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

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Full Length Research Paper

Smallholder farmers' practices and perception of forest, soil and water conservation Technologies in the Eastern Cape Province of South Africa

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Africa has indigenous natural resource management practices that have been existing many years ago among many diverse ethnic groups. Exploration of such practices can substantially contribute to the nature conservation and welfare improvement in predominately rural areas like the Eastern Cape Province of South Africa. On account of this postulation, this paper reviews selected case studies on indigenous natural resource management practices in Africa. However, the focus is on the survey of farmers' practices, knowledge and perception of forest, soil and water conservation (SWC) in the Eastern Cape Province of South Africa. Soil erosion is one of the major challenges threatening smallholder agriculture in South Africa. The study shows that there are local forest management practices that can be promoted to wider scale of application in the study areas. However, the local people have limited exposure to SWC measures. Very few farmers have knowledge on local and modern stone bund terracing for the purpose of SWC. Due to lack of awareness, many farmers do not practice SWC measures. These findings have important implications for policy development to achieve sustainable rural development in the study areas.

Key words: Natural resources management, forest, soil and water conservation, smallholder, farmers, Eastern Cape, South Africa.

INTRODUCTION

Since the 1990s, there have been national and global initiatives to identify local level indigenous natural resource management practices. In most African countries, such practices are often neglected by practitioners and the attempt to integrate them with scientific practices has been limited. On account of this, most dry land

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African countries have already being affected by the consequences of land degradation, climate changes and desertification (IPCC, 2014; Kong et al., 2014; Lal et al., 2012). East Africa and South Africa would be particularly vulnerable to climate-related changes (IPCC, 2014). These changes have serious socioeconomic and ecological implications. The other aspect that makes Africa vulnerable is heavy dependence on rain-fed agriculture, frequent floods and droughts, and poverty.

Moreover, adaptive capacity to these changes is low because of limited financial resources, poor skills and weak institutional capacity (IPCC, 2014). These problems call for identification and implementation of sound natural resource management (NRM) practices in the continent (in a broader term NRM in this study refers to the sustainable utilization of major natural resources, such as land, water, air, minerals, forests, fisheries and wild flora and fauna. Together, these resources provide the ecosystem services that underpin human life (Orquebiau and Taylor 2009). To reverse such adverse situations, there is a potential to use the existing indigenous forest, soil and water conservation (SWC) measures among many diverse ethnic groups in integration with scientific practices prevailing (Dreber et al., 2014). These measures are effective ways of improving water resources management and of reducing the degradation of soil, vegetation and biodiversity (Ackermann et al., 2014).

The objective of this study was to survey the existing forest and soil and water conservation (SWC) practices in two magisterial districts: Tsolo and Lusikisiki in O.R. Tambo district in the Eastern Cape Province of South Africa. Review of few of such practices in the four selected sub Saharan Africa (SSA) countries is presented to deduce some valuable lessons to be applied in the study areas.

Forest resources in South Africa are valued for their livelihood functions, biological diversity, medicinal and local uses and aesthetic and spiritual values (Cocks and Wiersum, 2003; Cocks and Dold, 2006; Shackleton et al., 2001; Makhado et al., 2009; Paumgarten and Shackleton, 2011). However, natural forest base of the country is small, highly exploited and fragmented and often subject to adverse impacts from surrounding land use (DWAF, 1995). South Africa is among the least forested countries in the Southern African region (Naidoo et al., 2013).

Moreover, South Africa is a water scarce country relatively with high levels of pollution among developing nations (National Treasury, 2010). Given this context, this study attempts to answer the following research questions. What are the farmers' practices and perception of forest, soil and water conservation in the study areas? What lessons can we derived from the local and selected African experiences to improve the natural resources management practices in the study areas?

NATURAL RESOURCES MANAGEMENT CHALLENGES AND PRACTICES

The NRM challenges

Indigenous or traditional natural resources management practices in Africa also known as 'ethno-engineering' include terracing mountain slopes, agroforestry, harnessing the runoff and developing small drainage systems (Jodha, 1990). Until recently, farmers were not able to benefit from research-based solutions and were forced to develop innovative and experimental plans to improve their farming practices (O'Neil, 1995; Chinkhuntha, 2004). Several factors have contributed to the many challenges smallholder farmers face in adopting and adapting to natural resources management practices in many African countries. Such factors range from the poor technological performance to policy and institutional deficiencies (Shiferaw et al., 2007).

In Africa, the adoption and scaling up of indigenous natural resources management practices have been hampered for a number of reasons. Farmers' practices have been downplayed and neglected by scientists. In the past indigenous practice, particularly in the African context, has long been ignored (Warren, 1992). For example, even though there are successful and worthy local practices of natural resources management in Ethiopia, there are multifaceted challenges faced by innovative small holder farmers. Challenges like negligence towards local practices and bias to standard structural SWC practices, lack of financial support, and government owned land tenure system may force land owners not to invest in long lasting SWC measures like planting perennial crops or trees (Mitiku et al., 2001; Tesfaye, 2003; Mitiku et al., 2006). In recent years, however, a growing number of African governments and international development agencies are recognizing that local-level practice and organizations provide the foundation for participatory approaches to sustainable social, political and economic developments (Dreber et al., 2014). Such challenges are often common across the continent and need to be addressed for the welfare of rural communities and for the conservation of our natural environment and biodiversity.

NRM Experiences from few SSA countries

This section focuses largely on documenting SWC practices from mountainous high lands of Ethiopia, important cases from Burkina Faso, Cameroon and South Africa, respectively. We showed that there are lessons to learn from the experiences of these countries.

The bench terrace '*kaha*' by the *Konso* people, '*daldal*' dams to trap silt water by *Irob-Tigre* people and *Gedeo's* agroforestry systems are best among the important

Investigation into the terracing practices used by Venda people in the Limpopo Province has shown that these systems have long been used, and that their primary purpose appears to be the conservation of fertile soils. In this relatively densely settled, well watered area of fertile apedal soils, land is allocated to individuals, and "the right to cultivate is effectively inalienable, and is inherited from father to son". Using participatory methods, researchers investigated farmers' perceptions of the problems they were addressing by building stone terraces in their hillside fields. They described the problem in terms of "loss of fertile soils", and most noted that this loss was being arrested by the construction of the terraces and associated measures (grass strips, contour ploughing, construction of diversion ditches above fields, check dams in gullies, etc.). Despite ancient examples of terracing existing nearby, much of the terracing is recent, and could be a response to increase pressure on the land by a growing population.
Source: Taken from (Oettle et al. 1998; Lotter et al., 2009)

Box 1. VhaVenda terraces in South Africa.

attributes of indigenous practice in agricultural development in Ethiopia (Meire et al., 2012; Mitiku et al., 2006; Tesfaye, 2005*).* The *Konso* SWC terraces are internationally recognized and registered by UNESCO. *Konso* are also well known for their crop diversification to minimize risk, mixed cropping and multi-story crop and tree production in traditional intensification (Mitiku et al., 2006).

As a result, the *Konso* people have controlled land degradation in hilly and mountainous areas where each terrace has been in place for over 50 years. Konso SWC terracing and agroforestry practices have a significant contribution in combating desertification and mitigating the effects of drought. Such practices can be replicated in similar agro climatic regions in the African continent. The innovative *'daldal'* technique by many Irob people aids in creating arable land and supplying clean water. The practice is sustainable in environmental terms, reduces soil erosion and makes use of soil and water that would otherwise have flowed into barren depressions and been wasted (Asfaha and Waters-Bayer, 2001; Reij and Waters-Bayer, 2001).

In *Gedeo* agroforestry system, nearly all the people live virtually in a home-garden land-use system (Tadesse, 2002). *Gedeo* agroforests contain an organized mix of crops, '*enset'* (*E. ventricosum*) is commonly known as "false banana" for its close resemblance with the domesticated banana plant. It is Ethiopia's most important root crop, a traditional staple crop in the densely populated south and Southwestern parts of Ethiopia) and coffee to long living multi-purpose trees to get maximum benefits on a sustainable basis. As a result, soil and water resources are well conserved and home garden agroforestry and biodiversity have been enhanced; and most areas are covered by evergreen vegetation. These agroforestry practices have been seen as one of the best measures to combat desertification and mitigate the effects of drought in the area (Mitiku et al., 2006).

Furthermore, there are traditional SWC practices that are widely common and practiced by different ethnic groups in many West African countries like Burkina Faso and Cameroon (Reij, 2001). For instance, a widespread indigenous practice of the 'zai' pit SWC and soil fertility strategy in Burkina Faso is widely known. In the South Sahelian area with 400-700 mm rainfall, farmers have been practicing runoff farming, such as the *Mossi* in the *Yatenga* region of Burkina Faso, use stone bunds, planting pits, mulching, etc.

Although, twenty different ethnic groups practice water harvesting in the *Mandara* Mountains of Northern Cameroon, the *Mafa* are the most skilled practitioners (Riddell and Campbell, 1986). Farmers have complicated system of indigenously developed terracing of steep slopes. For soil fertility management, they use household animal wastes and crop residues. Manure is spread into the soil; and they practice natural resources management practices like crop rotation, intercropping, silvopasture (Latin, silva forest) is the practice of combining forestry and grazing of domesticated animals in a mutually beneficial way. Advantages of a properly managed silvopasture operation are enhanced soil protection and increased long-term income due to the simultaneous production of trees and grazing animals). The two most important trees growing on the terraces of West African countries are *Acacia albida* and *Khaya senegalensis*.

Up until now, South Africa has been included under World Overview of Conservation Approaches and Technologies (WOCAT) project in 1998 and has started implementing the Land Degradation Assessment in Dry Lands (LADA) project, indigenous knowledge systems were poorly understood and their integration into modern agriculture was practically non-existent.

The WOCAT/LADA projects have identified natural resources management approaches and technology questionnaires are included in the South African data-base (Lotter et al., 2009*)*. For example, there is evidence of traditional approaches to soil conservation by "*VhaVenda"* people in Limpopo Province (Box 1). The *VhaVenda* terraces are among the WOCAT/LADA projects included in the data base. However, there is no endeavour to integrate this traditional SWC practice with scientific practices and it is not widespread across the country.

- **Proposition 1:** While modifying natural vegetation for their productive use, farmers develop and maintain agroforestry systems that make substantial contributions to biodiversity in multi-functional landscapes.
- **Proposition 2:** The increased uptake of agroforestry in multi-functional landscapes can reduce pressure on forests and protected conservation areas.
- **Proposition: 3** Agroforestry can create habitat for wild species in landscape matrices surrounding forest conservation areas.
- **Proposition: 4** Agroforestry developments can be implemented in a way that reduces the risk of alien invasive species to acceptable levels, if adequate precautions are taken.

Source: Swallow et al. (2009)

Box 2. Agroforestry and biodiversity.

In additions to SWC practices discussed above, agroforestry practices have considerable potential in helping solve some of Africa's main land use problems (Cooper et al., 1996; Sanchez, 1995) through provision of a wide range of tree products for domestic use or sale (Franzel et al., 2001). As shown in Box 2, Swallow et al. (2009) claimed that agroforestry farming can contribute to biodiversity conservation which needs further investigations in the context of South Africa.

METHODOLOGY

The survey was conducted from December 2011 to June 2012 in two magisterial districts: *Tsolo* and *Lusikisiki* in O.R. Tambo district in the Eastern Cape Province of South Africa. These study sites were selected because of their predominantly rural nature and an urgent need for the integration of natural resource management with rural development in the province to address the prevailing major socioeconomic and environmental problems (Figure 1).

In this study, the mixtures of purposive and systematic random sampling methods were used to draw the final sample from Tsolo and Lusikisiki areas in O.R. Tambo district in Eastern Cape Province of South Africa. A detailed questionnaire was used to answer the research questions posed in the introductory section. The questionnaire included both open ended and closed questions. In addition, focus group discussions were carried out with participants comprising experts, professionals and opinion leaders from local agencies working in relation to rural developmental.

However, there could be a possibility that responses would be distorted due to personal biases by both the interviewees and the interviewer. The training of enumerators and the increased number of responses may help reduce these biases. The questionnaire has many sections, however, the sections analyzed in this study are based on two main issues, namely local forest-resource management and SWC measures in the study areas. The questionnaire was administered in local language by local research assistants recommended by Tsolo Agricultural and Rural Development Institute.

RESULTS AND DISCUSSION

General characteristics of the respondents

This section provides a general description on the respondents included in the survey. A total of 300 respondents were included in the survey of which 53 percent are females and 43% are males. The number of respondents by district and gender is presented in Table 1. Female respondent are higher in *Tsolo* while male respondents are higher in *Lusikisiki*. The average household size is 7.14 (the maximum household size is 16 and the minimum is 1). The two study sites *Tsolo* and *Lusikisiki* have the population density of 132-193 and 194-600 person per square kilometer, respectively. These two magisterial districts are among densely populated areas in O.R. Tambo district.

As shown in Appendix 1, close to 32% of the respondents are in the age group of 50-59. Male respondents are more dominating in the female counterparts in this age group of 36.4 and 26.1%, respectively.

As shown in Appendix 2, 82% of the respondents have acquired either adult education or beyond. Only 13% of the respondents had tertiary level education. In all the levels of education, except 'some secondary education' level, male respondents dominated the female counterparts.

Analysis of NRM practices in the study areas

Here, we discussed the level of local knowledge in NRM practices and perceptions of farmers on these practices in the two study areas. In the study areas, smallholder agriculture is dominant livelihood practice owned and operated by smallholder farmers. We had a series of discussions with the research assistants and respondents to make sure that they understood what is meant by local knowledge or indigenous practices in NRM.

The purpose of investigation and discussion of these practices in this section is with the conjecture that integration of modern, science based NRM technologies with the local knowledge is instrumental to ensure sustainability in integrated rural development endeavors.

Value, attitude and use of indigenous practice in NRM

The respondents were asked whether they use indigenous

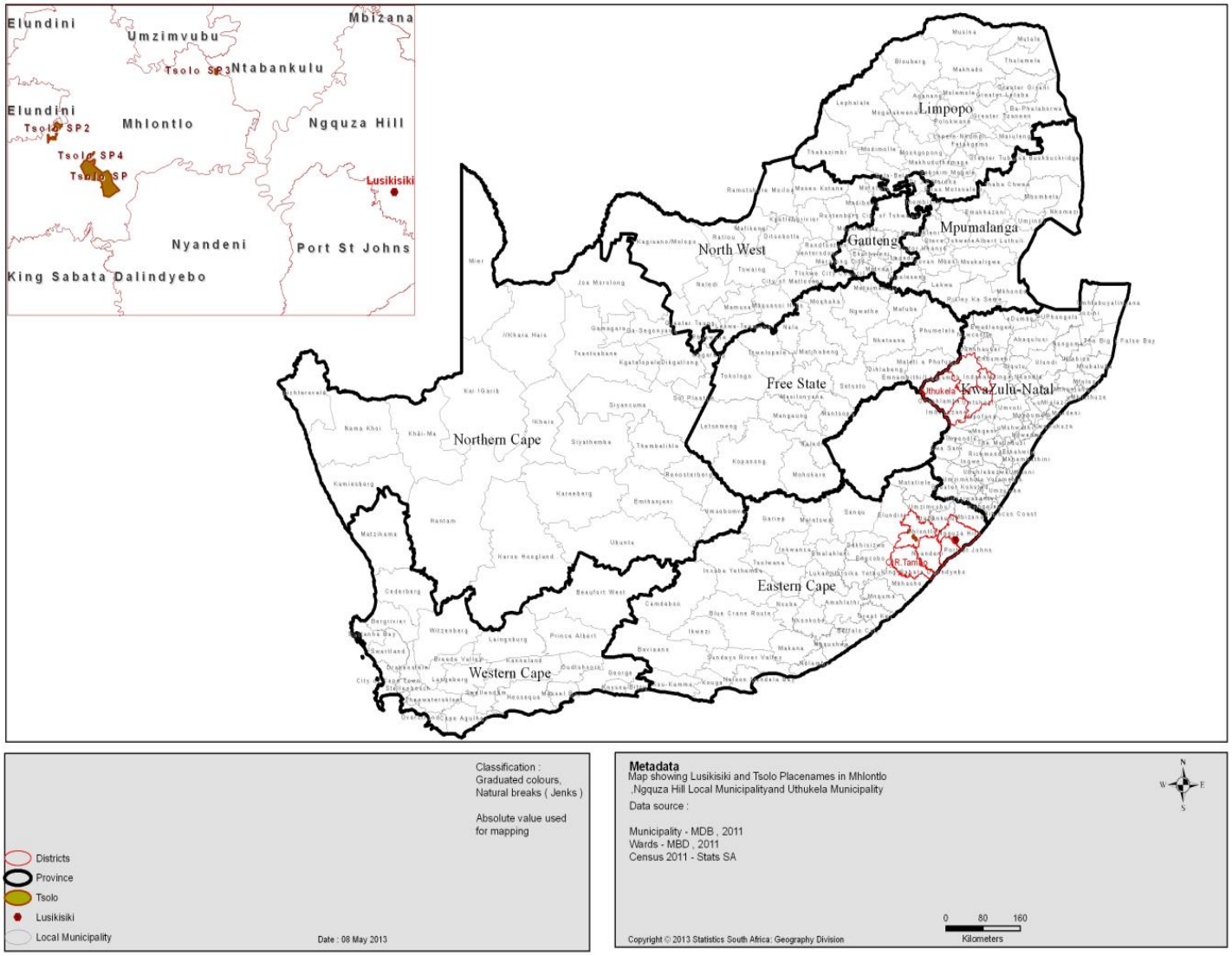


Figure 1. Map of the study sites.

Table 1. Number of respondents according to district and gender.

Gender of the respondents						
District	**Female**		**Male**		**Total**	
	%	**N**	**%**	**N**	**%**	**N**
O.R. Tambo- Tsolo	53.0	85	46.0	65	50.0	150
O.R. Tambo- Lusikisiki	47.0	75	54.0	75	50.0	150
Total	100.0	160	100.0	140	100.0	300

Source: authors, computed from survey data.

practices in NRM. Overall, as indicated in Table 2, more than 66% of the respondents confirmed that they use indigenous practice in NRM. Moreover, the attitude towards indigenous practices in NRM is overwhelmingly positive. As shown in Table 3, more than 75% of the respondents value the worth of NRM practices in their localities.

Table 2. Indigenous practice in NRM.

Do you use indigenous practices in NRM?	District					
	Tsolo		Lusikisisi		Total	
	%	N	%	N	%	N
No	33.6	41	54.2	64	43.8	105
Yes	66.4	81	46.0	54	56.2	135
Total	100.0	122	100.0	118	100.0	240

Source: Authors, computed from survey data.

Table 3. Attitude towards traditional/indigenous NRM practices.

Attitude towards indigenous practice in NRM	District					
	Tsolo		Lusikisisi		Total	
	%	N	%	N	%	N
Do not value NRM	5.2	7	14.3	17	9.4	24
Value NRM	88.1	119	60.5	72	75.2	191
Do not know	6.7	9	25.2	30	15.4	39
Total	100.0	135	100.0	119	100.0	254

Source: Authors, computed from survey data.

Table 4. Reasons for not planting trees.

Reason for not planting trees (exact words as suggested by respondents)	
Afraid it will bring snakes	Infertile land
Fear of damage by the free grazing animals in the vicinity,	My farm land is too small, I only cultivate vegetables
Lack of sufficient land,	My land is not fertile
Lack of experience,	No capital
Unavailability of tree seedlings	No money to nurture tress
Lack of knowledge	No need for planting trees now
Expenses	Roots destroy houses
Lack of space for planting trees	

Source: authors, extracted from survey data.

Indigenous tree and forest development practices

Table 4 highlight that some of the reasons why farmers have not planted trees. There are arguments listed in Table 4, however, there are also cultural believes like “trees will bring snakes” which are against tree planting initiatives in the localities.

Local practices listed in Table 5 will be instrumental to arrest land and natural forest degradations in the study areas and in the entire province. Scaling up such practices can substantially augment Government’s policy towards environmental protection. Table 5 summarises major indigenous NRM practices used in the forest management in the study areas.

The next question posed to the respondents was to request the degree of dependence on indigenous and modern practices in NRM. As shown in Table 6 most of the respondent uses both indigenous and scientific practice in their NRM endeavours. Here when we say scientific practices we are referring to practices often suggested by extension officers to smallholder farmers in the study areas.

Soil and water conservation (SWC) practices in the study areas

The respondents were also asked whether they had

Table 5. List of major indigenous tree and forest development practices in the study area.

List of major indigenous (local) NRM practices	District					
	Tsolo		Lusikisisi		Total	
	%	N	%	N	%	N
Wood lot establishments	4.2	6	.6	1	2.2	6
Ask for permission from leaders	6.3	9	3.8	6	5.0	15
Certain forest parts are preserved	3.5	5	1.9	3	2.7	8
Choice of seasons to cut trees	0	0	1.3	2	0.7	2
Farming trees with crops (Agroforestry)	9.9	14	1.9	3	5.7	17
Fire belt around forest	3.1	3	0.6	1	1.3	4
Pay for cutting trees and grass	0	0	7.6	12	4.0	12
Traditional wild fire management	0.7	1	0.0	0	0.3	1
Pruning trees	7.7	11	0.6	1	4.0	12
Removing unwanted trees	0.0	0	1.2	2	0.6	2
Rotational grazing practice	0	0	0.6	1	0.3	1
Selling aged trees in communal lands	0	0	0.6	1	0.3	1
Area closure	1.4	2	0	0	0.7	2
Use of forest guards to protect communal forests	0	0	3.1	5	1.6	5

Source: authors, computed from survey data.

Table 6. The degree of dependence on indigenous and modern NRM practices.

Degree of dependence on	District					
	Tsolo		Lusikisisi		Total	
	%	N	%	N	%	N
Indigenous Practices	5	7	12.0	19	11.0	26
Modern Practices	15	19	28.0	33	21.0	52
Both	80	100	60.0	66	68.0	16
Total	100.0	126	100.0	118	100.0	245

Source: authors, computed from survey data.

exposure to any traditional or scientific SWC practices. Less than one third of the sampled households answered this question. The reason is that most of the respondents in the study areas do not practice SWC on their farms. Only 113 respondents have exposure to local and modern stone bund terracing in both study sites (Figure 2). '*Fanajo*', grass planting, cut-off drain, check dam, flood diversion and other SWC measures are not known in their areas. However, soil erosion is among the most common environmental problems in Eastern Cape Province due to its mountainous topography.

All the stakeholders working for the betterment of the environment should work jointly in introducing SWC techniques to the farming system. Those who have been implementing SWC measures on their farms were asked why they practice such measures given the categories to choose from. Figure 3 depicts the reasons for practicing SWC measures on farm lands. Maintaining soil fertility status, reducing the risk of floods, conserving soil moisture, and combination of all those reasons justify practicing such measures.

As depicted in Figure 4, the most important reason for not practicing SWC measures in the study areas is lack of awareness. The Department of Agriculture, Forestry and Fishery (DAFF) in collaboration with Department of Environmental Affairs (DEA) need to formulate a strategy to create awareness among stakeholders on SWC in the study areas.

Conclusions

Natural resources management practices that include upgrading existing indigenous practices can play a significant role in reducing the degradation of soil, improving soil fertility, plant cover and biodiversity toward

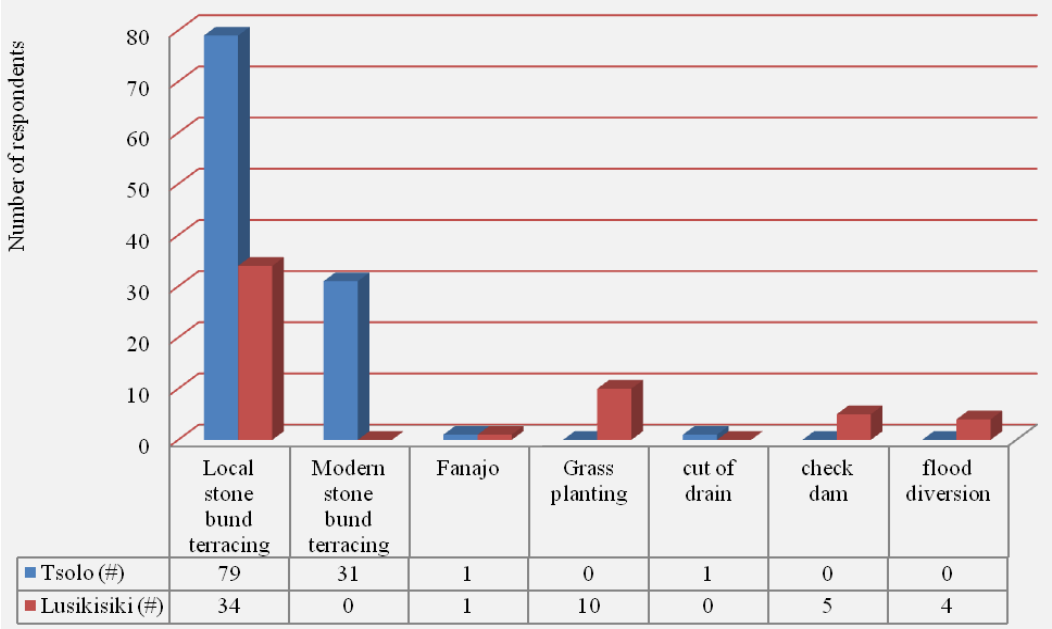


Figure 2. Experience of SWC measures in the study areas. Source: authors, computed from survey data.

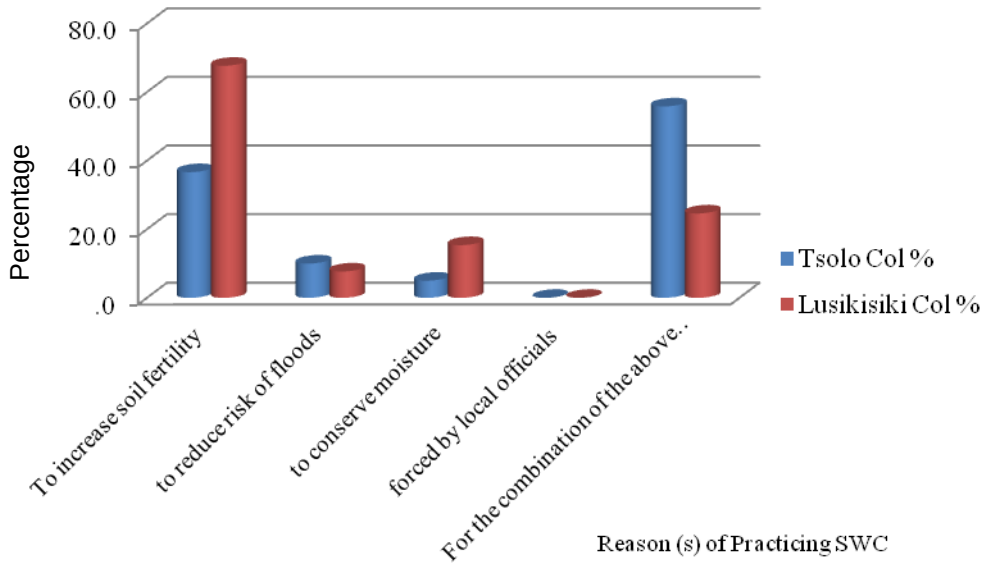
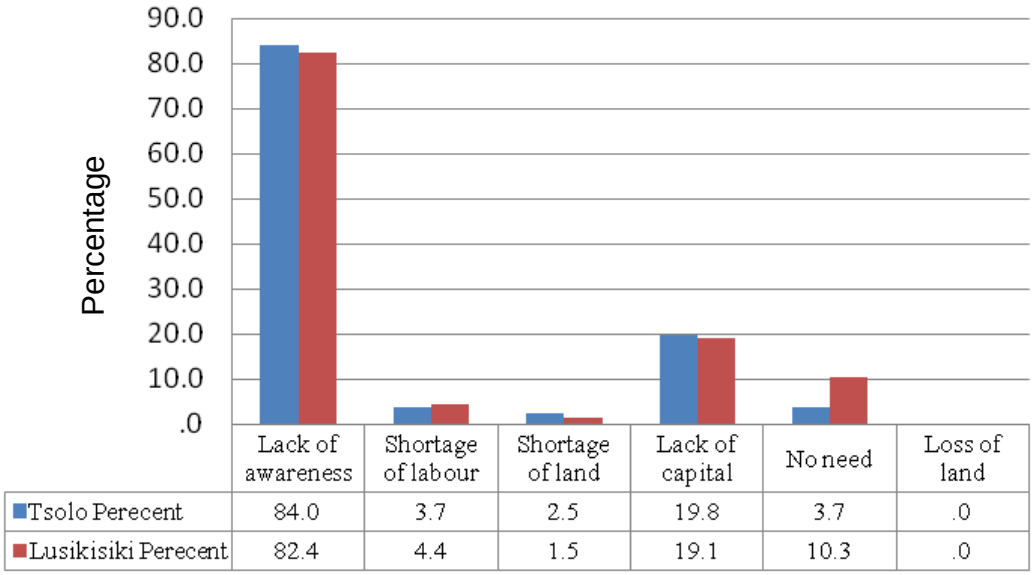


Figure 3. Reasons for practicing soil and water conservation measures. Source: authors, computed from survey data.

more secure livelihood and higher standard of living for rural communities. Experiences from SSA indicate that it is crucial to integrate local natural resources management practices with new scientific technologies into the farming systems of smallholder farmers in the study areas according to their financial status, age and social circumstances.

Exploration of indigenous natural resource management practices can substantially contribute to the conservation of nature and the improvement of welfare in predominately rural areas like the Eastern Cape Province of South Africa. The study shows that there are valuable



	Lack of awareness	Shortage of labour	Shortage of land	Lack of capital	No need	Loss of land
Tsolo Perecent	84.0	3.7	2.5	19.8	3.7	.0
Lusikisiki Perecent	82.4	4.4	1.5	19.1	10.3	.0

Figure 4. Reasons for not practicing soil and water conservation measures. Source: authors, computed from survey data

practices, knowledge and perception in forest, soil and water conservation in the Eastern Cape Province of South Africa. The rural people in the study areas have greater values attached to indigenous knowledge in forest and soil, and water conservation measures. They have developed positive attitudes towards indigenous knowledge in forest management. For example, the respondents have knowledge on wood lot establishment, they are aware of tree management , make use of traditional wild fire protection measures, practice farming of tress with crops (agroforestry), they participate in local enforcement measures towards environmental protection (Table 5). Scaling-up such practices can supplement governmental policy towards environmental stewardship and food self sufficiency in the areas. However, the local people in the study area do not have exposure to soil and water conservation measures. There are also major constraints hampering tree planting in the study areas, they are free grazing, financial constraints, small land size, lack of experience and know-how of tree management among youngsters, unavailability of public tree nurseries nearby and others.

The Department of Agriculture and Forestry should facilitate financial credit services and incentive scheme for those framers who have the experience and willingness to practice forest, soil and water conservation measures in the study areas and across the country. Training in soil and water conservation techniques to the farmers and extension agents would assist in reversing the current situation of soil erosion in the study areas. Training should be given to farmers on tree management practices (such as pruning, thinning and coppicing, etc.) and to individual tree and stand manipulation to reduce adverse ecological interaction with agricultural crop components of the system. The local government institutions can intervene to address problems associated with free grazing and supply of trees seedlings. It may be also worthy to learn best practices on forest, soil and water conservation from experiences of similar agro climatic regions in the African continent.

Conflict of Interests

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

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Appendix 1. Age groups of respondents (number of respondents).

Age group	Gender HH					
	Female		Male		Total	
	%	N	%	N	%	N
20-29 years	0.6	1	1.43	2	1.0	3
30-39 years	5.6	9	13	18	8.5	25
40-49 years	12.4	20	14.3	20	12.2	36
50-59 years	26.1	42	36.4	51	31.5	93
60-69 years	26.1	42	20.7	29	24.1	71
70+ years	29.2	46	14.3	20	22.7	67
Total	100.0	160	100.0	140	100.0	300

Source: Authors, computed from survey data.

Appendix 2. Education levels attained by farmers in the sample area.

Level of education	Female		Male		Total	
	%	N	%	N	%	N
No formal education	17	27	20	28	18	55
Adult Education	3	5	3	4	3	9
Some primary education	18	28	14	19	16	47
completed primary education	9	14	4	6	7	20
Some vocational education	0	0	4	5	2	5
Completed vocational training	3	5	8	11	5	16
Some secondary education	31	50	29	40	30	90
Completed secondary	9	14	4	6	7	20
Advanced level	1	1	4	5	2	6
College education	4	7	4	5	4	12
University education	6	9	8	11	7	20
Total	100	160	100	140	100	300

Source: Authors, computed from survey data.

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Full Length Research Paper

Seasonal botanical characteristics of the diets of Grant's (*Gazella granti* Brooke) and Thomson's (*Gazella Thomsoni* Guenther) in the dryland habitats of south-central, Kenya

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Understanding of dietary requirements of different wildlife populations is critical in wildlife habitat conservation especially in Sub-Saharan Africa where wildlife contributes much to the National GDP of many countries. This study was conducted to determine the seasonal (wet/dry) diet profiles of Thomson's and Grant's gazelles (Gazella Thomson and Gazella granti) in the Athi-Kapiti savannah ecosystem of south-central Kenya. Diet composition was determined using the micro histological faecal analysis technique. Plant species in the diets were categorized into grasses, forbs and browse. Botanical compositions for diet selection by the two gazelles were generally influenced by season. Forage classes were significantly (P<0.05) associated with the two gazelles. Grant's gazelle was a mixed feeder in the wet season and a browser in the dry season, whereas Thomson's gazelle was a grazer during wet season and a browser in the dry season. The two gazelles had diverse diets in the wet season with Thomson's gazelle having diverse diets in both seasons than Grant's gazelle. The degree of dietary overlap between the two gazelles was highest during the dry season with a significant (P<0.05) Spearman's rank-order correlation coefficient; R_n = 0.92. The results indicate that the two species are competitors during the dry season and complimentary feeders during the wet season. This implies that Wildlife Managers manning the conservation areas in the region need to consider the optimal stocking rates of the two gazelles during the dry season. The shift in dietary diversifications between the two species should be investigated further. The degrees of dietary overlap within the forage and forbs classes were highest throughout the two seasons. Therefore, key browse plants such as the Acacia spp, Grewia spp. and *Balanities glabra* and forbs such as *Hibiscus parvifolius* should be spared during bush control activities.

Key words: Grant's gazelle, Thomson's gazelle, herbivore diet, conservation management, Kenya.

INTRODUCTION

Kenyan rangelands cover nearly 70% of the country and are a home for thousands of pastoralists and agro-pastoralists and a wide range of domestic and wild herbivores. The rangelands play an important role in live-

stock production and wildlife conservation in Kenya, both of which are critical to Kenya's economy as they are key to supporting livelihoods and generating foreign exchange earnings through trade and tourism (GoK, 2002, 2003). Most of the south-eastern Kenya is rangelands which are mainly used for livestock production, wildlife conservation, and cultivation in the wetter areas. The rangelands provide habitat for countless mammals, birds, amphibians, and insects. Of these different types of animal species, Gazelles are the most common types of antelopes (AWF, Grant's and Thomson's gazelle's fact files). The different species of antelopes that inhabit the region include Thomson's gazelle (*Gazella Thomson*), Grant's gazelle (*Gazella granti*), gerenuk (*Litocranius wallen*), eland (*Taurotragus oryx*), greater kudu (*Tragelaphus strepsiceros*), lesser kudu (*Tragelaphus imberbis*) and the klipspringer (*Oreotragus oreotragus*) among others. Thomson's and Grant's gazelles' are the most common and conspicuous gazelle's species to the tourists visiting wildlife conservation areas in the region. They are often seen grazing together.

In late 1990s, the population of Thomson's and Grant's gazelles in Kenya was estimated to have declined by 64 and 58%, respectively (Boun and Blench, 1999; GoK, 1996). There has been a lot of concern as to what could be the underlying cause for the drop in their numbers. However, this trend is not unique for Kenya's wildlife. Land degradation and habitat loss to settlements, infrastructural development and encroaching cultivation among others are some of the leading causes of declining wildlife numbers inside as well as outside African parks (Western et al., 2009). In addition, climatic variation has placed further pressure on pastures, browse and habitat space for the wild animals including the two types of gazelles utilizing the rangelands. A significant change in habitat affecting the pastures is recognised to cause adjustments in the feeding habits of herbivores (Lamoot and Hoffmann, 2004). For efficient utilization of the shrinking rangeland through optimal allocation of the forage resource to the different species, knowledge of the feeding habits and habitat preference of the animal, and the prevailing climatic conditions of the area is essential (Hanley, 1982).

Thomson's and Grant's gazelles' often graze together and although outwardly similar, they differ fundamentally and are distinguishable using their morphology. Ecologically, the two gazelles have very different feeding characteristics. The two species select slightly different forage plants. Knowledge of the similarities and differences in diets of the two species of animals is thus important in making crucial grazing management decisions. Unfortunately, studies on common range-use by the two gazelles are old and far from complete (Estes, 1967; Field, 1975; Mugambi, 1982; Stelfox and Hudson, 1986; Stewart and Hofmann, 1972). Published studies addressing the problem of competition and ecological separation among other East African herbivores are common and include those of Casebeer and Koss (1970), Field et al. (1973) and Ng'ethe and Box (1976). More recent studies do not compare the feeding characteristics of the two gazelles (Kilonzo et al., 2005; Mugambi 1982; Spinage et al., 1980). This study aimed to evaluate the seasonal dietary botanical composition, diversity and overlaps between Thomson's and Grant's gazelles' with the hope that the findings would help in suggesting some management decisions affecting the two gazelles in the South-eastern rangelands of the country and in other areas with similar ecological characteristics.

MATERIALS AND METHODS

Study area

The study was carried out within the Athi-Kapiti ecosystem, about 80 km south of Nairobi along the Nairobi–Namanga highway between latitude 2°0' south and longitude 36°45' east. The study area falls under ecological zone IV characterized by low and erratic rainfall of bimodal distribution. Average annual precipitation ranges between 300 and 800 mm (Pratt and Gwynne, 1977). The long rains occur between March and May, while the short rains normally occur between October and December. Elevation varies from 600 to 2500 m above sea level. The vegetation consists primarily of scattered tree and open grasslands (Pratt and Gwynne, 1977). Open grasslands predominate in the Athi-Kapiti plains while Bush and woodland are found mostly in the central hills. *Themeda triandra*, *Pennisetum mezianum*, *Chloris* spp. and *Sporobolus* spp. are the dominant grass species (Rattray, 1960). *Balanites aegyptiaca, Acacia merifella* and *Acacia drepanolobium* are the dominant tree species on the plains. The drainage lines are dominated by *Acacia* species, specifically *A. seyal*, *A. xanthophloea* and *A. Paoli* (Croze, 1978; McDowell et al., 1983). The main economic activity of the area is livestock production and wildlife conservation in national parks, game reserves, and game ranches established in the area.

Determination of diet composition

Botanical composition of the gazelles' diets was determined by use of the faecal microhistological technique as described by Sparks and Malecheck (1968). The sampling period straddled a wet and a dry season. The samples of faeces were collected once per month. Wet season samples were taken from March through June and dry season from July through September. On the day of sampling, the researchers scouted the study area looking for fresh pellet piles of either type of gazelle. From each pellet pile, two pellets were picked. A total of ten pellet piles per gazelle species were identified. A total of 20 pellets were therefore collected per each sampling day. The pellets were stored in paper sacks, then air-dried for three days and oven-dried at 60°C for 24 h. Pellets from each type of

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gazelle and month per season were thoroughly mixed to make one composite sample. From each composite sample three sub-samples were taken for analysis. The pellets were then ground in a Wiley mill through a 1 mm screen. Handling and slide preparation of plant reference and faecal material as well as calculation for frequency, particle density, relative density, and percent dry-weight followed the procedures outlined by Cavender and Hansen (1970), Hansen et al. (1984) and Sparks and Malecheck (1968). Differences in amounts of forage classes identified in the diets of the two animal species were evaluated and statistical differences were accepted at the 5% level of significance.

Determination of diet diversity and overlaps

Diet diversity was calculated using the Shannon-Wiener index (Shannon 1948). The index gives an estimate of the variety and evenness of the components in the diet (Hurtubia, 1973). Overall similarity of diets for shared forage was calculated using Morisita similarity index (Morisita, 1959) as modified by Horn (1966). Overlap within each individual forage category (grasses, forbs and shrubs) was also calculated. The Spearman's rank-order correlation coefficients (Snedecor and Cochran, 1973) were used to compare food habits between the two gazelles. Differences in the variables used were evaluated using the *t*-test and statistical differences were accepted at the 5% level of significance.

RESULTS

Botanical composition of the diets

Data on Table 1 show plant species recorded in the diets of the Thomson's and Grant's gazelle during the wet and dry seasons. Certain species were prevalent in the diets throughout the two seasons, while others were prevalent only during one of the seasons. Commonly shared forage plants were similar while others differed in the diets throughout the two seasons.

Wet season diet composition

A total of 23 plant species were identified in the diets of Grant's gazelle during this season. The most abundant plant species in the diets were *Acacia* spp. mainly *A. mellifera* and *A*. *drepanalobium* contributing about 35% of the total diet of the Grant gazelle. Other abundant species include the *Hibiscus parvifolius* (13%), *Grewia* spp (9%) and *Pennisetum straminium* (7%). Twenty one (21) plant species were identified in the diet of Thomson's gazelle. Of these plants, the most abundant in the diet were the grass species namely the *Digitaria* spp. and *Cynodon* spp. each contributing an equal percentage of about 15% of the diet followed closely by *Pennisetum mezianum* and *P*. *straminium* equally contributing about 14% of the diet.

Relative proportion of each forage classes in Grant's gazelle diets were 61% browse, 24.3% grass and 14.7% forbs. For Thomson's gazelle, the proportions were 76.8% grass, 14.7% browse and 8.5% forbs (Figure 1). Forage classes were significantly associated with the two gazelles ($P<0.05$) when frequency of occurrence was analyzed. Grass, browse and forbs use were significantly different between the two types of the gazelles during the season. Thomson's gazelle relied largely on grasses while the Grant's gazelle on browse. Forbs were the least contributor to the diets of the two gazelles.

Wet season diet diversity and overlap

In the wet season, Thomson's gazelle had a Shannon-Wiener diversity index of 1.07, whereas Grant's gazelle had 1.01. This showed that Thomson's gazelle diets were more diverse during the wet season even though the number of plants species was less by 2 of that of Grant's gazelle. This meant that the proportions of the individual plants relied by the Grant's gazelle were higher than those of Thomson's gazelle. Overall diet similarity was 26.4% among common (15) forage species comprising Thomson's and Grant's gazelles' diets. Though the overall diet similarity was low, overlap within each forage class was higher with browse having 46.2%, followed by forbs 42.3% and grasses 31.8% (Figure 2). The Spearman's rank-order correlation coefficient was 0.24 and was not significantly different ($P>0.05$) implying that there was no strong link in the order in which the two species selected the common forage plants during the season. This showed that the two animal species do not compete with each other during the wet season.

Dry season diet composition

Twenty four (24) plant species were identified in the diets of Grant's gazelle while 18 were identified in the diets of Thomson's gazelles. Grant's gazelle consumed in abundantly *Grewia* spp, *Hibiscus parvifolius*, *Acacia* spp, *Balanities glabra* and *Themeda triandra* plant species each contributing about 38, 16, 9, 8 and 6% respectively. Relative proportion of each forage class were 58.6% browse, 22% forbs and 19.4% grass in Grant's gazelle diets. Relative proportions in Thomson gazelle diets were 65% browse, 19.8% forbs and 15.2% grass (Figure 3). Browse and forbs use were significantly different ($P<0.05$) between Grant's and Thomson's gazelles' during the wet season. Grant's gazelle relied largely more on browse and forbs than Thomson's gazelle. Grasses were the least contributor to the diets of the two gazelles.

Dry season diet diversity and overlap

Grant's gazelle had a Shannon-Wiener diversity index of 0.947, whereas Thomson's gazelle had 0.959. Grant's gazelle had a slightly less diverse diet than Thomson gazelle. This implies that the two types of gazelles relied more less on the same number of forage species for their diets though there could be slight differences in the proportions of individual plants foraged. Overall diet similarity index was 46% among the 15 common forage

Table 1. Mean relative density (%) of individual forage plant species in Grant's and Thomson's gazelles' diets during wet and dry season.

Forage species/classes	Wet season		Dry season	
	G. gazelle	***T. gazelle***	***G. gazelle***	***T. gazelle***
Grasses				
Bracharia spp.	3.1	0.4	0.6	0
Cynodon spp.	5.8	15.3	0.5	0
Digitaria spp.	2.0	15.4	0.9	3.3
Enterpogon macrostachyus	0	8.6	0	0.7
Eragrostis spp.	0.8	0.4	0.6	0
E*ustachyus paspaloides*	0.4	1.6	0	0
Hyparrhenia spp.	0	0.4	0	0
Lantana trifolia	0.7	0	0	0
Lintonia nutans	0	0.6	2.2	0
Panicum spp.	0	2.0	0.5	0.5
Pennisetum mezianum	0.5	13.9	1.8	0.8
Pennisetum straminium	7.2	13.9	5.9	2.0
Setaria spp.	0	0.6	0	0
Sporobolus spp.	0.7	1.7	0	0
Themeda triandra	3.1	2.0	6.4	7.9
Sub-total	24.3	76.8	19.4	15.2
Forbs				
Barleria spp.	0.7	1.9	0.6	1.8
Commelina spp.	0	2.0	0	0
Hibiscus parvifolius	12.8	4.6	16.2	13.9
Indigofera spp.	0.5	0	0	0
Ipomoea spp.	0.7	0	0.4	0
Monechmna debile	0	0	0.4	0
Sida spp.	0	0	0.9	0
Solanum incanum	0	0	0.9	0
Hermania spp.	0	0	0.6	0.9
Ochna inermis	0	0	2.0	3.2
Sub-total	14.7	8.5	22.0	19.8
Browse				
Acacia spp*	35.2	10.5	9.0	18.8
Asparagus spp	0.5	1.9	0	0.6
Aspilia mossambiscensis	2.8	0	0	2.1
Balanities glabra	4.6	1.4	7.5	10.8
Boscia spp.	0	0	0.9	0
Cadaba farinose	4.1	0.9	0.6	0.5
Commiphora spp	3.4	0	2.0	4.5
Duosperma spp	0.7	0	0.6	0.6
Grewia spp	9.2	0	38.0	27.1
Soricocomopsis spp	0.5	0	0	0
Sub-total	61.0	14.7	58.6	65.0
Total	100.0	100.0	100.0	100.0

species comprising the diets of the two species of gazelles. However, there were over 40% diet overlaps within each individual forage category with forbs having 49% followed by browse (46%) and grass (42%) (Figure

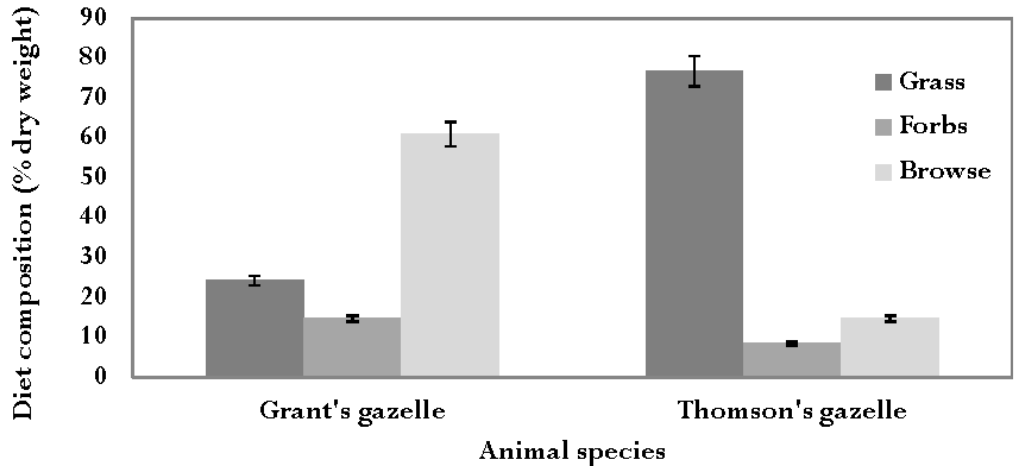

Figure 1. Dry weight percentage of total diet each forage class contributes to Thomson's and Grants gazelle diet during wet season.

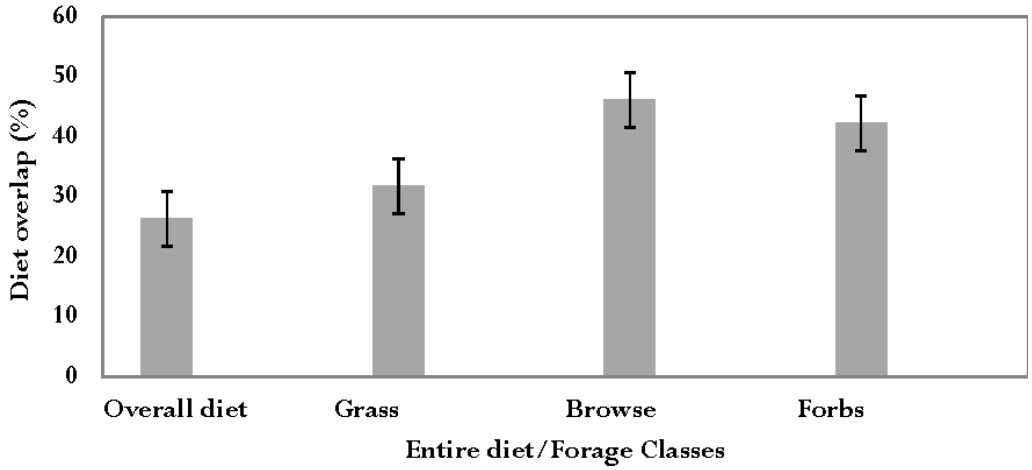

Figure 2. Percent overlap of overall diet and each forage class for Thomson's and Grant's gazelles during wet season.

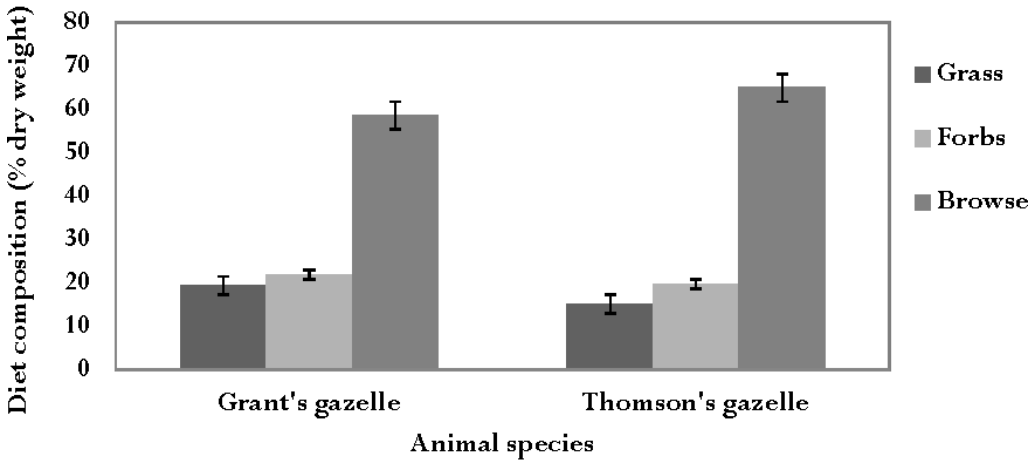

Figure 3. Dry weight percentage of total diet each forage class contribute to Thomson and Grants gazelles during dry seasons.

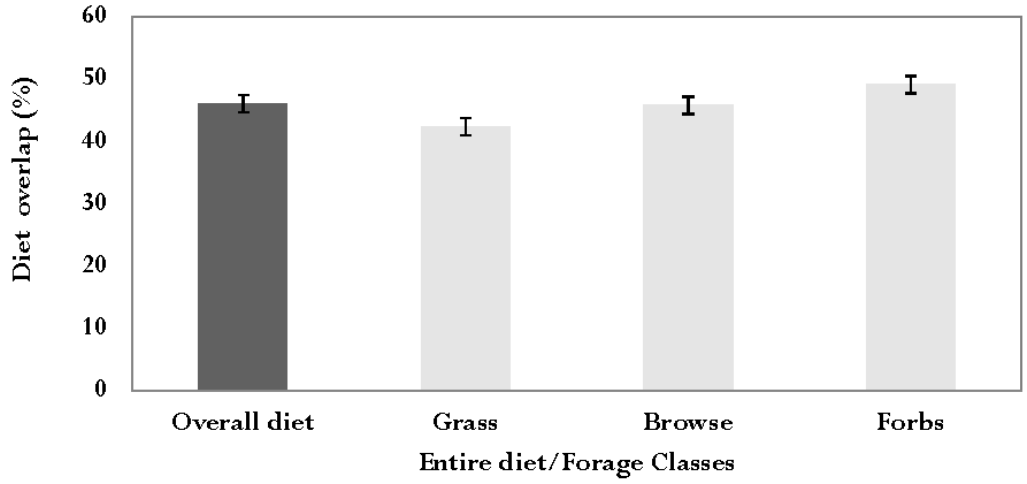

Figure 4. Percentage overlap of overall diet and each forage class for Thomson's and Grant's gazelles during dry seasons.

4). The forb similarity index was high because of the high prevalence of *H. parvifolius* by the two types of gazelles. The Spearman's rank-order correlation coefficient was high (0.92), implying a strong link in the order the two species selected the common forage plants during the season. This indicates that the two types of gazelles most likely compete with each other for the same forage resources during the dry season.

DISCUSSION

Diet composition

Overall, diets of the two Gazelles varied with seasons in terms of individual species composition and forage class proportions. Browse dominated the Grant's gazelle diets during both seasons though slightly higher in the wet season. The forbs component was higher in dry season than in the wet season. According to our results, Grant's gazelles could be firmly classified as a mixed feeder in the wet season and as a browser in the dry season. Studies that classified Grant's gazelle as mixed feeder and agree with our findings include those of Hoffman (1973), Kilonzo et al. (2005), Lamprey (1963), Schenkel (1966) and Sommeratte and Hopcraft (1994). Studies that classify Grant's gazelle as a browser are few and include those of Kingdon (1982) and Spinage et al. (1980). The study reported *Cynodon* spp. and *Pennisetum straminium* as major grass species in the wet season while *Themeda triandra* and *Pennisetum straminium* common in dry season. The prevalence of the three perennial grasses in the diets of the Grant's gazelle is attributable to their palatability and higher frequency in the area particularly *Themeda triandra* (Kilonzo et al., 2005). *Acacia* spp. notably *A*. *merifella* and *A*. *drepanolobium* and *Grewia spp* formed the bulk of the browse component contributing about 35 and 38% in wet season and dry season, respectively. The three woody species remain green and retain their leaves throughout the year. The gazelles were observed foraging *Grewia* spp. more than the two Acacia species. *H. parvifolius* was the most prevalent forb in the diets of the gazelle throughout the two seasons though it was more prevalent in the dry season than in wet season. The forb has been reported as relatively frequent in the area (Kilonzo et al., 2005).

Grass dominated the Thomson's gazelle diets during wet season (77%) and browse (65%) during the dry season. The forb component is only significant in the dry season. Thomson's gazelle was thus predominantly a grazer during wet season and a browser in dry season. Thomson's gazelle is predominately a grazer preferring well-water short grass plains. The results on the diets of Thomson's gazelle agree with that of Hansen et al. (1985), who reported high proportion (>50%) of monocotyledonous plant species in the diets of the gazelle living in northern Serengeti. However, Kingdon (1982) and Spinage et al. (1980) classified Thomson's gazelle as mixed feeder. *Enterpogon macrostachyus*, *Digitaria* spp., *Pennisetum mezianum* and *P*. *straminium* were reported as forming the bulk of grass component in the wet season, while only *Themeda triandra* was the most important grass species in the gazelle diet in the dry season. The prevalence of certain grass species could be partly attributed to the fact that they are perennial and partly to the fact that they had a high relative frequency and greater standing biomass than other species as reported by Ego et al (2003) and Kilonzo et al (2005) who did their research work in the same region. Thomson's gazelle only turned to browse shrubs and forbs in the dry season when grass is unavailable. The current study

reported *Grewia* spp., *Acacia* spp. and *Boscia* spp. as the most prevalent browse species contributing about 27, 19 and 11% of the entire diet respectively. *H. parvifolius* spp. was still the most prevalent forb in the diets of Thomson's gazelle throughout the two seasons.

Diet diversity and overlap

Seasonal diet diversity

Diet diversity indices were higher in the wet season and lower in dry season. Likewise, the indices were higher for Thomson's gazelle than Grant's gazelle in both seasons even though the numbers of plant species reported in their diets were less by 2 in the wet season and less by six in the dry season that of Grant's gazelle. What this meant was that Thomson's gazelle used higher proportions of the individual forage plants compared to the Grant's gazelle. Our results therefore indicate that the two gazelles tend to have wide and less variety of forage plants during wet and dry seasons' respectively. Larger species typically have greater diversity in species selection under normal conditions (Mackie, 1970; Schoener, 1971), but in our study Thomson's gazelle diets were more diverse than Grant's gazelle. Since diet diversity often increases under conditions of food resource shortages (Gullion, 1966), Thomson's gazelle probably selected more diverse diets because they were under dietary stress. Under more favourable conditions, Thomson's gazelle might have had a less diverse and more specialized diet than Grant's gazelle. Thomson's gazelle diets were more diverse in grass species in wet season and browse species in the dry season. This can be viewed as a resource utilization strategy whereby Thomson's gazelles make use of the grass when it is still growing and is high in nutrient content, before suddenly declining in quality as it matures. Unlike Thomson's gazelle, Grant's gazelle diets were more diverse only in browse species throughout the two seasons. Human disturbances currently being witnessed in the region might be the major cause in the change in the dietary diversity between the two types of gazelles. Harvesting or cutting of woody trees for charcoal burning can be very disastrous to the nutritional well being of the two types of gazelles.

Seasonal diet overlap

The seasonal overall diet similarity was highest (46%) during the dry season and lowest (26%) in the wet season. Though the overall diet similarity in wet season was low, the results also indicated higher similarities within browse and forbs categories. Our results indicate that the degree of overlap in the entire diets and within the three forage classes increased during the dry season. Dietary overlaps alone cannot tell whether the two species are competitors or complementarily feeders. The Spearman's rank-order correlation co-efficient technique was used to test whether there was any strong link in the order in which the two animal species selected the common forage plants during the two seasons. The Spearman's rank-order correlation co-efficient was highest (0.92) in the dry season and significantly different ($p<0.05$) unlike that of wet season (0.24). According to our results therefore, Thomson's and Grant's gazelles' are competitors during the dry season and complimentary feeders during the wet season. According to Schoener (1983), competition only occurs when the resources being shared are limited. This implies that there was limited forage available for the two species during the dry season and the two types of gazelles' are competing with each other for forage resources. During the wet season, the two types of gazelles were therefore ecologically separated and this demonstrates the feeding complimentary of these two species. This suggests that a combination of the Thomson's and Grant's gazelles' during the wet seasons provides a more efficient utilization of forage at the south-eastern dry lands of the country.

Conclusion and management implications

The botanical compositions for diet selection by the Grant's and Thomson's gazelles' were generally influenced by season. Certain species were prevalent in the diets throughout the two seasons, while others were prevalent only during a particular season. Commonly shared forage plants were similar while others were different in the diets throughout the two seasons. Grant's gazelle was a mixed feeder in the wet season and a browser in the dry season, whereas Thomson's gazelle was a grazer during wet season and a browser in the dry season. The two gazelles had diverse diets in the wet season with Thomson's gazelle having more diverse diets in both seasons than Grant's gazelle. Under normal conditions, Thomson's gazelle tend to have a less diverse diet compared to Grant's gazelle. This is an indication to the rangelands managers that the two gazelles are under nutritional stress and the problem needs some interventions. Human disturbances might be the main cause of this abnormality. The two species were competitors during the dry season and complimentary feeders during the wet season. The dry season conditions therefore may pose a threat to the survival of the two species in the area. This might have management implications to wildlife managers manning the conservation areas in terms of optimum stocking rates. Further study is needed to determine the sustainable stocking rates of the two species in the ecosystem. Dietary overlaps were higher within the browse forage and forb classes throughout the two seasons.

Therefore, any human activity interfering with the browse forage particularly the *Acacaia merifella*, *Grewia* spp and *Balanities glabra* and forbs like the *H. parviflora* should be stopped forthwith at any cost. We recommend a comparative study to characterise the nutritional requirements of the two types of gazelles in the study area. A census should also be conducted since the conservation of the two gazelles should be based on both their population status and habitat requirements.

Conflict of Interests

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

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Rare tree species in nurseries across the Visayas, Philippines

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Rare tree species make a significant contribution to the species richness in natural tropical forests but often they are endangered. Integrating them into plantation schemes is an important option for biodiversity conservation. In the Visayas, Philippines, we surveyed tree nurseries with a focus on 20 rare native species. Including the focal species, we found a total of 138 tree species in nurseries of which 73% were natives and 25% red-listed. Comparing results with earlier nursery surveys indicated that the cultivation of native tree species in nurseries had increased which may be attributed to the National Greening Program. Native dipterocarps such as *Shorea contorta* and *Parashorea malaanonan* were frequently found. Other species however, which are rare in near-natural remnant forests of the region, were clearly under-represented (for example, *Diplodiscus paniculatus* and *Wallaceodendron celebicum*) or absent (*Dracontomelon edule*) in nurseries. Knowledge gaps were declared by the nursery operators and may partly have influenced the non-production of specific species. We concluded that there is already a considerable number of native tree species in the nurseries of the Visayas. This indicated increase needs for sustenance and we think that extending the National Greening Program, knowledge generation and education may play vital roles.

Key words: Biodiversity conservation, reforestation, planting materials, native species, non-native species.

INTRODUCTION

Deforestation and the increasing extent of degraded land requiring remediation are of utmost concern to natural resource management in the tropics (Lugo, 1997; Parrotta et al., 1997), including the Philippines (Liu et al., 1993). With a view to reinstating the productive capacity and ecosystem services that forests provide and potentially restoring biodiversity, reforestation may represent the best land-use option (Lamb et al., 2005; Neidel et al., 2012; Parrotta, 1997). Reforestation to restore and/or conserve biodiversity can be achieved by planting non-native species in monocultures with a view to allow diverse understories of native trees to develop beneath the canopy (Ashton et al., 2014, in press; Lamb, 1998; Parotta, 1997), or by planting mixtures of native

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tree species (Lamb, 1998). The advantage of using non-native tree species is that it is easier to manage and it is probably more profitable than planting native species (Cubbage et al., 2007; Nguyen et al., 2014). However, where regeneration becomes successful beneath plantation canopies, it does not guarantee that species and mixtures of interest are supported. There are many factors that affect seedling establishment, for instance, the distance to the nearest native forest may hinder recruitment, especially for species that lack primary dispersal mechanisms (Elliott et al., 2013; Lamb et al., 2005). For any given species, and particularly rare ones, the outcome is often difficult to predict, and any natural succession can take a long time. However, where the main emphasis of reforestation is on biodiversity conservation, species that are rare in the natural forest must be considered. Rare tree species contribute much to the tree species richness of natural forests (Hubbell, 2013; ter Steege et al., 2013) and they are often endangered due to deforestation.

The potential of using native species in reforestation is widely recognized and more and more species are being tested for their performance, especially in open grasslands (Milan and Margraf, 1994; Schneider et al., 2014; Shono et al., 2007; van Breugel et al., 2011). Native tree species contribute to biodiversity conservation (Milan, 2012) and species that local people are familiar with are usually more readily accepted (Nichols and Vanclay, 2012). However, only a few native species are actually used in reforestation, despite the wide range of species to choose from (Condit et al., 1993). The specific species raised in nurseries depends on many factors including the availability of or access to planting materials, demand for the species and the available technology in producing the focal species (Carandang et al., 2006). Such constraints can potentially affect reforestation initiatives such as National Greening Program (NGP) in the Philippines. NGP is nationwide program which aims to reforest an area covering 1.5 million ha with 1.5 billion trees from 2011 until 2016 (EO 26 2011) using various species including commercial non-native fruit trees and non-native timber trees in production areas but also promotes planting of native species, especially in areas classified as protected forest.

In this context, nursery seedling production may provide the opportunity to establish a plantation that meets certain objectives such as biodiversity conservation. A number of nursery studies have been conducted in the past covering some parts of the Visayas that have focused on production systems and socio-economic and policy issues in the nursery sector, for example Leyte (Gregorio et al., 2004, 2010) and Cebu (Carandang et al., 2006). For the present study, we visited nurseries and carried out interviews with 29 nursery respondents in 18 municipalities across the Visayas in the Philippines in particular to document the presence of 20 selected native tree species in nurseries.

These species are the same species we surveyed previously in remnant forests (reported in Peque and Hölscher, 2014) which we found to be generally rare in the region, with some which are either still locally abundant or very rare or absent in some forests. The disproportionate abundance and distribution of these species is largely due to shrinking of forest areas resulting from human activities. Since the remaining natural forests in the Philippines and in the Visayas in particular are limited in area, and scattered with some which are already isolated, we think all the 20 focal tree species merits special consideration with respect to conservation and are important in promoting high-diversity reforestation (Brancalion et al., 2012). These species are mostly red-listed both in International Union for Conservation of Nature (IUCN 2001) and Philippine Red-lists (DAO 2007) and have been used in small-scale forestation and field trials, particularly through “Rainforestation”- an approach that uses a mixed of native species, the aim of which is to mimic natural forests (Milan and Margraf, 1994). For instance, the dipterocarps which is among the most important tree groups in the Philippines, are classified as critically endangered in IUCN but only few of them have been incorporated in reforestation in the Visayas and/or the Philippines. Documenting other native tree species grown in addition to the focal species is important to understand the range of species available in nurseries. This paper aims to answer the following questions: a) What are the tree species produced in the nurseries and are these similar to those used in the past? b) What is the current level of knowledge of respondents on focal species and how it is related to the cultivation of the species in nurseries? c) To what extent are focal species that are available in forests used in nurseries? The implication of these findings is also discussed and comments are made on the challenges of mainstreaming rare tree species in reforestation.

MATERIALS AND METHODS

The Visayas region

The Visayas is one of the three geographical divisions of the Philippines, along with Luzon and Mindanao, which is located in the central part of the country. It consists of six major islands including Samar, Leyte, Cebu, Bohol, Negros and Panay, and several hundred small islands making up the Visayan archipelago. Rugged terrain and high mountains characterize the Visayas, with the exception of Samar, which is hilly, and in general, soils in these islands are derived from volcanic or limestone substrates. In the lowlands, the climate is tropical and monsoonal with an average air temperature of 27.9°C. At higher elevations, annual rainfall reaches +4000 mm and falls to 1000 mm at leeward sites and in sheltered valleys. Little seasonal variation exists across the region, as rainfall is more or less evenly distributed throughout the year and, when occurring, a short dry season lasts for only one to three months either from December to February or from March to May.

The evergreen tropical rainforests of the Visayan hills and uplands mainly comprise the original coastal vegetation. Like other

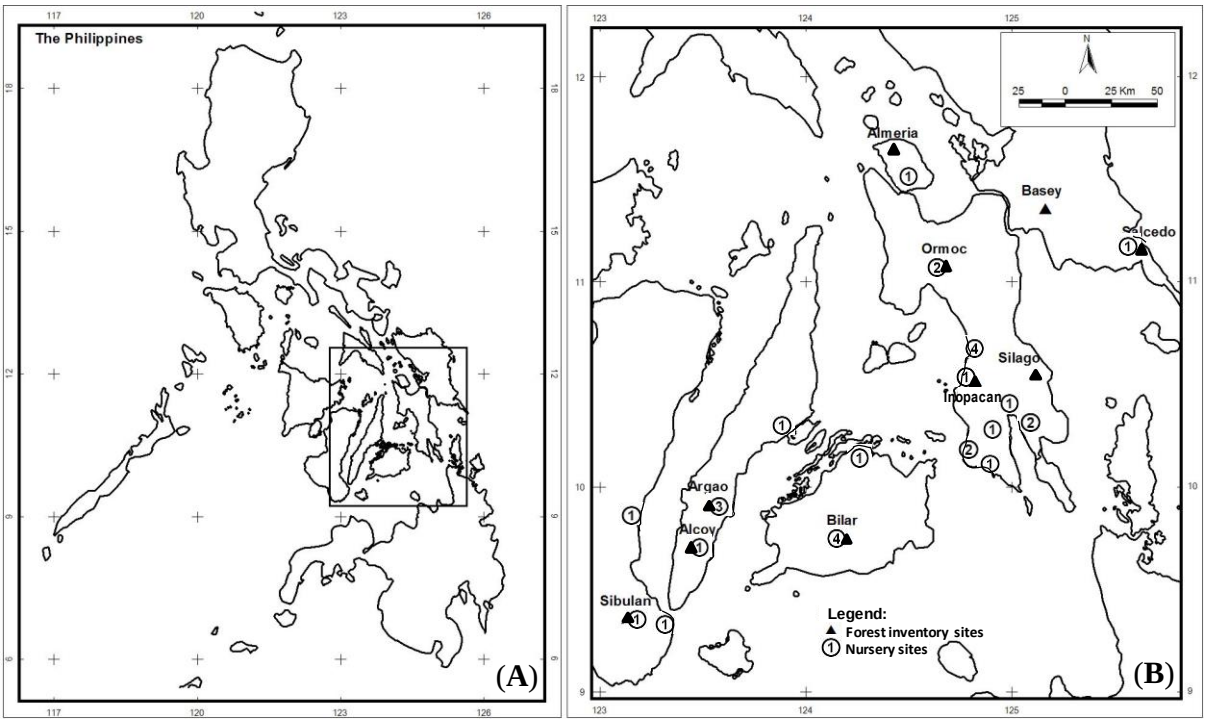

Figure 1. The location of the study area, studied nurseries and assessed remnant forests: (A) Philippines and (B) the study area. The number inside each circle represents the number of respondents in each location. Respondents far from remnant forests are CENRO nurseries and those based in universities while those that are near are either communal or individual/private nurseries. Solid triangles represent the forest inventory sites.

parts of the Philippines, the Visayas have not been spared from the onslaught of deforestation. The once forested landscape of the Visayas is now composed of a mosaic of coconut plantations, agricultural farms, degraded open grasslands covered with a few pioneer species and a little remnant forest. The current estimated forest cover (excluding mangroves) of the Visayas is 697,384 hectares representing some 12% of its total land area which is 1% higher than the 2003 reported figure (FMB 2012).

Selection of respondents and background information of study sites

The study covered 29 nurseries distributed across the Visayas, Philippines (Figure 1), most of which were located near remnant forest and on the same islands where we conducted our forest inventory. Since there were few active nurseries in the Visayas, identification of the sites and nurseries was done by snowball sampling. The number of respondents varied from one to four in each study location. The first respondent group comprised known seedling producers from the region as well as representatives from the Community, Environment and Natural Resources Offices (CENRO) of the Department of Environment and Natural Resources (DENR), as they have jurisdiction over all of the provinces of the Visayas and they maintain forest nurseries for their reforestation projects. Other nursery operators were located by referral by asking previously interviewed respondents about nurseries that existed near their areas. Local guides who helped during our forest inventory work also showed us toward some nursery operators.

Data gathering

Personal interviews were carried out with 29 respondents using a semi-structured interview schedule. The questionnaire was initially tested on a small number of nursery operators to check its appropriateness to the target respondents. The questions given to all respondents were the same and were structured to elicit information on the species they produced in nurseries, and particularly the 20 target study species (Table 1). The species are all presumed rare based on the IUCN and Philippine Red List. Particularly, these species were promoted in rainforestation farming (Milan and Margraf, 1994) and partly belong to the most preferred native tree species for smallholder forestry on Leyte, Philippines (Mangaoang and Pasa, 2003). In the Philippine red list, three species are listed as critically endangered, five as endangered, seven as vulnerable and five species which have not been evaluated. In IUCN (2001), 13 of the species are red-listed with the dipterocarps listed as critically endangered. The questionnaire contained socio-demographic information on the respondents. They were also asked about the species they produced, type and sources of plant material, familiarity of the species, and perception of conservation status of focal species. The summary of the main questions is presented in Table 2. Important observations in each nursery were also noted.

Data analysis

A combination of descriptive statistics, simple correlation and ordination techniques were used to address the objectives of the study. Knowledge was quantified in terms of the familiarity of respondents on the focal species and their perception of the conservation status of the species (Table 2). Principal component analysis (PCA) was conducted to see relationships among knowledge, species preferred by respondents from among the 20 focal species and the focal species that are grown in nurseries.

Table 1. The focal tree species surveyed in nurseries.

Species name	Species Code	Family	Official Common Name	Local names in the study sites	Conservation status*		Use in Reforestation
					DAO (2007)	IUCN (ver. 3.1)	
Dracontomelon dao (Blanco) Merr. & Rolfe	Ddao	Anacardiaceae	Dao	Dao	VU	NE	Yes
Dracontomelon edule Merr.	Dedu	Anacardiaceae	Lamio	Lamyo	VU	NE	Yes
Calophyllum blancoi Planch. & Triana	Cabla	Clusiaceae	Bitanghol	Bitanghol	EN	NE	Yes
Dipterocarpus validus Blume	Dval	Dipterocarpaceae	Hagakhak	Yakal lapad dahon	NE	CR	Yes
Parashorea malaanonan (Blanco) Merr.	Pmal	Dipterocarpaceae	Bagtikan	Bagkitan, Lauan	NE	CR	Yes
Shorea almon Foxw.	Salm	Dipterocarpaceae	Almon	Almon, Lauan	VU	CR	Yes
Shorea contorta Vidal	Shoco	Dipterocarpaceae	White Lauan	Lauan puti	VU	CR	Yes
Shorea palosapis (Blanco) Merr.	Shopa	Dipterocarpaceae	Mayapis	Mayapis, Mana	NE	CR	Yes
Diospyros philippinensis A. DC.	Dphi	Ebenaceae	Kamagong	Mabolo, Ituman	CR	EN	Yes
Intsia bijuga (Colebr.) Kuntze.	Ibij	Fabaceae	Ipil	Ipil	VU	VU	Yes
Pterocarpus indicus Willd.	Pind	Fabaceae	Narra	Narra, Naga	VU	CR	Yes
Wallaceodendron celebicum Koord.	Wacel	Fabaceae	Banuyo	Banuyo	NE	NE	Yes
Afzelia rhomboidea (Blanco) Vidal	Arho	Fabaceae	Tindalo	Bayong, Barayong	EN	VU	Yes
Toona calantas Merr. & Rolfe	Tcal	Meliaceae	Kalantas	Kalantas, Lanipga	CR	NE	Yes
Tristaniopsis decorticata (Merr.) Peter G. Wilson & J.T. Waterh.	Tdec	Myrtaceae	Malabayabas	Tiga	CR	NE	Yes
Artocarpus blancoi (Elmer) Merr.	Abla	Moracaeae	Antipolo	Antipolo, Tipolo	EN	VU	Yes
Palaquium luzoniense (Fern.-Vill.) Vidal	Pluz	Sapotaceae	Nato	Nato, Nato puti	VU	VU	Yes
Diplodiscus paniculatus Turcz.	Dpan	Tiliaceae	Balobo	Balobo, Barobo	EN	VU	Yes
Vitex parviflora Juss.	Vipar	Verbenaceae	Molave	Tugas, Hamorawon	EN	VU	Yes
Vitex quinata (Lour.) F. N. Will.	Vqui	Verbenaceae	Kulipapa	Kulipapa, Lima-lima	NE	NE	No

*CR- Critically endangered; EN - endangered; VU - vulnerable; and NE - not evaluated; DAO 2007-01 - Department of Environment and Natural Resources Administrative Order S. 2007; IUCN - International Union for Conservation of Nature.

Table 2. Summary of the main questions asked during the survey and the possible responses.

Question	Possible answers
Age classes, gender, educational attainment	< 30/30-49/50-69/≥70 years old; male/female; not completed primary/completed primary/not completed secondary/completed secondary/not completed tertiary/completed tertiary/post-graduate
Nursery type, years of operation	DENR/private/communal/NGO/municipal;<5 years/5-10 years/above 10 years
Sources and mode of acquisition, type of planting materials, preferred species	Native forests/trees outside forests; collected/bought; seeds/wildlings/both; list of species
Do you decide what species to produce	Yes/no
Familiarity on 20 focal species, reasons for cultivating or not cultivating	Very familiar/ familiar/ not familiar; availability of planting materials/demand/ lack of knowledge on propagation
Perception of the conservation status of focal species	Critically endangered/endangered/vulnerable/ no idea
Are you interested on focal species if planting materials are available and which species, reasons for interest, expected problem on producing the species of choice	Yes/no; list of species; excellent wood quality/ species are already rare; limited propagation skills/germination problem/germination problem/problem on pests

Figure 2. Use of wildlings in nursery. Freshly collected wildlings of *Diospyros* sp. ready for potting (A), and wildlings with leaves trimmed and transplanted into the pots (B).

Data were first standardized before running PCA. Pearson correlation was also conducted to see relationships between the focal species grown, species preference and knowledge on the species. Test of normality was performed using Shapiro-Wilk and non-normal data was first log-transformed before correlation with other variables was conducted. The categories of the variable "Familiarity" were reduced into familiar (very familiar + familiar) and non-familiar and only the counts of the former for each species were considered for correlation analysis. The same was done for perception wherein the categories critically endangered, endangered, and vulnerable were totaled and served as counts for each species. Relationship between education level and number of species (from 20 focal species) known by respondents were determined using Spearman. Chi-square test between education level and nursery grouping was also performed. We also combined nursery and inventory data by graphing the proportion of nurseries cultivating the 20 focal species and the frequency of occurrence of the said species in the 10 remnant forests in order to visually see relationships between them.

RESULTS AND DISCUSSION

Overview of the nurseries in the study sites

The 29 nurseries surveyed in this study included individual or family-operated (7%), group or communal (45%), non-government organization (NGO) (3%), CENRO-DENR (28%), university-based (14%) and a municipal nursery. Some of these nurseries were relatively new (≤5 years, 38%) while others (24%), such as the DENR nurseries, were long established (>10 years). Majority of the respondents were male (72%) and were in age classes 30-49 (52%) and 50-69 (48%). Unlike the more or less permanent nurseries of the DENR and those based in universities, individual and communal nurseries are generally temporary in nature, with communal lones being mostly dependent on DENR projects, and are likely to cease operations upon withdrawal of support from funding organizations (Edralin and Mercado Jr., 2010). Operators of communal nurseries are mostly members of different people's organizations (POs) that were formerly organized by DENR and which became active again following the recent implementation of the NGP. Most of them are also beneficiaries of Community-based Forest Management Program and the seedlings they produced were the ones to be planted in their respective project areas, paid for by DENR. Nursery operators are also open to seedling production through contracts with other agencies, e.g. with the Department of Agrarian Reform or local government units, both of which take part in NGP activities. For nurseries bound to a project, the species they produce are dictated by support agencies (Mercado and Duque-Piñon, 2008). Academic institutions offering forestry education also maintain nurseries for teaching and research purposes while the DENR mainly produce seedlings for reforestation projects and for limited free distribution to interested individuals or organizations.

Nurseries utilize any planting material in their production, but in most cases they use wildlings (Figure 2) for native trees as it is easier and faster to produce seedlings than from seeds and it is easier to meet production targets. Another reason is that wildlings can still be available, even when collection is delayed. Seeds of native tree species are only used if they are accessible and respondents know or have experience of growing them (for example, *Pterocarpus indicus* or *Vitex parviflora*). Seeds of dipterocarps are also rarely used due to their long fruiting interval. For the common non-native trees, seeds are usually used as planting material, with the exception of *Swietenia macrophylla* where both seeds and wildings are used. None of the nurseries employed vegetative or clonal propagation techniques.

Positive trend in growing native tree species in nurseries

A variety of tree species are produced in nurseries along with other growth forms, such as bamboo or rattan. A total of 138 tree species were recorded across the nurseries, 73% of which were native species (see some examples in Figure 3) with 25% being included in the list of threatened species of the Philippines (DAO 2007-01). A few of the native species (3%) are grown chiefly for their fruits (for example, *Canarium ovatum* and *Zyzygium cuminii*). In contrast, of the non-native trees, the majority is principally cultivated for fruit production such as coffee or cacao (54%), while 27% are grown for timber with the rest being grown for ornamental purposes, and particularly for urban forestry projects of the DENR.

The high frequency of native tree species produced in the current study is in contrast with that which was observed some ten years ago in the Visayas and part of Mindanao. In the current study, *S. macrophylla* belongs to the top 10 most common tree species grown in nurseries while the rest are native species (Table 3). For instance some dipterocarps such as *Shorea contorta* and *Parashorea malaanonan* are still among the most impor-

Figure 3. Native tree species in nurseries: (A) *Pterocarpus indicus*, (B) *Agathis philippinensis*, (C) *Shorea contorta*, (D) *Shorea almon*. Except for *Pterocarpus indicus* which was produced from seeds, these planting stocks were produced from wildlings.

tant native species produced in nurseries. The dominance of non-native tree cultivation in the past, as demonstrated by Mercado and Duque-Piñon (2008) for Mindanao, was due to the large demand for reforestation and tree farming which was promoted by the government. It should be noted however that the number of respondents in the previous studies were higher as compared to the current study due to the fact that a census of both active and inactive nursery operators was conducted as in the case of Gregorio et al. (2010). Nonetheless, the same groups of respondents were covered in all these studies which allows for comparison with the current study.

Although non-native timber species still represent important cultivars for nurseries in the current study, the numbers of nurseries producing them are much lower than those producing native species. What is also encouraging is the observed change in species preference of nursery producers, which are now more inclined to cultivate native trees. However, we think the large number of nurseries producing native species is more of a result of government programs and, partly, developmental NGOs, rather than an increase in seedling demand by smallholder tree farmers. In particular, the current interest of nursery producers towards native tree species can be attributed to the objectives of the NGP of DENR in increasing the range of species and placing importance on native species in addition to non-native species, which consequently created a market for this kind of planting material. However, it remains uncertain as to whether native trees will continue to be the dominant species in nurseries following the cessation of the NGP project in 2016. The types of species produced by communal nurseries are therefore influenced by the government (e.g. DENR), a situation that can similarly be observed for Vietnam (Hoang et al., 2011) or China (He et al., 2012).

The focal tree species

Nurseries can play a key role in forest conservation (Roshetko et al., 2010) by producing the desired regeneration species, which in our case includes the 20 focal species. The more important focal species produced in nurseries, such as *Pterocarpus indicus* (69%), *Vitex parviflora* (59%) or *Shorea contorta* (55%) (Table 3), also count among the common tree species previously grown in the Visayas (Gregorio et al., 2004, 2010). Five of our focal species (*Toona calantas*, *Afzelia rhomboidea*, *Intsia bijuga*, *P. indicus* and *V. parviflora*) were among the species tested for field trials in the Philippines a century ago (Orden 1960), but only the latter two species remain popular today. Other focal species such as *Diplodiscus paniculatus* (3%), *I. bijuga* (3%), *Vitex quinata* (7%) and *Tristaniopsis decorticata* (7%), were only produced in a few nurseries or none at all, as is the case of *Dracontomelon edule*.

Factors affecting the production of focal species

Nurseries that are distant from natural forests may experience difficulties in accessing planting materials, which could be the case for 28% of nurseries located in towns. A relatively high proportion of respondents mentioned non-availability of planting materials as the main reasons for not producing *A. rhomboidea* (62%) and *T. decorticata* (55%), while 45% cited the same reason for *Shorea almon* and *Diospyros philippinensis*. Respondents also indicated a preference for producing *Wallaceodendron celebicum* (66%), *Parashorea malaanonan* (59%) and *A. rhomboidea* (52%), but they were constrained by the non-availability of planting materials. Thus, most nurseries mainly raise focal species with seeds locally available, as was previously observed in Leyte (Gregorio et al., 2010). As a result, planting materials are also collected from trees outside forests or from any source that could include trees near nurseries (Wightman, 1999).

In our study, this is most likely the case for *P. indicus*, the country's national tree, where there are mature trees as seed sources planted in the premises of many government institutions and in parks and roadsides in urban areas. *V. parviflora* and *D. philippinensis* are also among the species where planting materials are additionally collected from trees outside forests, the latter species being common in schools because of its edible fruits. The practice of collecting planting materials from any sources however is not advisable as it may lead to the production of poor quality seedlings (Graudal et al.,

Table 3. List and ranking of most common tree species produced in the previous and current study in the Visayas (and Mindanao[b]). The same group of nurseries, e.g. government and communal nurseries (also supported by the government, for example, DENR) were covered in these studies. Species indicated by (-) means they are not reported and values inside parenthesis represent the number of nurseries surveyed.

Species	Percent of nurseries producing the species and year study was conducted				Origin of species with respect to the Visayas
	2003 (74)[a]	2006 (48)[b]	2008-2009 (96)[c]	2012 (29)[d]	
Pterocarpus indicus	30	29*	34	69	Native
Swietenia macrophylla	56	35	70	66	Non-native
Vitex parviflora	11	-	-	59	Native
Shorea contorta	15	-	26	55	Native
Diospyros philippinensis	-	-	-	41	Native
Calophyllum blancoi	-	-	-	34	Native
Parashorea malaanonan	-	-	-	28	Native
Artocarpus blancoi	-	-	-	24	Native
Dracontomelon dao	-	-	-	21	Native
Afzelia rhomboidea	-	-	-	21	Native
Cinnamomum mercadoi	-	-	-	21	Native
Gmelina arborea	49	30*	47	17	Non-native
Acacia mangium	32	-	35	17	Non-native
Eucalyptus deglupta	12	48**	-	none	Non-native

[a]Gregorio et al., 2004 (Leyte), [b]Carandang et al., 2006 (year conducted not reported, 75% of nurseries were from Mindanao), [c]Gregorio et al., 2010 (Leyte, data gathered through census and included inactive nurseries or nurseries no longer producing seedlings), [d]Present study. *Estimated (cited as most common species but figures not reported), **as reported but mostly produced in Mindanao.

Table 4. Pearson correlation matrix for the number of respondents growing each focal species, their preference, familiarity and perception on their conservation status. Unit of analysis is number of species (n=20).

Variable	Species grown	Preferred species	Perception of conservation status	Familiarity of species
Species grown				
Preferred species	0.03			
Perception of conservation status	0.90**	0.04		
Familiarity of species	0.90**	0.08	0.99**	

**p<0.01.

2009).

On the other hand, *Artocarpus blancoi* was considered by 51% of the respondents as being non-priority for production due to limited demand because of its abundance outside forests and probably due to its lower utility as compared to the dipterocarps and other known species.

Germination difficulties also discouraged a small proportion of respondents from growing *D. dao* and *V. parviflora.* Nevertheless, the non-familiarity of respondents with many of the focal species was also one of the reasons why some of the focal species were not produced, even if they were available in the nearby forests.

Local knowledge on focal species

Aside from availability of planting materials and demand as mentioned by the respondents, knowledge (in terms of familiarity) of species or lack thereof is among the most important factors why focal species were grown or not in nurseries. A particular species may not be produced even if it is available if nursery producers are not familiar with it.

Here our results show strong relationships ($p<0.01$) between the numbers of respondents familiar to the focal species and the respondents growing the species (Table 4). A strong relationship ($p<0.01$) also existed between species grown and perception of the conservation status

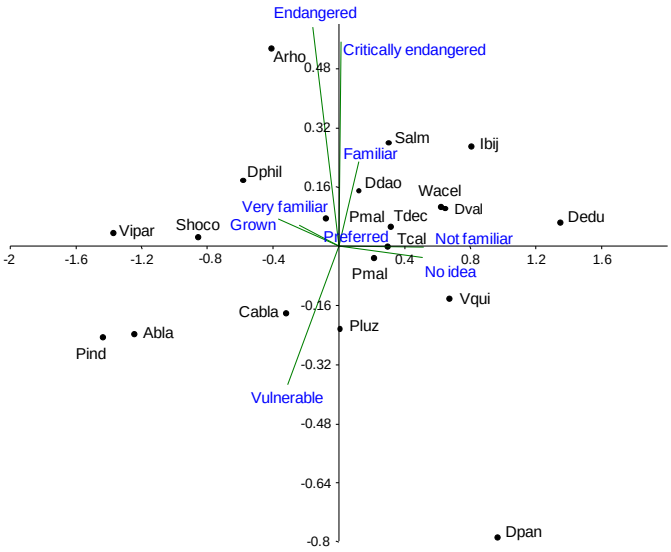

Figure 4. PCA biplot of number of focal species grown by respondents, their familiarity and perception on conservation status of species. Eigenvalues: PC1=0.62, PC2=0.07.

of focal species which is not surprising due to strong relationship ($p<0.01$) between perception and familiarity of the focal species. The species which are very familiar to the respondents (for example, *P. indicus, S. contorta, V. parviflora*) are likely to be grown in nurseries and those species which the respondents are not familiar with or have no idea about (for example, *Dracontomelon dao*, *Intsia bijuga, Dipterocarpus validus*) are likely not to be produced. The PCA biplot (Figure 4) showed a gradient of species (left to right of x axis) which are very familiar to not familiar. A study from Gadumire sub-county Uganda by Tabuti (2007) also showed similar results, with a strong relationship between community perceptions and findings from a quantitative study regarding the plant population dynamics of 16 woody species. Species preference did not show any correlation with the focal species grown, familiarity and perception of the conservation status which indicate that respondents may explore or select other tree species if planting materials are available.

Familiarity and perception of the conservation status of the focal species could possibly be influenced by the educational background of respondents. Here, our results showed strong relationship ($p<0.05$) between respondents' educational attainment and the number of focal species familiar to the respondents. We observed that the majority of respondents in government nurseries were highly educated, which was in contrast with respondents operating communal or individual nurseries, where most had low levels of education (Table 5). This result is similar with the finding of Vodouhê et al. (2010), who found that the level of education affects local people's perception of biodiversity and conservation.

Knowledge can also generally be associated with uses or economic value of the species. For instance, the so-called premium tree species (for example, *V. parviflora* and *P. indicus*) are popular because their wood is used for expensive furniture, and this is one of the reasons why they are already endangered.

Rarity of focal species in forests and nurseries and its implication for reforestation

We graphed the relationship between the presence of the focal species grown in nurseries and their actual occurrence in forest remnants (Figure 5). Some focal species (for example, *Palaquium luzoniense, Shorea palosapis* and *Calophyllum blancoi*) that are common and still widespread in natural forests are inadequately represented in nurseries. For high-diversity restoration, such species should be included as their planting materials are expectedly available. Some other rare species (*V. parviflora* and *P. indicus*) still found their way into nurseries as among those widely produced. While it appears that seedling production of these species is not that problematic, what is needed is to ensure that planting materials used are of good quality, both genetically and physically (Kindt et al., 2005). In addition, a few species that are relatively common in the forests are produced in a number of nurseries, suggesting higher chances of seeing established plantations composed of such species in the future. However, there are species (*D. edule, D. dao, A. rhomboidea, Dipterocarpus validus, D. paniculatus* and *W. celebicum*) that are more problematic because they are rare in the forests and even rarer in nurseries. Such species of course deserve special attention with respect to conservation. Many of our focal species are confined to only a few forest remnants or to one or a few islands in the Visayas. In this case, it is suggested as a first step to establish a localized plantation of focal species (Tolentino Jr., 2008), the composition of which will depend on the planting materials available in each area. Expansion to other areas and/or islands in the Visayas can follow later when enough sources of planting materials become available after the established plantations mature.

Challenges in producing the focal species for biodiversity conservation

Interest in some focal species is high and nursery growers are willing to take chances on alternative species where they know that demand or uses of the species exist (Nieuwenhuis and O'Connor, 2000), or where seed sources and, possibly, production technologies are available (Carandang et al., 2006). The bigger challenge is how to sustain such interest and extend it to actual tree planters so that they can include species that are already

Table 5. Results of x^2 tests of comparison between respondents' education level and nursery grouping (n=29). Education level were re-coded into three categories to minimize the number of cells with expected count of less than 5.

Nursery group	Education level			Chi-square	Degree of freedom	Significance
	Primary school and below	Reached/ completed secondary	Tertiary and post-graduate			
Smallholder (private and communal)	5	7	3	11.15	2	0.004**
Government (including NGO)	0	3	11			

**Significant at p<0.01; minimum expected count is 2.4.

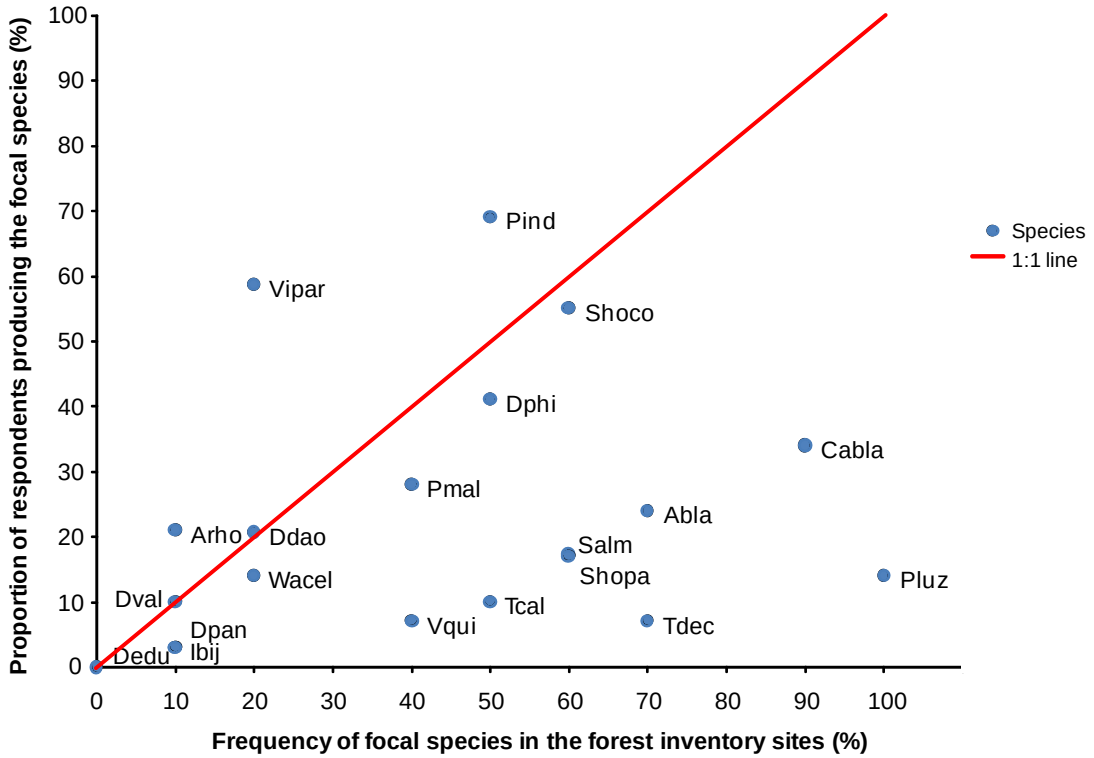

Figure 5. Relationship between the frequency of 20 rare tree species in remnant forests and in nurseries across the Visayas. Refer to Table 1 for species codes.

rare or endangered. Another obstacle is the common belief that growing native species is particularly difficult (Shono et al., 2007; Neidel et al., 2012; Schneider et al., 2014), which may discourage most tree planters. Information from recent studies in Leyte showed a positive performance of some native tree species in open grasslands (Schneider et al., 2014), which could serve as a guide for future tree planting programs. In addition, the concept of payment for environmental services seems fitting and a better alternative for tree planters' vis-a-vis harvesting planted trees (Yonariza and Singzon, 2012). Availability of planting materials is also another concern that affects the kind of species and sustainability of seedling production (Carandang et al., 2006; Gregorio et al., 2004; Harrison et al., 2008). This problem is aggravated by the lack of experience of many respondents in growing rare species, particularly from seeds. Thus, it is imperative to identify mother trees (Gregorio et al., 2004) within the region and make the information available to all.

The above issues are even more difficult than one might think and addressing them by a one-fits-all solution will probably not work. Mainstreaming rare trees in reforestation may only be possible when interest in such species transcends from nurseries to actual tree planters, which can possibly be achieved with help from various key players such as the DENR, developmental NGOs or universities that have a focus on forestry-related programs and activities in terms of advocacy, technical, market and legal support (Degrande et al., 2013).

Conclusion

The current study suggests that the production of native tree species has increased but we found that our focal species, irrespective of their status in the forests, are disproportionately cultivated in nurseries. Some species that are inadequately represented in nurseries, and especially the non-dipterocarps, are similarly rare in native forests while some species that are still common in forests are also rare in nurseries. Although the number of rare native tree species in the nurseries of the Visayas has increased, there is still a need to include more rare species. The production of seedlings in nurseries is influenced by a legion of factors including the availability of planting materials, knowledge on the species and, more prominently, the available market opportunities that resulted from the implementation of the NGP. In relation to the NGP and future forestry programs that may involve the planting of native species, it is essential to consider tree species identified as locally rare and endangered as priority species for production. Education has been found to influence knowledge on focal species, and together with training, they can play a key role in mainstreaming native species in reforestation programs. This is even more possible in relation to the implementation of NGP as DENR tasked selected universities in the country to help them augment their capacity to produce many quality planting stocks of native tree species (Philippines Official Gazette, 2012). Universities can play a crucial role in identifying and recommending to DENR priority tree species for conservation that are rare and endangered while developing and/or enhancing production technologies for these species. The production of rare species requires knowledge on the location of mother trees and potential seed sources as well as skills in collecting planting materials and production techniques to ensure that quality seedlings are produced.

Conflict of Interests

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

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Biodiversity of mushrooms in Patharia forest of Sagar (M.P.)-III

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Patharia forest is situated on Vindhyan ranges at about 457.2-533.4 m above msl. It is mixed and dry deciduous type, dominated by *Acacia* species, *Butea monosperma*, *Tectona grandis* and ground flora consisting of *Biophytum sensitivum, Cassia tora, Cynodon dactylon, Euphorbia geniculata, Heteropogon contortus, Lantana camara, Parthenium hysterophorus*, etc. During the period of July 2011-July 2013, wild mushrooms were collected from the Patharia forest and 18 mushroom species belonging to 12 families were identified viz. *Vascellum pratense, Lycoperdon pyriform, Coniophora puteana, Clitocybe geotrapa, Ganoderma tsugae, Microglossum virde, Panaeolus sphinctrinus*, *Pleurotus cornucopiae, Fomes fomentarius,, Tyromyces lacteus, Lenzites Betulina, Hypholoma elongatum, Pholiota highlandensis, Serpula lacrymans, Tremella mesenterica, Lepista nuda, Collybia butyracea* and *Omphalina ericetorum.* Among them some are edible like *L. nuda and Clitopilus prunulus* which are used for culinary purposes; some are medicinal like *G. tsugae, T. mesentrica M. viride* which are used to prepare indigenous medicines using traditional techniques.

Key words: Biodiversity, mushrooms, medicinal mushrooms, poisonous mushrooms.

INTRODUCTION

A perusal of Indian literature indicates that little attention has been paid to mushroom ecology in India (Bakshi, 1974; Sharma and Lakhanpal, 1981; Saini and Atri, 1984; Natrajan, 1987; Kumar et al., 1990a, b). Most of the past researches on ecology of fungi from India were centered on mycorrhizic association with trees (Semwal et al., 2006).

Mushrooms are a wide group of fleshy fungi, which include bracket fungi, fairy clubs, toadstools, puffballs, stinkhorns, earthstars, bird's nest fungi and jelly fungi. Generally, they live as saprophytes, however some are severe agents of wood decay. All types of mushrooms are important in decomposition processes, because of their ability to degrade cellulose and other plant polymers. Besides, they serve as nature trash burners and soil replenishers, and thus help rejuvenate the ecosystem. Ample species of wild edible and medicinal mushrooms occur in all the biodiversity rich regions

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during the rainy season. They can be found on wood of living or dead trees, on the leaf litter, on the soil through the branching mycelial infiltration. Some mushrooms are found growing in association with trees of a particular family or genus (Arora, 2008; Karwa and Rai, 2010).

Biodiversity refers to the variety and variability among living organisms and ecological complexes in which they occur. It plays a significant role in nature by enriching soil, maintaining water and climate cycle, humidity, precipitation, conservation and recycling of waste materials into nutrients. It is believed that modern developmental activities are detrimental to biodiversity and it is felt that development is inversely proportional to biodiversity. Rich biodiversity is an indicator of healthy habitat and its potential to sustain life. India is top ten mega biodiversity centers and has ample species of wild mushrooms which occur during rainy season. There are about 2000 species of edible fungi known to man out of 10,000 species of macro-fungi. India is richer in flowering plants than any other country of its size; the fungal wealth of India is also expected to be equally diverse. Many studies have been done to document mushroom wealth from east, west, north and south India but the efforts made in central India including Chhatisgarh and Madhya Pradesh States received very limited attention (Thakur et al., 2006). Patharia forest of the Sagar region, M.P. is rich in plant biodiversity and the climatic conditions together made the natural habitat conducive for the occurrence of large number of mushrooms (Dehariya et al., 2010).

Patharia hills are situated near the north of Tropics of Cancer on Vindhyan peaks. This area has a undulating topography with low rising hills of Sagar. The hills rise up to a height of 300 feet on the eastern side of Sagar Lake. The ridges facing the lake are denuded of forest, but the top and the east facing slopes have growth of varying density. The average annual rainfall of Sagar is 48 inches. The average monthly minimum and maximum temperatures are recorded as 11.1 and 25°C in January, 25.8 and 40.5°C in May and 23.3 and 28.6°C in July. The hills are built of Deccan Trap consisting of agate basalt, laid horizontally with localized entrapping ash, clay and impure lime. Thus, it would seem that the topography and the biotic factors together create a dynamic system of habitats, through time and space, for the struggling growth on the hills (Mishra and Joshi, 1952). The forest is a dry deciduous forest. It is dominated by *Tectona grandis, Butea monosprma, Accacia* sp. etc. and ground flora consist of *Lantana camara, Parthenium hysterophorus, Euphorbia geniculata, Heteropogon contortum, Cyanadon dactylon, Biophytum sensitivum, Cassia tora, Malvestrum* sp., etc.

Forest wealth and conducive environmental condition provide good amount of substrates for the occurrence of various mushrooms in the region. Considering the importance of mushroom diversity in the Patharia forest, we undertook the present study with the objectives of getting information on (1) Wild edible mushrooms in Sagar? (2) Research needed to be done in this area?

MATERIALS AND METHODS

During several visits from July 2011 to July 2013, we collected many species of mushrooms. For collection of the mushrooms various equipments such as hunting knife, plough, scissor, digging tools and wax paper pockets for wrapping the collected mushrooms were used. Collection sites other than Patharia forest are botanical garden, residential area in Sagar.

Collected specimens were then preserved in a liquid preservative (25:5:70 ml rectified alcohol + formalin + distilled water) (Hawksworth et al., 1995). Parts of the collected material were dried in a hot air oven. For identification of mushrooms various authentic keys (Arora, 1986; Singer, 1986; Hawksworth, 1974, 1995; Jorden 2000; Pegler and Spooner, 1997; Kuo, 2003; Upadhyay et al., 2008) were used. All the identified and un-identified specimens were deposited in the Museum, Department of Botany of Dr. H. S. Gour University, Sagar Madhya Pradesh. Length and width dimension of each mushroom collected were measured and photographs were taken.

RESULTS

During the investigation, mushrooms were collected and identified. At present, we were able to identified 18 genera belonging to 12 families. The identification of each organism was done on the basis of morphological features. The species identified were: *Vascellum pratense, Lycoperdon pyriform, Coniophora puteana, Clitocybe geotrapa, Ganoderma tsugae, Microglossum virde, Panaeolus sphinctrinus*, *Pleurotus cornucopiae, Fomes fomentarius, Tyromyces lacteus, Lenzites Betulina, Hypholoma elongatum, Pholiota highlandensis, Serpula lacrymans, Tremella mesenterica, Lepista nuda, Collybia butyracea* and *Omphalina ericetorum* (Figures 1 and 2). These species were recorded mostly during July to November. Among these species, some were edible, some poisonous but with medicinal value.

1. *Vascellum pratense*: Agaricaceae
Common name: It is commonly called Lawn puff ball.
Description: *Vascellum pratense* is a pear shaped body fruit with short stalk and a membrane separating the spore mass from the base. The fruit body is 2-4 cm in diameter, tapering below into a stalk like base, covered with small granules and spines which are easily rubbed off. The flesh is white and firm becoming olive brown and powdery. The spore deposit is olive brown. It is common in short grass habitat.
Scale: 20 × 15 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: July 2, 2013.
Collected by: Deepak Vyas.
Edibility: Edible.

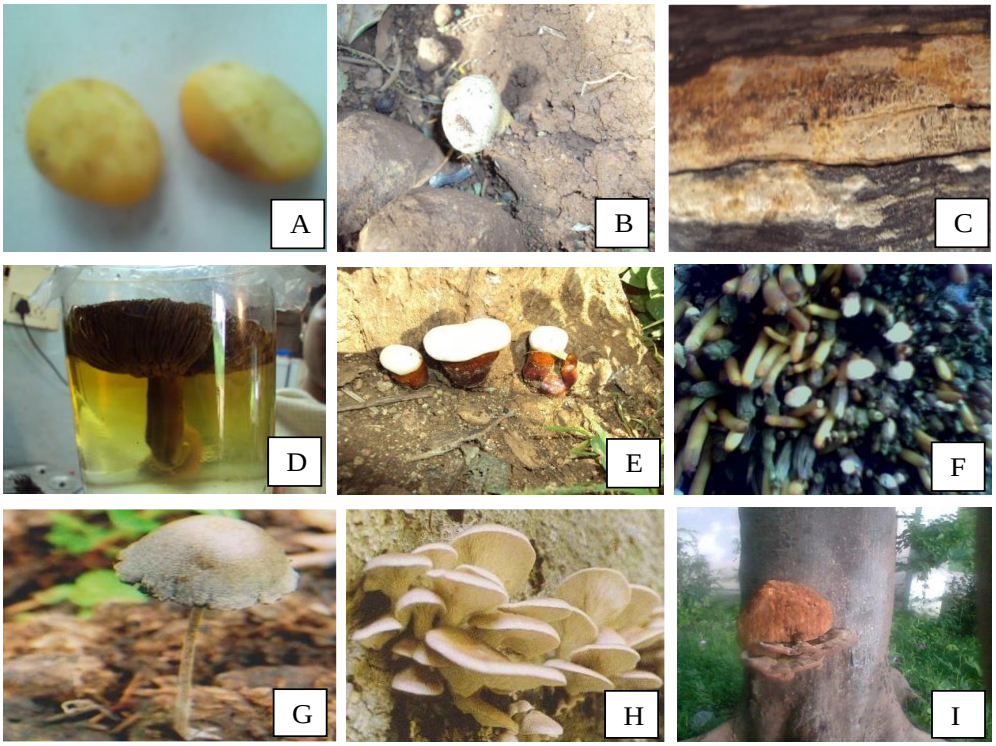

Figure 1. (A) *Vascellum pretense* (B) *Lycoperdon pyriform* (C) *Coniophora puteana* (D) *Clitopilus prunulus* (E) *Ganoderma tsugae* (F) *Microglossum virdae* (G) *Panaeolus sphinctrinus* (H) *Pleurotus cornucpoiae* (I) *Fomes fomentariu*

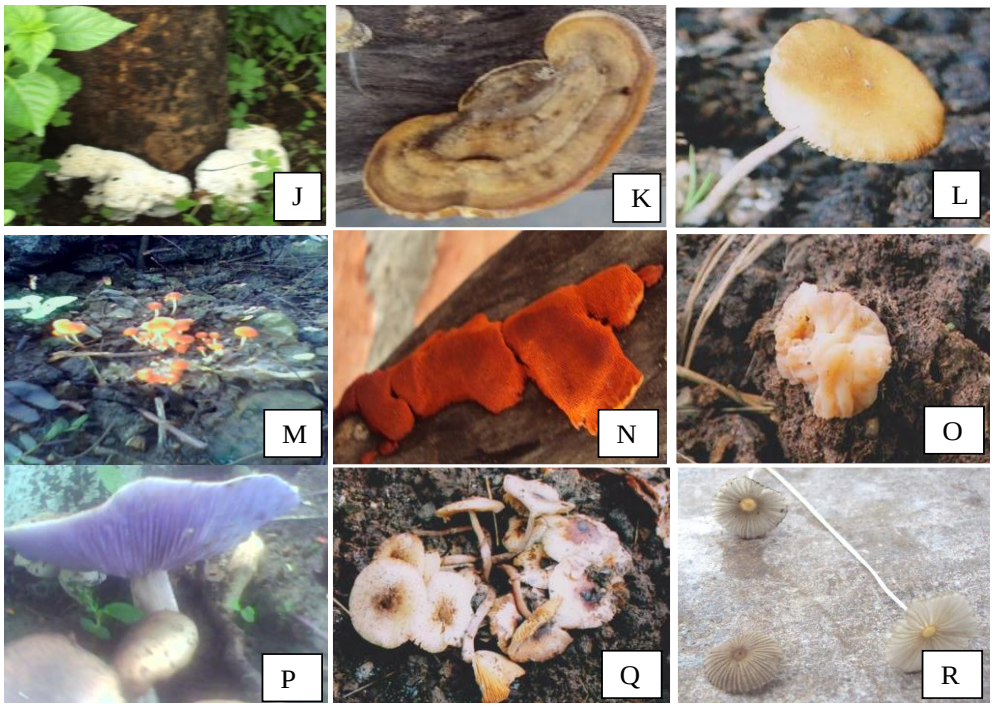

Figure 2. (J) *Tyromyces lacteus* (K) *Lenzites betulina* (L) *Hypholoma elongatum* (M) *Pholiota highlandensis* (N) *Serpulala Lacrymans* (O) *Tremella mesentrica* (P) *Lepista nuda* (Q) *Collybia butyracea* (R) *Omphalina ericetorum.*

2. *Lycoperdon pyriform (Schaeff)*: Agaricaceae.
Common name: It is commonly called stump puff ball or pear shaped puff ball.
Description: *Lycoperdon pyriform* grows on wood. Its fruit body is pear shaped, whitish at first and later becoming pale brown, with white branching cord like mycelium at the base. Its surface is scurfy at first, comprising tiny warts and granules which are soon lost, leaving a smooth inner wall. The inner wall is thin, papery with opening by a small irregular pore at the top.
Scale: 20×15 cm.
Specimen examined: Girls hostel, Sagar University.
Date of collection: August 30, 2012.
Collected by: Anjuli Chaubey.
Edibility: Edible.
Medicinal value: Spores of *Lycoperdon pyriform* are used to arrest the flow of blood from wounds and in treatment of piles (Sharma, 2003).

3. *Coniophora puteana*: Coniophoraceae.
Common name: It is commonly called cellar fungus or wet rot fungus.
Description: *Coniophora puteana* fruit body is closely related to the dead woody substrate. It is 18-35 cm in diameter with round patches of about 0.1 cm thick. Its surface is smooth-warty dark brown. Spore deposit olive brown.
Scale: 7×5 cm.
Specimen examined: Botany Department Dr. H. S. Gour University in Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: July 31, 2013.
Collected by: Anjuli Chaubey and Deepak Vyas.
Edibility: Inedible.

4. *Clitopilus prunulus:* Entololomataceae.
Common name: It is commonly called sweet bread or the miller.
Description: *Clitopilus prunulus* is whitish in color and large size gills of decurrent type. Its cap is 12 cm in diameter with a wavy margin and 6 cm length stipe. Its flesh is thick, white and firm. It has strong smell with spore of white deposit.
Scale: 18×23 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 14, 2012.
Collected by: Deepak Vyas.
Edibility: Edible.

5. *Ganoderma tsugae* (Murr.): Ganodermataceae.
Common name: It is commonly called wood decaying fungus.
Description: *Ganoderma tsugae* (Murr.) is of shiny varnished surface. Its cap is 2-12 by 5-30 cm in diameter, kidney shaped or fan shaped, reddish brown with some concentric zones and often with a white margin. Its spore deposit cinnamon-brown.
Scale: 1.5×1.5 cm.
Specimen examined: Stem of *Delonix regia* in Patharia forest of Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: November 3, 2011.
Collected by: Anjuli Chaubey and Poonam Dehariya.
Edibility: Inedible.
Medicinal value: This mushroom possesses many different medicinal properties that dependent on the stage and environment of its growth (Jong and Brimingham, 1992, Liu, 1999). Traditionally, it has been widely used in treatment of hepatopathy, chronic hepatitis, nephritis, hypertension, arthritis, insomnia, bronchitis, asthma, gastric ulcers. Scientific studies have confirmed that substances extracted from the mushroom can reduce blood pressure, blood cholesterol and blood sugar levels (Hobbs, 1995).

6. *Microglossum viride* (Persoon : Fries) gillet: Geoglossaceae.
Common name: It is commonly called green earth tongue.
Description: *Microglossum viride* (Persoon : Fries) gillet is an erect club shaped species with greenish fruit bodies characterized by the scurfy-scaly stem. Its fruit body is 3-6 cm high, narrowly clavate green or olive green in color with smooth upper fertile part. It is sharply delimited from the stem. Its stipe is 0.2-0.5 cm thick, often slightly compressed, cylindrical or curved. The surface is scurfy or scaly. Its flesh is pale greenish. It is clustered or gregarious.
Scale: 14×6 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 20, 2012.
Collected by: Deepak Vyas.
Edibility: Inedible.
Medicinal value: It has antiviral activity through stimulation of interferon production. It inhibit HIV-1 (Ng.T.B., 1998).

7. *Panaeolus sphinctrinus* (Fr. Quel): Psathyrellaceae.
Common name: It is commonly called grey mottle gills.
Description: *Panaeolus sphinctrinus* (Fr. Quel) is bell shaped, of cap size 2-3 cm in diameter, dark grey in color, smooth with a fringe of tiny white scales of the veil attached to the margin.
Scale: 4×6 cm.
Specimen examined: Botany Department Dr. H.S. Gour University in Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: September 12, 2008
Collected by: Deepak Vyas and Anjuli Chaubey.
Edibility: Inedible.

8. *Pleurotus cornucopiae:* Pleurotaceae.
Common name: It is commonly called oyster cap mushroom.
Description: *Pleurotus cornucopiae* is usually found growing on tree of sandal wood. The cap size is 5-12 cm in across and convex. It is whitish in color of almost a magnolia shade, it turns fairy dark brown with age. The stipe size is 5-8 cm. The gills are quite deep, the flesh is white spore deposit.
Scale: 13×5 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 14, 2012.
Collected by: Deepak Vyas.
Edibility: Edible.

9. ***Fomes fomentarius* (L.:Fr.) J. Kicks:** Polyporaceae.
Common name: It is commonly called tinder fungus.
Description: This is one of the largest bracket fungi. It cap is 4-20 by 10-50 cm in diameter. Its fruit body is like a horse hoof shaped with layer yellowish brown and brick coloured. Its tubes form annual layers. Its flesh is pale brown, very tough and leathery. Its spore deposit white.
Scale: 15×5 cm.
Specimen examined: From stem of *Delonix regia* of University campus. Sagar, M.P. examined India, 24° 27' N, 78° 4'E and 620.26 m.
Date of collection: October 21, 2011.
Collected by: Deepak Vyas, Anjuli Chaubey, Poonam Dehariya.
Edibility: Inedible.

Medicinal value: It is also known as “Agarics of sergeons” because of its use for stopping light hemorrhages. Its flesh was beaten with a mallet to make it supple and applied as non caustic haemostatic. It was also traditionally used by barbers to stop the bleeding of razor cuts. This mass was applied on wounds to stop bleeding. They were also using it to make warm compress for extremities and joints (Giovannini, 2006). In China it is used by indigestion and to reduce stasis of digestive vitality, for esophageal cancer and gastric and uterine carcinomas (Ying et al., 1987).

10. *Tyromyces lacteus* (Fr.) Murril: Polyporaceae.
Common name: It is commonly called milk white polypore.
Description: This is a soft white bracket fungi commonly found on deciduous trees. Its cap is 2-6 cm in diameter, semicircular, with a broad lateral attachment. Its tubes are 1-1.5 cm long. Its flesh is up to 0.3 cm thick with soft white fibrous. It has white spore deposit.
Scale: 18×28 cm.
Specimen examined: Trees of Patharia forest Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: August 2, 2012.
Collected by: Anjuli Chaubey.
Edibility: Inedible.

11. *Lenzites Betulina* (L) Fr. Limaceum: Polyporaceae.
Common name: It is commonly called Birch Lenzitis.
Description: It is a thin bracket fungus, found growing on dead wood. Its cap size is 2-9 cm in diameter, bracket to shelf shaped with a broad or narrow, lateral attachment, finely hairy, with narrow concentric zoning. Its pore surface is with thick radiating gills. Its flesh is 0.2-0.3 cm thick, white and tough. It has white spore deposit.
Scale: 6×9 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 30, 2012.
Collected by: Anjuli Chaubey.
Edibility: Inedible.

12. *Hypholoma elongatum* (Pers. ex) Ricken: Strophoriaceae.
Common name: It is commonly called swamp sulphur cap.
Description: *Hypholoma elongatum* (Pers. ex) Ricken is generally found in large groups. Its cap and stipe are yellow in color and is 1-3 cm in diameter of bell shape. Its stipe is 5-10 x 0.3-0.4 cm tall, slender and hollow. Its flesh is thin, white and brittle. Its spore deposit sooty brown.
Scale: 13×5 cm.
Specimen examined: Twigs, leaves and other debris of Patharia forest Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: July 30, 2012.
Collected by: Anjuli Chaubey and Poonam Dehariya.
Edibility: Inedible.

13. *Pholiota highlandensis* (Peck) A.H. S M & Hessler: Strophoriaceae.
Common name: It is commonly called charcoal pholiota.
Description: It is commonly found on burnt ground or burnt stumps, distinguished by the slimy cap and reddish brown gills. Its cap size is 3-5 cm in diameter, convex becoming flattened with a wavy margin, stipe length is 2-5 cm in diameter, brownish red, paler at the apex. Its flesh is thin. Its spore deposit is cinnamon brown.
Scale: 5×4 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 30, 2012.
Collected by: Deepak Vyas.
Edibility: Inedible.

14. *Serpula lacrymans*: Serpulaceae.
Common name: It is commonly called dry rot fungus.
Description: It was found growing on dead wood. It is destructive fungus of domestic wood, characterized by

fruit bodies with a rusty brown in color. It has fruit body spreading over the substrate and forming large pancake like patches with the age. Spore has yellowish brown deposit.
Scale: 3×5 cm.
Specimen examined: Botanical garden, Sagar University.
Date of collection: August 30, 2011.
Collected by: Anjuli Chaubey.
Edibility: Inedible.

15. ***Tremella mesenterica (*Retz: Fr):** Tremellaceae.
Common name: It is commonly called yellow brain fungus or witches' buffer.
Description: This fungus is bright orange yellow in color and irregular, brain like in shape, folded and lobed, gelatinous. Spore has white deposit.
Scale: 1.5×1.5 cm.
Specimen examined: From litter fall and cow dung in Pathariya forest of Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: September 22, 2011.
Collected by: Anjuli Chaubey and Deepak Vyas.
Edibility: Inedible.
Medicinal value: It has a long historical use in traditional Chinese medicine as an immune tonic and also for treating debility and exhaustion together with many other ailments including skin-care. It contains acidic polysaccharides, especially glucuronoxylomannan, readily extracted with hot water giving a smooth and stable solution used in oriental cosine. The polysaccharide of this fungus show anticancer activity. Clinical trials have shown it to be effective in treating radio and chemo therapy- induced Leukopenia, boosting immunological functions and stimulating leukocyte activity (Hobbs, 1995).

16. *Lepista nuda* (Bull.:Fr.) Cke.: Tricholomataceae.
Common name: It is commonly called wood blewit.
Description: *Lepista nuda* (Bull.:Fr.) Cke. cap is 7-13 cm in diameter, brownish violet and rounded in shape. Stipe is 4-8 cm thick and brownish. Gills violet in color, flesh thick with a faint fruity smell. Spore deposit pale pinkish.
Scale: 7×3.5 cm.
Specimen examined: Litter grass in Patharia forest of Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m was examined.
Date of collection: July 24, 2012.
Collected by: Deepak Vyas.
Edibility: Edible.
Medicinal value: It is resistant to Gram+ and Gram- bacteria (Ying et al., 1987; Giovannini, 2006).

17. *Collybia butyracea* (Bull: Fr) Lennox: Tricholomataceae.
Common name: It is commonly called greasy tough shank.
Description: *Collybia butyracea* (Bull: Fr) Lennox cap is yellowish brown to dark brown in color but remaining dark at centre. Its stipe is 3-6 x 0.5-1 cm, flesh pale and fibrous, lacking a distinctive smell. Its spore has white deposit.
Scale: 12 × 5 cm.
Specimen examined: Cow dung/Litter fall, Patharia forest of Sagar M.P., India, 24° 27' N, 79° 21'E and 620.26 m.
Date of collection: August 22, 2011.
Collected by: Deepak Vyas and Poonam Dehariya.
Edibility: Inedible.

18. *Omphalina ericetorum* (Pers. Quel. Biglow): Tricholomataceae.
Common name: It is commonly called umbrella naval cap.
Description: *Omphalina ericetorum* (Pers. Quel. Biglow) is very small in size with white cap and yellowish to brown stipe. Its cap size is 1-3 cm in diameter and the stipe is 1-3 x 0.2-0.3 cm cylindrical. It has pale decurrent gills, with wavy margin. Its flesh is thin white. Its spore has white deposit.
Scale: 3×5 cm.
Specimen examined: Girls hostel in Sagar M.P., India, 24°27' N, 79°21' E and 620.26 m.
Date of collection: July 25, 2013.
Collected by: Anjuli Chaubey.
Edibility: Inedible.

DISCUSSION

Mushrooms are a nutritionally functional food and a source of physiologically beneficial and non-inventive medicines. In nature, mushrooms grow wild in almost all types of soils, on decaying organic matter, wooden stumps, etc. They appear in all seasons; however rains favor rapid growth when organic matter or its decomposition products are easily available. About 10,000 species within the overall fungal estimates of 1.5 million belong to this group. Mushrooms alone are represented by about 41,000 species, of which approximately 850 species are recorded from India (Manoharachary et al., 2005). Mushrooms are of ancient lineage, universal, remarkably beautiful and diverse in their form and in their interaction with other biota.

The occurrence of mushrooms on such familiar substrate as wood, litter and soil, implies a role for them in these microhabitats. Forest litter and forest soils are often literally permeated by fungal threads and tubes (collectively known as mycelium) often forming 'Rhizomorph', capable of free and extensive spread in litter and soil (Subramanian, 1995).

During the isolation of the mushrooms, it was observed that the species were very much dependent upon the

habitat in which they occur. Species in this region were found to be associated with grasses, herbs, shrubs and trees. Their host specificity occurs due to complex pattern of interactions with the climate, the soil, plants and animals. Some species are specific only on dead woods or woody debris such as *L. betulina, S. lacrymans, L. pyriform, P. highlandensis, C. puteana, T. lacteus*. Some occur only on grassland and associated with grassroots such as *V. pratense*. Some species grow only on dung or enriched soil such as *H. elongatum, C. butyracea* and *T. mesentrica*. Some species are only association with living trees such as *L. nuda*, *F. fomentarius, C. geotrapa.* In some cases, it was observed that the morphological characters viz stipe length, stipe breadth, cap size, color conk size and brightness also varied with different host or localities, for example, two isolates of *G. tsugae* collected from living tree of *D. sisoo* and other from dead stump of *D. regia* showed wide variation in their size and color. The species which was collected from living tree of *D. sisoo* had greater conk than that collected from dead stumps of *D. regia*.

Thus, despite their growth on lignocellulosic wastes, to produce the mushroom fruiting bodies of great diversity in color, structure, size, texture, flavor and nutritional composition of essential amino acids and vitamins, unequivocally, they reflect on the magnificent capacities of the mushrooms for “biosynthesis” through different from “photosynthesis” (Rajarathnam et al., 1997).

Occurrence of mushrooms in forest has been reported by many workers such as Singer (1989) who reported 1320 species belonging to 129 genera under Agaricales. Sharma and Doshi (1990) who reported some new hosts of *Pleurotus* species from Rajasthan. Pradeep et al. (1998) reported occurrence of mushrooms from Western Ghats. Doshi and Sharma (1997) were recorded as wild mushrooms of Rajasthan. Thakur et al. (2006) reported mushroom wealth from Chhattisgarh and Madhya Pradesh States. Karwa and Rai (2010) reported edible fungal diversity from central India. Recently, Thakur et al. (2011) reported biodiversity of mushrooms of Chhattisgarh region. Vishwakarma et al. (2011) reported some medicinal mushrooms of Uttarakhand. Dwivedi et al. (2012) reported biodiversity of mushrooms from Amarkantak biosphere reserve forest of central India. Pushpa and Purushothama (2012) reported mushrooms diversity of Karnataka. In recent years, we have (Dehariya et al., 2010; Dehariya and Vyas, 2013) found variety of mushrooms growing in the Patharia forest of Sagar, M.P. A recent study by Chandulal et al. (2013) provided information regarding diversity of mushrooms in Gujarat.

Occurrence of variety of mushrooms in the forest of India sub-continent suggests a close link between mushroom production and forest health. Though, no earlier data on the mushroom diversity corroborating forest diversity is available from this region, yet it is deduced that due to recent conservation strategies adopted by the forest department, number of plants are growing and have enriched the flora of Patharia forest. Thus, the rich diversity of the forest facilitate conducive environment for production of wild mushrooms.

The results of the present study show that some of the mushrooms act as mycorhizal fungi because of their close dependency on associated tree species. It is interesting to note that richness and abundance of the mushrooms was much higher in the thick forest whereas because destruction and thinning of the forest mushrooms were decreased. According to Kroper and Albee (1996) and Buee et al. (2005) fruit body production of some fungi adversely affected disturbed forest due to thinning of trees. However, according to Shaw et al. (2003) some mushrooms increase their fruit body production, when thinning is increased. According to Arnolds (1988), most healthy forest ecosystem housed more than 45% ecto mycorhhizal fungi. Thus, it is deduced that mushrooms are comparable to plants in requiring particular site, condition to thrive.

With this study, it could be concluded that Patharia forest housed number of wild mushroom which have immense importance in the maintenance of forest ecology and wealth, secondly some of the wild mushroom have been found to have great medicinal properties. These wild mushrooms are good source of income generation for the unemployed youth of the region and finally it gives us an impetus to search an indicator mushroom species for the forest management.

Conflict of Interests

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

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Species diversity and habitat association of butterflies around 30 km radius of Kudankulam Nuclear Power Plant area of Tamil Nadu, India

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A detailed study on the butterfly species diversity was carried around 30 km radius of Kudankulam Nuclear Power Plant area, Tirunelveli, India during 2011-2013. The survey yielded 6347 individuals of 64 species, belonging to the families Nymphalidae, Pieridae, Lycaenidae, Papilionidae and Hesperiidae. A total of 64 species of butterflies belonging to 47 genera were recorded. The relative abundance was high for Nymphalidae (27 species) (41.93%) followed by Pieridae 15 (24.19%), Lycaenidae 11 (16.12%), Papilionidae 7 (11.29%) and Hesperiidae 4 (6.45%). The Nymphalidae were found to be the dominant family in terms species, general and individual relative abundance. Eight species of butterflies are listed as endangered in Wildlife (Protection) Act, 1972. Such studies on monitoring the species diversity and abundance of butterflies offer valuable information on their population dynamics. A detailed study on ecologically important local butterfly fauna in various habitats is in progress to construct a various habitat survey around 30 km radius of Kudankulam Nuclear Power Plant area.

Key words: Kudankulam, butterfly diversity, relative abundance, wildlife protection.

INTRODUCTION

Butterflies are taxonomically well studied group of insects, which have received a reasonable amount of attention throughout the world (Ghazoul, 2002; Robbins and Opler, 1997). The impact of human society on the global environment has triggered mass extinction of significant species and is causing widespread changes in the global distribution of existing species (Chapin et al., 2000; Thomas et al., 2004). Insects are the earth's most diverse organisms, accounting for half of described species of living things and three-quarters of all known animals and it is estimated that more species of insects than known at present remain to be discovered (Wijesekara and Wijesinghe, 2003) among insects, butterflies occupy a vital position in ecosystems and their occurrence and diversity are considered as good indicators of the health of terrestrial biota (Kunte, 2000b). Butterflies are one of the best insect studied groups and are highly sensitive to habitat disturbances; they are

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commonly used as an indicator of environmental quality (Varshney, 1993; Kremen, 1994; Kocher and Williams, 2000; Koh and Sodhi, 2004). Since the 18th century, about 19,238 species of butterflies have been studied worldwide systematically (Heppner, 1998). In Indian sub-continent, 1504 species of butterflies are recorded (Tiple, 2011) and 285 species found in southern India (Thomas, 1966) of which peninsular India and Western Ghats have 351 and 334 species, respectively. Southern parts of the Indian Peninsular are rich and diverse in butterflies as compared to other parts of Peninsular due to diverse habitats, microclimatic conditions and altitudinal ranges (Chakravarthy et al., 1997). One fifth of the world's total butterflies are available in India (Haribal, 1992). Many researchers have significantly contributed to our understanding of butterfly and abundance in Tamilnadu (Asaithambi, 1994; Baskaran and Eswaran, 2003; Ambrose and Raj, 2005; Eswaran and Promod, 2005; Rajagopal et al., 2011). Human dominated landscape form a substantial and ever increasing amount of the earth's land surface. These modified habitats often negatively influence butterfly species and their dynamics (Gascon et al., 1999) made a detailed study of butterflies of atomic energy campus and recorded a total of 1908 individuals representing 55 species (Ramesh et al., 2010) and seasonal dynamic of butterfly survey yielded 2177 individuals of 56 species (Jahir Hussain et al., 2011). However, comprehensive long-term ecological study to monitor the butterfly diversity of the nuclear power plant area remains serious lacuna. Such studies are imperative to improve the ecological utility of butterflies as indicator taxa. There is a unique relationship between butterflies and plants (Feltwell, 1986). Jha et al (2000) reported that butterflies diversity indirectly reflects overall plant diversity, especially herbs and shrubs in the area. Butterfly species varies in different habitats (Kunte, 1997). Natural vegetation is important for the survival of species and relatively minor perturbation in the habitat that are highly sensitive to change the environment (David et al., 1986). Biotic and abiotic factors influence the butterfly population (Pollard, 1988).

Among the lower invertebrates, butterflies are probably the best studied group in the Western Ghats (Ambrose and Raj, 2005; Baskaran and Solaiappa 2002; Arun, 2003; Gunathilagaraj et al., 1998) in national park and wild life sanctuary (Borkar and Komarpant, 2004; Baslstha et al., 1999; Guptha et al., 2012; Shamsudeen and Mathew, 2010). Study on butterfly diversity was done in university campus and tiger reserves (Chandra et al., 2002, 2007; Arun and Azeez, 2003). Similar studies are done in parks and dams (Perveen and Ahmed, 2012; Kumar et al., 2014).

According to WPA, the taxa listed under schedule I have the highest legal protection, Schedule II and IV, second and third highest level of protection (Kunte, 2000b). Eight species of endemic butterflies were listed under the Wildlife (Protection) Act 1972 scheduled under I, II, I and II and IV (Rufus and Sabarinathan, 2007). Studies on butterflies would help to explore their biodiversity and to understand the status of ecosystem and human pressure on natural resource which requires a reliable account of biodiversity (Kremen, 1992). The most important objec-tive of such applied biology is preserving biological diversity for future generation. The aim is to ensure long term conservation of entire flora and fauna of a region (Kerr, 1997; Araujo et al, 2004). The importance of biological diversity is now increasing and is recognized as a vital parameter to assess the global local environmental changes and sustainability. It is impractical to monitor each and every species; some of the key indicator taxa play a vital role in biodiversity monitoring studies. Butterflies are an excellent choice for monitoring the habitat quality (Kunte et al., 1999). Several studies have analysed how radiative substances affect uptake of food chains and ecosystems (Beresford et al., 2012), but ecological impact assessment studies are limited (Moller and Mousseau, 2006). Therefore, the present study, which aimed to contribute to our understanding of the species diversity in different habitats and explore the knowledge of conservation efforts in existing environ-ment, is to be collect and characterized baseline surveys of butterfly fauna in relation to flora in 30 Km radius of Kudankulam Nuclear Power Plant area.

MATERIALS AND METHODS

Study area

Field survey of butterflies was conducted from June 2011 to June 2013, following modified Pollard walking methods (Pollard, 1975) in six distinct habitats: pond area, scrub jungle area, cultivated area, plain area or barren land, sandy area and monoculture or cashew nut plantation around 30 km radius of Kudankulam Nuclear Power Plant area which is approximately 1350 km^2, which lies between latitudes 8° 5′ and 8° 28′ of north and longitudes 77° 28′and 77° 57′ of east (Image 1).

Butterfly species density and relative abundance were assessed quantitatively across the different habitats based on the vegetation. The entire study area was divided on the basis of habitats. In this method, permanent approximately 900 m long and 5 m wide line transect was set up in each habitat and marked in the field along with GPS data and landmark for repeated observations.

The transect in each habitat was slowly traversed at a uniform pace for 40 min at each habitat from 7.30 to 16.30 h during the good weather period without heavy rain. Butterfly species were recorded around the radius of five meters from the observer covering his either side, above and front. This was repeated in each season, maintaining the same spatial scale in each of the five habitats.

Collected butterfly individuals were identified either in the field and/or after reaching the laboratory also following the standard field guides (Gunathilagaraj et al., 1998; Kunte, 2000a). All the scientific names followed Varshney (1983) and family classification (Ackery, 1984). The vouchers of collected specimens were photographed and maintained at Manonmaniam Sundaranar University, Sri Paramakalyani Centre of Excellence in Environmental Science, Alwarkurichi.

The main vegetation types of 30 km radius include dry evergreen, scrub jungle, plain area, sandy area and pond area. The

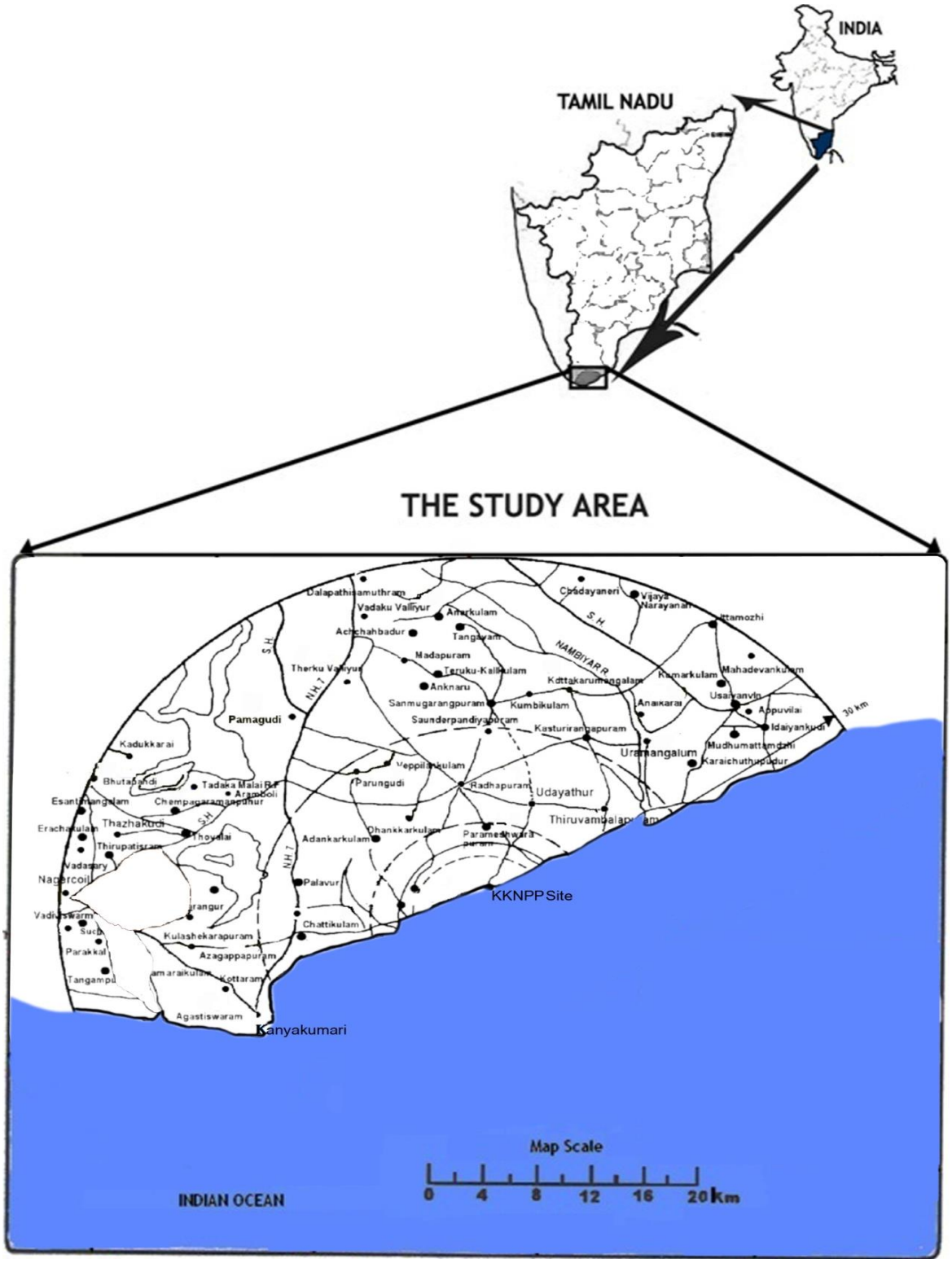

Image 1. Map of 30 km radius of Kudankulam Nuclear Power Project area.

dominant species of scrub jungle are *Acacia nilotica* (Fabaceae), *Prosobis juliflora* (Fabaceae), *Cassia auriculata* (Fabaceae) and *Lantana camera* (Verbenaceae). The plain area has mostly grasses and *Euphorbia antiquorum* (Euphorbiaceae). The sandy area has *Prosobis juliflora* and *Acacia nilotica*. The pond area has *Azima tetracantha* (Salvadoraceae). The trees, shrubs and herbs comprising members of predominant family belong to Anacardiaceae, Apocyanaceae, Laminaceae, Solanaceae, Rubiaceae, Euphorbiaceae, Cyperaceae, Fabaceae, Amaranthaceae and Convolvulaceae, Verbenaceae.

RESULTS AND DISCUSSION

The study revealed the occurrence of 64 species of butterflies around 30 Km radius of Kudankulam Nuclear Power Project area (Table 1). Occurrence of maximum number of species in the family Nymphalidae, Pieridae and Lycaenidae could be due to high availability of food plants in the study area.

Nymphalidae is the dominant family in terms of species composition and abundance, with 27 species and 41.93%, Pieridae (15 species, 24.19%), Lycaenidae (11 species, 16.12%), Papilionidae (7 species, 11.29%) and Hesperiidae (4 species, 6. 45%). In total, 6347 individuals from 14 transects in winter, summer, southwest monsoon and northeast monsoon were observed and identified. A large number of individuals was observed in Pieridae 2287 individuals followed by Lycaenidae 2089 individuals, Nymphalidae 1688 individuals, Papilionidae 207 individuals and very less individuals was observed in 76 individuals. Totally, 47 genera were observed in study area. Nymphalidae is the dominant genera (16 genera, 34.78%) followed by Pieridae (12 genera, 26.08%), Lycaenidae (10 genera, 21.74%), Papilionidae (4 genera, 8.70%) and Hesperiidae (4 genera, 8.70%) as presented in Table 2.

A similar pattern of predominance of Nymphalidae was also reported by different researchers. These results are similar to that found by Tiple (2012) and Murugesan et al. (2013) at the biosphere reserve of Seshachelam hills which were a total 50 species of butterflies in five families (Guptha et al., 2012). Ramesh et al. (2010) reported 55 species of butterflies inhabiting the Department of Atomic Energy, at Kalpakkam campus. The family Nymphalidae was the dominant one, followed by Lycaenidae, Pieridae, Papilionidae and Hesperiidae (Guptha et al., 2012). A total of 66 species of butterflies belonging to 47 genera and five families were recorded in Tropical Forest Research Institute, Madhya Pradesh (Tiple, 2012). Murugesan et al. (2013) observed total of 63 butterfly species belonging to 47 genera under the five families in Oussudu bird sanctuary, Puducherry. Shamsudeen and Mathew (2010) found 73 butterfly species in Shenduruny Wildlife Sanctuary. Chandra et al. (2007) observed 174 species, subspecies of 100 genera under 8 families in Madhya Pradesh and Chhattisgarh state. Wijesekara and Wijesinghe (2003) revealed 2158 species of lepidopterans, 234 species of butterflies in ten families recorded in Sri Lanka. Gunathilagaraj et al. (1998) observed that high percentage of Nymphalids may be due to the presence of flowers belonging to families Euphorbiaceae, Compositae, Rubiaceae and Verbinaceae. The great variety of butterflies, moths and skippers are recorded and supported by their food and host plants (Borkar and Komarpant, 2004). Availability of larval and adult food plants, habitat quality appeared to be one of the most important parameters to determine butterfly community (Barlow et al., 2007). Abundance of butterfly species is due to favourable tropical climate conditions, availability of host plants, food and vegetation (Ravindra et al., 1996); topographic features (Amala et al., 2011); predators, parasitoids and prevalence of disease (Mathew and Rahamathulla, 1993). Chandra et al. (2002) observed 38 species in 8 families in Pench Tiger Reserve, Madhya Pradesh. Around Nagpur, 145 species of butterflies, of which 62 species are new records seen. Nymphalidae showed the highest number of butterflies (Tiple and Khurad, 2009). Nymphalids butterfly feed on fourteen species of angiosperms whereas papilionids feed on eight species. Pieridae have six species of plants as feed, Lycaenidae feed on two species of plants but Hesperiidae prefer only one plant species (Raut and Pendharkar, 2010). The higher species richness of butterflies associated with gardens indicates availability and access to food plants. The exotic species, *L. camera* is an important nectar source for several species of butterflies in degraded and urbanized habitat (Raju and Reddy, 1995). Nymphalidae was the dominant species and the relative abundance recorded was 36.3% (Ramesh et al., 2010). The least number of butterfly species were recorded in the family Papilionidae (14%) and Hesperiidae (14%) with nine species each (Murugesan et al., 2013).

Eight species of butterflies are listed as endangered in Wildlife (Protection) Act, 1972. Among the eight, three species of butterflies are listed under the schedule I (Crimson rose, *Atrophaneura hector*; Southern Bird Wing, *Troides minos*; Common Pierrot, *Castalius rosimon*) and two species are in schedule II (Gram Blue, *Euchrysops cnejus*; Common Albatross *Appias albino* and Common Gull, *Cepora nerissa*) Schedule I, II and IV has only one species each are (Danaid Eggfly, *Hypolimnas misippus*) and Common Indian Crow, *Euploea core*. Totally, 64 species of butterflies were recorded and Nymphalidae are most dominant (36%) followed by Lycaenidae (27%), Pieridae (17%), Hesperiidae (11%) and Papilionidae (9%). Among the 64 species of butterflies, about 34% (22) were occurring very common, 27% of species (27) were common, 23% (15) were uncommon and 16% were rare (10) as shown in Figure 1. Guptha et al. (2012) reported that butterflies of Eastern Ghats of Seshachalam biosphere reserves were categorized as very common (VC) 40% (20 species), common (C) 36% (18 species), uncommon (UC) 10% (5 species), occasional (O) 8% (4 species) and rare (R) 6% (3 species). Five species of protected and seven rare species are distributed in Shendurny Wildlife Sanctuary, Kerala (Shamsudeen and Mathew, 2010). Among the 64 species 15 were found very common, 27 species common, 17 species not rare and five species were found rare. None of the species were observed in very rare category from the study area. Six species are under protection of the Indian Wildlife (Protection) Act 1972 (Nimbalkar et al., 2011).

Five endemic species were listed from encountered butterflies in the study area in different habitats. The

Table 1. List of butterflies present around 25 km radius of KKNPP Project area.

Family	Zoological name	Common name	Status
Nymphalidae	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	VC
,,	*Danaus genutia* (Cramer,1779)	Striped Tiger	C
,,	*Ariadne merione* (Cramer,1777)	Common Caster	UC
,,	*Ariadne ariadne* (Linnaeus 1763)	Angled Castor	UC
,,	*Acraea terpsicore* (Linnaeus, 1758)	Tawny Caster	VC
,,	*Neptis hylas* (Linnaeus, 1758)	Common Sailor	R
,,	*Phalanta phalantha* (Drury,1773)	Common Leopard	UC
,,	*Hypolimnas bolina* (Linnaeus, 1758)	Great Egg Fly*&**	C
,,	*Hypolimnas misippus* (Linnaeus,1764)	Danaid Egg Fly	C
,,	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	VC
,,	*Junonia iphita* (Cramer,1779)	Chocolate Pansy	C
,,	*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	VC
,,	*Junonia almana* (Linnaeus, 1758)	Peacock pansy	UC
,,	*Junonia oithya* (Linnaeus,1758)	Blue Pansy	UC
,,	*Junonia atlites* (Linnaeus,1763)	Grey Pansy	R
,,	*Cirrochora thais* (Fabricius,1787)	Tamil Yeoman	R
,,	*Euploea core* (Cramer,1780)	Common Indian Crow	C
,,	*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger	R
,,	*Tirumala limniace* (Cramer,1775)	Blue Tiger	VC
,,	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	UC
,,	*Mycalesis perseus* (Fabricius, 1775)	Common Bush Brown	UC
,,	*Mycalesis mineus* (Linnaeus, 1758)	Dark Brand Bush Brown	UC
,,	*Ypthima ceylonica* (Hewitson, 1865)	White Four Ring	R
,,	*Ypthima asterope* (Klug, 1832)	Common Three Ring	R
,,	*Euthala nais* (Forrstar,1771)	Baronet	UC
,,	*Argynnis hyperbius* (1763)	Indian Fritillary	R
,,	*Byblia ilithya* (Drury, 1773)	Joker	R
Pieridae	*Colotis danae* (Fabricius,1775)	Crimson Tip	C
,,	*Colotis etrida* (Boistuval, 1836)	Small Orange Tip	C
,,	*Ixias marianne* (Cramer, 1779)	White Orange Tip	VC
,,	*Ixias pyrene* (Linnaeus, 1764)	Yellow Orange Tip	R
,,	*Hebomoia glacippe* (Linnaeus, 1758)	Great Orange Tip	R
,,	*Belenosis aurota* (Fabricius,1793)	Pioneer	UC
,,	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	VC
,,	*Catopsillia pomona* (Fabricius,1775)	Common Emigrant	VC
,,	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	VC
,,	*Delias eucharis* (Drury,1773)	Common Jezebel**&***	UC
,,	*Cepora nerissa* (Fabricius, 1775)	Common Gull	C
,,	*Leptosia nina* (Fabricius,1793)	Psyche	UC
,,	*Colisa croceus* (Geoffroy, 1785)	Dark Clouded Yellow	UC
,,	*Colitis amata* (Fabricius, 1775)	Small Salmon Arab	VC
,,	*Appias albino* (Boisduval, 1836)	Common Albatross	UC
Lycaenidae	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	C
,,	*Arhopala centaurus* (Fabricius,1775)	Large Obakblue	R
	Discolampa centaurus (Fabricius, 1775)	Banded Blue Pierrot	R
,,	*Spindasis vulcanus* (Fabricius, 1775)	Common Silver Line ***	UC
,,	*Euchrysops cnejus* (Fabricius,1798)	Gram Blue	VC
,,	*Jamides celeno* (Grammer, 1775)	Common Cerulin	VC
,,	*Freyeria trochylus* (Freyer, 1845)	Grass Jewel	VC

VC- Very Common; C- Common; UC- UnCommon and R- Rare *Endemic species found in Peninsular India; **Sri Lanka; ***Southern India and WG- Western Ghats.

Table 1. Contd.

Family	Zoological name	Common name	Status
,,	*Tarucus plinius* (Fabricius, 1793)	Zebra Blue	C
,,	*Zizina otis* (Fabricius, 1787)	Lesser Grass Blue	VC
,,	*Zizeeria knysna* (Trimen, 1862)	Tiny Grass Blue	VC
,,	*Chilades parrhasius* (Fabricius, 1793)	Indian Cupid	VC
Papilionidae	*Troides minos* (Cramer, 1779)	Southern Bird Wing***WG	R
,,	*Papilio polymnastor* (Cramer,1775)	Blue Mormon *&**	R
,,	*Papilio polytes* (Linnaeus, 1758)	Common Mormon	R
,,	*Papilio demoleus* (Linnaeus, 1758)	Lime Butterflies	UC
,,	*Graphium agamemnon* (Linnaeus 1758)	Tailed Jay	R
,,	*Atrophaneura aristolochiae* (Linnaeus, 1758)	Common Rose	C
,,	*Atrophaneura hector* (Linnaeus, 1758)	Crimson Rose ** &***	VC
Hesperiidae	*Borbo cinnara* (Wallace, 1866)	Rice Swift	UC
,,	*Sarangesa purendra* (Moore, 1882)	Spotted Small Flat	R
,,	*Spialia galba* (Fabricius, 1793)	Indian Skipper	UC
,,	*Suaatus gremius* (Fabricius, 1798)	Indian Palm Bob	R

Table 2. Species, general relative abundance (%) of butterflies in the study area.

S/N	Family	No. of Genera (%)	No. of Species (%)	No. of Individuals (%)
1	Nymphalidae	17 (34.78%)	27 (41.93%)	1688 (26.59%)
2	Pieridae	12 (26.08%)	15 (24.19%)	2287 (36.03%)
3	Lycaenidae	10 (21.74%)	11 (16.12%)	2089 (32.91%)
4	Papilionidae	4 (8.70%)	7 (11.29%)	207 (3.26%)
5	Hesperiidae	4 (8.70%)	4 (6.45%)	76 (1.19%)
Total	5	47 (100%)	64 (100%)	6347 (100 %)

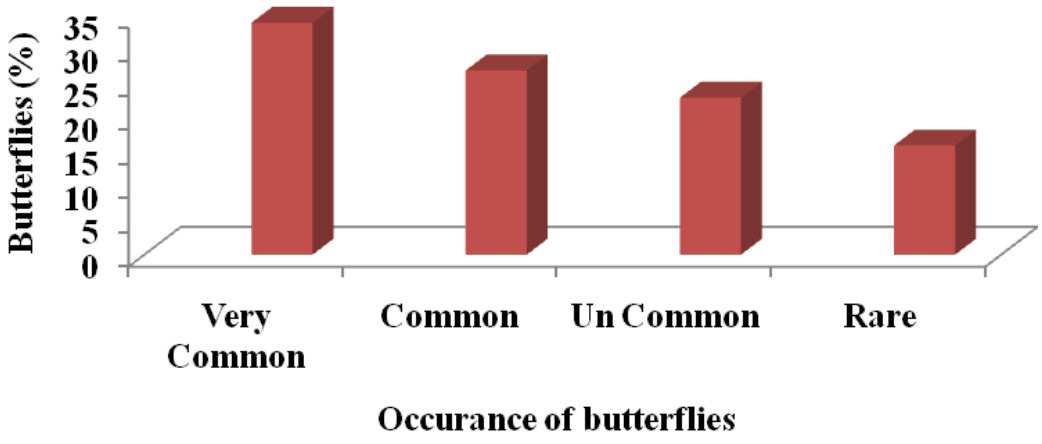

Figure 1. Status of butterflies recorded in the study area.

species like Crimson Rose, *Atrophaneura hector* and Southern Bird Wing, *Trodes minos* are endemic to the Western Ghats, Peninsular India and Sri Lanka, Danaid Eggfly and Common silver line are endemic to peninsular India and Sri Lanka. Blue Mormon, *Papilio polymnestor* are endemic to Peninsular India; Sri Lanka and Indian

Table 3. List of butterflies with status of endemism.

Zoological name	Common name	WPA 1972
Hypolimnas misippus (Linnaeus,1764)	Danaid Egg Fly	Sch I&II
Euploea core (Cramer, 1780)	Common Indian Crow	Sch IV
Cepora nerissa (Fabricius, 1775)	Common Gull	Sch II
Appias albino (Boisduval, 1836)	Common Albatross	Sch II
Castalius rosimon (Fabricius, 1775)	Common Pierrot	Sch I
Euchrysops cnejus (Fabricius,1798)	Gram Blue	Sch II
Trodes minos (Cramer, 1779)	Southern Bird Wing	Sch I
Atrophaneura hector (Linnaeus, 1758)	Crimson Rose	Sch I

Sch- Schedule.

subcontinent. In the study area, significant number of protected and endemic butterflies species need conservation. Minimizing the anthropogenic disturbances can help to improve the status of habitat specialized butterflies of 30 km radius of KKNPP area as given in Table 3.

Conservation of biodiversity covered 99 national parks 513 wildlife sanctuaries, 44 conservation reserves and 4 community reserves (Anonymous, 2008). Borkar and Komarpant (2004) reported that Wildlife Sanctuary of Goa 13 species are scheduled category and 8 are endemic species.

The Southern bird wings are endemic to Indian Subcontinent and Western Ghats and Grass jewel are endemic to Peninsular India. The study is dry evergreen and supports a variety of rare and endemic species, these areas are facing severe anthropogenic disturbances.

Kunte (2008) reported that 33 out of 333 butterflies are endemic to Western Ghats; eight species shared the WG and Sri Lanka biodiversity hot spots. Six species of butterflies are under schedule act and there is an urgent need to adapt conservation polices (Guptha et al., 2012).

Conclusion

The surrounding area of KKNPP site is rich in butterfly species, representing many families. The butterfly fauna of the microhabitats are to be protected as per the Wildlife (Protection) Act, 1972. The situation reflects on the availability of diverse habitats as well as microclimatic zones around the project sites.

Any change in the landscape, land use pattern, loss of vegetation in the habitats that are harmful to the butterfly diversity in terms of species richness leads to a potential loss of endemism and endangerment. Butterfly diversity depends upon the floral diversity (among other factors), so conservation of butterflies may possibly be by enhancement of vegetation composition of habitats around the project area.

Conflict of Interests

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

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Diurnal activity patterns of Burchell's zebra (*Equus quagga*, Gray 1824) in Yabello Wildlife Sanctuary, Southern Ethiopia

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A study on the diurnal activity pattern of Burchell's zebra (*Equus quagga,* Gray 1824) was carried out in the Yabello Wildlife Sanctuary, Southern Ethiopia during October 2009 to March 2010 including wet and dry seasons. Scan sampling methods were used to collect the data peaks in daily activity that occurred in early morning, mid day and late afternoon. Data on activity time budget were analyzed by assessing time allocated for different activities at different hours of the day as well as different seasons. Differences in seasonal and hourly time budget were tested using one way ANOVA, followed by Tukey multiple comparison test. The time devoted to grazing was peaked during the dry season and gradually decreased during the wet season. There was a significant difference in the amount of hours devoted to different activities (t =76.4=, p< 0.05). The proportions of time budget varied between two seasons. Grazing accounted for more than 55.5%. Peak activities were observed in early morning and late afternoon hours with resting peak during the mid-day. A well comprehensive management plan should be taken for zebras to ensure their continued existence in the sanctuary.

Key words: Diurnal activity pattern, Burchell's zebra, season, time budget.

INTRODUCTION

The plains zebra (*Equus quagga*) is considered as one of Africa's most adaptable and successful grazers (Estes, 1991). Zebras are primarily grazers and have dental adaptations for feeding on both short young shoot and long flowering grasses (Bauer et al., 1994; Arsenault and Owen-Smith, 2002; Moehlman, 2003). Its diet composed of 90-92% C4 plants (Eltringham, 1979; AWLF, 2008; Sponheimer et al., 2003), and they may not significantly alter the diet to browsing, even though they browse more during dry season to compensate for grass poor quality. They graze for up to sixteen hours a day due to the ineffective way they digest food (Hack and Rubenstein, 1998). Zebra must go to a water source once a day, which is where aggressive encounters are more likely to occur (Rubenstein, 1993). Burchell's zebra is a diurnal species. Its activity patterns can vary depending on seasons, the animal's sex, age or reproductive state. According to Kamler et al. (2007) and Joubert (1972),

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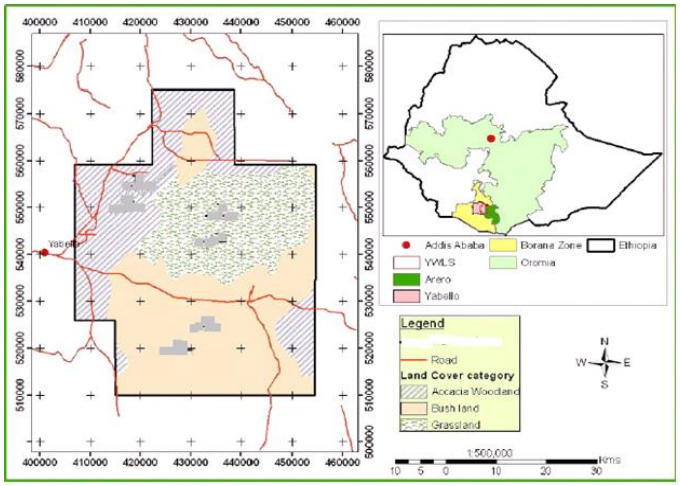

Figure 1. Map of Yabello Wildlife Sanctuary. Inset: the map of Ethiopia showing the location of YWLS. YWLS = Yabello Wildlife Sanctuary.

there are many factors that can influence the activity pattern of an animal such as temperature, climate, biological cycles, light and darkness, feeding bouts, phases of the moon, time of day/year, interactions and predation risks. The time Burchell's zebra have to spend on feeding every day can depend on different factors such as its requirements of nutrients and energy, the availability of digestible food and at what rate the food can be ingested (Beekman and Prins, 1989). As a single species may show different behavioural patterns in different environmental conditions (Delany and Happold, 1979), effective management of species depends on the knowledge of the way in which it interacts with its specific environment (Leuthold, 1977). One of the most useful methods of describing this interaction is to quantify the basic activity patterns, which exist for any species at a given time and place during the different seasons (Jarman and Jarman, 1973; Leuthold and Luthold, 1978; Norton, 1981). Annual cycles in ungulate activity are influenced by forage quality and quantity, digestive system constraints and energy conservation needs (Jarman and Jarman, 1973; Owen-Smith, 1982; Leuthold, 1977). There is no documented information regarding the diurnal activities and time budgets of Burchell's zebra in Ethiopia in general and the study area in particular. Therefore, the objective of this study was to investigate diurnal activity pattern of Burchell's zebras at different time of the day and season and give guidelines for a more comprehensive management plan for zebras in the sanctuary.

MATERIALS AND METHODS

The study area

Yabello Wildlife Sanctuary (4° 37'-5° 12' N and 38° 09'- 38° 37' E) is one of the protected areas and Wildlife Sanctuaries in southern Ethiopia. It has an area of 2496 km^2 located in the Borena Zone of the Oromia Region, east of the town of Yabello and it has an approximate North-South distance of 65 and 48 km East-West with an average altitude between 1800 and 2000 m above sea level. The area is not fenced and the boundary is not clearly demarcated. Borana lowland is mostly covered with East African evergreen and semi-evergreen bushland and thickets along the high lying areas with relatively higher rainfall (Agrotec-C, 1974). The commonest habitat inside the Yabello Sanctuary is savanna woodland dominated by various species of thorny acacia (*Acacia tortilis, Acacia brevispica*, *Acacia horrida,* and *Acacia drepanolobium*) and *Commiphora*, and broad leaved *Terminalia* and *Combretum* (Borghesio and Giannetti, 2005). In addition, small patches of juniper (*Juniperus procera*) forest can also be found in high altitude just outside the boundaries of the sanctuary, although grazing and logging threaten its persistence (Borghesio et al., 2004).

The present study identifies three major types of habitats: Acacia woodland, bushland and grassland (Figure 1). The rain fall regime in Borana dry lands is bimodal with two rainfall seasons. The main rainy season, known as the long rainy season is between March and May with the peak in April, and short rainy season is between September and November, with peak in October (Figure 2). The mean annual rain fall for the period 2000-2009 was 612.36 mm. The peak mean monthly rainfall was in April (152.9 mm) and October (127.6 mm). The least mean monthly rainfall was in January (17.6 mm). The hottest months were from January to February and temperature fluctuates between 27.9 and 28.9°C. The weather remains pleasant between June-August. The mean annual maximum temperature was 28.9°C and the mean annual minimum temperature was 12.2°C (Figure 2).

Methods

A study on diurnal activity pattern of Burchell's zebra was carried out in the Yabello Wildlife Sanctuary, Southern Ethiopia from October 2009 to March 2010 including wet and dry seasons. Observations on diurnal activity pattern of Burchell's zebra were made using unaided eye and/or 8 x 30 binoculars. Observation was facilitated by the animal's preference for short grass areas during the wet season and tall grass during the dry season and by selecting a strategic site on the hill; this enabled observation of more than one group. Scan sampling methods were used as adopted by Martin and Bateson (1993) and Altmann (1974). The activities recorded were grazing, walking, standing, resting, grooming and other activities. The latter included all activities that did not feature strongly in the general activity pattern such as playing, fighting, suckling and urinating.

The activity of each individual zebra in each group under observation was recorded and ticked on the sheet at ten minutes intervals. When unique activity was observed, it was recorded on a separate notebook. If the observed animals in the field disappeared from view, the time interval that the animals being observed out of sight was recorded. When the out of sight period was of longer duration than the duration of the common activities, it was deleted from the sample and duration of the sample period was deleted accordingly. The time budget and habitat association were analyzed using SPSS15.0 for windows.

RESULTS

The time budget of Burchell's zebra was recorded in each hour of the day during a sample of 20 days (10 in dry and 10 in wet seasons) over six months of the study period. A

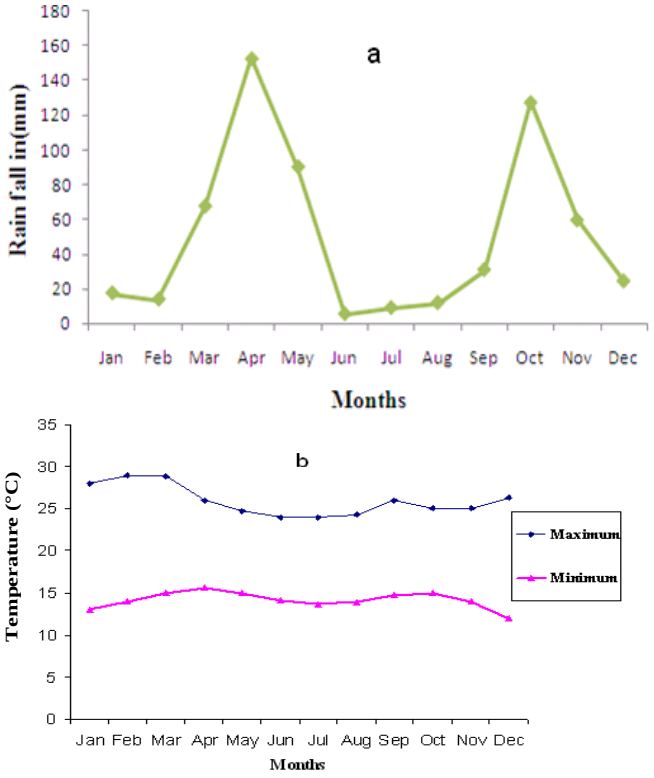

Figure 2. Monthly mean rainfall (mm) (a) and Monthly mean minimum and maximum temperature (b) in Yabello Wildlife Sanctuary from 2000-2009.

Table 1. Comparison of the different activities between dry and wet season using ANOVA.

Activity	F-value	P-value
Grazing	13.183	0.000
Standing	2.218	0.000
Walking	14.227	0.00
Resting	23.346	0.003
Grooming	2.144	0.144
Others	0.185	0.667

total of 1440 observations were taken between 0600 and 1800 h. The activities were recorded every 10 min and six observation unit per hour. Data on the various activity patterns recorded in the study period were grouped into form six major activities: grazing, walking, standing, resting/lying in the open or in the shade, grooming and other activities.

Grazing

There was an observed increase in the amount of time spent grazing during the 06:00-10:00 h and 15:00-18:00 h both in dry and wet seasons. Grazing activity remained at similar levels during the 06:00-11:00 and 14:00-18:00 h with a decrease observed during the 12:00-13:00 h time period during dry seasons. During the wet season, the animals significantly allocated more time to grazing at 09:00 h than 12:00, 11:00 and 13:00 h. In addition, time allocated for grazing at 09:00 h was significantly higher than 8:00, 15:00 and 18:00 h. There were two peaks in grazing during wet season, one between 06:00-1:00 h and the other is 14L00-18:00h. Over the dry season, grazing showed two peaks one is in the early morning between 06:00-10:00 h and the other is in the late afternoon between 14:00-18:00 h. The differences in the time devoted for each activity during different hours of the day during dry and wet season were significantly different for grazing, standing, walking and resting ($p < 0.05$), but there was no significant difference between, grooming and others ($p>0.05$). The time devoted to grazing during the dry season was significantly greater ($t=13.183$, $p<0.05$) than the wet season. Multiple pair-wise comparisons using the Tukey test indicated that Burchell's zebras spent more time in grazing in dry season than in wet season, and more time grazing during the time period. The difference in time allocation among six activity categories was statistically significant for grazing, standing, walking and resting ($F = 67.512$, d.f. = 11, $p<0.05$) during dry season and ($F = 47.532$, d.f.=11, $p<0.05$) during the wet season. The total time budget for each activity also showed significant difference for grazing, standing, walking and resting ($t= 69.265$, $p=0.001$, $t =19.058$, $p<0.004$, $t=22.572$, $p=0.03$, $t= 16.357$, $p<0.002$) over the two seasons, respectively (Table 1).

Walking

The animals walk for shorter distances and recommence grazing after 2-6 min. The adult male, which often acts as a guard, is frequently the one that leads the harem away during a disturbance.

Walking showed two peaks during the dry and wet seasons, respectively. Over the dry season, walking peaked in the early morning between 07:00-9:00h and in the late afternoon 15:00-18:00h and during the wet season, it peaked early in the morning 06:00-10:00h and late afternoon at 14:00-18:00 h.

The maximum time allocated to walking throughout the day during the wet season was 14% while over the dry season it was 9%. There was significant difference in time allocated to walking in both seasons ($p< 0.05$). Tukey multiple comparison tests indicated that time allocation for walking was significantly lower at 12:00 and 13:00 h as compared to 14:00 and 15:00 h. The majority of the walking activity during the wet and dry seasons was during the cooler periods 06:00 - 10:00 h and 15:00 - 18:00h of the day. The level of walking activity was at maximum during the 06:00-10:00 h and 1500 -18:00 h

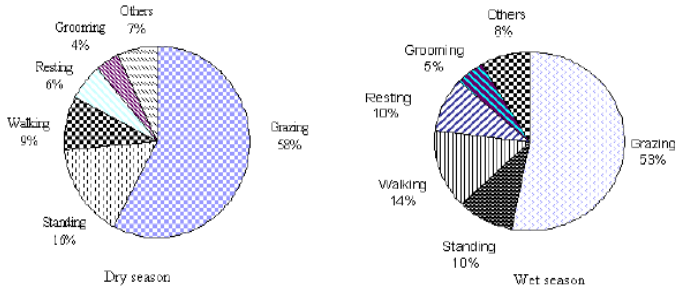

Figure 3. The average daily time budgets of Burchell's zebra during the wet and dry seasons.

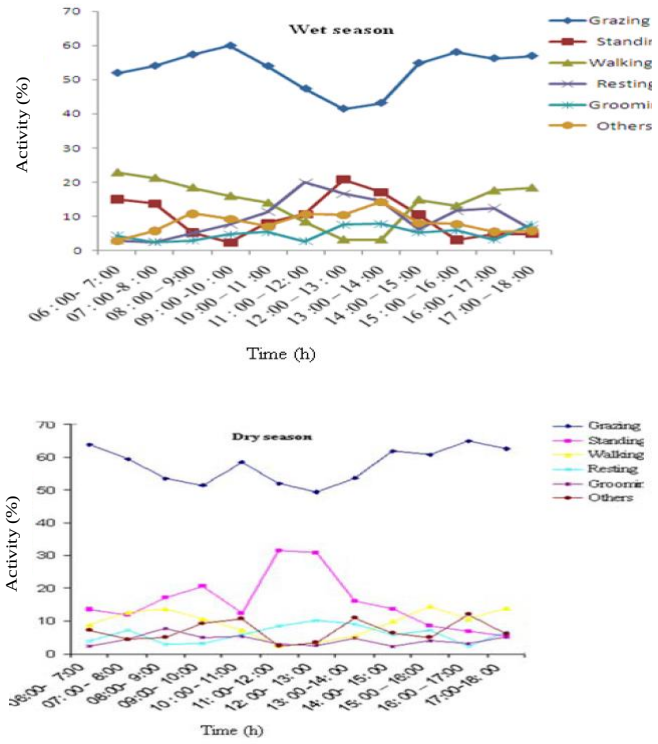

Figure 4. Diurnal time budget of Burchell's zebra during different hours of the day in the wet and dry seasons.

time periods and decreased during the 11:00-14:00 h time period. The maximum time allocated for walking throughout the day among the Burchell's zebras during the wet season was 24% (06:00 h) while over the dry season it was 14% (08:00 and 15:00 h).

Standing

In the study areas, when the Burchell's zebras were not grazing, they spend most of the time standing. Standing was the second frequent activity of Burchell's zebra next to grazing during the dry season, but the third frequent activity during the wet season next to grazing and walking. They were engaged in standing during the hottest part of the day during dry season (Figure 3). The time allocated to standing varies significantly with time of the day both in the wet and dry seasons ($p < 0.05$).

Resting

Resting was frequent during the hottest part of the day and the zebras at this time would spend more than 30 min in the bush and Acacia woodland.

Resting was increased in the middle of the day from 12:00-14:00 h (Figure 4). Data shows that Burchell's zebra were engaged more in resting for an extended time in the wet season than in the dry season. In the study area, adult zebras were never seen resting, but the young zebras spent more time in resting than adults.

Grooming

The time allocated to grooming did not vary significantly with time of the day either in the wet season or dry season. The maximum time allocated to grooming throughout the day in the dry season was 8% (08:00 h) while over the wet season it was 7, 8 and 6.5% at 12:00, 13:00 and 17:00 h, respectively. However, there was no significant difference in time allocated to grooming ($p > 0.05$) for both dry and wet seasons.

Other activities

During the wet and dry seasons, an increase in social activity was observed during the 12:00 -14:00 h time period. This can probably be attributed to the aggregation of Burchell's zebra under available acacia woodland shades, thus allowing a greater opportunity for interaction. Levels of social activity were higher during the wet season throughout the time period with peaks in the mid day from 11:00-13:00 h. Over the dry season, social activities were allocated less time at 11:00 and 12:00 h as compared to 07:00 and 08:00 h, but more time was allocated at 09:00, 10:00, 13:00 and 16:00 h respectively.

Burchell's zebras spent 58% of their time grazing, 16% standing, 10% walking, 6% resting, 4% grooming and 7% other activities in the dry season, while in the wet season, 53% in grazing, 10% in standing, 14% in walking, 10% in resting, 5% in grooming and 8% in other activities. In the dry season, grazing and standing were allocated significantly more time than other activities. Where as in the wet season, grazing and walking were allocated significantly more time than other activities.

The variation in trends between the time allocated for grazing, walking, standing, resting, grooming and other activities of Burchell's zebra of different age and sex

Table 2. Karl Pearson correlation coefficient between six activity patterns of Burchell's zebra in different hours of the day in the wet and dry seasons.

Activity	Correlation value
Grazing	-0.78(**)
Standing	0.290(**)
Walking	-0.313(**)
Resting	0.290(**)
Grooming	-0.210(**)
Other activity	0.167(**)

**Correlation is significant at the 0.01 level (2-tail).

categories in the three periods of the day showed significant differences ($p<0.05$). The time allocated for different activities also showed significant differences ($t =76.4$, $p=0.004$) during the wet and dry seasons.

The pattern of diurnal grazing was inversely correlated with walking, standing, resting, grooming and others ($r = -0.178$, $p < 0.01$; $r = -0.631$, $p< 0.01$; $r = -0.472$, $p< 0.01$; $r = -0.210$, $p< 0.01$; $r = -0.428$, $p <0.01$) respectively, reaching a peak in the morning and afternoon periods during dry and wet seasons (Table 2). The result of correlation analysis using Karl Pearson correlation coefficient showed statistically significant positive correlation between the pattern of diurnal resting and standing ($r = 0.29$, $p< 0.01$). The time allocated to walking activity was inversely correlated with standing, resting and grooming ($r = -0.313$, $r = -0.370$ and $r = -0.207$), respectively, during the wet and dry seasons. Standing activity also inversely correlated to grazing and walking ($r= -0.631$, $r = -0.313$, respectively). Furthermore, the time devoted to resting and grooming activities during different hours of the day were inversely correlated with grazing and walking ($r = -0.472$, $r = -0. 370$, $r = -0.210$, $r = -0. 207$), respectively. The diurnal activity budgets of other activities were inversely correlated with grazing ($r = -0. 428$).

Diurnal habitat preference of Burchell's zebra

Out of the total 1440 observations, Burchell's zebras were observed in the grassland (48.2%), woodland (39.9%) and bushland (11.8%). There was no significant change ($t=4.32$, $p>0.05$) in the pattern of habitat association of Burchell's zebra at Yabello wildlife Sanctuary. However, their habitat preference differed significantly in the morning, mid-day and afternoon ($t= 39.167$, $p<0.05$). They spent most (57.9%) of the morning hour in the grassland while most (55.4%) of the mid-day hours in the woodland. In the afternoon 52.4% was spent in the grassland and 39.9% in the woodland. Habitat preference exerted a considerable impact on the daily time budget of Burchell's zebra. ($t= 117$ $df=5$ $p<0.05$). Time of the day was also associated with activity patterns of Burchell's zebras ($t =232.245$, $df =11$, $P< 0.05$) (Table 3).

Livestock abundance

Livestock is the most commonly observed animal in the sanctuary. The increased number of livestock around the sanctuary was one of the important factors affecting the activity patterns and time budget of Burchell's zebras in Yabello Wildlife Sanctuary. Thousands of livestock competes directly for food with Burchell's zebras and other wildlife in the Sanctuary. Livestock distribution throughout the Sanctuary increased especially during the wet and late dry seasons, when the grasses were at grazable size. During the wet season, the number of livestock counted inside the Sanctuary was 6110 and during the dry season, these were only 4053.

Bush encroachment

Several native *Acacia* species such as *Acacia drepannolobium, Acacia oerfota*, *Acacia mellifera* and many others were observed to be an emerging rampant species replacing some of the valuable species at Yabello Wildlife Sanctuary. Due to its rapid expansion, *A. drepannolobium* was the most serious problem in the area. It had been observed during the field survey that this species had formed a pure stand replacing all other species that used to grow in the area.

DISCUSSION

Variations were observed in the activity patterns and time budget of Burchell's zebras during dry and wet seasons at different time of the day. There was significant differences in the amount of hours devoted to different activities ($t=76.4$, $p< 0.05$). Burchell's zebra devoted more time to grazing than any other activities during both seasons. Grazing was observed to be lowest at midday. The possible reason may be the influence of temperature which affects the turgidity of plants which in turn affects the plants' palatability. Grazing activity was minimum during the wet season. Decrease in grazing time with increase food availability during the wet season has been observed.

The difference in the distribution of time budgets of the wet and dry season may lead to the conclusion that temperature and food availability seem to be the determinant factors governing the activities of Burchell's zebra. Seasonal variations in daily activities were perhaps related to temperature, rainfall and ground plant biomass in reedbuck (Roberts and Dunbar, 1991). Resting reached a peak between 12:00-14:00h. No

Table 3. Diurnal habitat preference of Burchell's zebra in YWLS.

Time	No. of observation	Habitat		
		Grassland (%)	Woodland (%)	Bushland (%)
Morning	580	57.9	34.4	11.7
Mid-day	480	34.3	55.4	10.3
Afternoon	380	52.4	34.1	13.5
Total	1440	48.2	39.9	11.8

periods of rest were observed early in the morning and in the late afternoon. Resting is high during the midday in the dry season as the activities are affected by temperature. This behaviour was significantly different between wet and dry seasons. Around the middle of the day, Burchell's zebras remain standing or resting/lying down about 35 and 25% in dry and wet seasons, respectively under the shade of Acacia woodland to escape the intense heat of the day. The distribution of day time activity for Burchell's zebras in Yabello Wildlife Sanctuary with increased activities of grazing and walking concentrated in the early morning and late afternoon and a major resting/lying period during the middle of the day is similar to that observed elsewhere (Joubert, 1972; Sandra, 2009; Beekman and Prins, 1989; Gakahu, 1984; Grogan, 1978). The present study in Yabello Wildlife Sanctuary indicates that Burchell's zebra spent most of its time for grazing as evident from the activity time budget. Standing and walking were other major components of activity of the zebra. Grazing peak was in the morning from 06:00 to 10:00 h and after noon from 14:00-18:00 h.

Activity patterns of animals are determined by numerous factors. Biotic environmental factors such as light and temperature may influence optimum daily and seasonal activity patterns (Nielsen, 1983; Patterson et al., 1999). Body mass, human disturbance, social behaviour, predator avoidance, prey acquisition and competition also may affect activity in different forms (Rocowitz, 1997). Hence, important time when animals are active may be important for understanding their ecological niche and hence to develop conservation plans for imperiled species (Hwang and Garshelis, 2007). The common trend in the diurnal activity patterns of Burchell's zebra at Yabello Wildlife Sanctuary was generally to rest more in the middle of the day, and to graze more in the morning and afternoon.

Much of the time is generally spent feeding in mammalian herbivores (Beekman and Prins, 1989). Grazing Equidae spend up to 18 h of their time per day to graze (Fowler and Miller, 2003; Houpt et al., 1986; Pratt et al., 1986; Crowell-Davis et al., 1985; Sweeting et al., 1984). Three studies on Plains zebra shows that they devote around 60-70% of their time (out of a 24 h period) to grazing (Beekman and Prins, 1989; Gakahu, 1984; Grogan, 1978). The time devoted to grazing was peaked during the dry season and gradually decreased during the wet season. The increase in grazing time with decreasing food availability in the dry season has been reported for several African grazers (Owen-Smith, 1982). In the present study, the annual mean proportion of time spent grazing by Burchell's zebras at Yabello Wildlife Sanctuary was estimated to be 55.5%. This is in line with the findings of Kivai (2006) in which Grevy's zebras spent most of their time feeding than other activities in Northern Kenya; Rubeinstein et al. (2004) obtained similar results in a behavioral study of Grevy's and Plains zebras in Lewa Wildlife Conservancy, as did Moehlman (1998) where the adult Feral Asses spent 30.7 to 57.6% more of their time feeding. This finding was contradicts with the findings of Degu (2007) where Grevy's zebras spent more time for vigilance than any other activities in Chew Bahir, Southern Ethiopia.

Burchell's zebras were standing most in the midday; this may be due to the hot temperature. Standing was least in the afternoon, probably due to the higher need of grazing. This is consistent with Sandra (2009) in which Burchell's zebras were standing most in the midday and least in the afternoon. The activity budget of an animal varies in response to both internal and external factors that influence its survival strategy (Knoop and Owen-Smith, 2006). The diurnal activity of Burchell's zebras dependS on variation in climatic condition. Seasonal changes affect the timing of grazing and resting (lying down) activities. The foraging efficiency of ungulates may also be influenced by factors such as the time of day, temperature, season, vegetation type and reproductive status (Wobeser, 2006; Neuhaus and Ruckstuhl, 2002). Reta and Solomon (2013) reported that Burchell's zebra showed high preference for open grassland habitats and the distribution of the animal varied according to the season.

The activity pattern of Burchell's zebra in the study area was highly influenced by human activity, livestock over grazing and encroachments. Overgrazing increases competition for pastures especially during dry seasons. Ubiquitous presence of thousands of livestock competes on the same area with Burchell's zebra for food especially at Government cattle ranch in the Yabello Wildlife Sanctuary. Grazing activity became more difficult for Burchell's zebras when livestock arrived and occupied the more suitable habitat transformed into unsuitable

habitat which forced zebras to feed on lower quality pastures.

Some authors propose that there are four factors which influence ungulate activity budgets: seasonal changes of a pasture's biomass and quality (Moncorps et al., 1997); temperature variations throughout daytime hours and seasons (Shi et al., 2003); yearly life cycle (growth and reproduction (Duncan, 1980, Maher, 1991) and livestock movements and human activity (Schaller, 1998). Bush encroachments are the most serious problem that affects the time budget of Burchell's zebras in the study area to date. In the Borana rangelands of southern Ethiopia, a progressive increase in bush encroachment and loss of grass cover is associated with changes in patterns of livestock grazing (Bille et al., 1983; Coppock, 1994). Heavy livestock grazing in turn has reduced the herbaceous vegetation cover (Coppock, 1993).

Grazing was the dominant activity of the zebras, although the time spent in grazing differed significantly between the seasons. It occupied most of the time and, together with walking, standing and resting accounted for at least 90% of all diurnal activities. Diurnal grazing behaviour was strongly biphasic, with animals showing strong avoidance of energy consuming activities such as grazing and walking during the hottest period of the day. Such activities increased in the early morning and late afternoon hour and correlated with lower ambient temperatures. Energy conserving activities, such as resting and standing showed a strong inverse correlation with grazing and walking.

The study recommends that different conservation measures should be taken to decrease the number of livestock and encroachments in the sanctuary to create special areas for Burchell's zebras which are free from livestock movement and bush encroachments.

Conflict of Interests

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

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Full Length Research Paper

Diversity of life-forms within Sapindaceae Juss. in West Africa and Western Cameroon: A field guide

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One of the major challenges faced by biologist during field studies is the identification of plant species and this is most evident in the tropics where biodiversity richness is very high. Hence this study was conducted in order to document and produce a guide for the identification of the diversity of life forms that represents the family Sapindaceae in West Africa. In view of this, plant exploration was carried out in five West African countries with the aim of collecting and recording the different life forms in the family Sapindaceae as well as their specific locations. This revealed that Sapindaceae are widely distributed in West Africa and the highest number of species was recorded in Nigeria (47 taxa). A total of 104 species was recorded in the region and these are represented by diverse life forms ranging from trees (58 species) to shrubs (32 species) and climbers (4 species) with compound trifoliate (e.g. *Allophylus*), paripinnate (e.g. *Deinbollia*) or imparipinnate (e.g. *Paullinia*) leaves. Flowers are arranged in groups either as cymes or racemes. Fruits are in the form of berry (e.g. *Melicoccus*), capsules (e.g. *Blighia*) or drupes (e.g. *Deinbollia*); some are inflated (e.g. *Cardiospermum*) or trilobed and woody (e.g. *Chytranthus*). This study provides a guide to field identification of members of the family Sapindaceae in West Africa and can be seen as a step in solving taxonomic identification problems and biodiversity conservation as a whole.

Key words: Conservation, distribution, identification, Sapindaceae, West Africa.

INTRODUCTION

The family Sapindaceae Juss., is one of the families in the order Sapindales and can be divided into 5 or 6 subfamily depending on the treatment. Most Sapindaceae are large emergent trees or erect shrubs however some are tendril lianes (Acevedo et al., 2011). They are comprised of about 140-150 genera with 1400-2000 species worldwide. Many of these are lactiferous, that is, they contain milky sap, and many contain mildly toxic saponins with soap-like qualities in the foliage and/or the seeds or roots. Approximately one-third of the members of the family are found in the tribe Paullineae. Members include economic plants which are largely used as lumber trees or oil seed crops although some are edible.

The majority of species are native to Asia, although there are a few in South America, Africa and Australia (APG II, 2003). They occur in temperate to tropical regions throughout the world with about 18 (Hutchinson

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Table 1. Sites visited for plant collection.

Country	Herbarium	Botanic Gardens	Forest Reserve/ National Parks
Nigeria	University of Lagos (LUH), Lagos University of Ibadan (UIH), Ibadan Bayero University (BUH), Kano Ahmadu Bello University (ABU), Zaria Forestry Herbarium Ibadan (FHI) University of Benin	University of Lagos, Lagos Ahmadu Bello University, Zaria	Olokemeji, Ibadan Aponmu, Ondo Owena, Ondo Idanre hills, Ondo Omo, Ogun Sakponba, Benin Edondon Community forest, Obubra. Cross River National Park, Erokut Station Awi, Cross river
Cameroon	National Herbarium of Cameroon, (HCN) Yaounde Limbe Botanic Gardens	Limbe Botanic Gardens SABOGA, Bamenda	Bakingili, Limbe Bimbia/Mabeta, Limbe Buea Mountains Likombe, Buea Oku Elak, Oku Bali Ngemba, Bali
Ghana	University of Ghana (GC), Legon Forestry Research, Achimota	Aburi botanic garden University of Ghana, Legon	Achimota community forest Bia Legon hills
Togo	Lome		Lome
Ivory Coast			d'IDERT

and Daziel, 1958) to 26 (Adeyemi and Ogundipe, 2012) genera in west tropical Africa and 13 (Keay et al., 1964) to 18 (Adeyemi and Ogundipe, 2012) species in Nigeria.

Sapindaceae are recognizable by their often spiral, alternate, simple, or more commonly pinnately compound leaves that often have sub-opposite leaflets and a terminal rachis tip. Most often they are pollinated by birds or insects, with a few species pollinated by wind (Singh, 2004). The fruits are fleshy or dry. They may be nuts, berries, drupes, schizocarps, capsules (*Bridgesia*), or samaras (*Acer)* often red, containing seeds (Heywood, 1978). The embryos are bent or coiled, without endosperm in the seed, but frequently with an aril (Singh, 2004). Members of the family Sapindaceae are one of the most important forest species to be conserved and valued in Africa due to their multiple uses, high nutritional content and medicinal value. Globally, biodiversity is being threatened by climate change as well as human activities and this has aroused concerns about their conservation status. Hence, this current study is designed as an effort to aid in the conservation and identification of this plant family in Western Africa. Our aim is to explore the diversity of family Sapindaceae in West Africa, with emphasis on the collection, identification and preservation of the collected plant specimens as well as production of a field guide for field identification purposes.

METHODOLOGY

Study area

The study was carried out in the western part of tropical Africa and five countries were visited namely: Nigeria, Ghana, Togo, Ivory Coast and western Cameroon. The study area is characterized by tropical rain forest and prominent water bodies. The land is plain lying less than 300 m above sea level, though isolated high points exist in some areas.

Sample exploration

The national herbaria as well as local herbaria were visited so as to observe the samples in the repositories, take necessary morphological data from each of the samples and collect some of the samples examined where permission is given to do so. The visit provided information on the last location in which the sample was recorded in the region and this informed our decision on where to collect samples in the field.

Consequently, various national parks, forest reserves and botanic gardens were visited in West Africa for the collection of fresh samples of the plant specimens. Permission was obtained from the various authorities involved in each region in order to collect samples from the reserves.

Access to the reserves was possible only through the use of a 4x4 wheel drive vehicles and motorcycles due to the rugged and untarred nature of the roads. Some reserves could only be assessed by trekking some distances of up to 40-50 km as the case may be. A list of the herbaria and reserves visited is shown in Table 1.

Preservation and identification of samples

Preliminary identification was achieved with the aid of floras including that of Hutchinson and Daziel (1958), Fouilloy and Hallé (1973) and Cheek et al. (2000). For preparation of voucher specimens, a part (usually branch) of each plant sample was placed in between each old newspapers and this was kept in a plant press. The press was tied with twines and kept in the dryer for two days in order to prevent the decomposition of the plant material. Each of the dried specimens was then removed from the newspaper and mounted on white cardboard papers using white gum (glue). Label was attached to each of the herbarium specimen in order to give a full description of the plant, its location, the date of collection and the name of collector. This was then authenticated at the Forestry Herbarium, Ibadan and deposited at the University of Lagos Herbarium for reference purposes.

Data analysis

Data obtained was analyzed using Shannon and Wiener indices following Ubom (2010) Magurram (1988) and Kent and Coker (1985). The Shannon and Wiener Diversity Index, which accounts for species richness and how the species are distributed, is derived from the relation:

H1 = _ Pi ln Pi

I = 1

Where: H1 = Shannon-Weiner index; S = number of species; Pi = proportion of individuals or abundance of the i^{th} species expressed as a proportion of the total number of individuals of all species: In = log base10.

RESULTS

Sample exploration was carried out across five African countries and 35 plant species were collected from the field (Table 2) while 69 species were retrieved from the herbarium (Table 3), identified and authenticated at the Forestry Herbarium Ibadan. Our sampling revealed that Sapindaceae are widely distributed in West Africa being represented by 26 genera and 104 species. Of these species, 4 are climbers 32 are shrubs and 58 are trees representing 3.84, 30.76 and 65.38% of the total number of species, respectively. The largest population was recorded in the southern highlands of Nigeria (47 taxa), western region of Cameroon (45 taxa) and western and eastern River banks in Ghana (25 taxa) (Figure 1); however, taxa shared are highest between Nigeria and Cameroon. Leaf, stem, fruit and flower samples were collected and photographs were taken (Plate 1). Also, GPS coordinate of each sample was recorded and inputted into a map (Figure 2). Voucher samples of samples collected from the field have been deposited at the University of Lagos Herbarium (LUH) Nigeria.

Diverse life forms were encountered ranging from trees (*Aporrhiza* Radlk., *Blighia* Koenig, *Chytranthus* Hook. f., *Deinbollia* Schumach. and Thonn., *Dodonaea* L., *Eriocoelum* Hook. f., *Ganophyllum* (Chev.) Hauman., *Lecaniodiscus* Planch. ex Benth., *Lepisanthes* Blume, *Lychnodiscus* Radlk., *Majidea* J. Kirk ex Oliv., *Melicoccus* P. Browne., *Nephelium* L., , *Placodiscus* Radlk., *Radlkofera* Gilg., *Sapindus* L. and *Zanha* Hiern.), to shrubs (*Allophylus* L., *Glenniea* Hook. f., *Haplocoelum* Radlk., *Harpullia* Roxb., *Laccodiscus* Radlk. and *Pancovia* Willd.) and climbers (*Cardiospermum* L. *and Paullinia* L.) as shown in the appendix below. They possess compound trifoliate (For example *Allophylus*), paripinnate (for example, *Chytranthus*) or imparipinnate (example, *Paullinia*) leaves with an exception of *Dodonaea* which has simple leaves. Most species have leaves with entire margin but some possess serrated margins (example, *Allophylus* and *Cardiospermum*). The leaf surface is papery and glossy as in *Pancovia*, glabrous as in *Allophylus africanus* or pubescent as in *Laccodiscus ferrugineus* and *Allophylus hirtellus*). Flowers are arranged in groups either as cymes or racemes. Fruits are in the form of berry (example, *Melicoccus*), capsules (example, *Blighia*) or drupes (example, *Deinbollia*); some are inflated (example, *Cardiospermum*) or trilobed and woody (example, *Chytranthus*). The percentage number of samples collected per genera is shown in Table 4 while the number of life forms is shown in Figure 3.

DISCUSSION

Most of the samples collected from the field were found in Cameroon, due to the presence of large area of conserved forest, that is, 24 samples, followed by Nigeria (14 samples). Only 5 samples each was found in the other three countries visited: Ghana, Togo and Ivory Coast. However, the forestry herbarium in Nigeria houses the largest number of taxa (33) of all the herbarium visited. Taxa shared were highest between Nigeria and Cameroon with 9 taxa endemic to the mountains. A key item in the conservation of biodiversity is identification of species and this could be challenging especially in field studies. Over the years, this has been made difficult by the fast rate of disappearance of species largely as a result of changes in the climate as well as a wide range of unsustainable human activities hence the need for this study. All the observations made in this study are consistent with earlier description of the family given by Heywood (1978), Singh (2004), Acevedo-Rodríguez et al. (2011) and Adeyemi et al. (2013). With exception of a few species, members of Sapindaceae were largely found in lowland forest. Most of the taxa are native to the region with exception to *Melicoccus bijugatus* and *Nephelium lappaceum* which are exotic species. Also, 11 of the species encountered are yet to be identified at the species level due to absence of fruiting structures in the samples.

Several authors, including Alamu and Agbeja (2011) and Pelemo et al. (2011), have highlighted the main drivers of deforestation to include agriculture, logging and mining, use of fuel wood and logging all of which pose threats to biodiversity

Table 2. Samples collected in the field and their locations.

Species	Locations	Collector(s)	Voucher ID
Allophylus africanus P. Beauv.	Olokemeji and Bakingili forest reserves	Adeyemi, T.O and Ogundipe, O.T	LUH 1194
Allophylus bullatus Radlk.	Buea Mountain	Adeyemi, T.O	LUH1185
Allophylus hirtellus (Hook. f.) Radlk.	Bakingili forest reserve	Adeyemi, T.O	LUH 1190
Allophylus sp	Bakingili forest reserve	Adeyemi, T.O	LUH 3441
Allophylus spicatus Radlk.	Olokemeji forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 3442
Allophylus ferrugineus Taub.	Bakingili forest	Adeyemi, T.O	LUH 1192
Blighia sapida Koenig.	Oshodi Lagos, Limbe Botanic Gardens, Bakingili, University of Ghana and Idanre hills forest	Adeyemi, T.O and Ogundipe, O.T	LUH 1196
Blighia unijugata Bak.	Sakponba forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 3443
Cardiospermum grandiflorum Sw.	Owena and Idanre hills forest reserves	Adeyemi, T.O and Ogundipe, O.T	LUH 1196
Chytranthus macrobotrys (Gilg) Exell and Mendonca.	Bimbia/Mabeta forest reserve	Adeyemi, T.O	LUH 1187
Chytranthus setosus Radlk.	Bimbia/Mabeta and Bakingili forest reserves	Adeyemi, T.O	LUH 3444
Chytranthus sp. *i*	Bakingili forest reserve	Adeyemi, T.O	LUH 3445
Chytranthus sp. *ii*	Bakingili forest reserve	Adeyemi, T.O	LUH 3446
Chytranthus talbotii (Bak.) Keay	Sakponba and Aponmu forest reserves	Adeyemi, T.O and Ogundipe, O.T	LUH 3447
Deinbollia sp.	Bimbia forest reserve	Adeyemi, T.O	LUH 3448
Eriocoelum macrocarpum Gilg. ex Radlk.	Limbe Botanic Gardens	Adeyemi, T.O	LUH 1195
Laccodiscus ferrugineus (Bak.) Radlk.	Bakingili, Bimbia/Mabeta and Omo forest	Adeyemi, T.O and Ogundipe, O.T	LUH 1183
Lecaniodiscus cupanioides Planch.	Olokemeji, Sakponba and Idanre hills forest	Adeyemi, T.O and Ogundipe, O.T	LUH 3451
Majidea fosterii (Sprague) Radlk.	Limbe Botanic Gardens	Adeyemi, T.O and Ogundipe, O.T	LUH 1718
Glenniea africanus (Radlk.) Leenh.	Aponmu forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 3449
Pancovia atroviolaceus	Bakingili forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 1182
Pancovia floribunda Pellegrin.	Calabar	Adeyemi, T.O	LUH 12061
Pancovia sp. *i*	Bimbia/Mabeta forest reserve,	Adeyemi, T.O and Ogundipe, O.T	LUH 1188
Pancovia sp. *ii*	Bimbia/Mabeta forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 1186
Pancovia sp. *iii*	Buea/Likombe forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 3453
Paullinia pinnata L.	Limbe Botanic Gardens, Bimbia/Mabeta forest	Adeyemi, T.O	LUH 1193
Placodiscus leptostachyus Radlk.	Bimbia/Mabeta forest reserve	Adeyemi, T.O	LUH 3454
Placodiscus sp. *i*	Bimbia/Mabeta forest reserve	Adeyemi, T.O	LUH 3455
Placodiscus sp. *ii*	Aponmu forest reserve	Adeyemi, T.O and Ogundipe, O.T	LUH 3456
Radlkofera calodendron Gilg.	Bimbia/Mabeta forest reserve	Adeyemi, T.O	LUH 3457
Radlkofera sp. *i*	Aponmu forest reserve,	Adeyemi, T.O and Ogundipe, O.T	LUH 3458
Radlkofera sp. *ii*	Owena forest reserve,	Adeyemi, T.O and Ogundipe, O.T	LUH 3459
Radlkofera sp. *iii*	Beau Mountains	Adeyemi, T.O	LUH 3460
Sapindus saponaria L.	Limbe Botanic Gardens	Adeyemi, T.O	LUH 3461
Zanha golugensis Hiern.	Forestry Research Institute of Nigeria, Ibadan	Adeyemi, T.O and Ogundipe, O.T	LUH 3462

Table 3. Samples collected from the herbarium and their locations.

Species	Location	Collector(s)	Date	Voucher ID
Allophylus abyssinicus (Hochst.) Radlk.	Trinderet forest		16-Jan-64	FHI 20336
Allophylus cobbe (L.) Raeusch.	Buea Mountain	Bos, J.J	19-Dec-69	FHI 103688
Allophylus conraui Gilg ex Radlk.	Mambilla Plateau	Chapman,	12-Feb-72	FHI 78107
Allophylus didymanaeus				FHI 75205
Allophylus grandifolius (Bak.) Radlk.	Muyuka	Letouzey, R.	26-Aug-83	HNC 50596
Allophylus macrobotrys Gilg.	Limbe Botanic Gardens	Reekmans,	04-Jan-79	FHI 95067
Allophylus megaphyllus Hutch. and Dalz.	Ndian	Thomas, D.W.	24-Nov-86	HNC 64379
Allophylus nigericus Bak.	Calabar	Olorunfemi, J	27-Jun-79	FHI 92242
Allophylus rubifolius Engl. Abh. Preuss.	Ndian falls	Reekmans,	24-Nov-86	FHI 98646
Allophylus talbotii Bak.	Yaoundé	Letouzey, R	25-Jul-60	SFRK 28391
Allophylus zenkeri Gilg. ex Radlk.	Batouri	Letouzey, R	14-Apr-62	SFRK 6261
Aporrhiza nitida Gilg.	Sakponba	Emwiogbon	21-Jan-79	FHI 63061
Aporrhiza talbotii Bak.	Cross river	Amshoff, G	11-May-78	FHI 87370
Aporrhiza urophylla Gilg.		Alexandria, C.P.	29-Dec-65	FHI 6969
Cardiospermum corindium L.		Daramola, B.O		FHI
Cardiospermum halicacabum L.	Dumbi community	Ohaeri, A.O. 947	29-May-75	ABU 947
Chytranthus angustifolius Exell.	Makoku	Gentry, A.L	20-Jul-81	FHI 102936
Chytranthus atroviolaceus Bak. ex Hutch. and Dalz.	Kade	Hall, J.B	28-Mar-72	GCH 43435
Chytranthus carneus Radlk.	Bia National park	Abbiw and Hall, J.B.	26-Sep-76	GCH 4650
Chytranthus cauliflorus (Hutch. and Dalz.) Wickens.		Abbiw and Hall, J.B.	05-Jan-74	GCH 44715
Chytranthus gilleti De Wild.	Mbalam	Mbamba, Ekitike	23-Aug-82	HNC 48253
Deinbollia angustifolius D.W. Thomas	Makoku	Gentry A.L	20-Jul-81	FHI 84378
Deinbollia grandifolia Hook. f.	Bakwai	Hall, J.B.	09-Jun-79	GCH 47068
Deinbollia insignis Hook. f.	Obudu	Ariwaodo, J.O and Odewo, T.K.	18-Mar-86	FHI 102216
Deinbollia kilimandscharia Taub.		De WILDE, J.J and De WILDE, B.E.	17-Aug-65	GCH 7781
Deinbollia maxima Gilg.	Bakossi mountain	Thomas, D.W and Mcleod, H.L.	03-Jan-86	HNC 56603
Deinbollia mezilii Thomas and Harris	Kribi	De WILDE, J.J	24-Jun-75	GCH 44613
Deinbollia pinnata Schum. and Thonn.	Ondo	Odewo, T.K.	17-Apr-89	FHI 103697
Deinbollia pycnophylla Gilg ex Radlk.	Batouri	Letouzey, R.	30-Apr-62	GCH 6226
Deinbollia molluscula Radlk.	Bonsa	Abbiw and Hall	05-Nov-73	GCH 45939
Deinbollia pynaerti De Wild.	Batouri	Letouzey, R.	30-Apr-62	GCH
Deinbollia voltensis Hutch.	Kpondai	Hall, J.B.	15-Jul-70	GCH 40483
Dodonaea viscosa (L.) Jacq.	ABU, Zaria	Adeyemi, T.O	02-Jun-09	LUH
Eriocoelum kertstingii Gilg. ex Engler.	Mambilla Plateau	Ibhanesebhor	13-Nov-75	FHI 177683
Eriocoelum microspermum Radlk. ex De Wild.	Limbe Botanic Gardens			FHI
Eriocoelum oblongum Keay	Calabar	Onyechuson	28-Mar-64	FHI 154222

Table 3. Contd.

Species	Location	Collector(s)	Date	Voucher ID
Eriocoelum pungens Radlk. ex Engl.	Abidjan	De WILDE, J.J	29-Sep-63	GCH 53159
Eriocoelum racemosum Bak.	Benso	Enti, A.A	Sep-59	GCH 7306
Ganophyllum giganteum (Chev.) Hauman.	Youkadouma	Letouzey, R	2-Jul-63	HNC 7361
Haplocoelum gallaense (Engler) Radlk.		Letouzey, R	20-Jul-86	HNC 59423
Harpullia zanguebarica (Oliv.) Radlk.	Victoria			FHI 9291
Laccodiscus pseudostipularis Radlk.	Mamfe	Florey, J.J.	Nov-72	FHI 39252
Lecaniodiscus punctatus J.B. Hall	Kibi-Akwadum	Hall, J.B.	25-Nov-77	GCH 46960
Lepisanthes senegalensis (Juss. ex Poir.) Leenh.	Imo	Ohaeri, A.O.	13-Sep-88	ABU 2619
Lychnodiscus brevibracteatus R. Fouilloy	Yaoundé	Letouzey, R	6-Jul-72	SFRK 28388
Lychnodiscus danaensis Aubreville and Pellegrin.	Asukese	Enti, A.A	02-Mar-73	FHI 79666
Lychnodiscus grandifolius Radlk.	Kribi	Bos, J.J	15-Dec-69	HNC 31755
Lychnodiscus reticulatus Radlk.	Obubra	Ariwaodo, J.O	18-May-77	FHI 88761
Melicoccus bijugatus Jacq.	Victoria	Ogu	13-Apr-60	FHI 52431
Nephelium lappaceum L.	Kade	Hall, J.B	14-Jul-76	GCH 46110
Pancovia bijuga Wild.	Lagos	Jullick, R	06-May77	FHI 56562
Pancovia harmsiana Gilg.	Bertoua	Letouzey, R	20-Jan-60	SFRK 2926
Pancovia laurentii (De Wild.) Gilg ex De Wild.	Mesamena	Letouzey, R	21-Feb-62	SFRK 6223
Pancovia sessiliflora Hutch. and Dalz.	Cross river	Letouzey, R	16-Oct-73	SFRK 72404
Pancovia turbinate Radlk.	Marone	Abbiw and Hall, J.B.	12-Aug-75	GCH 45363
Placodiscus attenuates J.B. Hall	Kissi	Hall, J.B	2-Mar-75	GCH 47087
Placodiscus bacoensis Aubrév. and Pellegr.	Yakossi	Hall, J.B and Abbiw	6-Apr-76	GCH 3193
Placodiscus boya Aubrév. and Pellegr.	Yokadouma	Letouzey, R	08-Feb-71	SFRK 23551
Placodiscus bracteosus J.B. Hall	Ashanti	Vigne, G	Jan-30	GCH 2694
Placodiscus cuneatus Radlk. ex Engl.	Yaoundé	-	21-Nov-63	HNC
Placodiscus glandulosus Radlk.	Ndikinimiki	Letouzey, R	8-Jan-72	SFRK 28397
Placodiscus letestui	Cross river	Latilo, A and Oguntayo	28-Feb-73	FHI 67759
Placodiscus oblongifolius J.B. Hall	Beberi	Leewenberg, A.J.	23-Feb-59	GCH 2796
Placodiscus pseudostipularis Radlk.	Beberi	Hall, J.B and Abbiw	20-Aug-75	GCH 45568
Placodiscus pynaertii De Willd.	Congo	Abbiw and Hall, J.B.	14-Sep-46	FHI 15475
Placodiscus riparius Keay	Njala	Deighton, J.C.	17-Sep-51	FHI 39473
Placodiscus turbinatus Radlk.	Korup	Odewo, T.K	3-Apr-88	FHI 10543
Sapindus trifoliatus L.	Abeokuta	Daramola, B.O.	31-Aug-68	FHI 61564
Schleichera trijuga Willd.	Limbe Botanic Gardens	De WILDE, J.J	14-Mar-34	FHI 12061

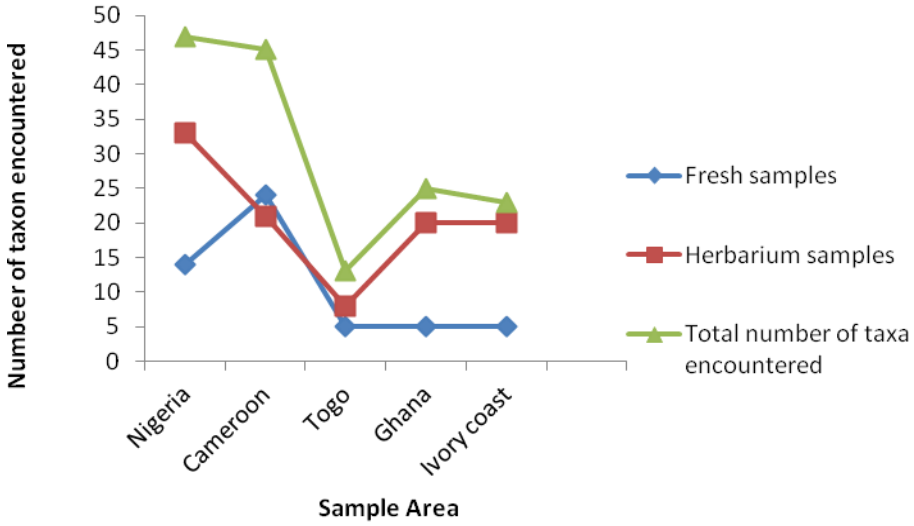

Figure 1. Number of taxa encountered per country visited.

Plate 1. Diversity of life forms within the family Sapindaceae in West Africa. (A.) Tree Species; (B.) Shrub (C.) Climbling Form (D.) Compound leaves with inflorescence in *Allophylus* (E.) Simple leaves of *Dodonea viscosa* (F.) Trifoliate leaves of *Allophylus* (G.) Drupe in clusters (H.) Trilobed dehiscent capsule of *Blighia* (I.) Trilobed inflated fruit of *Cardiospermum*. Scale: 20 mm.

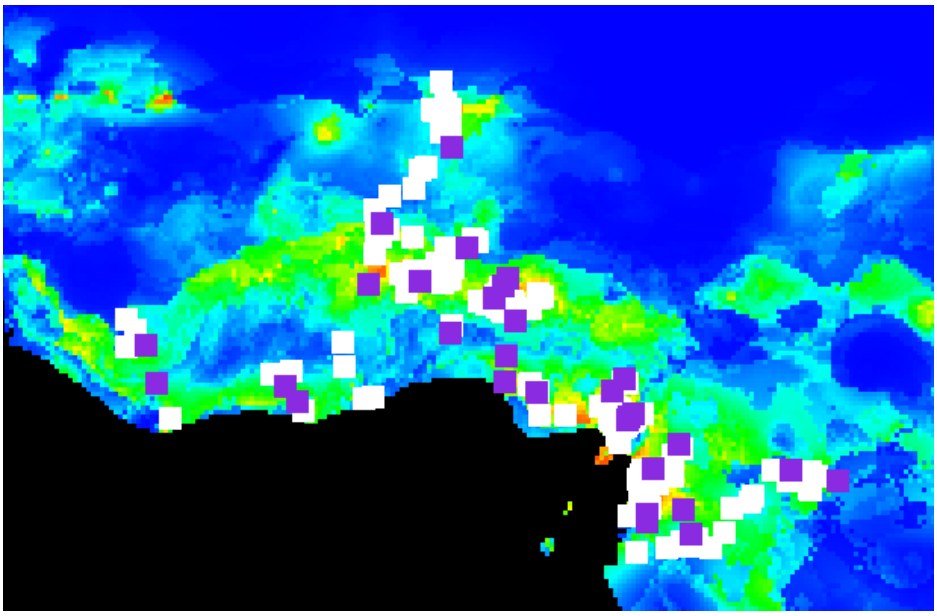

Figure 2. Distribution of sapindaceae in West Africa and western Cameroon: White dots show the locations.

Table 4. Percentage number of species encountered according to genera.

Genera	Number of species encountered	Percentage number of species
Allophylus	16	15.1%
Aporrhiza	3	2.8%
Blighia	3	2.8%
Cardiospermum	3	2.8%
Chytranthus	10	9.4%
Deinbollia	12	11.3%
Dodonaea	1	0.9%
Eriocoelum	6	5.7%
Ganophyllum	1	0.9%
Glenniea	1	0.9%
Haplocoelum	1	0.9%
Harpulia	1	0.9%
Laccodiscus	2	1.9%
Lecanodiscus	2	1.9%
Lepisanthes	1	0.9%
Lychnodiscus	4	3.8%
Majidea	1	0.9%
Melicoccus	1	0.9%
Nephelium	1	0.9%
Pancovia	10	9.4%
Paullinia	1	0.9%
Placodiscus	15	14.2%
Radlkofera	4	3.8%
Sapindus	2	1.9%
Schleichera	1	0.9%
Zanha	1	0.9%
Total	104	100

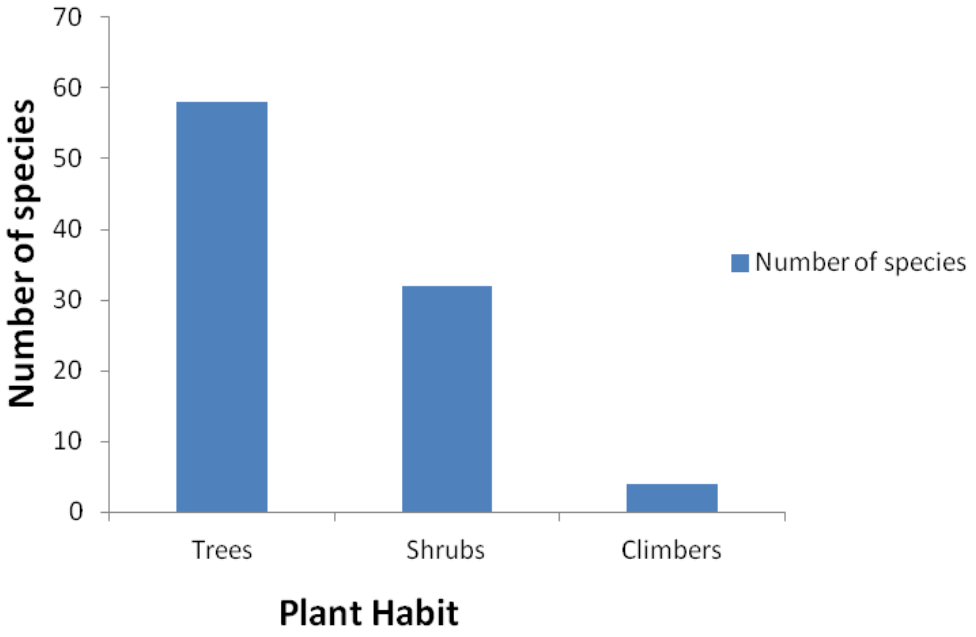

Figure 3. Number of life forms of family Sapindaceae represented in West Africa.

conservation. This is confirmed in this study as it was observed that some of the species earlier recorded in some of the reserves were no longer found largely due to the high rate of deforestation and agricultural activities going on in the reserves.

This study provides a virtual guide to field identification of members of the family Sapindaceae in West Africa and can be seen as a step in solving taxonomic identification problems and biodiversity conservation as a whole. It is therefore expected that this report will assist scientists in the area for on-the spot identification of plants in the field.

Conflict of Interests

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

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APPENDIX

Allophylus africanus showing flower

Allophylus spicatus

Allophylus sp

Allophylus welwitschii

Blighia sapida

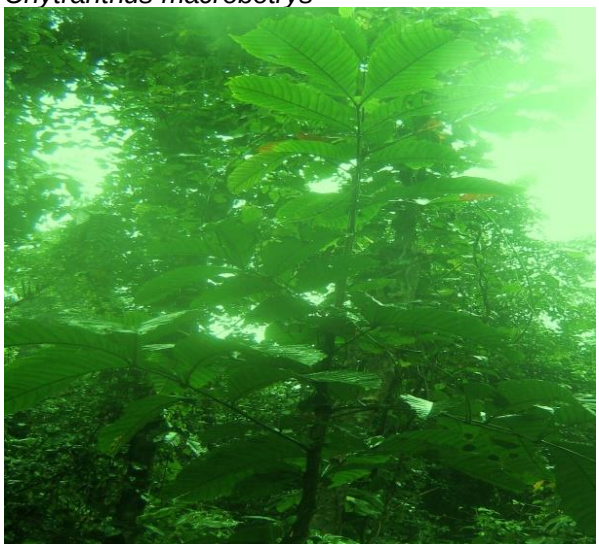
Blighia unijugata

Cardiospermum grandiflorum

Cardiospremum halicacabum

Chytranthus macrobotrys

Chytranthus setosus



Chytanthus sp ii

Chytranthus talbotii

Dodonea viscosa

Eriocoelum macrocarpum

Laccodiscus ferrugineus

Lecaniodiscus cupanioides

Majidea fosterii

Placodiscus sp (i)

Placodiscus sp (ii)

Radlkofera calodendron

Radlkofera sp (i)

Sapindus saponaria showing fruit

Zanha golungensis

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