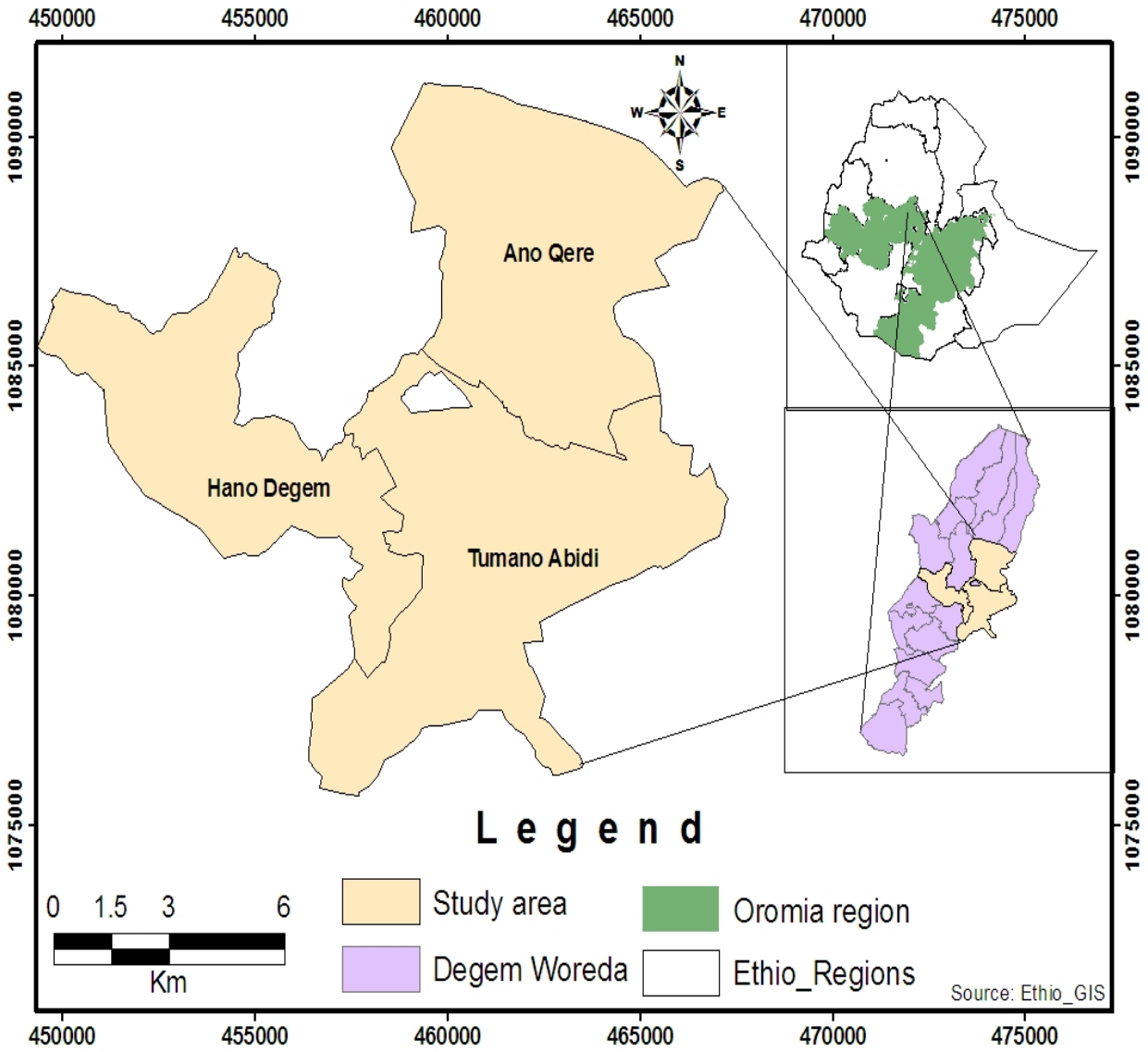

Figure 1. Map of Ethiopia, Oromiya and Degem wereda showing the study area.

and utilization) and *kebeles*, cooperative leaders, development agent (DA), Wereda agriculture and rural development office experts, working in activity related to barley genetic erosion and semi-structured interviews (a survey done with a structured questionnaire with individual farmers for quantifying and comparing data on on-farm barley genetic erosion) with 90 farmers.

Selection of respondents

During the survey, leaders of the peasant, associations and development agents working in each peasant association assisted in providing the list of farmers in each PA. From the list, informant was selected randomly, and this random sampling permitted all class, sex and age categories to be represented. Ninety randomly selected households, that is, 70 males and 20 females were involved in a household questionnaire survey from the three peasant associations.

Ninety smallholder farmers, 3-5 rich and poor (farmers in each group), and 3-5 women were selected and interviewed. The key informants were selected in order to conduct in-depth interview and discussion. They were selected from household heads of both sexes and different age groups based on their availability, willingness and practical knowledge on barley genetic resources of the area. The local administrators and DAs helped in identifying the names of the focus group.

The households were interviewed using a semi-structured questionnaire (Appendix 10). The questionnaire covered different topics such as information about the study area, landholdings, FV's of barley commonly grown, introduced improved varieties and specific information on the use and management of barley. The detailed information focused on cultural practices, the effect of new varieties on local genetic erosion, seed quality of FV's, and types of food prepared, and traditional values of barley. The respondents were also asked about their perception of the production of FV's of barley and the possible advantages of growing the crop as compared to

other cereal crops known in the area.

Focus group discussions and key informant interviews

In addition to personal interviews, focus group discussions and key informant interviews were carried out to complement the information obtained from individual farmers. For focus group discussion, three to five farmers from each PA were identified to conduct in-depth interview and follow-up on interesting issues that had surfaced during individual interviews.

Two approaches were used to quantify the loss of FV's. The first approach was a comparison of the number of FV's or botanical varieties found in an area during collection missions at two different times. A second approach was interviewing farmers about FV's formerly grown in the area. In both methods, evidence for genetic erosion was reflected in a decrease in the number of FV's or botanical varieties. Using the calculation scheme: gene erosion = 100% - genetic integrity, that is, the still extant FV's, a genetic erosion was calculated for Degem wereda. A digital camera was used to document the landscape and the different FV's of barley interaction with improved varieties of barley that had been identified by farmers.

Participatory varietal evaluation (on-farm exhibition, description and characterization of barley diversity on spike length, number of spikelet's per spike, plant height, days to heading and maturity or seed color), agronomic and socio-cultural preferences (seed rate, low input requirement, medicinal value, socio cultural value, for malt and yield) were used. Local cultivars that were once cultivated by farmers were also recorded during the study. Furthermore, key informants and focus groups were asked about the meaning of local names in cases there were special attributes were associated with the names. This evaluation was one of the methods employed for assessing and inventorying on farm GE. This was done around physiological maturity of the crop. An average of 33 farmers participated in each peasant association. Both women and men discussed the prevalence, distribution, medicinal and socio-cultural importance of each variety. Furthermore, wealth of traditional sayings, poems and songs were interviewed to obtain a picture of the importance of barley in society's daily life and expressions linked with barley production.

On-farm participatory variety selection was conducted with farmers on field experiment to compare the overall performance of the enhanced FV's using farmer's own evaluation criteria (plant height, spike length, kernel color, days to maturity, straw character, for food quality, low input requirement, medicinal value, socio cultural value, for malt and yield). Local cultivars that were once cultivated by farmers were also recorded during the study. Furthermore, key informants and focuses groups were asked about the meaning of local names in cases there were special attributes associated with the names.

Finally, they were asked about their opinion on the production status of barley. A gender-specific question within individual households was raised to see whether there were differences in the participation of the household in management and household (preference) use of barley and if a particular management functions, such as seed selection, as related to gender.

Quantification of genetic erosion: Genetic integrity and erosion were calculated as indicated by Hammer et al. (1996). Genetic integrity (GI) = ratio of the number of collected accessions per crop per area where farmer varieties (FVs) were presented in 1960s and 2010, that is, C2010/C1960s x 100. Information about the 1960s collections was obtained from the Ethiopian Institute for Biodiversity and Conservation. Then, GE was calculated as GE = 100% - GI. Using the indicated formula, number of collection made in the 1960s was compared with that of the collection made in this study, in the year 2010. Comparison of collection was made both in number and in name because of the similarity in the area of collection. Besides comparison of collections, survey methods such as on farm monitoring, semi-structured interview and focused grouped discussion were also used in assessing farm GE.

Collected data were subjected to descriptive statistics; Chi-square test and relative regression analysis and analyzed with SPSS software version 15.

RESULTS AND DISCUSSION

Distribution of farmers' varieties

In all study sites, barley has been growing in monoculture. The number of FV's that are traditionally used by farmers were considerably higher. All households involved in the survey had grown FV's of barley before 1990s. Interviewed farmers reported that previously they were growing a wider diversity of FV's for various reasons. Survey result in the study area indicated that 65.6% of barley grown before a decade was dominantly FV's. As seen from key informant and focus group discussion, at least seventeen FV's of barley (*Mugaa, Magee, Barsaddad, Buttujji, Abiso, Abichu, Karfee, Hadhoo, G/gurracha, Tolasee, Damoy adii, Damoy sayintee, Kasalee, Carree, Luqa'a* (*sanf kolo), Samareta, Qaxxee* and *G/adii)* had been grown. Yirga et al. (1998) reported that among the crops grown in the study area, barley showed the highest diversity (15 barley cultivars). Similarly, Shewayrga and Sopade (2011) reported that fifteen FV's were grown in north eastern Ethiopian highlands, which varied in maturity, yield potential, stress tolerance, end-use qualities and other agronomic traits. As of 1994, farmers had specialized on a few varieties that would meet their needs best (Table 1).

However, recently six FV's *G/gurracha, Tolasee, D. adii, D. sayintee, Qaxxee, Hahdoo* and *G/adii* have been grown in different proportion of plots in the study area (Table 2).

Among the lists, the four FV's, namely *D. adii, D. sayintee*, *Qaxxee*, and *G/gurracha* were found to be common in all the study sites and distributed on small plots. The dominance of the four major FV's found to be associated with the specific qualities were attached to each variety (Table 2).

Other local cultivars such as *G/adii*, *Tolasee* and *Hadhoo* were reported to be specific to only certain sites. Despite the initial wide genetic base, key informants and individual farmers confirmed that considerable numbers of local cultivars had been lost. There was clear evidence of ongoing genetic erosion, which had resulted in the complete loss of most of the FV's. According to the key informant farmers, eight FV's namely *Mugaa, Abichu, Barsaddad, Abiso, Samareta, Buttujji, Kasalee and Luqa'a (senef kolo)* were lost for several reasons (Table 2).

Genetic erosion of barley farmers' varieties

The estimated loss accounted for 65% (Genetic Erosion = 100%-Genetic Integrity). The current level of Genetic Integrity (GI) is 35% (the ratio of the number of currently available FV's to the number of FV's mentioned before from Degem expressed as a percentage).

Table 1. Trends on barley production at Degem wereda before and since ten years.

Proportion of farmers' and improved varieties between 1990-1994	N=90	%
FV's	59	65.6
Improved varieties	10	11.1
Both	21	23.3
Dominant barley varieties grown after 1994		
Qaxxee, Damoy, G/gurracha, Filatama	6	6.7
G/adii, Damoy, Qaxxee, Tolasee	7	7.8
Filatama,Qaxxee, Damoy, G/gurracha, Tolasee	11	12.0
Filatama, Tolasee, G/adii, G/gurracha, Damoy, Qaxxee	6	6.7
Filatama, Tolasee, Qaxxee, Damoy	13	14.0
Filatama (Hb42, HB1307, *Shagee)*	47	52.82

Source: own survey result 2010.

Table 2. Trends in barley production at Degem.

Varieties in production	Varieties rarely in production	Varieties lost	Reasons for loss of the varieties
Magee	*Karfee*	*Mugaa*	Climate change
G/adii	*Hadhoo*	*Barsaddad*	Degradation in soil fertility
G/gurracha		*Abichu*	Introduction of improved varieties
Damoy adii		*Abiso*	Replacements'by other crops
Damoy sayintee		*Kasalee*	Extension system focused on improved varieties
Filatama		*Buttujji*	
Tolasee		*Luqa'a*	
Qaxxee		*Samareta*	

Source: own survey result 2010.

Only 35% of FV's were cultivated in Degem during 2010 cropping season. These included, *Tolasee, G/adii, G/gurracha, D. adii, D. sayintee*, and *Qaxxee.* Similar results in many other crops reported that FV's are rarely seen in the fields (Mekonen, 1997; Tesemma, 1991; Mekonen and Mekbib, 1993) as cited in Tsegaye and

Berg (2007). On the contrary, Mekbib (2007) reported that there was no genetic erosion based on the number of FVs in sorghum.

Factors that contributed to genetic erosion of barley farmers' varieties

No single factor was solely responsible for FV's genetic erosion in Degem wereda. Introduction of improved varieties, replacement by other crops, recurrent drought, government policy, change in land size and cropping pattern were factor reported for barley genetic erosion at Degem wereda. Similarly, Tsegaye and Berg (2007) reported that the causes of genetic erosion are multifaceted, emanating from responses to changing natural, socio-economic and policy environments. The relative contribution of each factor varies across space and time. The main factors that contributed to the loss in the study area discussed below.

Introduction and expansion of improved barley, wheat and potato varieties

Improved food barley varieties and wheat along with improved production packages were promoted through the formal agricultural extension system since the early 1990s. In addition, access to agricultural inputs (improved seeds, inorganic fertilizers, herbicides), and information on improved production practices were made available along with the new varieties. Many farmers adopted the new varieties; as a result, the FV's were gradually left out of production. As 84.4% (76) of the respondent indicated, the main reason for genetic erosion was introduction of improved varieties, followed by replacement by other crops 15.6% (14) (Table 3). Similarly, Balcha and Tanto (2008) reported that agricultural development in developed and developing countries alike has been accompanied by the replacement of local populations of crops with a handful of modern varieties threatening genetic diversity. This finding was in contrast to Engels et al. (1991); Teklu and Hammer (2006) who reported that the main reason for the reduction or abandonment of cultivation of FV's was displacement of FV's by other crops and followed by introduction of improved varieties.

Van de Wouw et al. (2009) also reported that replacement of FV's with modern cultivars is a gradual process,

Table 3. Annual and seasonal rainfall (mm), 1997- 2007 at Degem Wereda.

Year	Annual mean	*Kirmet* mean	*Belg* mean	*Bega* mean
1997	238.19	854.8	117.2	127.9
1998	241.32	965.5	121.9	51.9
1999	246.72	1062.4	15.9	130
2000	242.31	1014.4	112.3	23.5
2001	233.07	873.8	132.5	22.8
2002	235.53	778.7	197.7	83.5
2003	244.58	919.1	214.5	43
2004	239.25	896.8	190.6	18.8
2005	229.82	776.5	143	64.1
2006	258.02	1060.5	182.5	105.5
2007	241.16	920	142.14	66.4

Source: EMA 2007. *Kirmet* (main rainy season, June-September), *Belg* (February-April), *Bega* (October-January).

and the length of the transition period will vary much between crops and regions. In developing countries, the replacement of FV's is currently in progress, while in North America, many European countries for many crops, FV's have become absent, and farmers grow only modern cultivars. The first cultivar introduced in an area will not immediately displace FV's, and therefore it is likely that the total diversity will initially show an increase. In the early stages, the contribution of the cultivars to the total diversity will be minor, while in the latter stages the FV's contribution will become small. For studying trends in diversity during the process of replacement of FV's with cultivars, the total diversity at a certain time should be taken into account. A possible modernization bottleneck due to the replacement of FV's by cultivars would be reflected in a higher diversity of the FV's before the introduction of cultivars as compared to the diversity of the cultivars after the replacement with the FV's is completed (van de Wouw et al., 2009).

Change in land use and change in land size are problems that limit local barley production and leads to genetic erosion. However, individual farmers allocated farm size to each FV's based on soil fertility and nutrient demand of the varieties (Figure 2). Rich households had relatively large land holdings (average 2.36 ha) as compared to the poor households (average 0.5 ha). Better-off farmers maintained more FVs varieties than poor did. Although it is just natural, farmer with limited plots of farmland would be forced to give up cultivation of FVs in favor of improved varieties. Hence, in another year no seeds of that FV's will be available within the informal seed system. This study is in agreement with Tsegaye and Berg (2007), the larger the size of total land holding, the larger is the wheat area of a household.

The net barley area has reduced from 1.72 ha in 2006 to 0.35 ha in 2010 for the period of 5 years. The mean area for each crop in the 2006, 2007, 2008, 2009, and 2010 are indicated in Appndix 4.

Introduction of other crop seeds were also factors for the loss of FV's. It was indicated that mean area allocated for wheat production relatively increased from 0.24 in 2006 to 0.56 ha in 2010 and mean plot area allocated for potato increased from 0.003 in 2006 to 0.114 ha in 2010. Likewise, mean plot area allocated for faba bean increased from 0.074 in 2006 to 0.153 ha in 2010. This showed that trends of plot allocation for FV's of barley were decreased (Annex 4). (Mekonen et al., 2000) reported similar result that the overall barley production area in Ethiopia has been gradually diminishing due presumably to the expansion of wheat and rye cultivation in some regions. Leur and Gebre (2003) also reported that the cultivated area of a number of traditional barley varieties is declining rapidly. On the other hand, plot allocation for improved barley, wheat, potato and faba bean gradually increased.

Lack of policy support for farmers' varieties

Policy makers and some local expertise have expected FV's as low yielding ones. All of the respondents reported that training and other awareness had been given on production of improved varieties of crop to increase production and to attain food self-sufficiency. Socio-cultural values for FV's, indigenous knowledge of the local people and local crop genetic resources have been given little or no attention by policy makers and development agents. However, this scenario was not always true. Study conducted indicated performance evaluation of FV's and improved varieties that there were high yielder FV's in yield and yield related parameters (Table 3). Tsegaye and Berg (2007) reported that in tetraploid wheat FV's have not been part of the agricultural extension package in Ethiopia. Inadequate attention has been given to improvement of FV's, as they have often been regarded as low yielding. The policy makers were interested in increasing grain yield and total food production in the short run.

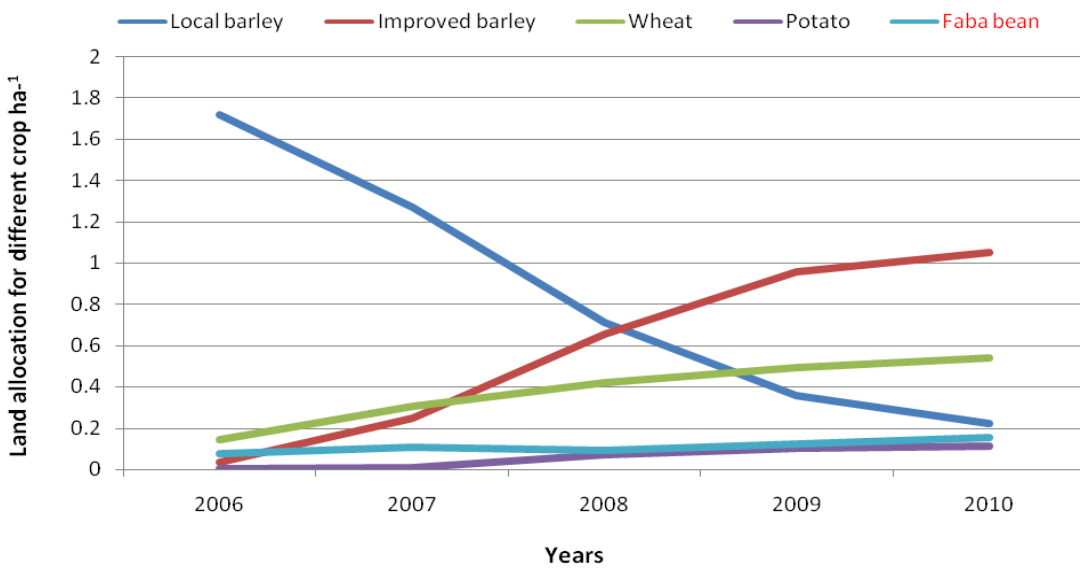

Figure 2. Trends in diversity of crop during the replacement of farmers varieties by improved varieties.

Table 4. Factor affecting on farm genetic erosion in barley.

Factor	N=90	Percentage (%)
Introduction of improved varieties	76	84.4
Replacement by other crops	14	15.6
Weather variability	14	15.6
Change in land use pattern	8	8.9
Change in land size	13	14.4
Policy	90	100

Source: own survey result 2010; Sum greater than 100 is due to double counting.

Weather variability

The erratic and unstable rainfall coupled with the longer growing period of FV's forced farmers to adopt early maturing and improved varieties or other crops that either escape or tolerate droughts. Before two-decade common planting time of barley was at the beginning of April and ended at the mid of May. The respondents reported that since fifteen years barley planting time has been changed due to lack and shift of rainfall. As a result, barley planting time at Degem changed from April 1st to May 10. Currently, planting for late maturing varieties was in the mid of May (Table 4). Inter-annual and seasonal variability of rainfall is a major cause of fluctuations in production of cereals in the central highlands of *Shewa*. Over the 1997-2007 decade, for which crop production data showed the patterns of inter-annual variability in productions of major cereals cultivated in the area, there are similar patterns of inter-annual variability in the seasonal or annual rainfall amounts (Table 3). Woldeamlak (2009) reported that sorghum exhibits the largest year-to-year variability in terms of area cultivated, total production and yield as compared to the other cereals. This high inter-annual variability is caused mainly by inter-annual variability in rainfall.

As Hammer and Teklu (2008) reported, there have been several catastrophic droughts in the country that caused complete crop failures and subsequently severe genetic erosion has taken place in the FV's that had been maintained through many generations. Farmers have been forced to consume the seeds normally kept for planting. The famine of the mid-1980s seriously threatened Ethiopia's biological resources. Generally, among the factors affecting farm genetic erosion of barley, improved varieties played a significant role (84.4%) (Table 4) followed by weather variability and replacement by other crops.

This finding is also in agreement with Friis-Hansen (2000) who noted that new varieties have had a dramatic impact on genetic erosion of local crops. Tsegaye and Berg (2007) reported for tetraploid wheat (*Triticum turgidum* L.) in two districts of East Shewa, where the expansion of *tef* and improved varieties of common wheat (*Triticum aestivum* L.) contributed significantly to the genetic erosion of tetraploid wheat FV's. Eticha et al. (2010) indicated that, a high yielding improved barley variety (HB-1307) is currently expanding and accelerating the loss of barley varietal diversity. On the contrary, Mekbib (2007) reported that improved varieties of sorghum were not the reasons for genetic erosion of FV's in the context of eastern Ethiopia and they contributed to the genetic enrichment of the existing on farm genetic diversity.

Socio-economic factors affecting genetic erosion

The three categorized independent variables: sex, level

Table 5. Number of barley varieties related to gender, education and class.

Independent Variable		Number of varieties grown			S.E	X^2	Sign.
		Increasing(N)	Decreasing(N)	Percent			
Gender	Male	5	65	78.8	0.0440	27.778***	0.000
	Female	1	19	22.2			
Level of education	Literate	1	18	21.1	0.0432	30.044***	0.000
	Illiterate	5	66	78.9			
Wealth	Rich	2	24	28.9	0.0480	16.044***	0.000
	Poor	4	60	71.1			

Source: own survey result 2010.

Table 6. Regression analysis for factors affecting genetic erosion.

Constant	Beta	S.D	t	Sig.
		0.455	**4.272*** **	**0**
Total farmland owned by the household	-0.23	0.906	-2.09*	0.04
Farmers age on genetic erosion	0.3	12.83	2.69***	0.009
Adoption of improved varieties	0.23	0.251	2.29*	0.024

Source: own survey result 2010.

of education and class had positive association with trend on FV's of barley genetic erosion. They were statistically and highly significant at $P < 0.001$ levels (Table 5). The reason for this could be that male farmers were socially powerful on the discussion of farming activities, had access to adopt new technologies than female farmers. Level of education also influenced access to extension on adoption of new technologies. Moreover, rich farmers owned more plots of farmland and maintained FV's than poor farmers. However, in order to obtain better yield and sustain their families' poor farmers used improved varieties, most of the time through seed exchange from their neighbor, which on the other hand positively correlated to genetic erosion.

From the regression analysis, significant result was observed that land holding and adoption of new varieties at $P< 0.05$. While age of the respondent was significant at $P<0.01$, land size showed negative association for genetic erosion, that is, with decrease in one hectare of farmland there was increase genetic erosion by -0.23. On the other hand, age of the respondent showed positive association with FV's conservation. An increase in one year of the respondent's age contributed to maintain FV's by 0.30. However, with one-year decrease in the age of the respondents, there was an increase in genetic erosion by 0.23. Likewise, adoption of improved varieties had positive association with the loss of FV's. From this study, one percent increment in adoption of improved varieties resulted in increased genetic erosion by 0.23 (Table 6).

Traditional songs and sayings related to barley

The diversity of foods and drinks prepared from particular FV's has motivated farmers to cultivate some FV's despite low yields realized under unfavorable edaphic and climatic factors. It was observed that farmers' beliefs, social and cultural situations have strong linkages with foods and drinks made from barley. The wealth of traditional sayings, poems and songs gives a picture of the importance of barley in society's daily life and growers show their feelings and expressions linked with barley production (Table 7).

Conclusions and recommendations

This study was conducted to assess the extent of genetic erosion and reasons for its conservation at community and household levels. Genetic erosion in cultivated crop species is a complex process. In this study, the most important factor possibly leading to genetic erosion is the replacement of FV's by modern cultivars followed by weather variability. The numbers of FV's before a decade at Degem wereda were reported to be 17. However, currently only five FV's are being grown on small plots of land in marginal environments (G/*adii*, *G/gurracha*, *Tolasee*, *Qaxxee* and *Damoy*). *Karfee* and *Hadhoo* were replaced*, Mugaa, Buttujji, Barsaddad, Abiso, Luqa'a, Abichu, Semareta* and *Kasalee* were lost. The estimated loss accounts for 65% (Genetic Erosion = 100% - Genetic Integrity). The current level of genetic integrity (GI) is 35%.

Plot allocation for improved barley, wheat and potato has gradually increased. On the other hand, farmland allocated to FV's of barley gradually reduced. Introduction of other crop seeds was also factor for the loss of FV's. It was indicated that mean area allocated for wheat

Table 7. Traditional songs and sayings related to barley.

Traditional sayingS	Meaning
Abalu garbuu dha	Description of a person who bears any kind of burden, stress or unforeseen risk.
Manyaan rakase garbuun kilo kore	Refers to increasing price and, hence, increasing importance of barley for highland farmers.
Dadhin bishaanumaa, itti buusi farsoo gaarin midhaanuma	Refers to end-use quality. *Farsoo* (local barley beer) is believed to be more nutritious than *Dadhi* (local drink made from honey).
Akkana sanyiin mootii, sila midhaanuma xajjii gooti.	The woman deserves respect since she makes *tej* from barley and indicates to the excellent brewing quality of barley.
Biroolee roobee daalen gasheen soore qabaa hin sarmu mee itt hammaari garbuu	Refers to the food and feed quality of barley. Horses fed with barley will become strong and powerful and more preferred for bridegroom during wedding.
Birrolee roobee xaafin badda hin- margu nyaadhu buddeen garbbuu	To indicate agroecological areas where barley is growing and most preferred for *injera* to *tef* for wedding in the high land.
Garbuu fi garbich hadagaa dada'a	Signifies to the tolerance of barley to stress.
Garbicha garbuu nyaatu gooftaa qamadii nyaatu	Barley is believed to be more nutritious than wheat. Therefore, hard working people should eat barley to become strong and persistent.
Annan bassootti dhagala'e	*Beso* (barley food) is as tasty as milk. Refers to the food quality of barley (to indicate well being of something).
Garbu hangafa midhani	Describe the long history of barley cultivation.
Biyya ormaa yaa gaaddisa mukaa aduun nama gubaa ,biyya ofii yaa gaaddisa garbuu aduun nama hin arguu	Signifies the importance of barley for household food security.
Biyya ormaa yaa gaaddisa mukaa aduun nama gubaa ,biyya ofii yaa gaaddisa garbuu aduun nama hin arguu	Signifies the importance of barley for household food security.
Carree nyataa harka nyanyaata	*Carree* type cultivar is very nutritious and gives strength to the workers.
Illaamu maraxame akka garbuu	*Illamu is* powerful tribe in Oromo local leader; barley is superior to cereals in highland areas.
Yaa garbuu kan sidhabe ijaan lafa hin argu	Anyone who does not have barley is vulnerable to food insecurity.
Biile daraaran garbuu anuu beekaa daarii dinbara hin darbu	As barley awns at its appropriate time, it is imperative for everyone to obey the law.

production relatively increased from 0.24 in 2006 to 0.56 ha in 2010 and mean plot area allocated for potato increased from 0.003 in 2006 to 0.114 ha in 2010. Likewise, mean plot area allocated to faba bean increased from 0.074 in 2006 to 0.153 ha in 2010. This showed that trends of plot allocation for FV's of barley were decreased (Annex 4). This indicates serious genetic erosion and vulnerability of genetic diversity of FV's of barley at Degem wereda. Losses of varieties from the study sites do not totally mean the extinction of varieties. Those varieties may survive and can be grown somewhere in the region or boundaries.

The erratic and unstable rainfall coupled with the longer growing period of FV's forced farmers to adopt early maturing and improved varieties or other crops that either escape or tolerate droughts. There are social, economic and political reasons that limit the use of FV's of barley production. Some of those are farmers' age, level of education, legislation coming into force and the lack of incentives for FV's. Old farmers mostly grow FV's; few of the young people, who are often not able to appreciate their biological and cultural importance, stay in the field of agricultural production. This makes it difficult to continue their cultivation if not to increase it, which is important for plant genetic resources conservation. Varieties that cannot meet changing demands by farmers and consumers become neglected and farmers abandon such varieties in favor of more promising varieties.

Barley, as a food and feed grain, is important to the livelihood of farmers in Degem wereda. It was observed that farmers' beliefs, social and cultural situations have strong linkages with foods and drinks made from barley. The wealth of traditional sayings, poems and songs gives a picture of the importance of local barley in society's daily life and growers show their filling and expressions linked with barley production.

Therefore, farmers' participation in barley improvement is very important in order to use their indigenous knowledge for varieties end-use and share their socio-cultural preferences. Attention should be given to on farm conservation and enhancement of farmers' varieties.

In conclusion, the use of genetic resources will remain the best way of meeting future food needs and driving the economic and social benefits for the world's rapidly gro-

wing human population. Thus, policy makers and researchers should give attention to conservation of FV's and indigenous knowledge of farmers for better use of genetic resources.

ACKNOWLEDGEMENTS

My Thanks go to Fitche Soil Research Center and Local Seed Business Project (LSBP) of Haramaya University for financing the research work, Farmers of Degem Woreda for their willingness to share their experience. Dr. Nigussie Dechassa, Dr. Chilot Yirga and Mr. Agajie Tesfaye for their material, financial, excellent, technical support and advice.

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Vol. 6(3), pp. 290-300, March 2014
DOI: 10.5897/IJBC2013.0659
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Response of a globally endangered canopy insectivore to habitat degradation in an East African tropical rainforest: The role of differential forest protection levels

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Accepted 4 February, 2014

This study examined the interplay between anthropogenic habitat degradation, forest protection level and density of Turner's Eremomela (TE) (*Eremomela turneri*), a globally endangered bird in Kenya's Kakamega forest. Sampling was conducted from May-June 2012 in two contiguous and one isolated forest blocks. Logging intensity, canopy height and cover, plant species richness and other key anthropogenic disturbance were used to characterize habitat quality. Density, encounter rates and TE spatial occurrence were determined using distance sampling. Combined TE density was 0.43 SE 0.09 ha^{-1}(N = 7, p = 0.03) and was higher in the most protected north block. Estimated overall population in closed canopy forest was 4,282 (CI = 3,417 to 5,147). High canopy cover boosted TE density (R^2 = 0.786, N = 7). Logging intensity was the key driver of forest disturbance (R = 0.742; p = 0.052) leading to reduced canopy cover (R = -0.658, p = 0.050) and reduced plant species richness (R = 0.771, p = 0.042). However, TE presence in the Kisere fragment suggests resilience to some level of isolation or forest disturbance provided sizeable near-primary forest is maintained. An effective medium term conservation strategy should include stricter forest protection and reforesting logged areas to reduce the impact of logging.

Key words: Eremomela turneri, human impact, habitat quality, forest protection.

INTRODUCTION

Species with narrow restricted ranges are among the most affected by perturbations in their highly specialized habitats. Turner's Eremomela *Eremomela turneri* (van Someren, 1920) (TE) is a forest canopy specialist bird that is endemic to the Guineo-Congolean rainforest system, which reaches its eastern limit in western Kenya forests of Kakamega and Nandi (Bennun et al., 2006). This globally-endangered species (IUCN, 2013) mainly inhabits the forest interior where it forages on arthropods in small locally itinerant groups of 3 to 10 individuals, mainly on large mature trees with closed or slightly open canopies (Kosgey, 1998 Unpublished MSc Thesis, Moi University, Kenya). Often, the groups form part of larger feeding parties involving other canopy Sylviids (Zimmerman et al., 1999). The Nandi forest system (South and North Nandi) are the main strongholds of the species (BirdLife International, 2013) but the spatially proximal Kakamega forest also holds

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substantial populations that are largely disconnected owing to years of anthropogenically-driven fragmentation and degradation (Schaab et al., 2010; Schleuning et al., 2011). The Kakamega and Nandi forests have similarities in habitat, floristic and edaphic character, though with slightly different altitudes (Bennun and Njoroge, 1999), as they both form part of the old Guineo-Congolean forest system which once extended to central Africa (Kokwaro, 1988). Analysis of photographic and remote sensing records and data over the past century suggests that the three forests were a contiguous unit as recent as one century ago (Doute et al., 1981; Tsingali et al., 2009; Schaab *et al.,* 2010). The species' westerly race *E. turneri kalinderi* still occurs only in forests of eastern Democratic Republic of Congo and western Uganda (BirdLife International, 2013).

Kakamega forest suffered several decades of massive unregulated logging until the late 1970s. Since the early 1980s, conversion to agriculture and settlement by the increasing adjacent human population has led to further forest loss and continued fragmentation and habitat degradation (Kokwaro, 1988; Akotsi et al., 2005; Farwig et al., 2008; Munyekenye et al., 2008; Schleuning et al., 2011). Moreover, different levels of official protection related to overlapping institutional management mandates have contributed to corresponding variations in habitat quality and suitability for various forest species, especially the forest specialists such as TE (Bennun et al., 2006). Our study aimed to evaluate the effects of tree removal, canopy structure change and other key aspects of anthropogenic impacts on the density and encounter rates of TE in zones of different protection levels of the forest. Being a forest specialist and upper canopy species, TE is vulnerable to habitat modification associated with loss of high canopy trees due to anthropogenic disturbance (Kosgey, 1998; Bennun et al., 1999; Otieno et al., 2011). To evaluate effects of protection on the species' response to habitat change, the study was carried out in three forest blocks with varying levels of formal protection. Protection level is used here to refer to the relative degree to which the forest blocks are actively managed to control access to the forest, minimize encroachment for agriculture, settlement, conversion or other anthropogenic activities such as infrastructure (Lakanavichian, 2006). It also refers to the degree of control of harvesting and use of forest products such as illegal logging, through patrols and law enforcement (Geist and Lambin, 2002; Lakanavichian, 2006). As we expected, the levels of forest protection influenced levels of forest disturbance and habitat quality, which in turn determined the species' density and distribution across the forest.

MATERIALS AND METHODS

Study area

Kakamega forest, Kenya's only true tropical rainforest is located in western Kenya between 0°07′–0°27′ N, 34°46′–34°57′ E with an altitude ranging from 1520 – 1680 m above sea level (Bennun and Njoroge, 1999; Fashing and Gathua, 2004) (Figure 1). Mean annual rainfall is 2000 mm and is bi-modally distributed with peaks of long and short rains in April-May and September-October, respectively (Fashing and Gathua, 2004; Mulwa et al., 2012). The absolute average temperature is 20°C with mean daily minimum and maximum of 12 and 26°C, respectively (De Meyer, 2001). The soils are well drained but deeply weathered and of low fertility. Soils of the northern part of the forest are alkaline alfisols, while those of the southern end are predominantly acidic ultisols (BIOTA, 2005).

The forest covers a total of 12000 ha but only 9500 ha still comprise closed canopy forest, 3500 ha of which occurs in the northern and 6000 ha in the southern block, respectively (Schaab et al., 2010). The northern block was gazetted as a National Wildlife Reserve in 1986 (Munyekenye et al., 2008; Schaab et al., 2010) and is under the management of Kenya Wildlife Service, KWS, while the southern block which includes Isecheno Nature Reserve, Ikuywa and Yala River Nature Reserve, is managed by the Kenya Forest Service, KFS (Fashing and Gathua, 2004; Akotsi et al., 2005; Munyekenye et al., 2008). Ikuywa is predominantly a secondary forest zone with high disturbance levels (Table 2) and a high proportion of exotic coniferous plantations forming a matrix of patches within the larger southern block (Fashing and Gathua, 2004; Munyekenye et al., 2008; Schaab et al., 2010). The non-canopy and non-forested areas include grassy and bushed glades, plantations for commercially exploited wood as well as a scattered area of cash-crop and subsistence cultivation (Akotsi et al., 2005; Schaab et al., 2010). Kisere Forest Reserve, also managed by KWS and totaling 458 ha (Munyekenye et al., 2008), is a distinct fragment which is suspected to historically have been contiguous with Kakamega forest (Schaab et al., 2010).

The forest constitutes one of Kenya's 61 Important Bird Areas (IBAs), hosting at least 350 bird species (BirdLife International, 2013), many of which are range-restricted or endemic species characteristic of the wider Guineo-Congolean forest system (Kokwaro, 1988). Of the birds, two (TE and Chapin's Flycatcher *Muscicapa lendu*) are globally endangered while a further 15 are regionally threatened (BirdLife International, 2013; Mulwa et al., 2012). There are at least 850 plant species recorded in the forest, 150 of which are woody species, although there is no significant endemism (Bennun and Njoroge, 1999; Fischer et al., 2010).

As a result of massive exploitation through legal and illegal logging between the 1960s and through the early 1980s, a mixture of large secondary-growth trees now dominates the forest flora with minimal natural primary-growth stands. Even for this secondary forest, significant stands of closed canopy and contiguity exists only in the northern part of the forest, consisting of the Buyangu block, now protected as a National Wildlife Reserve. The southern sector, comprising of the Isecheno, Yala and Ikuywa as well as the detached units of the Kisere, Kaimosi and Malava blocks (Figure 1), are managed as Forest Reserves. Due to stricter protection controls by KWS over the past few years, there has been a considerably lower intensity of illegal logging and general anthropogenic disturbance in the northern sector than in the southern block under KFS in which regulated access for controlled use of some forest products such as fuel wood, grass thatch or cattle grazing was allowed for several years in keeping with the definition of Forest Reserves under conservation legislation (Schleuning et al., 2011). The small, isolated Kisere block continues to suffer the most severe anthropogenic impact as it is only partially protected as a reserve and therefore anthropogenic access is less strictly controlled (Schaab et al., 2010). Apart from logging pressure, the south and Kisere blocks also experience impacts from the local community in the form of cattle grazing, charcoal burning and harvesting of firewood, thatch grass and honey. Some of this is allowed in quota determined under concessional controls regulated the KFS. Demand on the KFS for agricultural land by the local community

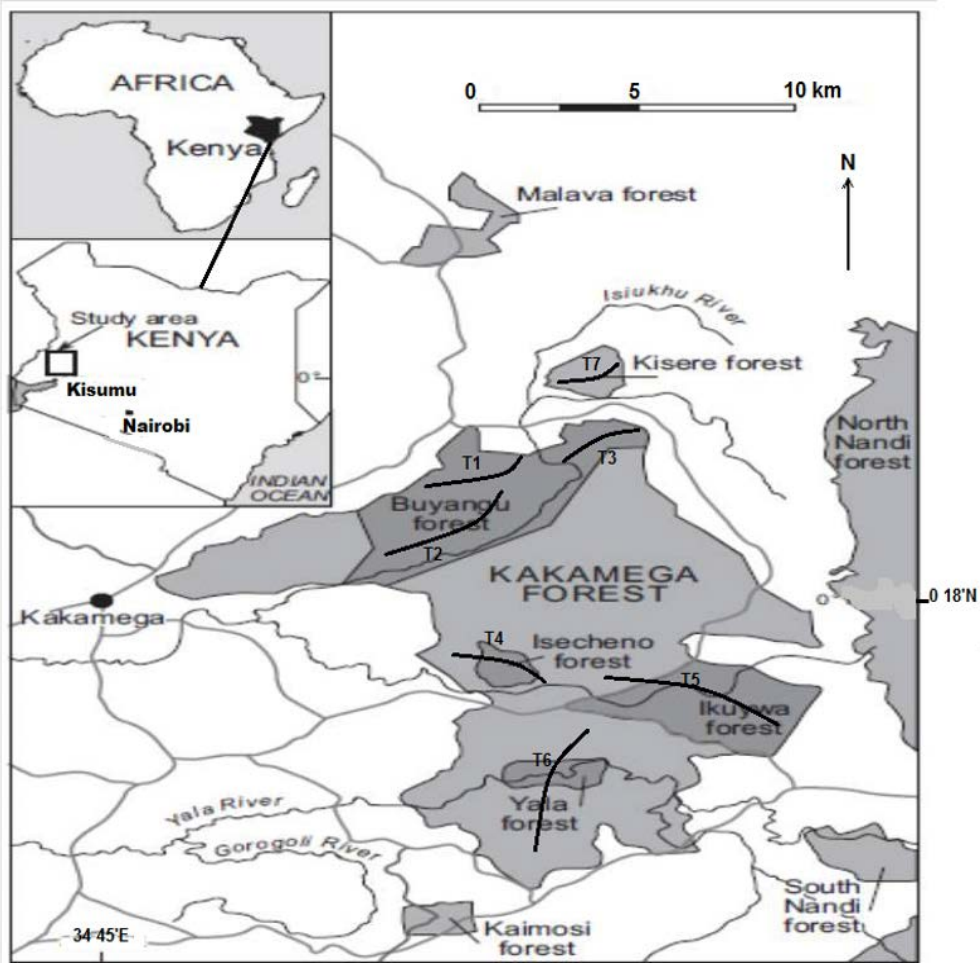

Figure 1. Map of Kakamega Forest showing the various blocks and survey transects. The transects are indicated in bold dark trace. Transect key: T1 = Buzambuli; T2 = Salazar; T3 = Primate/birding area; T4 = Isecheno Nature Reserve; T5 = Ikuywa forest area; T6 = Yala River Nature Reserve; T7 = Kisere forest (Adopted from Munyekenye *et al.,* 2008).

with a high population estimated to range between 220-600 persons per km^{-2} or 6 persons per ha^{-1} (Farwig et al., 2008) is an additional challenge that is already observable in the form of small-scale farming encroachment on some parts of the forest edge (Schaab et al., 2010).

Habitat stratification

The study was carried out from May to June 2012. Field sampling was conducted in closed canopy forest within three forest blocks: the northern sector of the forest (National Wildlife Reserve), the southern sector of the main body of the forest, (Forest Reserve); and Kisere Forest Reserve (Figure 1). Three transects each were established in the northern and southern blocks, and one in Kisere block making a total of 7. The transects were selected in a stratified fashion to reflect the degree of protection and relative disturbance levels: lowest disturbance and highest active protection level with no utilization in the northern block; moderate disturbance with regulated access in the southern block; high disturbance with moderate to low protection level in Kisere block (Table 2). The stratification was aimed at obtaining representative samples as well as facilitating spatial comparison of results (Nomani et al., 2012). In selecting and laying the transects, the main challenge was logistical especially as much of the closed-canopy TE habitat both in the north and the south was characterized by thick under-storey, thus precluding straight transects.

Bird survey

The 7 transects for survey of TE covered a total of 14 km. The surveys were conducted between 07.00 and 10:00 h along randomly selected 2-km transects in each forest block using distance sampling protocol (Buckland et al., 2001). Randomness was achieved by ensuring that transects originated from points where different existing small tracks/trails met or formed multiple arms or forks. At such points, only the right-facing track was selected. Further, it was ensured that transects were located at a separation distance of not less than 200 m from the adjacent ones, to avoid double counting (Nomani et al., 2012). Such a mix of systematic and random transect layout has been found to improve precision in density estimates using distance (Nomani et al., 2012).

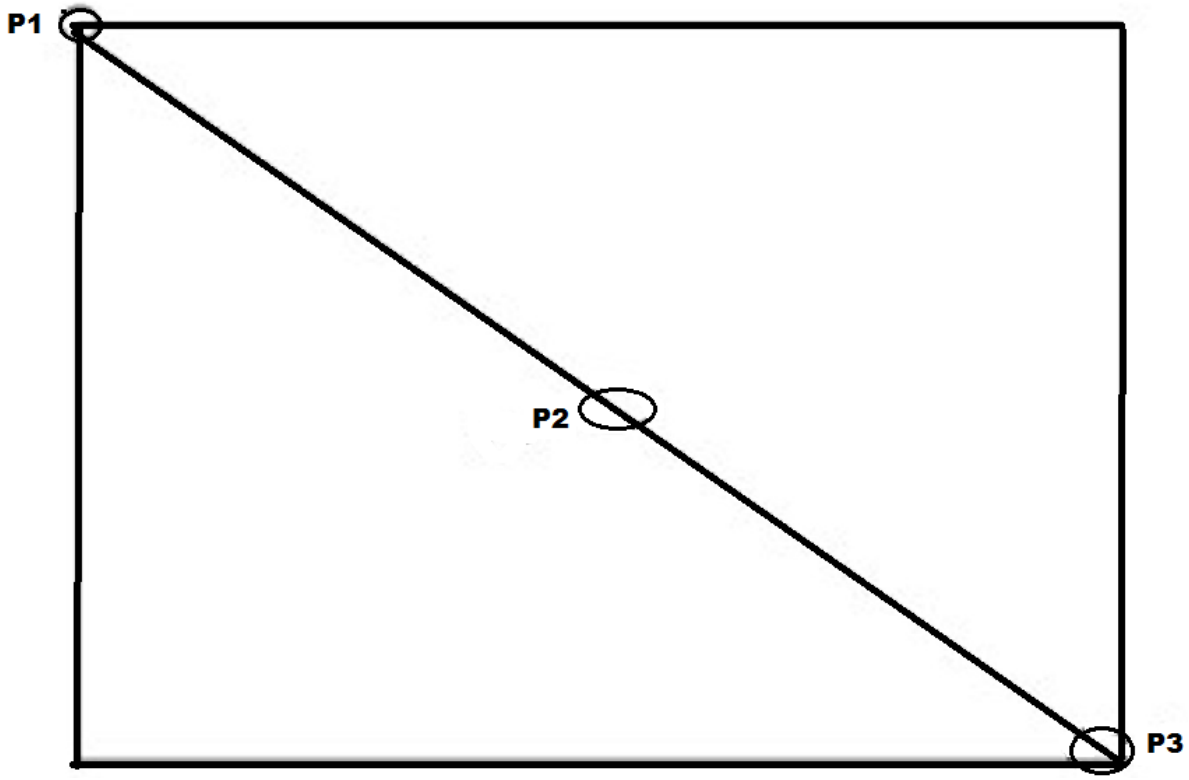

Figure 2. Sampling points for measuring percent forest canopy cover on quadrats. The three points P1, P2 and P3 represent the replicate points along a diagonal running through the centre of each 10x 10 m quadrats along belt transects used for surveying birds and assessing vegetation. Readings from all points in each quadrat were averaged to one value of percent cover.

Surveys commenced from different ends of each transect each time as recommended by Bibby et al. (998). Transects passed through the under-storey some of which had to be slightly cleared. The bird transects had a fixed width of 50 m (25 m on either side) and birds were counted by moving slowly and recording all encounters of TE (Bennun and Howell, 2002; Bibby et al., 1998). Transect method was used in favour of point counts because of the rarity of TE that would otherwise have yielded many zero counts in point counts. Fixing transect widths had two main advantages. First, it helped to maximize detection probability of the species in the closed nature of the forest habitat where this parameter declines rapidly with increased perpendicular sighting distance (Bibby et al., 1998). Secondly, it helped to improve accurate identification of TE that is not only small in size but also tends to move constantly while feeding high in the canopy in mixed flocks with other similar warblers.

Two observers working in pairs, one observing with a pair of binoculars and listening and the other recording, moved at a slow steady pace looking out for and listening to TE calls. When detected, records were also made of flock size and the perpendicular distance of each sighting from the transect centre, using a range finder (Fewster et al., 2009; Buckland et al., 2001). For a cluster of birds, the perpendicular distance was estimated to the centre of the cluster. Biases related to pseudo-replication were reduced by ignoring birds flying from behind and by the 200 m distance maintained between adjacent transects (Bibby et al., 1998). Using a range finder was helpful in improving distance estimates from detected birds to transect centre. Further, bird surveys were conducted twice along each transect on alternate weeks and on days separate from/prior to habitat sampling to reduce undue disturbance of birds.

Vegetation assessment and anthropogenic impact

Vegetation structure was assessed along the same transects used for birds, to determine the relationship with the assemblages of TE. Ten quadrats of 10 x 10 m were established on alternate sides of transects at 190 m intervals and within these, estimates of canopy height and canopy cover from three different points along a diagonal line down the quadrat, were scored. Canopy cover (defined here as canopy closure) was determined using a convex spherical densitometer (Korhonnen et al., 2006). Measurement was done while standing at three points in each quadrat: one corner, quadrat centre and the opposite quadrat corner along a diagonal line (Figure 2) The densiometer was set horizontally at elbow level about one foot from observer such that its levelling bubble was at the centre and to further improve its horizontal positioning especially in sloppy terrain, a camera tripod stand was used to steady the instrument. Standing at a point under that canopy for each measurement, an observer assumed four equally-spaced dots in each square of the grid and counted the number of dots equivalent to the quarter-square canopy openings. This was then multiplied by 1.04 to obtain and record the percent overhead space not occupied by canopy (Jennings et al., 1999; Korhonnen et al., 2006). By subtracting this from 100, percent canopy cover was derived for that particular point. This was repeated for each of the

Table 1. Results of the detection function Chi-square goodness of fit test results for model selection in estimating density of Turner's Eremomela.

Forest block	Cut points	Observed values	Expected values	χ^2	df	P<0.05
Block 1	0.00	11	11.1	<0.01	1	0.07
Block 2	7.50	13	9.32	1.45		
Block 3	15.0	3	6.57	1.94		
Total	-	-	-	3.39	1	

The results are defined by Half Normal Cosine fit on the basis of the lowest AIC value to estimate Turner's Eremomela density. The differences between observed and expected abundances were insignificant.

other two points in the quadrat end finally a mean value calculated for each quadrat (Jennings et al., 1999; Sutherland, 2006). Measurement was made consistently by one observer. The mean percent canopy cover were then scored as open (0 to 33%), medium (34 to 66%) or closed (more than 66%).

Canopy heights were measured using a Nikon Forestry Pro range finder. Again three measurements were made at three different points in each quadrat by the observer standing successive directly underneath each of the tallest canopy points and looking directly above the top of the crown and determining the height directly after correcting the observer's own eye-level height by adding it to the recording.

All plant species were identified in each quadrats. Plants were identified with expertise from a member of the Kakamega Environmental Education Programme with 15 years' experience in botanical field work specifically in the study forest (who is also a co-author here). Use was also made of plant field guides and references such as Blundell (1999), Dharani (2002) and Fischer et al. (2010). Any plants not readily identified in the field was collected, pressed and sent for further specialized identification at the East African Herbarium at the National Museums of Kenya.

While walking slowly and occasionally stopping along stretches of 200 m on transects, observations and assessment of evidence of human activities were made and recorded. Various forms of activities including fuel wood collection, cattle grazing, charcoal burning, logging, vegetation clearing or harvesting, game snaring, roads and track or farming encroachment, were recorded. Logging intensity was assessed in each of the quadrats by counting all stumps of cut trees of diameter sizes of 10 cm and above using a tape measure (Fewster et al., 2009). Logging is generally regarded as the most profound cause of habitat destruction in Kakamega forest (Bennun and Njoroge, 1999; Schaab et al., 2010; Schleuning et al., 2011). Human activities, observed along the transects were assessed by scoring the frequency of occurrence of each form at every 200 m stretch for each transect and block to determine overall disturbance indices. The 200 m stretch assessment of activities was considered more appropriate than entire-length transect assessments to clearly discern the most key forms of anthropogenic disturbance of the forest habitat from overall disturbance scores (Miller et al., 1998).

Statistical analyses

To improve distribution of count data towards normal distribution, counts of TE, plant species and stems cut, were transformed using logarithms (Zar, 1999) and analyses proceeded after attaining reasonable normality tested by using normal distribution plots. Proportion or ratio data such as percent canopy cover score and overall habitat disturbance scores were transformed by arc-sine square root to minimize departure of variance from the mean (Zar, 1999). Densities of TE were determined per hectare for each forest block using the Conventional Distance method from DISTANCE v 6 software (Buckland et al., 2001). The half normal detection function model with Cosine adjustment that had the lowest Akaike Information Criterion (AIC) value was selected in density estimation (Buckland et al., 2001). Based on the relatively small total number of detections of TE and also on the Chi-squared goodness of fit test results, it was found suitable to fit the species' detection functions curves from the three separate forest blocks into one single global pool (Buckland *et al*., 2001). This was because the of the small difference between the total Half Normal Cosine AIC values (165.08) of the three component detection functions and the combined value (168.76) which was only 2.2%, suggesting no confounding effect of perpendicular sighting distance (Bibby et al., 1998; Buckland et al., 2001). The model also provided the closest approximation of expected TE abundance estimation from the observed ones (Table 1). Apart from density, encounter rates were also determined for TE to establish relative likelihood of sighting the species across transects and blocks surveyed. Encounter rates for each transect were calculated for each block and transect from the relationship: $ER = n/L$, where ER = encounter rate; n = total number of TE individuals encountered in each block or transect in the entire survey and L = total transect length covered for the block/transect.

Plants species richness for each transect was evaluated as the total cumulative number of species recorded in all quadrats along transect while mean number of stems cut was derived from all stems cut of all size classes averaged by the number of quadrats in a transect and number of transects in a block. Percent canopy cover scores were coded on a scale of 1 to 3 such that open (0-33%) scored 1; moderately open (34-66%) scored 2; closed (>66%) scored 3. From this, the mean canopy cover score was derived for each transects and ultimately, for each forest block. Mean canopy height was also obtained from combined canopy heights in all quadrats divided by the number of quadrats in each transect, or divided by number of transects for each block.

Overall human habitat disturbance indices for each forest block were determined as mean scores obtained from frequencies of encounter rates of each form of activity within all 200 m stretches along transects. Thus overall disturbance index was calculated as follows:

$D_I = [\Sigma(a_{fi}*10)/A_f)]\ Tt*100$, where D_I= overall habitat disturbance index; a_{fi} = the sum of encounter rates of the *ith* activity in a 200-m stretch of a transect; A_f = the sum of all encounters of all forms of activity in all transects; T_t = the sum of all transects in a forest block and *10* = the number of 200-m stretches in each transect (Otieno et al., 2012).

Analysis of covariance (ANCOVA) was performed to test any co-linearity amongst vegetation variables and bird density estimates. We treated the vegetation variables as fixed variables and bird densities as random effects (Zar, 1999). We used linear regression to evaluate the relationships between the remaining key parameters with TE density (dependent variable) across all transects. A Chi goodness of fit test was employed to test for any associations of TE to either the northern (National Wildlife Reserve) or the southern (Forest Reserve) forest blocks. For this, a priori assumption was

Table 2. Estimated encounter rates of Turner's Eremomela across the forest with corresponding habitat disturbance levels in each block.

Block	Transect location	Disturbance index	TE ER
North	Buzambuli Trail	0.50	2.50
	Primate/birding trail	1.30	3.50
	Salazar Village	0.30	2.50
South	Isecheno (Nature Reserve)	1.50	3.25
	Ikuywa	1.40	0.75
	Yala River Nature Reserve	0.30	4.75
Kisere	Kisere	1.90	3.00

Forest disturbance expressed as overall indices of intensity determined from combined observed evidence of all individual human impacts. TE ER = Turner's Eremomela encounter rate km^{-1}. For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment.

Table 3. Estimated densities of Turner's Eremomela in each forest block surveyed.

Fragment	Density (ha^{-1})	DCV	EST	EST LL	EST UL	AIC	ESW (m)	Dp (%)
North	0.53	0.33	1,855	1,252	2,458	61.7	15.0	93.5
South	0.39	0.32	2,340	1,584	3,096	76.6	20.0	95.4
Kisere	0.33	0.47	151	79	230	26.9	22.5	91.8
Overall	0.43	0.20	4,282	3,417	5,147	168.8	17.7	94.3

Results are based on AIC with minimum value; DCV = density coefficient of variation; EST = population estimate; LL = lower limit; UL = upper limit; AIC = Akaike Information Criterion (with cosine adjustment function and distances scaled using right-truncation); ESW – Effective strip width; Dp = mean detection probability. For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment.

that the latter is comparatively more disturbed.

RESULTS

We detected 81 individuals of TE in 27 encounters across all transects and forest blocks. The combined density of the species was 0.43 ha^{-1} (SE0.09) with a projected population estimate of 4,282 (CI = 3,417 – 5,147, p = 0.03) for closed canopy forest (Table 3).

Density estimates were highest in the northern block, and lowest in the Kisere fragment (Table 3). The same applied for encounter rates of the species in all surveys with 2.92 birds km^{-1} (n = 6) in the northern block and 2.90 birdskm^{-1} (n = 6) in the southern block (Table 2). In Kisere, the encounter rate was 3.00 birds km^{-1} (n = 2) though the notably higher rate might arise from the single transect run in the block. The species was sighted at the shortest overall perpendicular distance in the north due its more near-natural state because of stricter protection as compared to the more disturbed south and open Kisere (Figure 3).

However, the estimated population for the species was highest in the southern block of the forest at 2,340 (CI = 1,584 - 3,096) due to its larger size relative to north block which recorded 1, 855 (CI = 1,584 –2,458) and Kisere with 151 (CI = 79–230), N = 7, p = 0.02).

Analysis of variance showed no statistically significant difference in abundance of TE among forest blocks but Kisere block recorded the highest plant species richness despite the greatest logging pressure (Table 4) which has contributed to massive disturbance and comparatively lower overall canopy cover (Figure 4).

Tree logging was the most significant form of anthropogenic forest disturbance and although the presence of foot paths and tracks was the most frequent form of anthropogenic feature across all blocks (Table 5) tree logging had the most prominent impact on forest disturbance and negative influence on TE density and occupancy. The other forms of human activity showed no direct significant relationship to TE density or encounter rates.

Analysis of covariance showed a strong co-linear link between percent tree canopy cover and canopy height, and hence the latter was removed from the Spearman's rank correlation of the multiple variables. Subsequently, canopy cover was selected as the better predictor of TE density and was used in linear regression of the two variables and TE had a strong positive correlation to percent canopy cover (R = 0.886, p < 0.01). Furthermore,

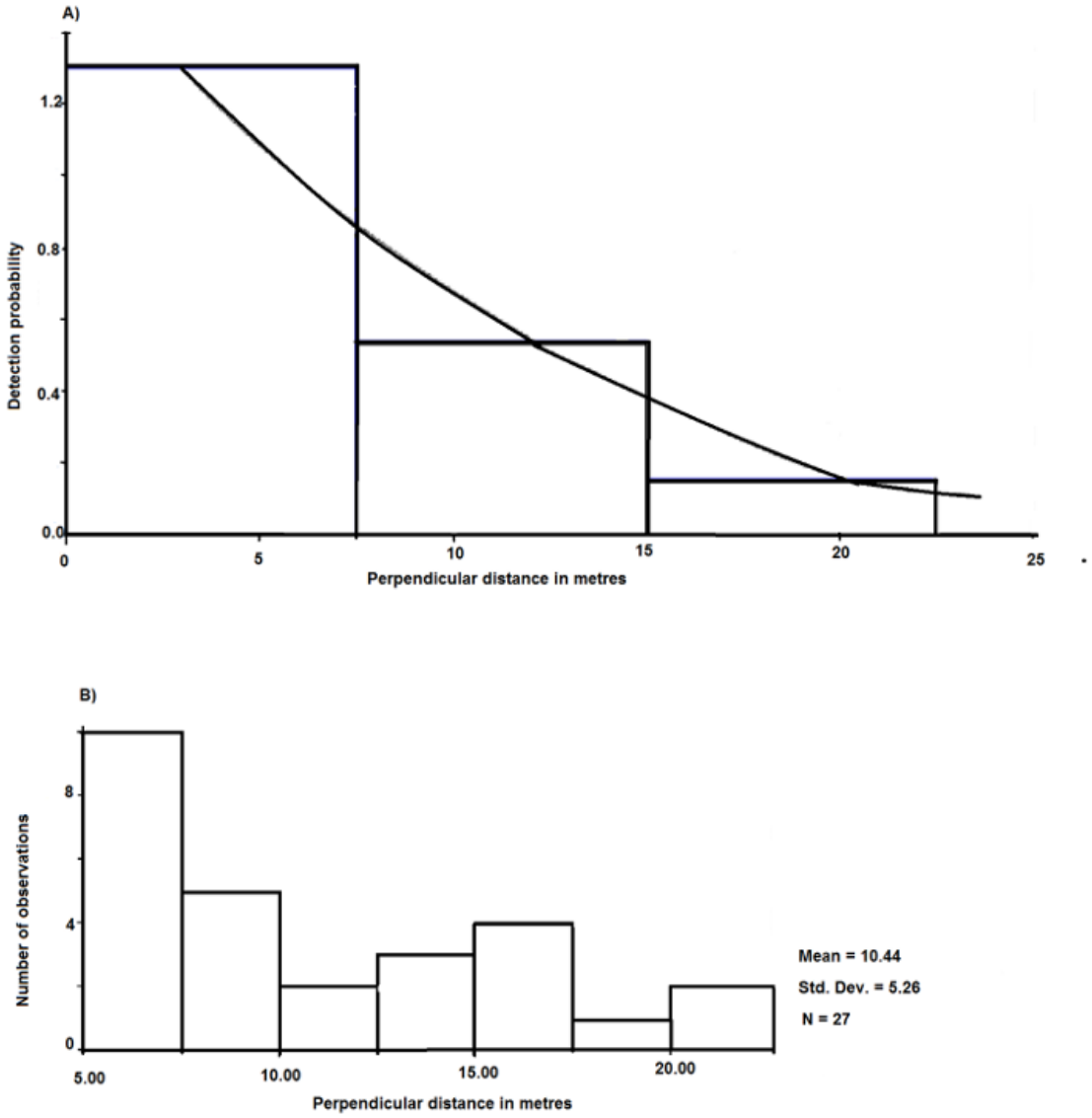

Figure 3. Detection probability and observations of Turner's Eremomela from density estimation using distance. (A) The curve of the detection probability represents the species' detection function g(x); (B) Histogram of observations of Turner's Eremomela across all transects. Both the detection curve and histogram arise from a global analysis of the density calculation.

Table 4. Plant species and means of other vegetation parameters across the forest blocks and transects surveyed.

Forest block	Transect name	Spp BT	Spp BB	SCut BT	SCut BB	CanC BT	CanCBB	CanH BT	CanH BB
	Buzambuli	15.70		0.10		2.20		20.60	
North	Primate	14.30	15.10	0.40	0.23	2.20	2.20	21.30	20.90
	Salazar	15.20		0.20		2.30		21.0	
	Ikuywa	8.50		0.60		1.90		19.70	
South	Isecheno	14.40	12.90	0.30	0.30	2.50	2.43	23.30	23.00
	Yala	15.70		0.00		2.90		26.0	
Kisere	Kisere	16.80	16.80	2.6	2.60	2.16	2.06	21.70	21.70

For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment. Spp = Species; SCut = mean number of stems cut, representing logging intensity; CanC = mean percent canopy cover; CanH = mean canopy height; BT = by transect; BB = by forest block.

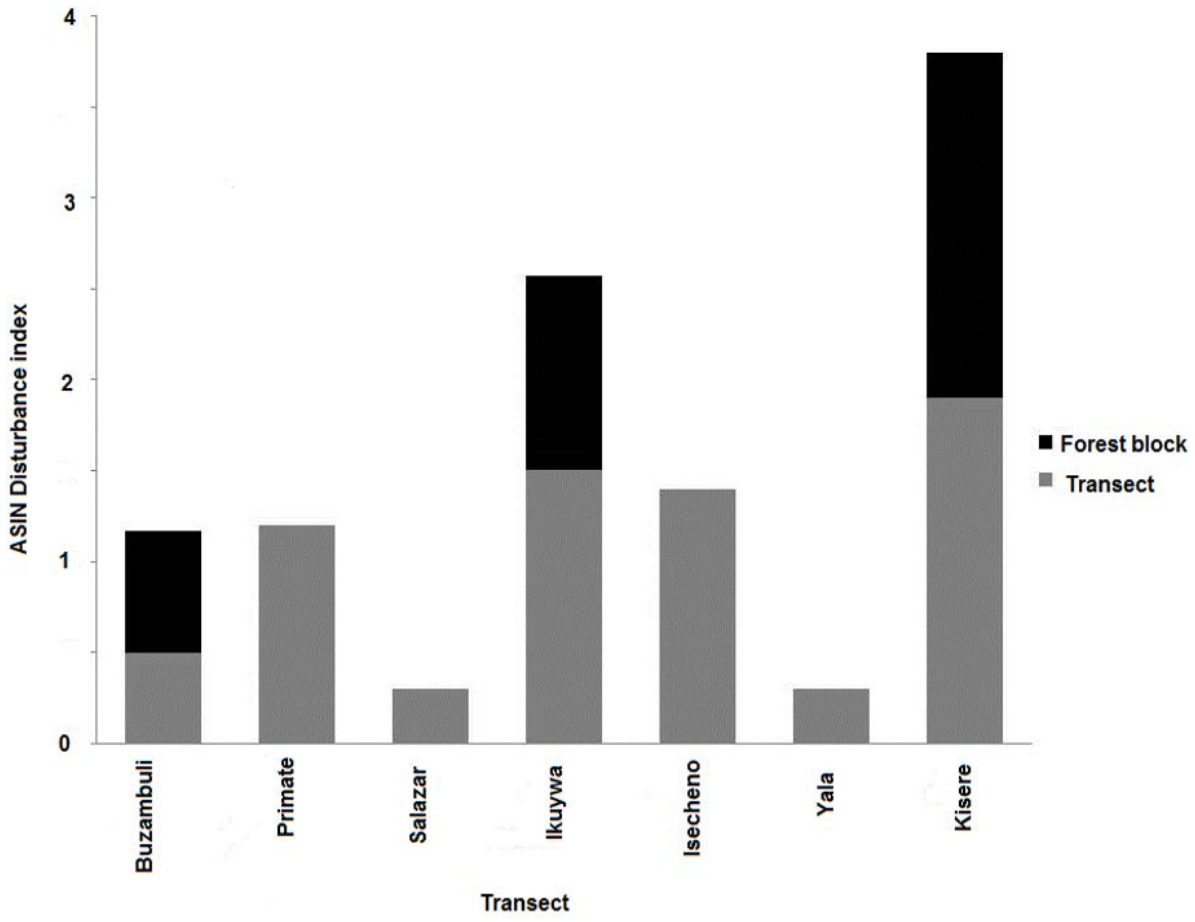

Figure 4. Variation in levels of disturbance across transects and forest blocks. The disturbance refer to indices of anthropogenic impacts on as derived from indices determined from amalgamation of all component human activities recorded. The forest blocks are north (National Reserve); south (Forest Reserve); and Kisere Nature reserve. ASIN = Arcsine transformation of disturbance score.

Table 5. Percent frequency proportion of major human activities. Percent frequencies are derived from encounter frequencies of all activities within 200-m stretches along all transects surveyed.

Forest block	Presence of paths/roads	Fuel-wood collection	Cattle grazing	Logging or vegetation clearing	Game hunting or snaring	Total
North (Wildlife Reserve)	13.4	2.7	0	0	0.7	
South (Forest Reserve)	16.5	13.8	0	1.7	1.4	
Kisere Forest Reserve	18.9	11.8	2.4	11.8	0	
Total	48.8	28.3	2.4	13.5	2.1	100

linear regression yielded the predictive equation: $Y = 0.126\ X + 1.614$ between TE density and percent canopy cover, where Y = TE density and X = arc-sine of percent canopy cover ($R^2 = 0.786$, N = 7) (Figure 5).

This strong effect of percent canopy cover on TE density is presumably due to logging intensity which negatively impacted canopy cover (R = -0.658, p = 0.051) and significantly contributed to overall disturbance of TE habitat (R = 0.742; p = 0.050). TE density was also positively correlated to overall plant species richness (R = 0.771, p = 0.042) and negatively to overall disturbance (R = -0.520, p = 0.049) but despite the differences in disturbance levels (Figure 3) and TE densities (Table 3) between the north and the south blocks, there was evidently no significant differences in spatial occurrence of the species across the total whole of the surveys area

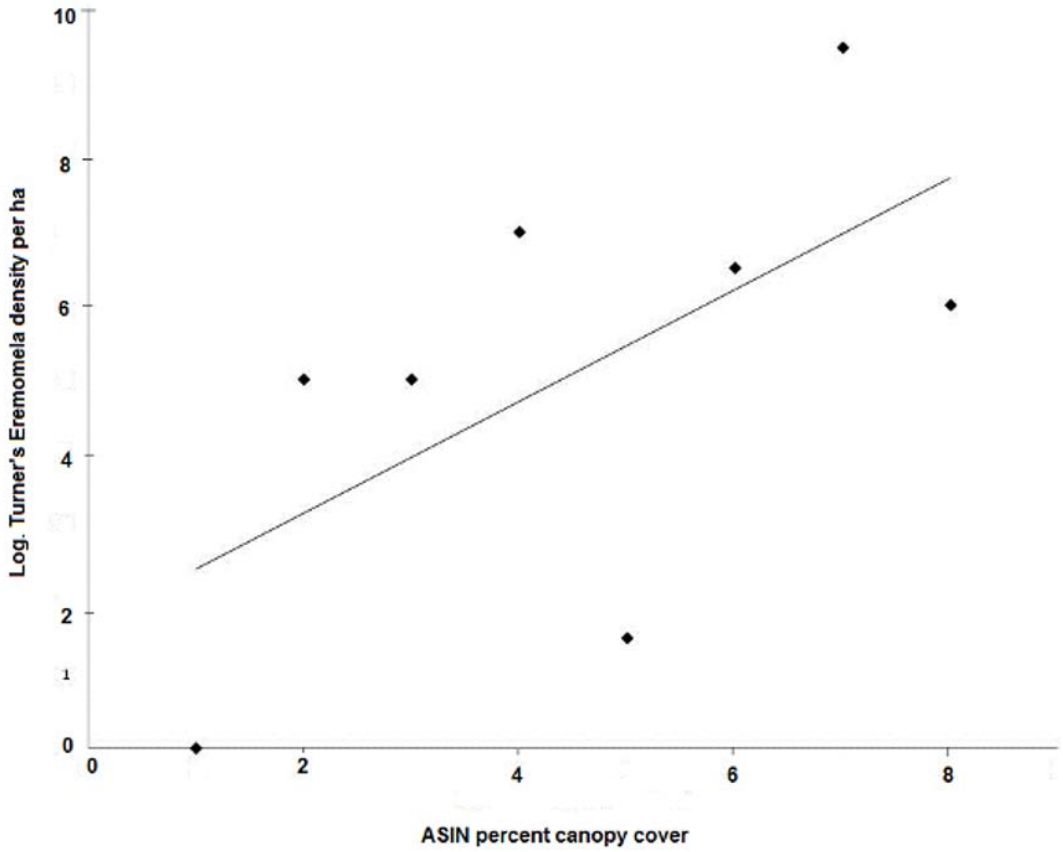

Figure 5. Regression plot of relation between tree canopy cover and Turner's Eremomela density. Canopy cover is derived from percent tree cover characterized as either open, moderate or closed which was subsequently arcsine transformed. ASIN = Arcsine.

in general (χ^2 = 34.5, p = 0.05, df = 2).

DISCUSSION

As a forest-specialist (Tews et al., 2004; Bennun et al., 1996), TE is sensitive to habitat perturbations, arising from persistent human impacts (Brooks et al., 1999; Woltmann, 2003; Kirika et al., 2008). Accordingly, our results show a negative effect of overall forest disturbance on the species' density. Lowest measures of forest disturbance especially logging were observed in the northern block characterized by a greater degree of protection from wildlife authorities as compared to the southern block or the Kisere fragment. The significant negative role of tree removal on TE is further underscored by the direct relationship between the species 'density and canopy tree canopy cover. Apart from changing the canopy structure and contributing to habitat loss, logging accelerates habitat fragmentation (Githiru and Lens, 2004) which, in turn hampers effective dispersal (Laurence at al., 2004). Thus TE was observed in lowest densities in the Kisere Forest Reserve, a fragment characterized by high disturbance and open canopy resulting from severe deforestation (Bruhl et al., 2003; Diaz, 2006).

It is worth noting that forest contiguity and closed canopy are not in themselves sufficient to guarantee high habitat quality standards desirable for specialist canopy-feeding birds such as TE if the vegetation characters no longer reflect near-natural conditions (Fernandez-Juricic, 2004). Thus, even a contiguous, canopy-closed forest but consisting of predominantly exotic or non-native trees incapable of habouring preferred arthropod prey, would still not provide suitable habitat conditions for TE (Farwig et al., 2008). To underscore this point, a closer examination of individual transects surveyed in the present study shows that Ikuywa transect, despite its location in with median levels of overall disturbance, recorded the lowest encounter rates of TE and also lowest plant species richness (Table 4). This is mainly because Ikuywa consists of considerable stands secondary forest and non-native plantation trees (Farwig et al., 2008) which present a generally lower native habitat complexity for the species, than more naturally vegetated areas.

The estimated TE population of 4,282±865 with a density of 0.43 ha^{-1} (SE 0.09) is low as compared to South Nandi forest where density was estimated to be 1.11 ha^{-1}

(SE 0.38) with a population of 14,418 (CI = 8,839 – 19,997). This owes to the fact that the current projection is restricted to the area still covered by closed-canopy forest whereas the South Nandi estimate was attributed to the entire forest cover. We feel that the estimates for Kakamega are realistic in view of the ongoing encroachment pressure from the rapidly increasing human population who depend heavily on natural products from the forest (Schleuning et al., 2011).

Consequences of human-induced habitat degradation for sensitive species may be manifested at different intensities along various spatially explicit units, which are otherwise characterized by closely comparable habitat attributes (Newmark, 2005). This often arises from variations in intensity of the anthropogenic impacts, or in temporal longevity scales over which such impacts have operated (Lindenmeyer and Fischer, 2006). For this reason, the lower density of TE in Kakamega forest as compared to South Nandi forest can be attributed to the longer period over which forest exploitation and degradation has occurred in the former, compounded with a higher density of population of adjacent communities with the consequence of greater destruction severity, a more rapid reduction in overall forest size and loss of the species' habitat (Schaab et al., 2010; Schleuning et al., 2011).

Despite higher levels of deforestation in Kakamega forest relative to Nandi, TE appears resilient in a number of ways. First, it has persisted in Kakamega during decades of massive forest habitat loss and modification (Schleuning et al., 2011). Second, the species maintained a population in the small Kisere fragment despite its insularized, heavily-logged condition. Third, the species was encountered on most transects of closed canopy forest blocks indicating that it is widely dispersed rather than clumped in a few key spots, even though densities were not the same in all sites. Fourth, although the widely-held assumption that all satellite forest fragments of Kakamega once formed one contiguous block (Doute et al., 1981; Kokwaro, 1988) is now being contested (Schaab et al., 2010), recent mapping research (Tsingalia and Kassily, 2009), appear to strengthen the argument for a historical connection with a consequent possibility of genetic mixing between sub populations of TE amongst the separated fragments (Bennun and Njoroge, 1999).

Conclusion and recommendations

Despite TE's non-clumped occurrence across the three forest blocks studied in Kakamega forest, especially the fairly well protected northern block, the species remains vulnerable to increasing anthropogenic pressure from an increasing adjacent human population. The strong positive correlation between the species' density and mature canopy cover underscores an urgent need to curb logging pressure throughout Kakamega forest and more effectively control other human-induced impacts that degrade its habitat. Apart from controlling tree removal through stricter protection of all forest blocks, rehabilitation of logged areas can offer a good chance of conserving the species by re-connecting fragmented habitats and facilitating movement thus minimizing insularization of sub-populations or groups.

ACKNOWLEDGEMENT

We are grateful to the Kenya Wildlife Service and Kenya Forest Service for granting us permission to carry out the study in Kakamega forest, the Kakamega Environmental Education Programme for arranging logistics for the survey team, the Kakamega Forest Professional Guides Association for seconding field assistantships and the National Museums of Kenya for availing additional material support especially in plant identification at the east African Herbarium of the Botany Department.

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